Transportation Safety Board
of Canada

Bureau de la scurit des transports
du Canada

AVIATION OCCURRENCE REPORT

TAIL STRIKE ON LANDING

CANADIAN AIRLINES INTERNATIONAL
BOEING 767-375 C-FOCA
HALIFAX, NOVA SCOTIA
08 MARCH 1996

REPORT NUMBER A96A0035

Canada

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Synopsis

The Boeing 767-375, Canadian Airlines International flight 48 (CDN48), was on a flight from Toronto, Ontario, to Halifax, Nova Scotia. During the landing at Halifax, the aircraft crossed the runway threshold about 20 feet above ground level (agl) and touched down 200 feet past the threshold. The tail of the aircraft struck the runway, causing substantial damage to the tail skid and rear fuselage.

The tail strike occurred because the crew responded to a visual illusion with an unwarranted power reduction between the minimum descent altitude and touchdown. The upslope illusion led both crew members to believe the aircraft was higher than it actually was, and the crew did not respond to visual cues from the precision approach path indicator, 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 400 feet agl. Also contributing were the lateral navigation/vertical navigation 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 centre of gravity.

Ce rapport est également disponible en français.

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1.0 Factual Information

1.1 History of the Flight

Canadian Airlines International (CAI) flight 48 (CDN48), a Boeing 767-375, departed Toronto, Ontario, at 1655 eastern standard time for Rome, Italy, with an en route stop at Halifax, Nova Scotia. This flight is normally a direct flight from Toronto to Rome; however, the aircraft was stopping in Halifax to pick up a special charter group of 197 people.

The cruise portion of the flight to Halifax was routine with the exception of a "pack trip" valve malfunction. The crew dealt with this problem by following the appropriate checklist, and, as a result, the air conditioning pack was isolated.

The captain was the "pilot flying" (PF). The active runway at Halifax was 06, and the crew received clearance for the non-precision localizer back-course approach for that runway. The crew was asked to maintain an airspeed of 170 knots to the Golf non-directional beacon (NDB) because of traffic behind them. During descent, the pilots noticed that the left engine bleed air light illuminated and that it was intermittently flickering on and off for the duration of the approach. The pilots discussed the consequences of the loss of left engine bleed air and what it would mean to their use of reverse thrust after landing.

The aircraft touched down at 1941 Atlantic standard time (AST), 200 feet past the threshold, with a vertical acceleration of 2.2 g. During the landing roll, the first officer noticed that the tail skid light was illuminated. After arriving at the boarding gate, the captain examined the tail skid and discovered that there was substantial damage to the tail skid and aft fuselage. The two flight attendants who occupied the aft cabin positions reported that they had heard a bang when the aircraft touched down and that the landing had seemed very rough. Although the flight crew indicated that the landing had been firm, the aircraft had not seemed very nose-high to them, and they were surprised the aircraft was damaged. The aircraft was removed from service.

1.2 Injuries to Persons

	Crew	Passengers	Others	Total
Fatal	-	-	-	-
Serious	-	-	-	-
Minor/None	9	91	-	100
Total	9	91	-	100

1.3 Damage to Aircraft

The Boeing 767 is equipped with a tail skid that extends and retracts with the landing gear. A tail skid light illuminates if the tail skid position disagrees with the extended or retracted position of the landing gear. During the touchdown, the tail skid contacted the runway surface with sufficient force to shear the tail skid hydraulic actuator attachment pin and drive the actuator upward, striking the stabilizer ball screw assembly. This caused the tail skid light to illuminate. The damage required the replacement of the tail skid hydraulic actuator, the left and right tail skid housings, and all hydraulic lines and hoses common to the actuator. There was also some minor damage to the stabilizer position switches and their associated mounting brackets.

After the tail skid actuator failed, the lower skin on the tail section of the aircraft contacted the runway surface, causing multiple scrapes and buckles to the skin between stations 1417 and 1540 and stringers 36 right and 36 left. The skin in this area, five frames, and numerous stringers and stiffeners were replaced before the aircraft was returned to service.

1.4 Other Damage

There was no other damage.

1.5 Personnel Information

	Captain	First Officer
Age	52	49
Pilot Licence	ATPL	ATPL
Medical Expiry Date	01 Jun 96	01 Apr 96
Total Flying Hours	17,300	14,100
Hours on Type	2,215	1,846
Hours Last 90 Days	180	197
Hours on Type Last 90 Days	180	197
Hours on Duty Prior to Occurrence	4	4
Hours Off Duty Prior to Work Period	72	72

1.5.1 Aircraft Captain

The captain was licensed and qualified for the flight. At the time of the incident, the captain held a valid class 1 medical with the restriction that glasses must be available. 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 occurrence. 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 non-precision approaches, which he did successfully.

The captain last flew a non-precision, back course localizer approach at Montreal several years prior to this occurrence. This was a night approach during a winter snowstorm and had been conducted using the aircraft's autoflight capability. The captain was uncomfortable with the approach in that, when visual reference with the runway was established, the aircraft was lower than he had anticipated, and he had to manoeuvre the aircraft to land on the runway. Almost all of the captain's recent flying was to large airports with instrument landing system (ILS) approaches and runways generally longer than runway 06 at Halifax.

1.5.2 First Officer

The first officer was licensed and qualified for the flight, and has been a first officer with the company for over 20 years on the Boeing 737, 767, and the DC10. He was described as being a quiet person and not assertive. Prior to the occurrence, he had never attended a CRM course.

At the time of the incident, the first officer held a valid class 1 medical with the restriction that glasses or contact lenses must be worn.

1.6 Aircraft Information

1.6.1 General

Manufacturer	Boeing Company
Type and Model	767-375
Year of Manufacture	1990
Serial Number	24575
Total Airframe Time	25,213.4 hours
Engine Type (number of)	GE CF6-80C2 (2)
Maximum Allowable Take-off Weight	407,000 pounds
Recommended Fuel Type(s)	Jet A, Jet B
Fuel Type Used	Jet A1

According to the Boeing 767 Flight Crew Training Manual, a normal aircraft body attitude during approach at a speed of V_{REF30}+5 is 3°. Landing flare body attitude at the same speed is given as 5° to 6°. Information provided by the manufacturer indicated that a five-knot decrease in approach speed will increase the body attitude by 1°.

The aircraft's tail skid will contact the runway when the aircraft has a 10° body attitude with the main landing gear oleos extended. Tail skid contact will occur at a body attitude of 8° if the main landing gear oleos are compressed.

1.6.2 Flight Management System

The Boeing 767 is equipped with Flight Management System (FMS), which is an integration of subsystems designed to aid crews in controlling the aircraft's lateral (LNAV) and vertical (VNAV) flight path. These flight-path subsystems contain submodes, including those to track a front course localizer (LOC), and a back course localizer (B/CRS and LOC - two switches selected). The selector buttons for the various modes are found on the Mode Control Panel (MCP), which is located on the glare shield between the two pilots. Either pilot is able to make mode selections.

1.6.3 Weight and Balance

The aircraft departed Toronto with a centre of gravity (C of G) of about 13% mean aerodynamic chord (MAC), which is in the forward portion of the allowable C of G range. The C of G moved further forward as fuel was burned during the flight. The C of G on landing was at about 12% MAC, which was within the company's specified forward limit of 11.1% MAC (the certificated forward C of G limit is 7%). The landing weight was about 276,000 pounds, with the maximum allowable landing weight being 320,000 pounds.

