Transportation Safety Board of Canada | Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT
A04H0004

REDUCED POWER AT TAKE-OFF AND COLLISION WITH TERRAIN

MK AIRLINES LIMITED
BOEING 747-244SF 9G-MKJ
HALIFAX INTERNATIONAL AIRPORT, NOVA SCOTIA
14 OCTOBER 2004

NOT FOR RELEASE BEFORE NOON 29 JUNE 2006

Canada

1.0 Factual Information

1.1 History of the Flight

The series of flights for this crew originated at Luxembourg-Findel Airport, Luxembourg, on 13 October 2004, as MK Airlines Limited Flight 1601 (MKA1601),[1] destined to Bradley International Airport, Windsor Locks, Connecticut, United States. The aircraft operated as MK Airlines Limited Flight 1602 (MKA1602) from Bradley International Airport to Halifax International Airport, Nova Scotia, and was to continue as MKA1602 to Zaragoza, Spain, and return to Luxembourg.

The flights were operating with a heavy crew,[2] comprised of two captains, one first officer, and two flight engineers. A loadmaster and a ground engineer were also on board. The crew members for MKA1601/MKA1602 arrived at Luxembourg-Findel Airport at different times and dates. The captain and first officer of MKA1601, and flight engineer of MKA1602 operated a flight from Nairobi, Kenya, to Luxembourg-Findel Airport on October 12. The captain of MKA1602 and flight engineer of MKA1601 arrived in Luxembourg from Johannesburg, South Africa, on October 12 as operating crew of their first flight after a two-week period off duty. On October 13, the ground engineer and loadmaster arrived at Luxembourg as crew on the occurrence aircraft.

The planned departure time for MKA1601 was 1000 coordinated universal time (UTC).[3] At 0848, just before the crew's departure from the hotel in Luxembourg, the MKA1601 captain received a phone call from the MK Airlines Limited station liaison officer in Luxembourg, advising of a delay to the planned departure time due to the late arrival of the aircraft and late preparation of the cargo.

The captain, first officer, and flight engineer of MKA1601 checked out of the hotel at 0925. At 0941, the captain was advised that the aircraft loading was under way, and the captain, first officer, and flight engineer proceeded to the airport. The captain and flight engineer of MKA1602 checked out of the hotel at 1052 and proceeded to the airport.

When the MKA1601 captain arrived at the airport, he received the flight documentation from the Luxembourg station liaison officer. The flight documentation was prepared by the MK Airlines Limited operations centre in Landhurst, East Sussex, United Kingdom. It included the flight brief, the trip schedule, flight routing, weather, flight plan, planned fuel requirements, and planned payload. After the captain reviewed the flight documentation, he requested that 4000 kilograms (kg) of cargo be offloaded to carry additional fuel. The crew made the necessary adjustments to their flight documentation.

Another delay developed when the loadmaster noted that some of the pallets were contaminated with soil and would not be accepted by the authorities at Bradley International Airport. A vacuum cleaner was obtained and the MK Airlines Limited station liaison officer and loadmaster began to clean the pallets. So as not to delay the flight unnecessarily, the loadmaster took the vacuum cleaner on board to finish cleaning the pallets en route. The flight departed at 1556.

The first officer was identified as the pilot communicating with air traffic control (ATC) for the flight from Luxembourg to Bradley, except for a three-hour period during which time the voice communicating with ATC was that of another crew member. MKA1601 landed at Bradley International Airport at 2322.

At Bradley International Airport, all the cargo from Luxembourg-Findel Airport was offloaded. However, the cargo loading at Bradley was prolonged due to unserviceabilities with the aircraft's cargo loading system. With a captain and flight engineer crew change, MKA1602 departed Bradley International Airport for Halifax International Airport at 0403 on October 14, carrying another delay. The MKA1602 captain was the pilot communicating with ATC; the first officer was the pilot flying (PF).

MKA1602 landed on Runway 24 at Halifax International Airport at 0512 and taxied to the ramp. After shutdown, loading of the aircraft was started. During the loading, two MK Airlines Limited crew members were observed sleeping in the upper deck passenger seats. After the fuelling was complete, the ground engineer checked the aircraft fuelling panel and signed the fuel ticket. The aircraft had been uploaded with 72 062 kg of fuel, for a total fuel load of 89 400 kg. The ground engineer then went to the main cargo deck to assist with the loading.

Once the loading was complete, the ramp supervisor for the ground handling agent went to the upper deck to retrieve the MKA1602 cargo and flight documentation. While the loadmaster was completing the documentation, the ramp supervisor visited the cockpit and noted that the first officer was not in his seat. Approximately 10 minutes later, the ramp supervisor, with the documentation, left the aircraft. At 0647, the crew began taxiing the aircraft to position on Runway 24, and at 0653, the aircraft began its take-off roll. See Section 1.11.4 of this report for a detailed sequence of events for the take-off.

During rotation, the aircraft's lower aft fuselage briefly contacted the runway. A few seconds later, the aircraft's lower aft fuselage contacted the runway again but with more force. The aircraft remained in contact with the runway and the ground to a point 825 feet beyond the end of the runway, where it became airborne and flew a distance of 325 feet. The lower aft fuselage then struck an earthen berm supporting an instrument landing system (ILS) localizer antenna. The aircraft's tail separated on impact, and the rest of the aircraft continued in the air for another 1200 feet before it struck terrain and burst into flames. The final impact was at latitude 44º52'51" N and longitude 063º30'31" W, approximately 2500 feet past the departure end of Runway 24, at an elevation of 403 feet above sea level (asl). The aircraft was destroyed by impact forces and post-crash fire. All persons on board (seven crew members) were fatally injured.

1.2 Injuries to Persons

	Crew	Passengers	Others	Total
Fatal	7	-	-	7
Serious	-	-	-	-
Minor/None	-	-	-	-
Total	7	-	-	7

1.3 Damage to the Aircraft

The first damage to the aircraft occurred when, on rotation, the aircraft's lower aft fuselage struck the runway twice and remained on the ground to a point 825 feet beyond the end of Runway 24. Severe damage occurred when the aircraft's lower aft fuselage struck the berm and the vertical stabilizer and both horizontal stabilizers separated from the fuselage. The final impact was in a wooded area where impact forces and an extensive post-crash fire destroyed the remaining aircraft structure forward of the aft pressure bulkhead (see Photo 1).

Photo 1. Main fuselage and number 4 engine

1.4 Other Damage

Grass was uprooted in the area beyond the end of the runway where the aft section of the aircraft fuselage had dragged on the ground; as well, a number of approach lights for Runway 06 were destroyed. The ILS localizer antenna structure sustained significant damage when the aircraft struck the berm. Telephone and power lines adjacent to the main crash site were severed just before final impact. The surrounding wooded area was heavily damaged by the post-crash fire. Unburned fuel contaminated the soil in the immediate area of the crash site, requiring an extensive environmental clean-up.

1.5 Personnel Information

1.5.1 General

The operating flight crew of MKA1602 consisted of one captain, one first officer, and one flight engineer. The captain and flight engineer of MKA1601, a ground engineer, and a loadmaster were also on board.

	Operating Flight Crew		
	Captain	First Officer	Flight Engineer
Licence	Airline Transport	Airline Transport	Flight Engineer
Medical Expiry Date	01 July 2005	17 August 2005	13 August 2005
Total Flying Hours	23 200	8537	2000
Hours Last 90 days	254	245	186
Hours on Type Last 90 Days	254	245	186
Hours off Duty Prior to Work	29	17	17

	Non-Operating Crew			
	Captain	Flight Engineer	Ground Engineer	Loadmaster
Licence	Airline Transport	Flight Engineer	Maintenance	Not required
Medical Expiry Date	15 July 2005	27 January 2005	Not required	Not required
Total Flying Hours	6000	1991	Unknown	Unknown
Hours Last 90 Days	171	202	Unknown	421
Hours on Type Last 90 Days	171	202	Unknown	Unknown

1.5.2 Operating Captain

The pilot-in-command (operating captain) of MKA1602 held a Ghanaian airline transport pilot licence (ATPL) with a valid instrument rating. He was qualified and certified in accordance with the *Ghana Civil Aviation Regulations* (GCARs). His licence was annotated with the remark "holder to wear spectacles which correct for near vision and shall have available a second pair whilst exercising the privileges of the license." Based on a review of the captain's medical records, there was no indication of any pre-existing medical condition or physiological factors that would have adversely affected his performance during the flight.

The captain had been with the company since its inception and started flying the McDonnell Douglas DC-8 with MK Airlines Limited in 1990. He was in one of the first groups of company pilots to transition to the Boeing 747-200 (B747). The captain successfully completed his United States Federal Aviation Administration (FAA) type rating training on the B747 in 1999 at the Pan Am Training Center in Miami, Florida. The captain's total flying time on the B747 was approximately 4000 hours.

In 2000, the company changed its B747 standard operating procedures (SOPs) and required all B747 flight engineers and pilots to undergo additional training. During this additional training, the captain had some difficulties adjusting to the new SOPs and his training was suspended. After two weeks of review and study, the captain returned to training and completed the course without further difficulty. Records indicate that there were instances where supervisory pilots had to counsel the captain regarding non-adherence to SOPs; however, in the period before the accident, he had demonstrated a marked improvement.

The captain trusted other crew members to perform their duties with minimal supervision. He was not comfortable using personal computers and software, such as the Boeing Laptop Tool (BLT) (see Section 1.18.1 of this report). He was more comfortable using manual methods to complete performance calculations, such as using runway analysis charts[4] or Volume 2[5] of the aircraft flight manual (AFM). Generally, those who flew with him reported that he was competent flying the aircraft. He was respected and exercised adequate command authority in the aircraft, although he preferred to work in a casual manner.

1.5.3 Operating First Officer

The first officer held a Ghanaian ATPL with a valid instrument rating. He was qualified and certified in accordance with the GCARs. His last medical was conducted on 17 August 2004 with no annotations on the licence, although the medical records indicated that spectacles were worn for the eye test. The previous medical assessments were annotated with the remark "holder to wear spectacles which correct for distant vision and shall have available a second pair whilst exercising the privileges of the license." Based on a review of the first officer's medical records, there was no indication of any pre-existing medical condition or physiological factors that would have adversely affected his performance during the flight.

The first officer was reported to be a competent pilot and comfortable using personal computers. As the only first officer for the series of flights, he would have had to be an active crew member on duty on the flight deck for all take-offs, departures, arrivals, and landings for the series of flights.

1.5.4 Operating Flight Engineer

The flight engineer's licence was valid until 12 August 2005 and was endorsed for B747 aircraft. He was qualified and certified in accordance with the GCARs. His last medical was completed on 13 August 2004 and, based on a review of his medical records, there was no indication of any pre-existing medical condition or physiological factors that would have adversely affected his performance during the flight.

1.5.5 Loadmaster

The loadmaster was trained and qualified in accordance with company standards. Although a flight medical was not required in a licensing capacity, the loadmaster completed a company medical on 16 September 2000. He was found fit for employment and, based on a review of his medical records, there was no indication of any pre-existing medical condition or physiological factors that would have adversely affected his performance. Records indicate that the loadmaster had flown 421 hours on MK Airlines Limited aircraft during the previous 90 days.

1.5.6 Non-Operating Captain

The non-operating captain held a Ghanaian ATPL with a valid instrument rating. He was qualified and certified in accordance with the GCARs. His licence was annotated with a requirement for corrective lenses. His last medical was conducted on 15 July 2004 and he was found fit for duty. Based on a review of his medical records, there was no indication of any pre existing medical condition or physiological factors that would have adversely affected his performance. The non-operating captain was the pilot-in-command during the flight from Luxembourg-Findel Airport to Bradley International Airport.

1.5.7 Non-Operating Flight Engineer

The non-operating flight engineer's licence was valid until 26 January 2005 and was endorsed for B747 aircraft. He was qualified and certified in accordance with the GCARs. His last medical was completed on 27 January 2004 and, based on a review of his medical records, there was no indication of any pre-existing medical condition or physiological factors that would have adversely affected his performance.