The landing C of G was forward of the usual values because of freight in the forward hold and a small passenger load. The aircraft's body attitude on approach is increased the further forward the C of G is located. The increase in aircraft body attitude between a mid-range C of G and a forward C of G is about three quarters of a degree.

When the aircraft's C of G 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 captain indicated that the control column force seemed lighter than usual during the landing.

1.6.4 Landing Distance

The Federal Aviation Administration approved Flight Manual landing distance for the Boeing 767-300, from a threshold crossing height (TCH) of 50 feet, is 5,400 feet for a wet runway. Runway 06 at Halifax is 8,800 feet long. 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 .36, and based on their experience, there should have been adequate stopping margin. The CDN48 flight crew indicated that the aircraft decelerated well; the aircraft turned off the runway at taxiway "D", which is about 6,500 feet from the runway threshold.

The aircraft is equipped with an automatic brake system, with five landing brake settings, 1 to 4 plus MAX AUTO. The normal setting for a wet runway would be 3 or 4. 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.

1.7 Meteorological Information

The area forecast for Halifax, issued at 1330 Coordinated Universal Time (UTC) on 08 March 1996, predicted an overcast cloud layer based between 1,000 and 2,000 feet above sea level (asl) and topped at 24,000 feet asl. Frequent snow ceilings of 400 to 800 feet asl would result in visibility between one-half and two miles in snow, light snow, and blowing snow. The precipitation was forecast to become light freezing rain and ice pellets in the vicinity of Halifax, which was near a warm front. Moderate rime icing was forecast in cloud between 7,000 and 11,000 feet asl, with moderate to severe clear icing below 4,000 feet asl in the freezing rain and ice pellets.

The terminal forecast for Halifax for the time of the occurrence predicted scattered cloud at 800 feet agl with an overcast ceiling of 2,000 feet agl and visibility four miles in light snow. There would be occasional obscured ceilings of 900 feet agl with the visibility one mile in light freezing drizzle, light snow, and fog.

The 2300 UTC weather, a regular special observation, was: partially obscured, clouds 300 feet overcast, visibility one and one-half miles in light freezing drizzle and fog, temperature -3.7° Celsius (C) and dew point -4.5°C, wind of 070° true at 7 knots, and an altimeter setting of 29.15 inches Hg (mercury).

A special observation taken at 2328 UTC, 13 minutes before CDN48 landed, was as follows: clouds 300 feet overcast, visibility one and one-half miles in very light freezing drizzle and fog, and wind of 080° true at 7 knots.

The 2346 UTC special weather observation for Halifax, four minutes after the occurrence, was as follows: clouds 300 feet overcast, visibility one and one-half miles in light freezing drizzle and fog, temperature -3.7°C, dew point -4.5°C, and wind 090° true at 6 knots.

Automatic terminal information system information “Papa” for Halifax was first broadcast about 1922 AST, 19 minutes before CDN48 landed. The information was as follows:

> Halifax International Airport information Papa, 2300 Zulu weather - Partially obscured, measured 300 overcast, visibility one and a quarter mile in light freezing drizzle and fog, temperature minus four, dew point minus five, wind 090 at 5 to 10 knots, altimeter is two niner one three. IFR (instrument flight rules) approach localizer back course runway 06, landing and departures runway 06. Runway 06 has been reported 160 feet wide, and that portion was 10 per cent bare and dry, 20 per cent light snow, 10 per cent compact snow, 60 per cent ice, outside of that is 100 per cent dry snow. Was sanded at one niner one five. JBI runway 06 temperature minus four, decimal 36 at 2304.

The crews of several aircraft that landed before and after CDN48 were contacted and asked if they had encountered icing conditions that evening in the vicinity of Halifax. Their responses varied from encountering no ice at all to a moderate accumulation in cloud. The crew of CDN48 reported that they had not observed any accumulation of ice on their aircraft during the descent. Although the aircraft engine anti-ice was selected on during the descent, the crew did not select the wing anti-ice on. According to CAI procedures, wing anti-ice can be used as a de-icer or anti-icer, and the primary method is to use it as a de-icer by allowing ice to accumulate before turning wing anti-ice on. Ice accumulation on the cockpit front window frames, windshield centre post, windshield wiper post, or side windows can be used as indication of airframe icing conditions and the need to turn on the wing anti-ice system.

Several Halifax ramp personnel were asked to comment about any ice accumulation they had observed on aircraft arriving that evening. Many had not noticed any ice and some had observed slight ice buildup on the landing gear and radomes of a few aircraft. The pilot of a Boeing 737 aircraft reported that he had observed an ice buildup of 3/8 inches on his aircraft's stabilizer during a walkaround after arriving at Halifax that evening.

1.8 Aids to Navigation

The approach to runway 06 at Halifax uses a localizer back course signal and the Golf NDB located 4.8 nautical miles from the runway threshold. It was determined that the localizer and Golf NDB were operating normally at the time of the occurrence. (See Appendix A.)

The last flight inspection to check the calibration of the localizer for runway 06 had been completed on 27 November 1995. During this inspection, it was found that the facility met all operational requirements and that the localizer signal was within the approved technical tolerances.

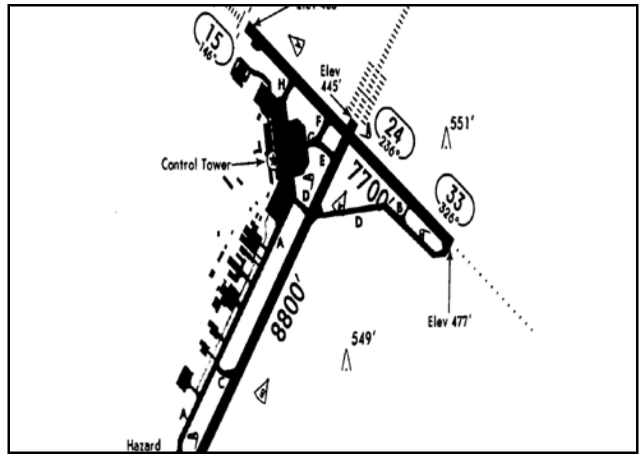
1.9 Communications

Communications between the crew of CDN48 and Air Traffic Control (ATC) were normal throughout the flight.

During the approach, the captain was advised by ATC 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 CDN48 did not ask for a current braking action report from the Airbus, apparently because it would have added to the workload of the crew of CDN48.

1.10 Aerodrome Information

1.10.1 General



Halifax International airport, located at 44°52' North and 63°30' West, is a certified aerodrome operated by Transport Canada. The field elevation is 477 feet asl.

Runway 06/24, which is oriented 056/236° magnetic, measures 8,800 feet long by 200 feet wide. The first quarter of runway 06 has a 0.77% upslope. At taxiway Charlie, the runway begins to slope down by 0.5% to about the runway halfway point. The remainder of the runway is basically level. There is no information contained in the aviation publications about the overall slope for runway 06. The slope of a runway is published by the *Canada Air Pilot* (CAP) when the average slope is 0.3% or greater. For example, the average slope for runway 33 at Halifax is 0.55% down, which is significant enough to be noted on the CAP approach plates for that runway.

Jeppesen approach charts were used by CAI, and those charts do not provide runway slope information. To determine the slope, a crew member would have to determine the difference between the two threshold heights, which are provided if known to Jeppesen, and divide by the runway length. 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.

According to TP312, *Aerodrome Standards and Recommended Practices* Standard 3.1.2.3, the maximum upslope in the first quarter of the runway with a length of 8,800 feet (runway code number 4) is 0.8%.

1.10.2 Runway 06 Instrument Approach

The CAP non-precision localizer back course approach to runway 06 at Halifax has a beacon crossing altitude of 1,700 feet asl over the Golf NDB, final approach fix, with a minimum descent altitude (MDA) of 760 feet asl or 298 feet agl. The touchdown zone elevation is 462 feet asl. The Jeppesen approach plates used by CAI use the same altitudes as the CAP approach plates.

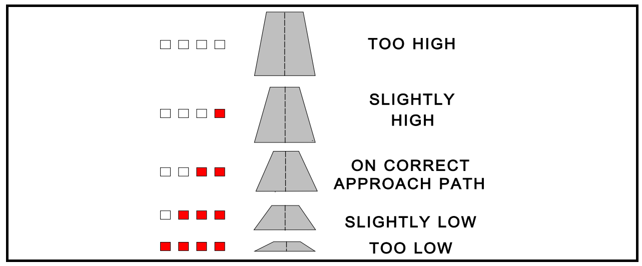
The standard method of conducting the runway 06 back course approach would be to cross the approach beacon at or just above 1,700 feet asl, descend to the MDA and level off, and proceed until visual reference with the runway is established or until the estimated time to the missed approach point has expired. If adequate visual reference were established, a pilot would continue the approach and use the PAPI (precision approach path indicator) for glide path guidance. This method, although more difficult than using a constant rate descent provided by a glide path has been used safely and successfully for many years. Operators of FMS-equipped aircraft have exploited the capability of the onboard systems to generate a pseudo 3-degree flight path by adjusting the crossing altitudes of the final approach fix.

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.

1.10.3 Runway 06 Visual Approach Aids

An omni-directional approach lighting system (ODALS) is installed for runway 06. The ODALS consists of a 1,500-foot row of bright, non-variable, sequenced strobe lights, with a strobe light at each corner of the threshold. In addition, there are green threshold lights, white runway edge lights, and white runway centre line lights, all with variable intensity. It could not be determined what setting the lights were on when CDN48 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 runway is served by a type 3 PAPI, suitable for aircraft with an eye-to-wheel height of up to 45 feet (Boeing 747 and smaller). The PAPI consists of four light units in a wing bar, located on the left side of the runway, 1,307 feet from the threshold, and provides a 3° glide path to the touchdown zone. A pilot's on-slope indication is two white lights and two red lights visible. If four red lights are visible, the aircraft is too low.



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 further down the runway."

It was determined that all visual approach aids were functioning normally at the time of the incident. In the fall of 1994, Transport Canada (TC) received several complaints from pilots regarding poor vertical reference on runway 06 at Halifax with the ODALS in operation. In response, on 19 October 1994, TC inspectors conducted a number of night approaches to runway 06 in visual flight conditions, and found that approaches made with reference to the PAPI provided the desired glide path. Transport Canada, in its 10 January 1995 report regarding the complaints and the testing carried out, indicated that it solicited comments from pilots who used the airport frequently. According to the Transport Canada report, the pilot comments ranged from "comparable to any other ODALS system" to "the worst black hole approach in Canada." The 10 January report concluded that no further action was required.

The captain indicated that he was less experienced with PAPI indicators than with VASIS (visual approach slope indicator system) indicators, and that he preferred the older VASIS indicators. He reported that, on final approach, he noticed that the PAPI indicated mainly 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 1,000-foot runway marks, and it was his intention to touch down near the 1,000-foot marks. The first officer indicated that he did not observe the PAPI.

1.11 Flight Recorders

1.11.1 General

The digital flight data recorder (DFDR) and cockpit voice recorder (CVR) were removed from the aircraft and sent to the TSB Engineering Branch for analysis.

The CVR was a Loral A100, model number 93A100-30, which recorded the crew and cockpit area microphone channels on a 30-minute continuous loop. Aircraft electrical power continued to be supplied to the CVR for several hours after the aircraft's arrival at the boarding gate, which resulted in the incident data being overwritten.

The DFDR, model number 980-4100-AXUS, was manufactured by Allied Signal. The DFDR was played back without removal of the tape, and the entire 25 hours of data was retrieved using the TSB's Recovery, Analysis, and Presentation System. A computer animation of the flight was developed to assist in the analysis of the incident. Radar data supplied by the Moncton Area Control Centre were used to verify the accuracy of the ground track derived from the recorded flight data.

1.11.2 DFDR Flight Reconstruction

The following information has been extracted from TSB Engineering Report LP 36/96 - FDR/CVR Analysis, Boeing 767-375, C-FOCA, 08 March 1996.

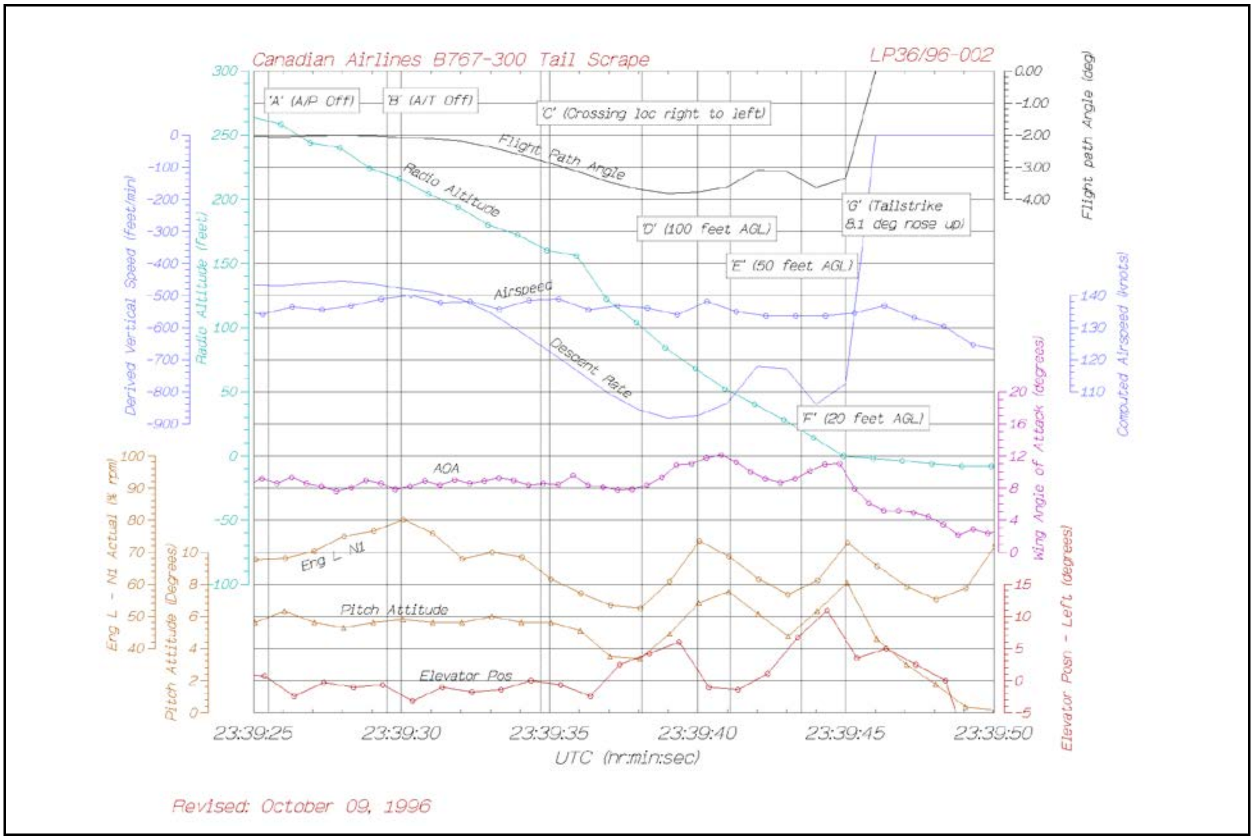
As the aircraft turned on to final for runway 06, descent was initiated from 2,200 feet asl and the aircraft was slowed to approximately 178 knots indicated airspeed (KIAS). The autopilot pitch and roll modes were selected to VNAV and LNAV respectively, with the auto-throttles selected to the speed mode.