1.5.8 Ground Engineer

The ground engineer held a Ghanaian maintenance licence endorsed for B747 aircraft. The ground engineer was not subject to a medical for licensing purposes. During his last company medical, he was found fit and, based on a review of his medical records, there was no indication of any pre-existing medical condition or physiological factors that would have adversely affected his performance.

1.6 Aircraft Information

1.6.1 General

Manufacturer	The Boeing Company
Type and Model	B747-244SF[6]
Year of Manufacture	1980
Serial Number	22170
Certificate of Airworthiness	Issued 03 May 2004; valid until 02 May 2005
Total Airframe Time/Cycles	80 619 hours/16 368 cycles
Engine Type (number of)	Pratt & Whitney JT9D-7Q (4)
Maximum Allowable Take-off Weight	377 842 kg
Recommended Fuel Type(s)	Jet A, Jet A-1
Fuel Type Used	Jet A-1

On 08 October 2004, the number 2 and number 3 engines were replaced. The throttles for the number 2 and number 3 engines were significantly staggered from the number 1 and

number 4 engines at reduced thrust power settings. This defect was written in the aircraft's logbook.

1.6.2 Aircraft Weight and Balance

1.6.2.1 Aircraft Empty Weight

The most recent calculations for the occurrence aircraft's weight and centre of gravity were conducted after a C-check in Jakarta, Indonesia, on 18 September 2004. A review of the 9G-MKJ *Aircraft Weight and C.G. Determination* document produced by Garuda Maintenance Facilities (GMF) AeroAsia, of the Garuda Indonesia Group, indicated an aircraft basic empty weight of 157 977.5 kg and an empty centre of gravity of 32.50 per cent mean aerodynamic chord (MAC).

A review of a duplicate copy of the BLT software for the occurrence aircraft, weight and balance summary page, indicated that the operating empty weight[7] was 157 977 kg; this was actually the basic empty weight of the aircraft. The BLT also indicated that the empty centre of gravity arm was 32.3 per cent MAC; this varied slightly from the 9G-MKJ *Aircraft Weight and C.G. Determination* document produced by GMF AeroAsia, which indicated 32.50 per cent MAC.

The occurrence aircraft carried a spares kit (also known as a fly-away kit) on board at the time of the accident flight. The kit contained spare aircraft parts and tools; MK Airlines Limited estimated the weight of the kit to be 800 kg. The aircraft also carried approximately 50 kg of catering for the crews. MK Airlines Limited used standard weights for the weight of the flight crew in the cockpit, totalling 270 kg. None of these three weights, which totalled 1120 kg, had been included in the operating empty weight in the BLT, or the mass and balance sheet that was used to calculate the aircraft weight for take-off.

1.6.2.2 Bradley International Airport Weight and Balance

The occurrence aircraft had a number of cargo floor power drive units (PDUs) removed from the aircraft and blanked off because they were unserviceable. As part of the cargo load, a large roll of steel was placed on a 20-foot-long pallet for a total weight of 13 206 kg. When the steel was being loaded onto the aircraft, it could only be moved by the cargo loading system as far as the functioning PDUs would permit. Normally, pallets can be manhandled into position if the PDUs are unserviceable, but, because of the weight of this pallet, it could only be loaded into positions LR and MR (see Figure 1).

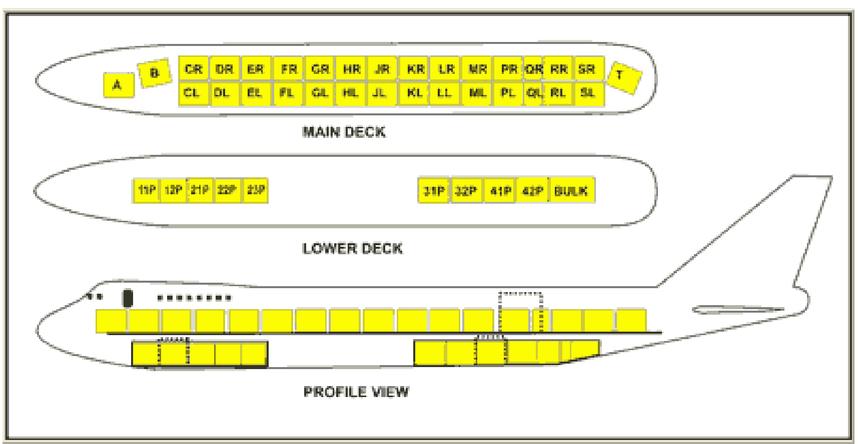


Figure 1. Cargo positions

The weight limits for positions LR and MR are 4264 kg respectively, for a total weight limit of 8528 kg. The weight of the steel and the pallet exceeded the limits by 4678 kg. The

MK Airlines Limited operations manual (OM), Part A, Chapter 8, stated in part that "the loadmaster/captain must comply with additional structural limits as specified in the loading manual with regard to the maximum mass per cargo compartment." If all the PDUs had been serviceable, the steel load could have been properly placed in positions HR and JR, where the limit was 13 608 kg.

In addition to the cargo loaded at Bradley International Airport, the aircraft was loaded with 5921 US gallons of Jet A fuel. The take-off mass for Bradley was 239 783 kg, with an MAC of 25 per cent and a stabilizer trim setting of 4.0 units. The lateral imbalance was 18 248 kg, which was within allowable limits. The aircraft was within the centre of gravity limits of 13 to 35 per cent MAC for that weight.

1.6.2.3 Halifax International Airport Weight and Balance

The cargo uploaded in Halifax was comprised of 18 cargo pallets. On 13 October 2004, a local freight forwarder delivered these pallets to the MK Airlines Limited cargo handling agent at Halifax International Airport. Each pallet contained hundreds of individual STYROFOAM™ packages of fresh seafood, supported on wooden skids and secured by a cargo net. The cargo handling agency created a cargo manifest spreadsheet for the flight by taking the gross weight of each pallet, which had been supplied on the cargo manifests by the local freight forwarder. The agency then added 130 kg tare weight for the weight of the pallet and netting, for the total gross weight per pallet. There were 86 wooden skids supporting the fresh seafood on the cargo pallets. The weight of the wooden skids was not accounted for in the cargo pallet gross weight provided by the local freight forwarder, nor in the cargo manifest spreadsheet. Generally, wooden skids weigh between 20 and 25 kg; therefore, approximately 1900 to 2000 kg of extra weight was not accounted for in the cargo manifest. The local freight forwarder did not weigh the built-up pallets nor did the ground handling agent at Halifax International Airport have the facilities to weigh built-up cargo pallets that were provided by others.

In addition to the cargo loaded at Halifax, the aircraft was loaded with 88 637 litres of Jet A-1 fuel. The mass and balance sheet left behind at Halifax by the crew of MKA1602 indicated a total ramp fuel of 90 000 kg, a take-off mass of 350 698 kg with an MAC of 23 per cent, and a stabilizer trim setting of 5.8 units. The lateral imbalance was 88 kg. The aircraft was within the centre of gravity limits for that weight. The company pre-planned flight documentation indicated a minimum of 86 690 kg of fuel and a planned cargo load of 109 920 kg for a planned take-off mass of 353 310 kg.

When the weight of the wooden skids (2000 kg) and the combined weight of the fly-away kit, catering, and the flight crew (1120 kg) were added to the 350 698 kg weight calculated by the crew, the actual aircraft weight would have been approximately 353 800 kg.

1.6.3 Take-off Thrust

The B747-200 was originally certified in 1971 with JT9D-7 engines, which had a maximum thrust of 46 300 pounds (dry) and 47 900 pounds when using water injection (wet)[8] on take-off. In 1979, the JT9D-7Q engine was certified for use on the B747-200. It had a maximum thrust of 53 000 pounds; the occurrence aircraft was equipped with JT9D-7Q engines.

The maximum thrust available to an engine is dependent on the air density (pressure altitude and temperature of the air) in which the engine is operating. The maximum thrust that can be used for take-off is provided in the approved AFM, and before every take-off, the flight crew must calculate the power setting of the engine to achieve the maximum thrust. To extend engine life, it is common practice to use de-rated or reduced thrust, or a combination of both, for take offs when maximum thrust is not required, such as when taking off from long runways or with light loads.

De-rated thrust is a take-off thrust level less than the maximum take-off thrust for which a separate set of limitations and performance data exists in the AFM. The occurrence aircraft had a de-rated thrust of 46 300 pounds (JT9D-7 dry) and was referred to as "Rating II (RTG II)" in MK Airlines Limited documentation. Reduced take-off thrust is a thrust setting up to 25 per cent less than the maximum or de-rated take-off thrust. A reduced thrust setting is not restrictive in that it allows the flight crew to use maximum thrust at any time during the take off, if desired.

The MK Airlines Limited OM stated that, when setting take-off thrust, the operating crew must advance thrust levers to 1.10 engine pressure ratio (EPR),[9] check that engine indications are stable and symmetrical, then advance thrust levers to approximately 1.20 EPR and call for "max thrust"[10] to be set by the flight engineer.

1.6.4 Aircraft Performance Data

According to the B747 AFM, Section 4, Performance, the stall speed for flap 20, at idle power and 353 800 kg, is 133 knots calibrated airspeed (KCAS). The stall speed is based on the aircraft in-flight and out-of-ground effect. The expected minimum unstick speed (Vmu)[11] for the Halifax International Airport configuration was determined to be approximately 150 ± 2 KCAS. The B747 has an over-rotation stall warning system that activates a control column shaker during take-off when the rate or angle of rotation is excessive. The warning is deactivated when a body landing gear leaves the runway. Two stall warning systems are activated when the nose gear leaves the runway. Control column shaker was not a recorded value on the flight data recorder (FDR).

The B747 AFM indicated that, for the pressure altitude and airport temperature at the Halifax International Airport at the time of the occurrence, an EPR setting of 1.60 was required for maximum thrust, with a maximum reduction of 0.21 EPR for reduced thrust. The de-rated maximum thrust EPR setting was 1.43, with a maximum reduction of 0.14 EPR for reduced thrust.

Climb power for the occurrence flight, derived from the MK Airlines Limited quick reference handbook (QRH), was 1.33 EPR. During a reduced thrust take-off, some pilots at MK Airlines Limited would set climb EPR rather than take-off EPR if the climb EPR was the higher value. Go-around power from the QRH was 1.52 EPR.

1.6.5 Tail Strike Information

According to the aircraft manufacturer, the B747-200 lower aft fuselage will contact the ground at a pitch attitude of 11.1º with static body gear oleo compression, and 13.1º with the body gear fully tilted and the oleos fully extended. The MK Airlines Limited OM indicated that the normal target pitch attitude for rotation is 12º with a rotation rate of 2º to 3º per second; lift-off should occur at approximately 10º pitch attitude. The manufacturer has determined that, for every five knots of airspeed below rotation speed (Vr),[12] the angle of attack must be increased by 1º to gain the equivalent amount of lift during the rotation.

1.7 Meteorological Information

The 0600 Halifax International Airport weather was as follows: wind 250º true (T) at five knots, visibility 15 statute miles (sm), overcast clouds at 1700 feet above ground level (agl), temperature 10ºC, dew point 9ºC, and altimeter setting 29.67 inches of mercury (in Hg). The weather issued at 0700 was as follows: wind 260ºT at six knots, visibility 15 sm, overcast clouds at 1800 feet agl, temperature 10ºC, dew point 9ºC, and altimeter setting 29.67 in Hg. The airport's terminal area forecast corresponded to the actual weather.

1.8 Aids to Navigation

At the time of the accident, the crew was using visual references for the take-off and was not relying on ground-based navigation aids. No discrepancies were discovered with the aids to navigation.

1.9 Communications

All communications between the Halifax International Airport air traffic controllers and MKA1602 were normal, and there were no deviations from published procedures. There were, however, some problems with the Aircraft Rescue and Fire Fighting (ARFF) communications (See Section 1.14.3 of this report).