Just after the crew reported by the Golf NDB inbound, the aircraft's landing gear was extended and the flaps were set first to 20°, then 30°. Airspeed decreased to the approximate "Flaps 30" reference speed plus 5 knots (V_{REF30}+5) of 139 KIAS as the flaps were fully extended. The descent rate averaged about 560 feet per minute (fpm) on a glide path of 2.3°, and the engine power averaged about 67% N1. Aircraft body attitude averaged about 4°.

The crew indicated that they saw the runway environment at minimum descent altitude (760 feet asl). At about 730 feet asl, the autopilot pitch mode changed to altitude capture, and, approaching 700 feet, the aircraft began to level off. Aircraft body attitude increased from 4.5° to 6.3° and engine power increased to 80% N1. The autopilot was then disengaged as the flight director went into altitude hold at about 700 feet. Four seconds after autopilot disengagement, the auto-throttles were disengaged.

After auto-throttle disengagement, the aircraft's nose lowered to 5.3°, the engine power was reduced to 70% N1, then further reduced to 50% N1 at about 150 feet agl. The descent rate, which had been steady at about 550 fpm, increased to approximately 850 fpm. LNAV had been in use, placing the aircraft slightly right of the actual localizer centre line, and, simultaneously with the reducing pitch, a slight turn to the left was initiated, followed by small turn to the right.

The aircraft crossed the runway threshold at approximately 20 feet agl, the engine power was increasing through 58% N1 (to 72% N1 at touchdown), body attitude was increasing through 5.8°, and the aircraft was



descending at 800 fpm. In the last 10 seconds before touchdown, the N1 averaged about 8% lower than the previous steady value during the approach, which equates to about 20% less thrust. Airspeed had decreased to 134 KIAS (V_{REF30}). The aircraft touched down, without slowing its descent, about 200 feet beyond the threshold, 40 feet left of the centre line, with a peak vertical acceleration of 2.2G (load factor)and peak pitch attitude of 8.1°.

DFDR data indicated that the use of reverse thrust and auto braking was discontinued within 30 seconds of touchdown, and that the aircraft was capable of stopping within about 4,000 feet.

1.12 Wreckage and Impact Information

There was no wreckage, and the applicable impact information is contained in section 1.3, Damage to Aircraft.

1.13 Medical and Pathological Information

Not applicable.

1.14 Fire

There was no evidence of fire before or after the occurrence.

1.15 Survival Aspects

Not applicable.

1.16 Tests and Research

1.16.1 Performance Evaluation

DFDR data for the time of the incident were sent to the aircraft manufacturer for analyses on an engineering simulator. A comparison of theoretical aircraft performance with actual aircraft performance in Halifax was done. Also, flight data for a previously recorded landing in Hawaii, in atmospheric conditions non-conducive to ice accretion and in relatively smooth and stable flight, were used for comparison.

Aircraft performance was considered to be normal until descent through about 400 feet agl, at which time theoretical simulations suggested a loss in aircraft performance (increased drag and decreased lift). The reason for the performance loss in the final portion of the approach could not be determined; however, possible explanations include partial speed brake deployment, ice accretion, and/or wind shear.

Speed brake handle position and spoiler control surface position are not recorded DFDR parameters on this aircraft[1], but speed brake deployment and retraction were evident from changes in other DFDR data earlier in the descent. During the latter portion of the approach, where the performance loss became evident, there was no evidence that the speed brakes were fully extended, and the crew indicated that there were no indications of speed brake extension.

According to the manufacturer, the aircraft was designed so that flight in icing conditions should not affect its control, trim, or handling. The horizontal tail, with no de-icing capability, was designed to minimize its susceptibility to the accumulation of ice. The size of the horizontal tail was designed to allow it to operate at tail lift levels at or below the levels where leading edge ice would affect the tail's ability to generate the required lift.

The CAI Boeing 767 Operations Procedure, which discusses the effect of wing ice contamination, indicates that

[1] Other B767 aircraft do record speed brake handle and control surface positions.

lift decreases and drag increases at high angles of attack. The manufacturer indicates that there is no lift loss attributable to ice contamination until the wing angle of attack increases above 15°. The angle of attack reached a peak of 12° during the accident flight as the aircraft descended through 50 feet agl. The CAI Operations Procedure also indicates that during take-off, wing contamination would cause the aircraft to behave as if it were trimmed in a nose-up direction; no trim information is provided for the approach phase.

The recorded DFDR data indicate that the aircraft encountered some turbulence during the approach, and the surface wind reported by the tower was 100° magnetic at five knots. Other flights did not indicate the presence of windshear at the point of landing.

1.16.2 Simulator Tests

Simulator trials were conducted at the CAI facility in Vancouver to review company procedures, study approach profiles, and assess available visual cues, performance degradation, and aircraft handling techniques. The trials were conducted during two 3-hour sessions in the Boeing 767-375 simulator, set up to simulate the conditions of aircraft weight, C of G, and weather encountered on the occurrence flight.

Halifax is not one of the airports in the simulator's data base so a generic airport with the same basic runway configuration was used. The simulator was not able recreate approach-end runway slope or the same lighting, and the simulator runway display had a PAPI indicator on each side of the runway, not just on the left side of runway as is the case for runway 06 at Halifax. The following observations were made during the trials:

- Workload during a non-precision 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 2,050 feet asl was used to produce a 3° VNAV glide path, the transition to visual flight for the landing was easier and smoother than with a 2.3° glide path;

- When the simulator was "flown" at the 2.3° glide path (using an NDB crossing altitude of 1,700 feet asl), the PAPI at MDA showed a below-slope indication (four red lights). After raising the NDB crossing altitude to 2,050 feet asl, the PAPI at MDA showed an on-slope indication (two red and two white lights);

- With the MDA set on the MCP window and the autopilot engaged, the approaches became unstable in pitch and thrust when the autopilot began to level the aircraft;
- While conducting the simulator tests, partial speed brake extension was demonstrated, and below 800 feet agl the following indications were observed:
  - SPEED BRAKE EXT message on engine indicating and crew alerting system (EICAS)
  - The SPEED BRAKE caution light is illuminated

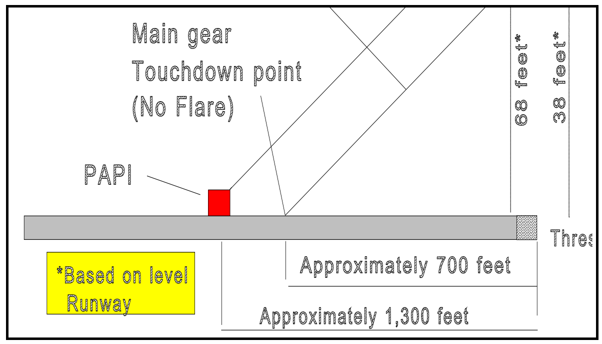
- Both master caution lights are illuminated
- A level-B aural caution sounds

- Because of simulator design, it was not possible to effectively simulate the effect of airframe icing; and,

- Only one instance of simulator "aircraft" body attitude high enough to produce a tail strike was noted, and unnatural pitch control inputs were required to produce it.