1.10 Aerodrome Information

1.10.1 Introduction

The Halifax International Airport is located at latitude 44º52.85' N and longitude 063º30.52' W, at an elevation of 477 feet. It is a certified aerodrome operated by the Halifax International Airport Authority (HIAA) on land leased from Transport Canada (TC). Runway 24 was in use at the time of the accident. It is oriented 234º magnetic (M), constructed of asphalt and concrete, and is 8800 feet long by 200 feet wide. Runway 24 has a published take-off run available of 8800 feet and a clearway of 1000 feet, providing a take-off distance available of 9800 feet.

1.10.2 Airport Electrical Power Supply

Just before impact, the aircraft severed a power cable and several telephone cables supplying the airport. Four diesel generators with auto-start capability, available to provide backup power to the airport power grid, started when the power cable was cut. Three of the generators supplied power to the airport grid; however, a circuit breaker tripped due to a power surge when the aircraft cut through power lines adjacent to the main crash site, preventing the fourth generator from supplying power. Approximately one hour after the accident, power from the fourth generator was restored when technical personnel manually reset the main circuit breaker. The control tower at Halifax International Airport was equipped with a separate stationary uninterruptible power unit and an independent backup power generator; consequently, there was no loss of electrical power to the tower.

The Halifax International Airport fire hall normally would receive backup power from two of the four generators mentioned above. The generator with the tripped circuit breaker should have powered a relay to permit operation of the following fire hall systems: bunkroom lights, vehicle bay lights, and the automatic opening of the vehicle bay doors. Because these systems were not powered, the firefighters had to respond in a darkened environment, and the vehicle bay doors had to be opened by pushing the manual door-open button at each bay. Because the door motors were powered by an operating generator, the doors then opened. The vehicle bay lights in the fire hall were "high-pressure sodium bulbs," which take approximately 10 minutes to reach full brightness; therefore, they would have been ineffective in a quick response scenario.

Had the fourth generator operated as expected, it would have taken 25 to 30 seconds for the bunkroom lights to come on, because of the time it would have taken for the fourth generator to reach full capacity. The fire hall had been equipped with self-contained battery-operated lights; however, when the emergency power generators were installed, these lights were removed.

1.10.3 Runway 24 Slope

In 2002, TC requested that NAV CANADA[13] publish a slope of 0.17 per cent down for Runway 24 at Halifax International Airport in the *Canada Flight Supplement* and the *Canada Air Pilot*. TC's TP 312, *Aerodrome Standards and Recommended Practices*, Section 3.1.2.1, described how to calculate runway slope. Using TP 312, investigators from the Transportation Safety Board of Canada (TSB) calculated the slope for Runway 24 to be 0.19 per cent up. This error in direction and magnitude was not detected by NAV CANADA personnel before this information was published, nor was the error detected during subsequent reviews of these publications by the airport operator.

There are no standards for publishing slope values or slope changes for runways at Canadian airports, except that NAV CANADA documentation indicates that a slope of less than 0.3 per cent is not to be published.

Runway 24 has several slope changes. The two most significant are from the threshold of Runway 24 to the highpoint of the runway, which is 6975 feet from the threshold. The slope for this section is 0.24 per cent up. The slope for the remaining 1825 feet is 0.55 per cent down. The total absolute change in slope is 0.079 per cent up.

A review of non-Canadian aeronautical publications available to flight crews revealed conflicting information. One of these publications did not indicate any slope information for Runway 24. Another publication had the correct value and direction. A third described the slope for Runway 24 in two segments. The BLT runway information for Runway 24 was imported from a SITA[14] data file on 19 September 2003 at 0952. It stated that Runway 24 had a slope of 0.08 per cent up and a field length of 8800 feet, plus 150 feet of paved overrun.

International Civil Aviation Organization (ICAO) Annex 15, Aeronautical Information Services, Part 3, specifies that the detailed description of runway physical characteristics for each runway is to include information on the slope of each runway and its associated stopways. Chapter 2 of ICAO Annex 4, Aeronautical Charts, Paragraph 2.17.1, states in part, "States shall insure that established procedures exist in order that aeronautical data at any moment is traceable to its origin so to allow any data anomalies or errors, detected during the production/maintenance phases or in the operational use, to be corrected." The *Canadian Aviation Regulations* specify that the operator of an airport shall review each issue of each aeronautical information publication on receipt thereof and, immediately after such review, notify the Minister of Transport of any inaccurate information contained therein that pertains to the airport.

1.10.4 Earthen Berm

An earthen berm, with a concrete slab on top to anchor the localizer antenna, was located 1150 feet from the end of Runway 24 on the extended centreline (see photos 2, 3 and 4). This berm was constructed in the fall of 2003 to support a new localizer antenna at a height necessary to meet ICAO localizer signal coverage requirements. The berm was 11.6 feet high, but since the terrain sloped downwards from the end of the runway, the concrete pad on top of the berm was in fact the same elevation as the end of the runway. The localizer antenna projected another 10 feet from the top of the berm. At the same time, a similar berm was constructed off the end of Runway 06 at a distance of 650 feet from the end of the runway. There are similar earthen berms in use at other airports in Canada, including one at Fredericton, New Brunswick, and several at Toronto/Lester B. Pearson International Airport, Ontario.

NAV CANADA submitted an Aeronautical Obstruction Clearance Form to TC on 27 August 2003 for the construction of both berms to support new localizer antennae. Approval was received on 08 September 2003. However, airport personnel raised a number of concerns when the berm on the approach to Runway 24 was first being constructed, primarily because it was thought to be a potential hazard. The HIAA corresponded with TC and requested clarification on whether the berm would affect the airport's certification. Based on an inspection of the berm by TC personnel, TC advised the HIAA in a letter dated 08 October 2003 that the berms for the new localizers on both Runway 06 and Runway 24 were not in conflict with airport certification standards.

In a follow-up letter from TC to the HIAA on 22 October 2003, TC stated, "Based on information supplied by NAV CANADA, we have determined that the subject localizers are in compliance with airport certification standards. Additionally, clearways are not affected and the existing TODAs [take-off distances available] will remain unchanged." The letter concludes, "Thus, from an airport certification perspective, we have no concerns about the installation of the new localizers on Runway 06 or Runway 24."

Airport certification standards are contained in TP 312. Each end of runways 06 and 24 had a clearway to ensure that there was an obstacle-free zone for departing aircraft. An obstacle-free zone comprises the airspace above the approach surface, inner transitional surfaces, and that portion of the strip bounded by these surfaces that is not penetrated by any fixed obstacle other than one that is required for air navigation purposes, is low mass and frangibly mounted. The HIAA did not list any obstacles, as defined in TP 312, for the departure paths for runways 06 and 24. The earthen berm was not considered an obstacle because it did not penetrate into the obstacle-free zone.

TP 312 uses the ICAO phraseology of "standard" or "recommended practice" to identify specifications considered to have a direct impact on the safety of flight from those that affect only operational efficiency. Only the standards contained in TP 312 are mandatory for the certification of Canadian airports; recommended practices are optional and might or might not be implemented. One of the recommended practices in TP 312 is to establish a runway end safety area (RESA). A RESA is defined as an area symmetrical about the extended runway centreline and adjacent to the end of the strip, primarily intended to reduce the risk of damage to an aeroplane undershooting or overrunning the runway.

According to TP 312 recommended practices, a RESA should extend from the end of a runway strip for as great a distance as practicable, but at least 90 m (295 feet). The runway strips for runways 06 and 24 at Halifax extend for 60 m (197 feet) beyond the threshold of each runway. The minimum distance specified for a RESA in the recommendations therefore would be at least 150 m (492 feet) at Halifax International Airport. The berms for the localizers for runways 06 and 24 are both located beyond these minimum recommended distances. There is no RESA published for the Halifax International Airport. ICAO considers a RESA to be a standard (ICAO Annex 14, Section 3.5.1) rather than a recommended practice.

1.10.5 Halifax Automatic Terminal Information Service

The following automatic terminal information service (ATIS) broadcasts were issued during the time MKA1602 arrived and departed Halifax International Airport:

- Halifax International Airport information Victor, weather at 0400 Zulu[15] - wind 260 [degrees] at 7 [knots], visibility 15 [sm], ceiling 2200 [feet asl] overcast, temperature 10 [ºC], dew point 9 [ºC], altimeter 2966 in Hg, approach ILS Runway 24, landing and departing Runway 24, inform ATC that you have information Victor.

- Halifax International Airport information Whiskey, weather at 0500 Zulu - wind 260 at 5, visibility 15, ceiling 1800 overcast, temperature 10, dew point 9, altimeter 2967 in Hg, approach ILS Runway 24, landing and departing Runway 24, inform ATC that you have information Whiskey.

- Halifax International Airport information X-Ray, weather at 0600 Zulu - wind 270 at 5, visibility 15, ceiling 1700 overcast, temperature 10, dew point 9, altimeter 2967, approach ILS Runway 24, landing and departing Runway 24, inform ATC that you have information X-Ray.

1.11 Flight Recorders

1.11.1 Cockpit Voice Recorder

The cockpit voice recorder (CVR) was a Collins model 642C-1, part number 522-4057-010, serial number 1660, that was fitted in March 2004. The CVR was found under debris in its mounting bracket near its installed location (see Photo 5), and it had been exposed to fire and extreme heat for an extended period. The recording tape had melted; consequently, no CVR information was available to investigators. Although this model of recorder was not required to meet the more stringent fire test requirements that exist today, the conditions of extreme heat were such that the likelihood of any tape-based recorder surviving in those conditions is considered very low.

1.11.2 Flight Data Recorder

The flight data recorder (FDR) was a Sundstrand, part number 981-6009-011, serial number 2756, that was fitted in April 2004. It had a 25-hour recording capability and recorded a total of 107 parameters. The recording medium was Vicalloy tape. The FDR was found in the main cabin area forward of the wing root (see Photo 5). The FDR suffered impact and heat damage in the crash and the tape broke in two places. The FDR contained information from the previous six flights and good data for the accident flight. A small portion of data for the accident flight was not available because of the necessity to splice the tape where it had broken during the impact sequence.

1.11.3 Flight Data Recorder Data Losses

The FDR data had several areas where data were lost due to signal distortion and dropouts. In some areas, the distortion was such that no recovery could be made. Data cycling causing dropouts was observed during the taxi segment, the initial portion of the take-off and the final 12 seconds of the recording. The data cycling was left as valid data to show this characteristic on the data plots (before and at the start of the take-off roll), even though the recorded data for the affected parameters were not valid. This cycling was tagged as invalid in the last 12-second segment of the flight to remove the dropouts from the data plots.

1.11.4 Halifax Take-off - Flight Data Recorder Recorded Events

After push back, the aircraft began to taxi, the flaps were extended to 20º, and the horizontal stabilizer was set to 6.1 trim units,[16] where it remained for the duration of the flight. The flight control checks were completed during the taxi. The aircraft entered Runway 24 at Taxiway Delta and backtracked to the threshold. The aircraft then made a 180º turn to the right and, upon lining up with the runway (234ºM), the thrust levers were advanced and a rolling take-off was commenced at 0653:22.

At the start of the take-off roll, the thrust levers were smoothly advanced from ground idle thrust (approximately 1.0 EPR) to take-off power with all final EPR settings indicating between 1.3 and 1.33. The aircraft accelerated through 80 KCAS (0653:46) approximately 1800 feet from the threshold.

At 130 KCAS, the control column was moved aft to 8.4º to initiate rotation as the aircraft passed the 5500-foot mark of Runway 24 (3300 feet of runway remaining). The commanded elevator deflection was consistent with the control column input, and the aircraft began to rotate (see Appendix C - Take-off Sequence). The initial rotation rate was approximately 2.2º per second. The pitch attitude stabilized briefly at approximately 9º nose-up, with airspeed at 144 KCAS. The tilt switch[17] on the FDR continued to record GROUND. The control column was then moved further aft to 10º, and the aircraft responded with a further pitch up to approximately 11º; initial contact of the lower aft fuselage with the runway occurred at this time. The aircraft was approximately at the 8000-foot mark and slightly left of the centreline (see Photo 2). The control column was then relaxed slightly, to 9º aft.

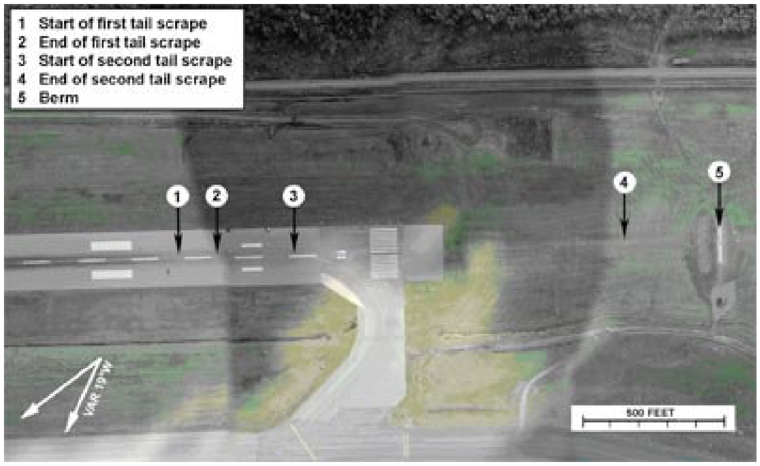


Photo 2. Location of scrape marks and berm

The pitch attitude stabilized in the 11º range for the next four seconds, and the lower aft fuselage contact with the runway ended briefly. With approximately 600 feet of runway remaining, the thrust levers were advanced to 92 per cent (100 per cent is full forward) and the EPRs increased to 1.60. With 420 feet remaining, the lower aft fuselage contacted the runway a second time. As the aircraft passed the end of the runway, the control column was 13.5º aft, pitch attitude was 11.9º nose-up, and airspeed was 152 KCAS. The highest recorded nose-up pitch of 14.5º (0654:24) was recorded after the aircraft passed the end of the runway at a speed of 155 KCAS, during which time the tilt switch discrete changed to AIR. The aircraft became airborne approximately 670 feet beyond the paved surface, the point where the ground scars ended. When the recorded tilt switch position changed to AIR, the airspeed was approximately 155 KCAS, consistent with the Vmu of 150 ± 2 KCAS, indicating that there was sufficient lift to fly. At this point in the FDR data, there were gaps in the recorded information due to data dropouts and data cycling (as described in Section 1.11.3 of this report).

Two additional pitch samples were recorded indicating rapid nose-down pitching to -20º (0654:29). This information was consistent with lower aft fuselage impact with the localizer berm and loss of the tail section, resulting in a subsequent nose-down pitching moment.

1.11.5 Halifax Take-off Compared to the Bradley Take-off

The FDR data for the take-off from Halifax International Airport (calculated aircraft weight of 353 800 kg) was compared with the Bradley International Airport take-off (aircraft weight of 239 783 kg) to determine what similarities, if any, existed between the two flights (see Appendix A - Flight Data Recorder Engine Data Comparison Between Bradley and Halifax and Appendix B - Flight Data Recorder Flight Controls Comparison Between Bradley and Halifax). The comparison focused on the take-off speeds, engine performance, rotation characteristics, and corresponding control inputs and control surface movements.

On both take-offs, the rotation speed was approximately 130 KCAS and 20º of flap was used. During the Bradley take-off, the aircraft reached rotation speed approximately 13 seconds sooner, indicating a higher rate of acceleration compared to the occurrence flight. The engine data were very similar for both take-offs, with the EPRs set in the 1.30 to 1.33 range. In both cases, the engines spooled up normally and stabilized at take-off thrust with no anomalies noted. On the Bradley take-off, the initial pitch rate at rotation was approximately 1.2º per second, and the aircraft climbed away four seconds later as the pitch angle increased through

6º. On the Halifax take-off, the pitch rate was higher at 2.2º per second; however, the aircraft did not lift off the runway as the pitch attitude stabilized near 10º. The pitch attitude subsequently reached the 11º range and eventually at least 14.5º.

1.12 Wreckage and Impact Information

1.12.1 Impact Information

The first indication of aircraft contact with the runway was a scrape mark, which began 830 feet before the end of Runway 24 and was 30 inches left of the runway centreline; it became progressively wider, ending 705 feet from the end of the runway. The scrape mark formed a line approximately one-half degree off the centreline toward the left (see Photo 2).

A second scrape mark began 412 feet from the end of the runway and was initially about 3 inches wide, expanding to about 24 inches wide at the runway threshold. There were aluminum scrapes and shavings all along this scrape mark. It continued through the paved runway overrun area and across the grassy area. On the grassy area, the ground scar was initially about 24 inches wide and 2 inches deep, eventually fanning out to about 30 inches wide (see Photo 3). The ground scar became less pronounced until it disappeared at a point approximately 315 feet before the berm, indicating that the aircraft became airborne. The only indication of aircraft contact with the ground was the ground scar caused by the lower aft fuselage. There was no indication that the tires contacted the ground beyond the paved surface. No primary aircraft structure was found in the debris trail before the berm.

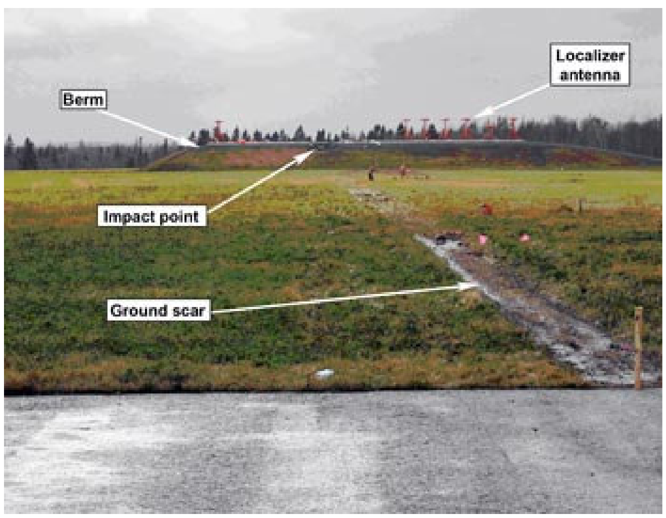


Photo 3. View of ground scar and initial impact point with the berm

Fuselage structure, comprising the fuselage joint of the aft pressure bulkhead at Station 2360 and some adjacent belly skin, was found embedded in the berm. These pieces were embedded approximately 18 feet to the left of the extended runway centreline, about 30 inches below the top of the concrete pad, and had penetrated about 24 inches into the berm. Black rubber transfer marks, consistent with aircraft tire contact, were on some of the fractured pieces of the ILS antenna, indicating that the tires had struck the antenna (see Photo 4). No similar marks were observed across the concrete pad on top of the berm, indicating that the tires were above the concrete pad as the aircraft passed over it. The pieces of aircraft belly skin found embedded in the berm were identified as coming from the centreline of the aircraft and included roughly the same amount of structure from each side of the centreline. This is consistent with the aircraft having struck the berm in a roughly wings-level attitude. The aircraft pitch was between 15º and 24º at berm impact. If the aircraft was pitched at less than 15º, the wheels would have struck the top of the berm, and if the aircraft was pitched at greater than 24º, the tires would not have struck the antenna.

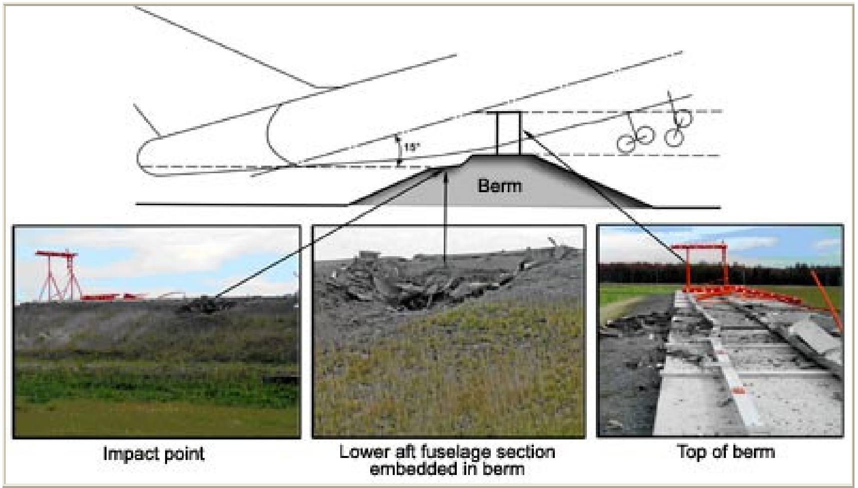


Photo 4. Minimum aircraft pitch attitude at point of impact with berm

Immediately beyond the berm, there was extensive debris that included the vertical and horizontal stabilizers, a section of aft pressure bulkhead, the tail cone, the auxiliary power unit, and some pieces of aft fuselage belly skin. In the wooded area beyond the berm, there were numerous smaller pieces of aircraft structure and cargo. The debris trail then diminished until the main impact, suggesting that, following the separation of the empennage, the rest of the aircraft remained relatively intact until impact (see Photo 5).

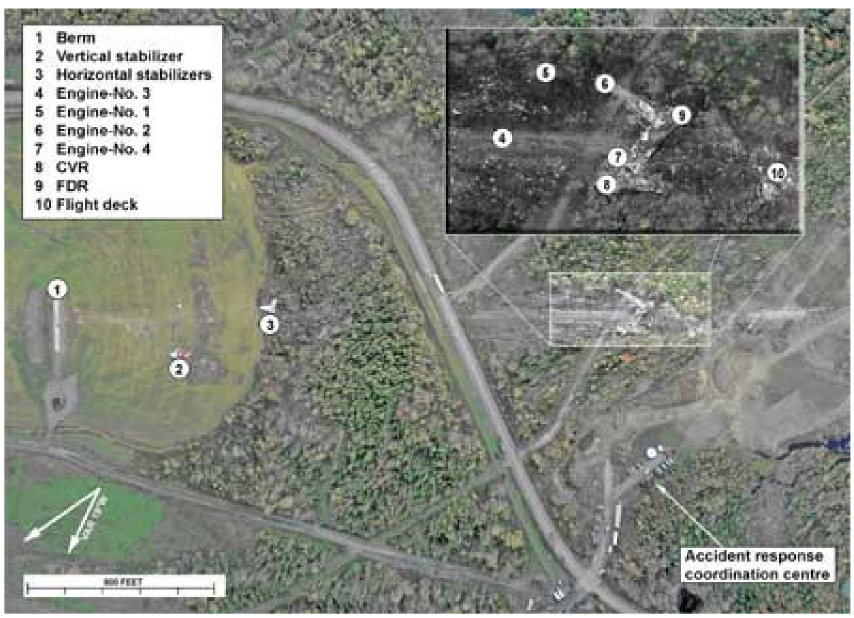


Photo 5. Accident site and wreckage location

The aircraft struck a wooded area beyond the airport boundary fence in a downward trajectory of approximately 6º to 16º, in a roughly wings-level attitude. It struck nose-first, with sufficient force that the forward fuselage section separated from the remainder of the fuselage, resulting in severe structural break-up and an intense post-crash fire. The debris trail extended approximately 1000 feet into a quarry. There was no indication of pre-impact fire damage.

1.12.2 Wreckage Examination

The primary flight controls (rudders, elevators, horizontal stabilizers, and ailerons) and secondary flight controls (spoilers, trailing edge flaps, leading edge variable camber, and Krueger flap) were examined, and no discrepancies were noted that would have indicated a pre-existing condition that would have prevented normal operation. Stabilizer position was determined to be between 5.5 and 5.6 units[18] aircraft nose-up based on actuator ballscrew measurements. Three of the four trailing-edge flaps were in the flaps 20 position, and the fourth flap was found in the flaps 10 position, based on ballscrew measurements. However, based on FDR data, it is likely that the fourth flap was in the flaps 20 position during take-off and was repositioned during the impact sequence.