1.16.3 Main Gear Touchdown Point

When using the location of the PAPI at runway 06 at Halifax, but not accounting for the runway upslope, the main gear touchdown point can be determined using the approximately 30-foot difference between eye-level path and gear path for the Boeing 767-300, as depicted in figure 4. Assuming no flare, the main wheels would contact the runway at about 700 feet. With normal flare and round out, a touchdown could be expected at about 1,000 feet.



1.17 Organizational and Management Information

1.17.1 General

Aspects of the airline's management which might have influenced the crew's performance as well as the dispatch of the flight were examined in more detail.

1.17.2 Company Training

CAI conducts bi-annual recurrent pilot training in their Boeing 767 simulator located in Vancouver. A training session is followed by a PPC. The training includes emergency procedures, crew coordination, and approach procedures for both precision and non-precision approaches. The airport locations used in the training alternate between Vancouver, various European stations, and Toronto, giving the flight crews approaches for both North America and Europe every year. In many cases, the training for non-precision approaches is scripted so as to result in a missed approach and/or an engine failure, thus the transition to landing would not be practised as often as a precision approach such as ILS.

CAI training emphasizes that their pilots use the VNAV capability on non-precision approaches for vertical guidance and use the localizer back course approach (B/CRS and LOC) mode for lateral guidance rather than LNAV. VNAV allows the pilots to fly the approach with a constant glide path in the same way they would follow a glide slope on an ILS approach. LNAV provides the flight crew with lateral guidance in a way similar to that of the localizer on an ILS; however, LNAV is inherently not as accurate as tracking the localizer using LOC or B/CRS and LOC. Crews tend to use LNAV to intercept the localizer, because it will perform a smoother intercept. LNAV can then be engaged to track the localizer. During training, flight crews are instructed to set the missed approach altitude in the MCP window shortly after passing the final approach fix.

CAI teaches their pilots that using the above procedures should allow them to reach the visual reference point at MDA during a non-precision approach provided the weather is sufficient. The pilot must then follow the visual vertical guidance provided by a PAPI or VASIS. There is no specific information to indicate that the aircraft may require adjustment to the visual flight path after completing a VNAV approach. The importance of not flying below the proper glide path (described in some literature as "ducking under") in a wide body aircraft is discussed with the pilots.

1.17.3 Flight Crew Operating Manual

The CAI Flight Crew Operations Manual (FCOM) in use at the time of the occurrence contained information regarding the completion of non-precision approaches using the autoflight system. In Volume 1 of the FCOM, commencing at page 02.07.04, the pilot flying (PF) is told to use LNAV or heading select to track the approach or to establish an intercept course for a back course approach. This FCOM section then indicates that the PF is to select B/CRS and LOC for the back course approach. At the final approach fix, the pilot not flying (PNF) is to set MDA or the next lower 100-foot level on the MCP. The PF is to use VNAV (or select V/S mode and appropriate vertical speed) to descend to MDA. Approaching MDA, the PF is to allow the engagement of ALT HOLD mode (or select ALT HOLD when using V/S). The PNF is directed to then set the missed approach altitude on the MCP. The PF is to disengage the autopilot when descending below MDA and to disengage the auto-throttle prior to landing. The Boeing Flight Crew Training Manual describes the procedure for a non-precision approach and landing in a similar manner.

1.17.4 Standard Operating Procedures

Also contained in the CAI FCOM is an insert labelled “Standard Operating Procedures” (SOP), dated 23 December 1991, with a subject of “V-Nav Non-Precision Approach (AFDS).” The CAI SOP under “general” states that “the approach may be conducted in LNAV/VNAV when conditions permit, or in any other suitable roll and pitch mode.” The SOP does not contain any explicit instruction for crews to select B/CRS and LOC during the approach, and in one section implies that LNAV could be used unless there is a disagreement between the map display and the “raw” navigational data.

The SOP, in a section entitled “Final Approach,” provides guidance regarding the selection of gear and flaps. It states that, at approximately 30 seconds or 1.5 miles before the final approach fix, the landing gear down and flaps 20 should be selected. Landing flaps are to be selected at the final approach fix and speed is to be reduced to the final approach speed. The SOP indicates that the aircraft should arrive at, or near, the visual descent point by MDA. Crews are told to set the missed approach altitude in the MCP window when “approaching MDA” and to be prepared to land or go-around at MDA.

A preamble to the CAI SOP on page 02A.07.3 states that, “....Standard Operating Procedures supersede and take precedence over the Boeing Operations Manual, Vol. 1, Chapter 2, Normal Procedures.”

1.17.5 Pre-Flight Considerations

The captain had been watching the weather patterns for the east coast of Canada for several days prior to the occurrence flight. On the day of the occurrence, 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 captain would then fly them direct to Rome. Because of logistical limitations in getting the passengers to Toronto, it was decided instead that an extra pilot would board the flight in Halifax. This would permit a longer crew day in the event of a requirement to make an intermediate stop in the flight from Halifax to Rome. Possible weight limitations on departure, due to the slippery runway, could have created a need for an intermediate stop.

Alternate airports were further than normal from Halifax because the eastern seaboard weather was below alternate limits, but adequate fuel reserves were on board to allow for a diversion.

1.18 Additional Information

1.18.1 Approach Procedures

The crew of CDN48 had never flown together before. Prior to the flight, they took time to discuss crew coordination and company standard operating procedures.

CAI policy is for the PF to initiate the descent for the final approach. During the approach to runway 06, the captain selected VNAV, but the system went to altitude hold because 2,300 feet was still set in the MCP. The first officer (the PNF) reset the altitude to 700 feet and then initiated the final descent on VNAV. Standard procedure is to lower the gear and select flaps 20 between 1½ and 2 miles prior to the final approach fix (FAF). In this incident, the DFDR data show that flaps 20 and gear down were selected just after NDB (FAF) passage. The crew indicated that the late selection of gear and flaps was related to resetting the speed in the speed intervention window, as called by the first officer, and because of dealing with the numerous "left bleed" EICAS messages. The captain had briefed the use of the B/CRS and LOC functions; however, LNAV was used.

With 1,700 feet, the minimum height at the FAF, set on the MCP, the glide path was approximately 2.3° 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 10 feet to the 48-foot TCH given by the aircraft's data base for the approach to runway 06.

Another Canadian air carrier uses company-designed approach plates for non-precision approaches, including one for runway 06 at Halifax. When setting up the VNAV for runway 06, the pilots input a final approach fix (NDB) altitude of 2,050 feet to produce a glide path coincident with the 3° PAPI indication. A note on the approach plate advises that the lowest NDB crossing altitude is 1,700 feet asl.

After crossing the FAF, the crew set 700 feet, the next lower 100-foot level below the MDA of 760 feet, on the MCP window. When the aircraft reached about 730 feet, the autopilot began to capture the altitude and the auto-throttles added power to maintain the selected speed. At this time, the captain disconnected the autopilot, then the auto-throttles, reduced power manually, and lowered the nose of the aircraft.

CAI policy is that, if the first officer notices an unsafe condition, he or she should immediately and, if necessary, forcibly, bring this to the captain's attention. The first officer stated that he did not observe the PAPI and at no time did he feel the landing was unsafe. The first officer observed the 800 to 900 fpm descent rate during the final stage of the approach, but did not call out the rate of descent to the captain, nor was he required to do so by the company SOPs. Rates of descent of 1,000 fpm or greater are to be called out by the pilot not flying. The captain indicated that at no time did he feel the landing was unsafe.

1.18.2 Channelized Attention

Channelized attention is the focussing of one's attention on a particularly limited area to the exclusion of other areas or cues. The phenomenon can be exacerbated by fatigue, lack of knowledge, excessive motivation, or the novelty of the situation.

1.18.3 Effects of Smoking

Smoking can affect the health of individuals, but it can also 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 hypoxia. The vision loss is about 5% per 2,000-foot increase in altitude. Inhaling carbon monoxide as a result of smoking increases carboxyhemoglobin (COHb) and results in hypemic hypoxia (degradation of the oxygen transport mechanism). A smoker will often have between 5% to 12% COHb, versus 1% for a non-smoker; 5% COHb has the same effect as being about 8,000 to 10,000 feet above sea level.

At least one study carried out in a vehicle simulator indicates that smokers and non-smokers 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[2]. The captain indicated that he combatted nicotine withdrawal while flying by using Nicorette gum.

1.18.4 Visual Illusions

Deviating below the proper glide path can be an intentional action if the pilot deliberately wants to land short on the runway. In other cases, a pilot can believe that a good glide path is being maintained while unintentionally deviating below the glide path. The flatter the glide path, the more difficult it is to visualize changes in the descent rate.

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. An obscuring phenomenon that reduces the brightness of the threshold and runway lights, threshold and runway lights that are on a dim setting, or an up-sloping runway surface can contribute to the illusion that the aircraft is higher than it

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[2] Teresa Sommese and John C. Patterson, "Acute Effects of Cigarette Smoking Withdrawal: A Review of the Literature," *Aviation, Space, and Environmental Medicine*, February 1995: 164-167.

really is. According to material published by Transport Canada,[3] 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 they are used to. There is a strong tendency in these conditions for the pilot to fly low on the approach and to delay the flare. The illusion is usually increased as visibility decreases and fewer visual references are available to the pilot. The reported visibility when the crew of CDN48 established visual reference with runway 06 was 1½ miles. The illusions are known to "affect even the most experienced pilots...". The Transport Canada document provides guidance to pilots to counteract the effects of runway illusions. Three of these procedures are as follows:

- In your planning, find out the length and width of the runway so as to anticipate any illusions. Do the same with runway slope.

- Initiate your descent at the same point and establish the pitch and power settings that produce a constant airspeed and rate of descent.

- If an approach slope indicator system is in operation, visual illusions are easily countered by keeping on the glide slope.

[3] Transport Canada Safety and Security, "Human Factors for Aviation: Basic Handbook," pp 81 - 85.

2.0 Analysis

2.1 Introduction

The analysis discusses the events leading up to landing at Halifax, including company operations, crew procedures, the flight path flown and the deviations below the normal flight path, the actions of the captain in landing the aircraft, and aircraft performance. Also discussed are the runway environment, the activity of the crew, and influences upon the actions of the pilots.

2.2 Dispatch of the Flight to Halifax

The flight to Halifax did present some challenges to the crew. The runway was slippery, which created difficulties for the landing at Halifax and the planned departure from Halifax to Rome. Company Operations had addressed the concerns expressed by the captain regarding the departure from Halifax at a heavy aircraft weight. Operations had arranged for another pilot to join the crew in case a decision was made to lighten the fuel load, thereby necessitating an intermediate stop which would have extended the crew day. The landing distance required for CDN48, given the runway condition at Halifax, was expected to be less than the runway available. The amount of runway actually used by CDN48 during the landing, less than 6,500 feet, supports the conclusion that the landing distance available was adequate.

The weather in Halifax was forecast to be above approach limits for the estimated time of arrival, and the surface winds were not forecast to be a factor. However, icing conditions were forecast in cloud and freezing precipitation. Alternate airports were further than normal from Halifax , but sufficient fuel was on board to allow for a diversion if necessary.

Because of the weather conditions, the crew was justified in taking extra care in planning for the flight to Halifax and Rome, but there does not appear to have been an operational reason to cancel their flight.

2.3 Approach Design

The airline's procedures for completing non-precision approaches, like the back course procedure to runway 06, call for the use of FMS VNAV for descent guidance. The procedure is intended to place the aircraft below cloud in good position for a visual landing. CAI, like other airlines operating FMS-equipped aircraft, have adjusted their approach procedures to allow the approach to be flown using FMS vertical guidance.

The approach for runway 06 was set up by the crew using a beacon crossing altitude of 1,700 feet asl, in accordance with the company's procedures, which produced a virtual glide path angle of about 2.3°. The extra 10 feet added to the threshold crossing altitude, 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 3° 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 calculation of the data required to produce a constant 3° glide path, although possible, would have represented a significant challenge to most flight crew, and was outside of the scope of the airline's procedures or training. Other operators addressed this problem by providing crews with beacon crossing altitudes that produced a glide path angle of 3.0°, which reduces the problems in transitioning from the instrument approach to visual landing.

The use of a beacon crossing altitude that produces a shallower than normal (or optimal) 3° 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 levelling the aircraft at about 700 feet asl, which caused the flight path angle to change unexpectedly. Thus, the 2.3° virtual glide slope did not directly cause the approach of CDN48 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 and or going too high.

2.4 Procedural Deviations

During the investigation, it was noted that the crew did not always follow standard procedures in conducting the approach to Halifax. In some cases, it was difficult to determine exactly what procedure should have been followed. Some of the deviations were unintentional and were followed by prompting or correction by the co-pilot. The landing gear and 20°-flap selection were made later than normal; the selection of 30°-landing flaps was made slightly below the normal altitude given by the CAI FCOM, and the aircraft was configured properly for the landing. The late gear and flap extension caused an increase in the crew's workload at the time the aircraft crossed the beacon.

The use of LNAV on final approach instead of B/CRS and LOC, which appears to have been unintentional, resulted in the aircraft being positioned slightly right of the runway centre line as the runway became visual. The initiation of a left turn as the captain assessed his vertical references would have added to his workload and contributed to the approach becoming unstabilized.

There is a difference between the method taught by the airline to conduct back course localizer approaches and that contained in the CAI FCOM, CAI SOP, and the Boeing Flight Crew Training Manual. Crews that follow the procedures outlined in the manuals could be prone to difficulties such as having the approach become unstabilized or becoming very workload intensive if the weather is close to the approach limits.

2.5 Landing and Performance

As the captain acquired visual reference with the runway environment at MDA, the autopilot began to level the aircraft at about 700 feet asl, as a consequence of the VNAV procedures used. The engine thrust increased, the body attitude increased, and the flight path angle decreased. This caused the engine power to increase above approach value, disturbed the stable descent path, and initiated problems in the captain's landing of the aircraft. It would be reasonable to expect that, when the captain disconnected the autopilot, he had sensed that the aircraft was levelling out and that engine power was increasing. This would have given him 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 the 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 aircraft came close to landing short of the runway, which was potentially very hazardous. 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. An analysis of reported braking action and landing distance calculations indicate that, even if the aircraft had touched down 1,500 feet from the runway threshold, it could have been stopped safely on the remaining runway. However, the crew did not have a chart or table available to indicate that there was adequate stopping distance, based on the reported JBI.