The auto throttle speed indicator was recovered with a reading of 037 through the viewing window. Based on smear and dirt patterns, it was concluded that the likely value of the indicator after impact was 147. The captain's airspeed indicator (ASI) was recovered; the instrument face was missing and there were no plastic bugs on the external ring.

A number of paper documents were recovered from the accident site and examined by TSB investigators. The most significant of these was the voyage report sheet for this series of flights, which contained the MKA1601 captain's comments regarding duty time (see Section 1.18.5.3 of this report). The completed take-off data card used by the crew for the accident take-off was not found.

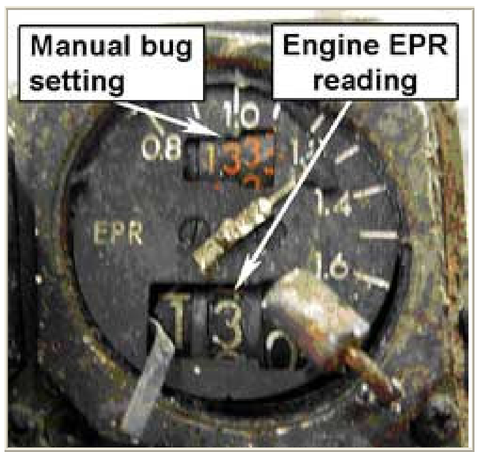


Photo 6. Engine number 4 EPR gauge

The number 2, number 3 and number 4 EPR gauges were recovered and examined. The number 2 EPR gauge had a manual bug setting of 1.32 and an engine indication reading of 1.01; the number 3 EPR gauge had a manual bug setting of 1.3X (the last digit had broken off at impact) and an engine indication reading of 1.02; and the number 4 EPR gauge (see Photo 6) had a manual bug setting of 1.33 and an engine indication reading of 1.305. The EPR settings on the three recovered instruments were set to 1.32-1.33. These readings were considered to be reliable, with the slight differences attributed to movement during the impact sequence.

FDR recorded data indicated that the engines were operating at a high power setting at the time the aircraft struck the berm; after impact, the data show that the power was reduced before final impact with the terrain. An on-site examination of the engines showed damage consistent with the engines still producing power at the time of final impact. The landing gear was in the down position.

Fuel tests performed on the fuel supplier's fuel storage tanks did not identify any discrepancies.

All the thrust reversers were stowed at the time of the impact. Aircraft records indicated that the thrust reverser system of the number 3 engine was "locked out" (in the stowed position). The FDR data indicated that the thrust reversers had not been deployed before impact.

2.0 Analysis

2.1 Introduction

In this accident, the flight crew's take-off performance calculations resulted in an error that remained undetected until the aircraft reached a point where the crew's response was too late to avert the accident. The analysis will focus on those events, conditions and/or underlying factors that were causal or contributing to the accident. Areas where there were additional and undesirable risks to the system will also be discussed.

2.2 Halifax International Airport - Accident-Related Issues

2.2.1 Electrical Power Supply

The Halifax International Airport fire hall electrical system was configured to provide two separate sources of emergency power (generators) in case of a power failure. However, one failed to provide power because the main circuit breaker had tripped, preventing some of the associated electrical systems in the fire hall from operating as designed. The firefighters, therefore, had to respond in very dim light conditions during their initial response. Aside from creating some confusion, there was an increased risk of injury to the firefighters and the potential for a delayed response. The earlier system of self-contained battery-operated lights, which had been removed following the installation of an emergency power generator, would have provided immediate illumination of the bunk room and vehicle bay.

2.2.2 Grid Map

Grid coordinates were not used to direct the Halifax International Airport ARFF unit or any other responders at any time during the response to this accident. Because the weather conditions and visibility were good, the first responders were able to easily locate the accident site. There was, however, some confusion with other responding units as to the exact location of the accident site.

The air traffic controllers regularly assist the airport firefighters with grid run training, yet the controllers are not required to use grid coordinates when directing ARFF to an accident site. The use of grid coordinates during an emergency would prevent confusion and could reduce critical response time.

2.2.3 Persons and Dangerous Goods On-Board Information

Air traffic controllers were initially unsuccessful in their attempts to get information on the number of persons and dangerous goods on board the aircraft. One hour after the accident, MK Airlines Limited provided information regarding the number of persons on board and indicated that no dangerous goods were loaded in Halifax. Since all the dangerous goods carried on MKA1602 had been loaded at the previous stop, Bradley International Airport, no one in Halifax had any information regarding the dangerous goods. It was not until 10 hours after the accident that ARFF received a listing of the dangerous goods that had been loaded at Bradley. A lack of timely information concerning dangerous goods could have jeopardized the safety of the ARFF personnel and other responding personnel. In the case of a survivable aircraft accident, knowledge of the number of occupants could be critical to successful rescue efforts.

2.2.4 Runway Slope

The slope for Runway 24 was published incorrectly in the *Canada Flight Supplement* and the *Canada Air Pilot* as 0.17 per cent down. Slope information is a consideration when calculating aircraft take-off and landing performance. If published slope information is incorrect, aircraft performance data could be incorrectly calculated. It could not be determined how the

0.17 per cent value was determined. The incorrectly published runway slope was not a factor in the take-off performance of MKA1602.

2.2.5 Earthen Berm

NAV CANADA obtained the required approval from TC for construction of the berm at the end of Runway 24. As part of the approval process, the berm was evaluated for obstacle clearance in accordance with TC's TP 312. The berm was not considered an obstacle by definition because it did not penetrate the plane of the obstacle-free zone. Obstacles are only considered hazards if they will affect the climb profile of an aircraft that has met its certification criteria.

There are no specific standards or recommended practices regarding the construction and risk assessment of berms or similar immovable objects in the runway overrun/undershoot areas, except in the case where they constitute an obstacle or they impinge on an established RESA. TC's guidance considers a RESA only to be a recommended practice, yet ICAO considers it to be required standard. There was no RESA published for Runway 06 or Runway 24 at Halifax International Airport. The ILS localizer berms were both located beyond the minimum recommended RESA distances.

2.2.6 Radio Communications

The various communications devices that emergency response personnel tried to use for communication at the crash site and between the crash site and other areas did not provide reliable communications. These communication difficulties complicated coordination during the response, and in other circumstances, could have hampered a rescue attempt or quick evacuation of an injured person.

2.3 Weight and Balance

The aircraft operating empty weight did not include crew and operational equipment carried on board the aircraft. Therefore, every time a mass and balance sheet was completed for the occurrence aircraft, the crew would not be aware that the aircraft was actually 1120 kg heavier than calculated. In some cases, this could have put the aircraft over its maximum allowable take-off or landing weight.

The ground handling agent at Halifax International Airport did not have the facilities to weigh built-up pallets that were provided by others, and because the manifest provided by the freight forwarder was believed to be accurate, an incorrect cargo manifest spreadsheet was created. The unverified cargo weight at Halifax allowed the extra weight of the wooden skids to go unaccounted for and could have also contributed to an overweight condition. As well, the failure to detect an error in the load weight could result in adverse aircraft performance and, potentially, an accident. In this case, the aircraft was still within the allowable weight and balance limits for the take-off at Halifax.

MK Airlines Limited was aware that some loadmasters had been using an unapproved electronic version of the load planning sheet for approximately 2½ years before the accident. The company did not prevent the loadmasters from using this software, even though it had not been verified that the software and database were free from errors. Therefore, there was a risk that an aircraft could have been improperly loaded without the crew's knowledge. This was an example of the company not exercising adequate oversight to correct a known adaptation of company procedures by flight crews.

2.4 MK Airlines Limited

2.4.1 MK Airlines Limited Expansion

MK Airlines Limited had grown significantly during its relatively short history. The company's commercial success and subsequent expansion increased demands on its infrastructure. The addition of the B747 aircraft added significantly to the Training Department's challenge of meeting the demand for qualified flight crews. At the same time, flight crew turnover was increasing as individuals found more attractive employment elsewhere. Also, the company's policy of recruiting from southern Africa limited the pool of new potential crew members. All these factors contributed to a shortage of flight crew required to meet the flying or production demand. This shortage of flight crews increased the potential for increased fatigue and stress among the personnel.

2.4.2 Rest, Duty and Flight Time

Although the OM stated that flights would not be planned beyond 24 hours, the Crewing Department at MK Airlines Limited routinely scheduled flights in excess of that limit. There was no effective program in place to monitor how frequently these planning exceedences occurred, nor was there a program to detect and monitor exceedences beyond the planned duty days. In the absence of adequate company corrective action regarding these exceedences, crews developed risk mitigation strategies that included napping in flight and while on the ground to accommodate the longer scheduled duty days. This routine non-adherence to the OM contributed to an environment where some employees and company management felt that it was acceptable to deviate from company policy and/or procedures when it was considered necessary to complete a flight or a series of flights.

There is a reasonable limit to the time a flight crew can remain on duty before acute fatigue begins to induce unacceptable human performance deficiencies. This is regardless of the crew composition and the adequacy of the rest facilities on board the aircraft. Examination of the occurrence crew's work/rest/sleep and duty history indicated that the operating crew would have been at their lowest levels of performance because of fatigue at, or shortly after, their arrival in Halifax. This state of fatigue would have made them susceptible to taking procedural shortcuts and reduced their situational awareness. This period of low performance would have been present when the take-off performance data were calculated, the before-flight SOPs were not followed, and the inadequate take-off performance was not recognized.

The company's flight and duty scheme allowed flights to be scheduled up to 24 hours with only three pilots required. This meant that there would be either only one captain or one first officer in the crew. Because most crew members were only qualified to occupy either the left or right pilot seat, two of the assigned pilots would have to be present for every take-off, departure, arrival, and landing for the entire route. This resulted in the lone captain or first officer being subjected to a disproportionate amount of flight deck duty and, therefore, more vulnerability to fatigue. For this series of flights, the first officer was the critical crew member in this respect.

The first officer had checked out of the hotel in Luxembourg at 0925 on October 13, but it is known that he was awakened earlier than 0848, perhaps as early as 0630 or 0700. It is probable that he was not in the cockpit for a few hours on the first flight, but it is unlikely that he would have slept or had a good rest because of circadian rhythm effects. As other MK Airlines Limited flight crews indicated, it was not easy to get rest on the flight to Bradley International Airport because of the time of day. The flight from Bradley to Halifax took 1 hour 9 minutes, and the first officer would have been in the cockpit during this flight. Therefore, he would likely have been the most fatigued pilot.

The aircraft was on the ground at Halifax International Airport for 1 hour 42 minutes. Twice during this time, it was noted by ground personnel that the first officer was not in the cockpit, and it was common for flight crew to nap or rest if the turnaround time was long enough. It is likely that he took a nap between the time the take-off performance data were calculated and when he was required to be back in the cockpit to prepare for the departure.

If the first officer had been sleeping while the aircraft was on the ground in Halifax, he would have been susceptible to sleep inertia for 10 to 15 minutes after waking up. As a result, he would have been less alert than usual when he first entered the cockpit, the period when the performance data would have been set from the take-off data card information. In addition, if the captain had carried out some of the first officer's pre-flight duties to allow him to sleep, this would have further removed the first officer from the cockpit environment and decreased his situational awareness.

At the time of the occurrence, MK Airlines Limited rest, duty and flight time scheme was one of the least restrictive among ICAO signatory states. The company's increase of the maximum flight duty time for a heavy crew from 20 to 24 hours also increased the potential for fatigue.