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 captain noticed that the controls seemed lighter than normal. This may have been a perception stemming from the apparent lack of aircraft response; however, in light of the observed performance loss, the possibility of altered control forces cannot be discounted. 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°, close to the value for the tail skid contact angle of 8.0°, with oleos compressed, given in the B767 Flight Crew Training Manual.

Because of the forward C of G position, the minimum airspeed flown on the approach and the flatter than normal approach path, the margin between the pitch angle on approach and the angle required to strike the tail was reduced by about two degrees. Given the dynamics of the last few seconds of the flight, it is not possible to conclude that a further aft C of G would have prevented the tail strike. However, the crew was not aware of the pitch-angle increase.

Engineering analysis indicated that, in the last 400 feet of the approach, the accident aircraft exhibited a loss of lift and an increase of drag when compared to theoretical data. This loss of performance may have contributed to the captain's inability to arrest the descent rate during the landing flare. Performance tests and DFDR data indicate that speed brakes were not extended. It could not be determined whether wind shear or ice accretion may have influenced the performance loss. 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 angle-of-attacks 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. Missing DFDR parameters (speed brake) and the sampling rate of other parameters, such as angle-of-attack, contributed to the uncertainty of the origin or the magnitude of the performance loss.

2.6 Influences on Crew Actions

At several points during the approach and landing, the crew's performance was degraded by external and self-generated difficulties. It should be noted that an exact analysis of the flight events was precluded by an absence of CVR information.

The captain was concerned about making the flight to Halifax because of the runway condition and weather. He had suggested that the passengers be flown to Toronto to eliminate the Halifax stop. Events during the flight would have added to his concern. The weather had deteriorated to less than that forecast. While on approach, a bleed air malfunction occurred which had the potential of affecting reverse thrust. The localizer back course approach to landing was a type of approach that he had not flown often in the airline's B767 routes or during simulator training. The captain did not have good experiences in conducting actual back course approaches, he demonstrated difficulties during training involving these approaches, and now he had to complete this type of approach in minimum weather. There are several indications that the captain was overly concerned about the runway condition, leading to a condition of channelized attention, and a loss of situational awareness.

The captain reported an hour earlier than usual to begin flight planning, which is not a problem, but was inconsistent with his concerns about an extended crew day in the event that an intermediate stop had to be made after departure from Halifax. The captain's selection of the brakes to MAX AUTO, a selection almost never considered necessary, also indicates the extent of the captain's concern. The last aircraft to land prior to CDN48 had difficulty exiting the runway because of slippery conditions in the vicinity of taxiway Delta, and this information was passed to the crew of CDN48. The captain did not ask ATC to get a braking action report from the crew of that aircraft, which could have given him a better indication of actual runway braking conditions. This suggests that the captain's plan of action for dealing with what he anticipated would be a very slippery runway was already well developed.

Runway 06 has an upslope of 0.77% in the first portion of the runway, which is close to the normal limit specified by TP312. The illusion created by the 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. There was nothing on the approach chart to indicate that the first portion of the runway was sloped up. Also, there does not seem to be any way for the crew to have determined that runway 06 had an upslope in the first portion of the runway. Only average slope is provided if the average runway slope exceeds 0.3%. The visibility present during the landing would limit the amount of runway that could be seen, which would have made the first portion 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. An absence of published information in the form of a cautionary note, or a slope indication on an approach chart, deprived the crew of a possible strategy in overcoming the runway illusions present. This could explain why the power was reduced to 50% N1 by the captain, leading to an unstabilized approach as the aircraft descended through 150 feet agl. A call of the 800 to 900 fpm descent rate, even though it was not required by company SOPs, might have been helpful to the captain. The lack of a call may indicate that the first officer was affected by the visual illusions and failed to appreciate the unfolding situation. 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 levelling of the aircraft near MDA because of the VNAV procedures used. The ability to successfully cope with workload demands varies from one individual to another, and can also vary for an individual based on his or her state of mind. 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.

3.0 Conclusions

3.1 Findings

1. The flight crew was certified and qualified in accordance with existing regulations.

2. The CVR recording of the accident was overwritten after the aircraft was parked because power to the CVR was not removed.

3. 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.

4. The weather conditions at Halifax were conducive to ice accretion on aircraft during the approach.

5. Wing anti-ice was not used during the approach, nor was it required by SOPs.

6. The aircraft flew a 2.3° glide path on the approach to runway 06 because of the NDB crossing altitude selected as per company SOPs.

7. After reaching MDA in visual conditions, the captain flew the aircraft below the visual glide path angle indicated by the PAPI.

8. Theoretical flight simulations indicated that there was a loss in aircraft performance below 400 feet agl. The reason for the performance loss could not be determined.

9. The captain used the aircraft's LNAV for lateral guidance during the approach instead of B/CRS and LOC.

10. In following LNAV, the aircraft was displaced slightly to the right of the runway centre line at MDA, which required last-minute corrective action by the captain.

11. The aircraft began levelling off unexpectedly at MDA because of VNAV procedures used by the crew.

12. Procedures used in the operator's training for LNAV/VNAV approaches differed from the operator's published procedures for flying the approach.

13. The captain had previously experienced difficulties performing localizer back course approaches during his recurrent training.

14. The captain had not performed an actual localizer back course approach for several years.

15. There was limited training regarding landing from non-precision VNAV approaches and the change

of VNAV flight path to visual flight path near MDA.

16. Neither the captain nor the first officer had received formal CRM training.

17. The first officer did not observe the PAPI or notice any unsafe condition during the approach.

18. The first officer did not call out the rate of descent during the approach, nor was he required do so by company SOPs, because the rate of descent was less than 1,000 feet per minute.

19. The first quarter of runway 06 at Halifax has a 0.77% upslope, which is not noted on instrument approach charts.

20. 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.

21. There were no charts available to the crew to indicate the adequacy of the runway length for the runway surface conditions.

3.2 Causes

The tail strike occurred because the crew responded to a visual illusion with an unwarranted power reduction between the minimum descent altitude and touchdown. The upslope illusion led both crew members to believe the aircraft was higher than it actually was, and the crew did not respond to visual cues from the precision approach path indicator, 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 400 feet agl. Also contributing were the lateral navigation/vertical navigation 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 centre of gravity.

4.0 Safety Action

4.1 Action Taken

4.1.1 VNAV Procedures for Non-Precision Approaches

On 14 May 1996, CAI issued a Flight Operations Bulletin (B767-10-96) entitled *3 Degree Glide Path Conversion Chart*. The stated purpose for the chart is "to provide B767 crews conducting non-precision approaches with a smooth transition at the minimum descent altitude to the visual airport vertical guidance system." The chart enables pilots to calculate the beacon (FAF) crossing altitude to produce a 3° glide path using VNAV, with a TCH of 50 feet. The chart provides a height value (in feet), based on the distance of the FAF from the runway, to be added to the runway threshold height to produce a revised FAF crossing altitude.