2.4.3 MK Airlines Limited Company Risk Management

MK Airlines Limited flight crews often flew into airports with poor facilities, experienced frequent delays and equipment malfunctions, and were scheduled for lengthy duty periods, often with limited on-board rest facilities. Many of the crews, supervisors and managers were accustomed to difficulty, hardship, and overcoming challenges. The growth and success of the company also had a great deal to do with the familial environment. Unfortunately, some of the strengths that this environment brought also generated weaknesses. These weaknesses were in the form of accepting shortcuts and deviations from procedures when it was deemed appropriate. An example of this was the acceptance of non-adherence to company direction and procedures by both management and line personnel.

Acceptance of non-adherence to company direction and procedures by managers was often tacitly accepted in the belief that it did not generate an unacceptable risk. Although three previous accidents should have been significant risk indicators for the company, there was an overall acceptance that the commercial growth (production) was being managed adequately in terms of risk (protection).

Several of the operating norms that were identified were similar in nature to those in James Reason's book. For example, shortcuts (non-adherence to procedures) had become a habitual part of routine work practices. Reason states, "This gradual reduction in the systems safety margins renders it [the company] increasingly vulnerable to particular combinations of accident-causing factors."

SOPs are established for the safe and efficient operation of an aircraft and are considered to be a critical defence toward ensuring consistent and safe operational outcomes. For this crew, the SOPs were critical for ensuring that the take-off performance data were calculated correctly, and any potential errors in that data were detected before the take-off was attempted. Non-adherence to SOPs, as was shown in this accident, can have catastrophic consequences.

2.4.4 Company Oversight of Operations

The company OM, which had been approved by the GCAA, contained a description of how the company was to conduct flight operations safely and within the regulations. Many areas of the OM were incomplete, out of date or inadequate. Moreover, the Operations Manager was over tasked to a point where adequate supervision and management of day-to-day flight operations was not always possible. The familial nature of the company also interfered at times with ensuring that company personnel consistently adhered to company policies and procedures.

2.4.5 Company Introduction of the Boeing Laptop Tool

The BLT was introduced by MK Airlines Limited without direction, assistance or approval from the GCAA. Although advisory and guidance references of the FAA and Joint Aviation Authority were used, the introduction was without adequate training and evaluation. The crew reference material was self-study and there was little direct training provided. Furthermore, the quick reference information provided in the Notice to Flight Crew of 29 March 2004 did not specifically remind pilots that, when returning from the weight and balance page, the take-off weight as listed in that page would appear in the planned take-off weight block on the performance page. This feature is believed to be a key element in how the incorrect take-off performance data were generated. It is unknown if the user(s) of the BLT in this occurrence was fully conversant with the software, in particular this feature.

2.5 Regulatory Oversight of MK Airlines Limited

In general, the safety oversight the GCAA conducted on MK Airlines Limited was limited. The GCAA's oversight effectiveness was adversely affected by the necessity to maintain a greater amount of scrutiny on another Ghana-registered airline, even though the following significant risk indicators were present at MK Airlines Limited:

- the company had had three previous accidents;
- it had been in a continuous period of growth for some time; and
- there had been deficiencies noted related to non-adherence to OM policy and SOPs identified.

The delay in obtaining Ghana parliamentary approval for new regulations and the diversity of the company's operations also affected the oversight activities. Particularly noteworthy was the undetected, ongoing and substantial exceedences related to crew flight and duty times.

In general, the regulatory oversight of MK Airlines Limited by the GCAA was not adequate to detect serious non-conformances to flight and duty times, or ongoing non-adherence to company directions and procedures.

2.6 Halifax Take-off Performance Data

Without a CVR, it was difficult to determine the exact reasons the flight crew used a low EPR setting and a low rotation speed; however, a comparison of the Bradley take-off performance data against the Halifax take-off performance data was very revealing. The first part of this section will discuss possibilities that were likely not a factor in the take-off performance of the aircraft.

One possibility is that the flight crew did not change the airspeed bugs from their positions after the Halifax landing. If this were true, two white bugs would have been set together at 133 knots, appearing to be a single airspeed bug position. The command speed bug would have been set at 143 knots, appearing to be the second airspeed bug position.[28] This would have appeared unusual to the flight crew for a take-off because the command speed bug would usually be the third bug in order, not the second. Also, when Vr was called at the second bug, the FDR would have recorded the aircraft rotating after 143 knots. The FDR data showed the aircraft rotating at 130 knots. This scenario is unlikely.

Another possibility is that the flight crew used the Bradley take-off data card since the power settings and rotations were similar. Had the flight crew not completed their post-flight activities in Halifax and not put the Bradley take-off data card in the trip envelope, then it could have been possible to mistakenly use the Bradley take-off data card. However, the card would have had a weight of 240 000 kg written on it, with a stabilizer trim setting of 4.0 units.

It is likely that the captain would have noticed the lower weight and a different trim setting from the one used in Halifax when he compared the mass and balance sheet to the take-off data card. The trim setting that had been determined by the crew in Halifax was appropriate for the aircraft actual take-off weight at Halifax. The correct trim value for Halifax was also confirmed by examination of the FDR data, the trim indicator and the screw jack measurements. If the Bradley data card had been used in Halifax, then a flight crew member would also have had to erase or cross out the Bradley trim value and replace it with the Halifax value. This scenario is unlikely.

If the flight crew had completed a new take-off data card for the Halifax International Airport, they would have had three options to calculate the take-off data: runway analysis charts, Volume 2, or the BLT. Since the runway analysis charts had been removed from all the aircraft, this scenario is only possible if one of the flight crew members had his own personal copies; this is unlikely. The take-off speeds chart of Volume 2 does not provide for obstacle clearance. If the crew had calculated the speeds based on the obstacles by using Volume 2, it would have been time consuming because of the work involved in finding and interpreting all the graphs, tables and charts. If the crew used only the take-off speeds chart of Volume 2, they would have first written the flight planned take-off weight of 353 tonnes onto the take-off data card, then transcribed a V1 of 150 knots, a Vr of 161 knots, and a V2 of 172 knots. Also, if Volume 2 had been used, it would not explain the thrust setting of 1.33 EPR. The BLT had been in use for several months and it was reported that it was being used for take-off performance calculations. Therefore, it is unlikely that Volume 2 was used. The BLT was most likely the source used for the take-off data. Consequently, it is most likely that the performance data error came from the misuse or misunderstanding of the BLT.

There are various scenarios that would have created the erroneous data. Assuming that the user input the correct airport, runway, and atmospheric information, then the only factor that would determine the V speeds and the EPR settings is the weight of the aircraft used in the planned weight box. If the user mistakenly used the zero fuel weight (262 000 kg) or landing weight (281 000 kg), the rotation speeds would be too high compared to what was found on the FDR. Another possibility is that the user input 253 000 kg instead of 353 000 kg by mistake; again, this weight is too high for the rotation speed in Halifax recorded on the FDR. Therefore, the only weight that generates the same rotation speed and EPR settings as found in Halifax is the Bradley weight, 240 000 kg.

The user would likely transcribe the weight of 353 000 kg from the flight plan on a white take off data card. When the BLT program was launched, all the previous settings, data, and information from the last use would have been populated in all the fields. The BLT was last used at Bradley International Airport with RTG II. Therefore, once the user opened the software on the RTG II page, he would have had to change all the fields to the Halifax International Airport, runway and ATIS. If the maximum thrust rating (7Q engines) had been selected, the lowest EPR value that could have been generated by the BLT was 1.40 EPR; therefore, the RTG II page had to have been used. Anytime after that, if the user opened the weight and balance page, for whatever reason, and returned to the take-off performance page, the planned weight dialogue box would be populated with the take-off weight from the weight and balance page, that is Bradley (240 000 kg). If the user did not know about this feature or did not notice the change and selected "calculate," the V speeds and EPR setting would have been identical to those for take-off from Bradley (see Figure 6).

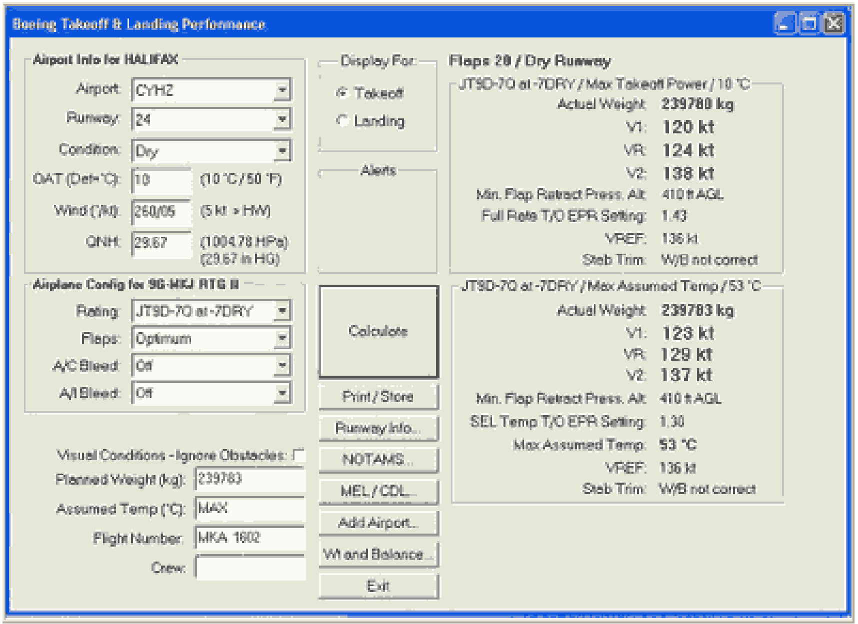


Figure 6. Bradley weight at Halifax

A more comprehensive training program for the BLT that emphasized human factors and the potential for human error as described in the guidance material, combined with a method of ensuring that individuals were competent using the software, would certainly have reduced the possibility of this type of operator error.

If the user then wrote these performance numbers on the take-off data card with the correct planned weight of 353 000 kg for Halifax, it is likely that the error would not be noticed at this point. For this error to proceed to the next level, the other crew member either did not do a cross-check or did a cross-check and made the same error.

It is highly unlikely that both crew members would make the same error. For the incorrect V speeds to be set on the ASIs, it is likely that the gross error check for the planned weight of 353 000 kg was not done, because if it had been, the error would have been detected. Once the bugs were set on both ASIs, any subsequent checks would just validate the erroneous settings. If the weight of 353 000 kg was written on the card, then it would further support the numbers being correct when the captain signed and cross-checked the mass and balance sheet, and when the flight engineer set his total weight indicator.

If the Boeing T-card or a company-amended version of the T-card had been used, the take-off weight used to generate the performance data would have been printed on the T-card and it would not have matched the aircraft weight calculated by the loadmaster and noted on the mass and balance sheet.

2.7 Failure to Recognize Inadequate Take-off Performance

In this accident, the take-off was attempted using a thrust setting and take-off speeds significantly lower than those required to become safely airborne. The company's standard call for "Set MAX POWER" during every take-off would not have provided any additional opportunity to make the crew aware if the power being set was maximum or reduced. Once the take-off began, the flight crew did not recognize that the aircraft's performance was significantly less than the scheduled performance, until they reached a point where their response was insufficient to avert the accident.

Several similar accidents and incidents have shown that there have been other crews throughout the aviation industry that have not recognized inadequate take-off performance.

Some of these occurrences have resulted in substantial aircraft damage and, in several cases, substantial loss of life. Notwithstanding over 30 years of effort within the industry, there still does not appear to be an acceptable industry "in-cockpit" defence that would provide crews with timely information when take-off performance is inadequate to become safely airborne.

2.8 Summary

The take-off data card was most likely completed using performance data from the BLT. The FDR data for the Halifax take-off was nearly identical to that of the Bradley take-off, indicating that the Bradley take-off weight was used to generate the performance data in Halifax. The Bradley weight in the weight and balance page was likely unknowingly transferred to the performance page due to a reversion feature of the software. The user subsequently selected "calculate," which resulted in the generation of take-off performance data containing incorrect V speeds and thrust setting for Halifax. The flight crew used the incorrect V speeds and thrust setting during the take-off attempt; however, the settings were too low, especially the thrust setting, to enable the aircraft to take off safely.