Subsequently, the TSB forwarded an Aviation Safety Advisory to Transport Canada (TC) on the use of ad hoc VNAV procedures for non-precision approaches. The advisory suggested that TC consider publishing guidelines on the use of VNAV for non-precision approaches, and consider amending non-precision approach charts to facilitate the use of VNAV systems. It was further suggested that TC encourage operators which use VNAV for non-precision approaches to establish applicable Standard Operating Procedures (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 Standard Operating Procedures and associated training.

The International Civil Aviation Organization (ICAO) Programme for "The Prevention of Controlled Flight Into Terrain" is considering requirements for the design of non-precision instrument approach procedures to take into account the need for a stabilized approach technique with a minimum glide path angle of 3°.

4.1.2 Preservation of CVR Recording

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. The item was discussed at a company flight safety meeting and the pilot union representative agreed to remind members to take steps to preserve the CVR.

4.1.3 CRM Training

The first officer completed CRM a few weeks after the occurrence. The airline is conducting CRM training at a rate of two courses per week. The CRM training that has been provided has been reviewed and the airline intends to place increased emphasis on the assertiveness portion of future CRM training. The Canadian Air Regulations (CARs) which came into force on 10 October 1996 require that airlines which operate large aircraft (generally 20 or more passengers) have an approved CRM training program.

4.1.4 JBI Charts

The Board 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 Boeing 767 crews to determine, for a specific runway and JBI, the maximum landing weight which will facilitate a safe stopping distance. This Information Circular contains a table that would have indicated to the crew that adequate landing performance was available for the existing aircraft weight and runway JBI.

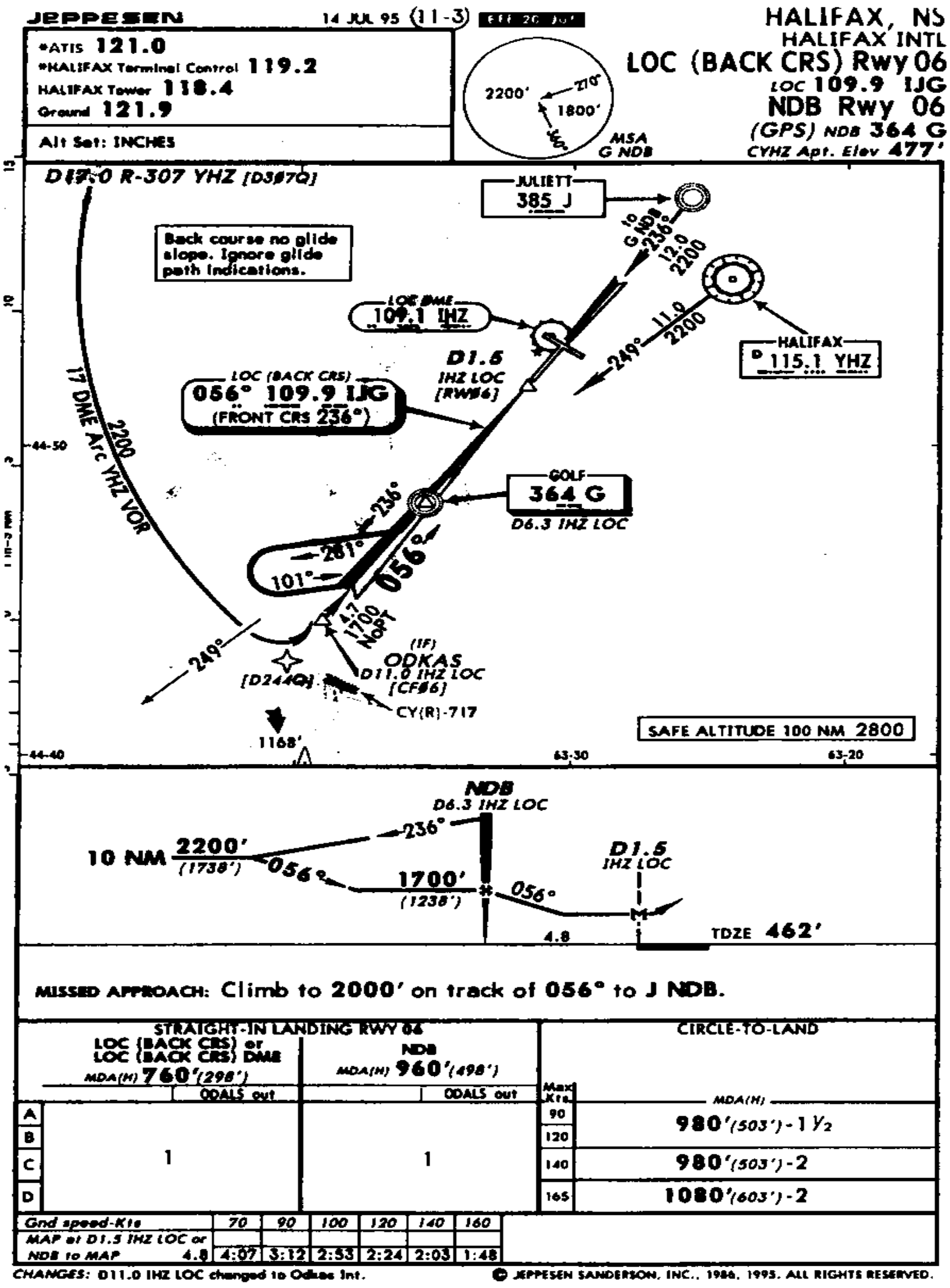
4.1.5 Provision of Runway Slope Information

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 it does not document a threat to safety caused by the current method of providing runway slope information. Transport Canada 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.

This report concludes the Transportation Safety Board’s investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 27 November 1997.

Appendix A - Localizer Back Course Approach



Appendix B - List of Supporting Reports

The following TSB Engineering Branch Report was completed:

LP 36/96 - FDR/CVR Analysis, Boeing 767-375, C-FOCA, 8 March 1996.

This report is available upon request from the Transportation Safety Board of Canada.

Appendix C - Glossary

AFDS	autopilot flight director system
agl	above ground level
asl	above sea level
AST	Atlantic Standard Time
ATC	air traffic control
ATIS	automatic terminal information system
ATPL	Airline Transport Pilot Licence
B/CRS	back course
C of G	centre of gravity
CAI	Canadian Airlines International
CAP	Canada Air Pilot
CDN48	Canadian Airlines International flight 48
COHb	carboxyhemoglobin
CRM	crew resource management
CVR	cockpit voice recorder
DFDR	digital flight data recorder
EICAS	engine indicating and crew alerting system
FAF	final approach fix
FCOM	Flight Crew Operations Manual
FMS	flight management system
fpm	feet per minute
hr	hour(s)
ICAO	International Civil Aviation Organization
ILS	instrument landing system
JBI	James Brake Index
KIAS	knots indicated airspeed
LNAV	lateral navigation
LOC	localizer
MAC	mean aerodynamic chord
MCP	mode control panel
MDA	minimum descent altitude
N1	low-speed rotor speed
NDB	non-directional beacon
ODALS	omni-directional approach lighting system
PAPI	precision approach path indicator
PF	pilot flying
PNF	pilot not flying
PPC	pilot proficiency check
SOP	standard operating procedure
TC	Transport Canada
TCH	threshold crossing height
TSB	Transportation Safety Board of Canada

UTC	Coordinated Universal Time
VASIS	visual approach slope indicator system
VNAV	vertical navigation
'	minute(s)
°	degree(s)
%	percent