Factors that likely contributed to the incorrect take-off data being generated and then not being detected before the take-off attempt were flight crew fatigue, non-adherence to procedures, inadequate training on the BLT, and personal stresses. Once the take-off had commenced, the crew's situational awareness likely was not sufficient to allow them to detect the inadequate acceleration before it was too late to take off safely. Factors that likely contributed to this condition were flight crew fatigue and a dark take-off environment.

3.0 Conclusions

3.1 Findings as to Causes and Contributing Factors

1. The Bradley take-off weight was likely used to generate the Halifax take-off performance data, which resulted in incorrect V speeds and thrust setting being transcribed to the take-off data card.

2. The incorrect V speeds and thrust setting were too low to enable the aircraft to take off safely for the actual weight of the aircraft.

3. It is likely that the flight crew member who used the Boeing Laptop Tool (BLT) to generate take-off performance data did not recognize that the data were incorrect for the planned take-off weight in Halifax. It is most likely that the crew did not adhere to the operator's procedures for an independent check of the take-off data card.

4. The pilots of MKA1602 did not carry out the gross error check in accordance with the company's standard operating procedures (SOPs), and the incorrect take-off performance data were not detected.

5. Crew fatigue likely increased the probability of error during calculation of the take off performance data, and degraded the flight crew's ability to detect this error.

6. Crew fatigue, combined with the dark take-off environment, likely contributed to a loss of situational awareness during the take-off roll. Consequently, the crew did not recognize the inadequate take-off performance until the aircraft was beyond the point where the take-off could be safely conducted or safely abandoned.

7. The aircraft's lower aft fuselage struck a berm supporting a localizer antenna, resulting in the tail separating from the aircraft, rendering the aircraft uncontrollable.

8. The company did not have a formal training and testing program on the BLT, and it is likely that the user of the BLT in this occurrence was not fully conversant with the software.

3.2 Findings as to Risk

1. Information concerning dangerous goods and the number of persons on board was not readily available, which could have jeopardized the safety of the rescue personnel and aircraft occupants.

2. Failure of one of the airport emergency power generators to provide backup power prevented the operation of some automatic functions at the fire hall after the crash alarm was activated, increasing the potential for a delayed response.

3. Grid map coordinates were not used to direct units responding to the crash and some responding units did not have copies of the grid map. The non-use of grid coordinates during an emergency could lead to confusion and increase response times.

4. Communication difficulties encountered by the emergency response agencies complicated coordination and could have hampered a rescue attempt or quick evacuation of an injured person.

5. A faulty aircraft cargo loading system prevented the proper positioning of a roll of steel, resulting in the weight limits of positions LR and MR being exceeded by 4678 kg (50 per cent).

6. The company increase of the maximum flight duty time for a heavy crew from 20 to 24 hours increased the potential for fatigue.

7. Regulatory oversight of MK Airlines Limited by the Ghana Civil Aviation Authority (GCAA) was not adequate to detect serious non-conformances to flight and duty times, nor ongoing non-adherence to company directions and procedures.

8. The delay in passing the new *Civil Aviation Act, 2004* hindered the GCAA's ability to exercise effective oversight of MK Airlines Limited.

9. Company planning and execution of very long flight crew duty periods substantially increased the potential for fatigue.

10. The company expansion, flight crew turnover, and the MK Airlines Limited recruitment policy resulted in a shortage of flight crew; consequently, fewer crews were available to meet operational demands, increasing stress and the potential for fatigue.

11. There were no regulations or company rules governing maximum duty periods for loadmasters and ground engineers, resulting in increased potential for fatigue induced errors.

12. The MK Airlines Limited flight operations quality and flight safety program was in the early stages of development at the time of the accident; consequently, it had limited effectiveness.

13. The berms located at either end of runways 06 and 24 were not evaluated as to whether they were a hazard to aircraft in the runway overrun/undershoot areas.

14. The operating empty weight of the aircraft did not include 1120 kg of personnel and equipment; consequently, it was possible that the maximum allowable aircraft weights could be exceeded unknowingly.

15. The ground handling agent at Halifax International Airport did not have the facilities to weigh built-up pallets that were provided by others. Incorrect load weights could result in adverse aircraft performance.

16. Some MK Airlines Limited flight crew members did not adhere to all company SOPs; company and regulatory oversight did not address this deficiency.

3.3 Other Findings

1. An incorrect slope for Runway 24 was published in error and not detected; the effect of this discrepancy was not a significant factor in the operation of MKA1602 at Halifax.

2. The occurrence aircraft was within the weight and centre of gravity limits for the occurrence flight, although the allowable cargo weights on positions LR and MR were exceeded.

3. Based on engineering simulation, the accident aircraft performance was consistent with that expected for the configuration, weight and conditions for the attempted take-off at Halifax International Airport.

4. There have been several examples of incidents and accidents worldwide where non adherence to procedures has led to incorrect take-off data being used, and the associated flight crews have not recognized the inadequate take-off performance.

5. No technical fault was found with the aircraft or engines that would have contributed to the accident.

4.0 Safety Action

4.1 Action Taken

4.1.1 Safety Advisory A040058-1

On 20 October 2004, the Transportation Safety Board of Canada (TSB) issued Safety Advisory A040058-1 (*Verification of Cargo Weights*) to Transport Canada (TC). The Safety Advisory indicated that TC might wish to examine the adequacy of cargo handling procedures, both inside and outside Canada, and, in particular, the adequacy of load weight verification and the regulatory oversight of these issues.

On 09 December 2004, TC responded to Safety Advisory A040058-1. The letter quoted several regulations applicable to commercial operations: International Civil Aviation Organization (ICAO) standards and recommended practices, *Canadian Aviation Regulations, Joint Aviation Requirements* (JARs), and *Federal Aviation Regulations* (FARs). TC stated that the intent of the regulations is to ensure that the actual weight of the cargo, including the weight of the contents, the packing material, the packaging, the pallet or unit load device, the strapping, the wrapping, and any other device or material being transported with the cargo is accounted for in the total weight of the cargo. TC further stated that the regulations clearly indicate that it is an operator's responsibility to ensure that proper weighing procedures are in place to support its operations.

It is TC's position that the existing regulations and standards adequately address the issues raised in the Safety Advisory. However, in light of the recent accident in Halifax, Nova Scotia, and to reinforce the absolute necessity for accurate load control, TC published a Commercial and Business Aviation Advisory Circular on this issue on 04 June 2005.

4.1.2 Safety Advisory A040059-1

On 22 October 2004, the TSB issued Safety Advisory *A040059-1* (*Runway Slope Information - Publication Errors*) to TC. The Safety Advisory raised a concern about the accuracy of published runway slope information. The slope datum for Runway 24 at Halifax International Airport published in Canadian aeronautical information publications was incorrectly depicted as 0.17 per cent down, when it should have read 0.17 per cent up. The Safety Advisory suggested that TC might wish to ensure that similar runway slope information errors do not exist for other aerodromes. A review of quality assurance measures regarding the provision and depiction of aerodrome information in Canadian flight information publications was suggested.

On 09 December 2004, TC responded to Safety Advisory A040059-1. TC indicated that a preliminary review has not uncovered further errors in published runway slope data. The error in the Halifax data is the result of a human transposition error. The error in the slope value for Runway 24 was discovered in the course of this accident investigation. TC was advised of the error, and a NOTAM (Notice to Airmen) was issued instructing holders of the Canada Air Pilot to delete the slope information for all runways at the Halifax International Airport.

Subsequently, it was discovered that, in accordance with NAV CANADA's *Aeronautical Information Publication* (A.I.P. Canada) specifications, only slope values greater than 0.3 per cent are published. Therefore, a second NOTAM was issued, instructing holders of the applicable documents to re-insert the slope value for Runway 33, and delete the value for Runway 24.

Additionally, as a result of this Safety Advisory, an Aerodrome Safety Urgent Bulletin was sent to TC regional offices for distribution to all airports and registered aerodromes. The Urgent Bulletin reminds all airport/aerodrome operators of their responsibility to verify the accuracy of all published data, and to report immediately, via a NOTAM, the corrections to be made to aeronautical information publications. Direction concerning the methodology for the calculation of runway slope data is being reviewed and coordinated with NAV CANADA and other interested stakeholders.

NAV CANADA subsequently advised the TSB that, between 01 January 2004 and 01 October 2004, only two requests were received to amend runway slope information contained in its aeronautical information publications. After the issue of Safety Advisory A040059-1 and up to 01 December 2005, NAV CANADA had received a total of 73 requests to amend or to add runway slope information.

4.1.3 Ghana Civil Aviation Authority

In a letter dated 01 November 2004, the Ghana Civil Aviation Authority (GCAA) instructed MK Airlines Limited to cease use of the Boeing Laptop Tool (BLT) until such time as approval is given by the GCAA. Additionally, the GCAA instructed MK Airlines Limited to comply with the crew rest requirements listed in Section 8.11 of the *Ghana Civil Aviation Regulations* (GCARs) until the company submits a new schedule for approval; and apply Section 8.11.1.3(a)(4) of the CGARs for loadmaster rest and Section 9.4.1.16 of the CGARs for ground engineer crew rest.

4.1.4 MK Airlines Limited

4.1.4.1 Notices to Flight Crew

On 20 October 2004, MK Airlines Limited issued a Notice to Flight Crew that stated, "Loadmasters and Station Officers are required to query weights on dead-load weight statements when two and/or several pallets are reflected at or near the same weights. Where necessary, a check weight on a suitable calibrated scale must be carried out prior to loading. DO NOT under any circumstances accept freight that has not been weighed over a calibrated and current aircraft pallet scale from a Company approved handling agent/company. Any occurrence of any nature in this regard requires an occurrence report to be completed and submitted to the FSO [Flight Safety Officer]."

On 20 October 2004, MK Airlines Limited issued a Notice to Flight Crew on the above topic that stated, "With immediate effect to avoid any confusion, the weight and index for the total number of people on board (flight deck and all passengers) must be shown in the 'correction' box in both the B747 and DC-8 load sheets. The basic weight does not include 'crew'."

Within two weeks of the accident, MK Airlines Limited issued a Notice to Flight Crew to immediately cease use of the BLT and use alternate procedures. A formal submission has been made to the United Kingdom Civil Aviation Authority (CAA) in accordance with Temporary Guidance Leaflet No. 36: Approval of Electronic Flight Bags (EFBs).

On 03 February 2005, MK Airlines Limited issued a Notice to Flight Crew on the above topic that stated that the EFBs (JeppView® computers) are not to be used until such time as their use has been formally approved in compliance with the JAR guidelines.

4.1.4.2 Operations

At the request of MK Airlines Limited, the United Kingdom government, in cooperation with the GCAA, conducted a full audit for ICAO compliance on 16 November 2004. As a result of the audit, MK Airlines Limited decided to obtain JAR compliance in accordance with the United Kingdom authorities.

The United Kingdom CAA publication entitled *Avoidance of Fatigue in Air Crews* (CAP 371) lists the regulations for the avoidance of fatigue in aircrew. MK Airlines Limited has asked the GCAA for approval to use this flight time limitation scheme and has amended its operations manual (OM) accordingly. This scheme was approved in May 2005 and has been fully implemented, and United Kingdom CAA inspectors are monitoring compliance. A crew notice was issued concerning the noting of duty times on voyage reports to enable better monitoring of required rest times.

The MK Airlines Limited rostering staff has been briefed on the CAP 371 limitations and will monitor crew scheduling with in-house developed software to prevent exceedences. Crews were briefed on the new flight time limitations and their responsibilities for compliance. Flight documents are subject to close inspection to ensure that captain's discretion reports are completed when required.

A crew notice was issued concerning counselling to reduce fatigue and stress in light of the accident and the continued political and security situation in southern Africa. A new pay scheme introduced in December 2004 improved the financial security of crew members and has been well received.

The audit program of ground service contractors has been enhanced by the qualification of MK Airlines Limited loadmasters to the British Standards Institution (BSI) Lead Assessor standard. More detailed audit procedures have been developed under control of the newly appointed Director, Safety and Quality. The new Safety and Quality Department will coordinate audit activities across the technical, operational, security, and traffic disciplines.

A safety management system was established throughout the company, and a new company safety policy was drafted. A program of flight data monitoring is being implemented as part of the flight operations quality system. This forms part of the safety management system, which integrates safety, quality, and security management of the company. Key staff attended a flight operations quality assurance course from 04 April to 07 April 2005, at Cranfield University, United Kingdom.

A safety culture questionnaire was drafted and included in the latest company safety magazine to acquire employee feedback.

4.1.4.3 Training

There have been extensive revisions to the training manual under United Kingdom CAA guidance to achieve JAR compliance. A new Assistant Training Manager was appointed, who has an extensive background in training management. Training is now compliant with JAR-FCL (flight crew licensing)/JAR-OPS (operations) requirements. Non-JAR-licensed aircrew have commenced study courses for JAR licences.

Numerous companies and consultants were contracted or employed to oversee training standards:

- **CTC Crew Training Centre, Bournemouth, United Kingdom** - Type Rating Instructor (TRI) training.
- **Global Air Training, Cheshire, United Kingdom** - Crew Resource Management Instructor (CRMI) and Security Instructor training.
- **Consultant** - former Flight Operations Training Inspector, United Kingdom CAA. Responsibilities include monitoring instructor training standards.
- **Consultant** - former British Airways B747 Type Rating Examiner (TRE). Providing expertise in B747 type specific instructor training and standardization.
- **Assistant Training Manager** - former British Airways Senior Flight Engineer Instructor. Specific responsibilities include ensuring that training documentation and policies under development are of the required standard before submission to authorities.

The company's OM (Part A, Section 8 - Draft for approval by United Kingdom CAA) has been updated with various flight briefings to improve the level of situational awareness. Procedures were developed to ensure continued alignment of company training manuals with current national and international regulations and manufacturer's service bulletins. The training record system for each fleet was reviewed and aligned with the requirements of the training manual. A training expiry database was developed and will be reviewed to ensure that Part D, *JAR-FCL* requirements are met. Airworthiness directives and manufacturers service bulletins procedures are in Section 2.11 of the maintenance control manual and are being rewritten in the Maintenance Organization Exposition to comply with Section 145 of the JARs. An Information Management Department was established.

A system has been developed to improve the crew qualification system for categories B and C aerodromes. Crew participation in information gathering and updating of aerodrome information has been implemented, incorporating a risk assessment and controlled flight into terrain analysis. Part C of the OM now includes route and aerodrome briefs. In addition to the air operating certificate (AOC) application, MK Airlines Limited will apply for Type Rating Training Organization (TRTO) in accordance with the JARs. MK Airlines Limited is in the process of publishing a TRTO manual for approval, which will contain all the requirements for instructors, instructor training, standards, and facilities.

MK Airlines Limited has initiated a process to ensure that all company instructors and examiners are qualified to JAR-FCL, Subpart I. For example:

- Section 680 of JAR-FCL, Issue 4, has been distributed to all potential TRI and TRE for licensing purposes. Authorization and accreditation for TRIs and TREs will be sought only after licences have been issued and all criteria in sections 1.365 and 1.405 of JAR FCL, and CAA standards document 24, version 4, have been met.

- In respect of the above, 14 instructors have attended the JAR-approved TRI course at the CTC Crew Training Centre in Bournemouth. This training included CRMI (simulator/line) training. Three B747 training personnel have completed a TRI course on the B747 and have received approvals from the United Kingdom CAA. A standardization course is planned for the above instructors as soon as they have gained the necessary experience for approval as TRE.

- United Kingdom CAA-recommended persons will conduct standardization courses when instructors are upgraded from TRI to TRE status.

- Four instructors (two pilots, one flight engineer and one loadmaster) have completed a JAR-approved CRMI (Ground) course at Global Air Training in Cheshire.

The first Boeing 747 training course, in accordance with the new JARs, commenced in May 2005. Work is under way at the company operations centre at Landhurst to add a Training Department wing to the existing structure. The new wing will house the Boeing 747 simulator, the Training Department personnel offices, and the Safety and Quality Department.

Proficiency check rides for each flight crew member have been updated to reflect the requirements of sections 1.240, 1.295 and 4.240 of JAR-CFL, Appendix 2. MK Airlines Limited has initiated a biennial technical ground training program for aircraft systems. Syllabus and course material comply with Subpart N of JAR-OPS. MK Airlines Limited has completed a program of initial and recurrent training for loadmasters to include crew resource management training. The chief loadmaster attended CRMI training from 10 January to 14 January 2005. Eight 3-day courses were conducted for all loadmasters between 16 January and 12 February 2005.

Enhanced ground proximity warning systems (EGPWS) have been added to the ground and simulator training for the B747 fleet. A two-hour EGPWS lecture was programmed for January to June 2005 during recurrent training. An interactive CD ROM was issued to each crew member for home study.

A biennial training requirement for aircraft performance and de-icing was added to the recurrent ground training program. De-icing holdover times in the OM, Part A, Section 8.2.4.8.3, were amended on 21 December 2004 to bring them in accordance with the Association of European Airlines tables (19th edition, September 2004). A Crew Notice was issued on 21 December 2004 to ensure crew awareness and to provide interpretation information.

4.1.4.4 European Aviation Safety Agency Certification

MK Airlines Limited has applied for a United Kingdom AOC.

The company organization has been revised to comply with or surpass the JARs, with the addition of several new, full-time appointments of highly qualified staff. The AOC project plan is managed by the Director, Safety and Quality and was completed in late 2005.

In support of the AOC application, the following activity has been initiated and/or completed:

- The OM was rewritten in compliance with JARs and submitted to the United Kingdom CAA.

- There have been extensive revisions to the training manual to achieve JAR compliance.
- A new JAR-compliant organizational structure has been developed:
  - The position of Director, Safety and Quality was created.
  - The new Director, Safety and Quality is an airline transport pilot licence holder with extensive aircrew, safety management system and specialized regulatory experience.
  - The Flight Safety Officer (Accident Prevention Advisor) is now part of the coordinated safety team.
  - An Aircrew Liaison Officer has been appointed as Flight Operations Quality Assurance interface with a confidential safety management function.
  - The position of Ground Operations Manager was created and filled.
  - The position of Training Manager was created and filled.
  - The position of Assistant Training Manager was created and filled.
- Terms of reference in the company OM for these positions were revised for United Kingdom CAA approval.
- Part D, Training, of the OM was re-written to meet the JAR-FCL requirements and was submitted to the United Kingdom CAA for approval. This document has recently been approved.

A revised B747 JAR-compliant minimum equipment list, based on the United Kingdom CAA master minimum equipment list, was submitted for approval. Changes were required and the amended version has been resubmitted as part of the AOC application.

The newly appointed Ground Operations Manager has implemented tighter oversight of contracted ground handling companies.

4.1.4.5 Airworthiness

A full check of aircraft equipment by the United Kingdom CAA was undertaken and confirmed that all aircraft were fully ICAO-compliant. Fuelling and loading procedures were reviewed to ensure standardization across both B747 and DC-8 fleets.

In February 2005, the company commenced the application process for European Aviation Safety Agency (EASA) Part M (maintenance management) and EASA Part 145 approval. In March 2005, MK Airlines Limited started the recruitment of EASA Part 66 licensed staff and introduced training for existing staff to convert licences. In the first six months of 2005, the company undertook or completed several safety actions regarding airworthiness:

- completed response actions to the United Kingdom CAA audit of November 2004;
- received United Kingdom CAA confirmation of MK Airlines Limited compliance with ICAO standards and recommended practices;
- recruited a new Engineering Manager (37 years of experience);
- completed a review of engineering procedures and a restructuring of engineering manuals to ensure compliance with EASA requirements;
- undertook a review of Engineering Quality Department procedures and the recruitment of additional staff;

- undertook an internal audit of all engineering departments and maintenance bases against EASA requirements;

- submitted applications for registration of the B747 fleet in the United Kingdom and EASA Certificate of Airworthiness; and

- completed staff training in human factors and EASA regulatory requirements.

4.1.5 Boeing

On 11 November 2004, Boeing released a BLT Operator Message to all users of the Boeing laptop computer. The message reviewed the built-in feature of the software that automatically overwrites any entry in the planned weight field on the main screen when a user views the weight and balance summary page, and the performance data will be calculated on the weight in that field. The message urged all operators to ensure that their crews were properly trained on that feature.

4.1.6 Halifax International Airport Authority

The Halifax International Airport Authority (HIAA) has indicated that it has made the following change to the Aircraft Rescue and Fire Fighting (ARFF) operation:

- Three extra self-contained battery-operated lighting fixtures have been installed at the fire hall to provide more emergency lighting in the event of a power failure.

The HIAA has also indicated that it plans the following changes to the ARFF operation:

- The lighting system in the fire hall vehicle bay will be modified. The high-pressure sodium bulbs will be replaced with eight-foot fluorescent lights that will come on immediately when emergency power is available.

- An uninterruptible power supply will be installed in the alarm room to ensure a power supply to the relay that activates all the automatic features triggered by the crash alarm.

4.1.7 United Kingdom Civil Aviation Authority

Since the MKA1602 accident, the United Kingdom CAA has continued ramp and in-flight inspections of MK Airlines Limited. The United Kingdom CAA held discussions with management personnel of MK Airlines Limited about the ICAO definition of "principal place of business" and if it was still appropriate for MK Airlines Limited to hold an AOC issued by Ghana. During the last part of November 2005, with the mutual agreement of MK Airlines Limited management, the GCAA and the United Kingdom CAA, the United Kingdom CAA conducted a comprehensive audit of MK Airlines Limited. The audit was conducted by approximately five inspectors over a period of five days. Nothing of an immediate threat to safety was detected, and MK Airlines Limited continued to operate out of the United Kingdom.

4.1.8 United States Federal Aviation Administration

On 30 April 2005, the Federal Aviation Administration (FAA) announced publicly that Ghana was not complying with ICAO international safety standards. As a result, the FAA lowered the safety rating for Ghana from Category 1 to Category 2. The FAA statement said that it will remain engaged with the GCAA and will periodically review the situation with the intention of encouraging improvements that will qualify Ghana for a Category 1 rating.

4.2 Action Required

4.2.1 Take-off Performance Monitoring System

In this accident, the take-off was attempted using a thrust setting and take-off speeds significantly lower than those required to become safely airborne. The company's standard call for "Set MAX POWER" during every take-off would not have provided any additional opportunity to inform the crew if the power being set was maximum or reduced. Once the take off began, the flight crew did not recognize that the aircraft's performance was significantly less than the scheduled performance until they were beyond the point where the take-off could be safely conducted or safely abandoned.

Several similar accidents and incidents have shown that there have been other crews throughout the aviation industry that have also not recognized inadequate take-off performance. Some of these occurrences have resulted in substantial aircraft damage and, in several accidents, substantial loss of life. Although several efforts have been undertaken to develop procedural and technical solutions that would alert crews to inadequate aircraft acceleration performance during take-off, these efforts still have not resulted in a reliable methodology or system being introduced and/or installed in transport category aircraft. Without such a system, there continues to be an unacceptable level of risk to crews and the travelling public.

Therefore, the Board recommends that:

> The Department of Transport, in conjunction with the International Civil Aviation Organization, the Federal Aviation Administration, the European Aviation Safety Agency, and other regulatory organizations, establish a requirement for transport category aircraft to be equipped with a take-off performance monitoring system that would provide flight crews with an accurate and timely indication of inadequate take-off performance.

A06-07

4.3 Safety Concerns

4.3.1 Man-Made Objects in Runway Undershoot and Overshoot Areas

Although the berms constructed at Halifax met ICAO and TC required obstacle-clearance standards, the aircraft's lower aft fuselage did strike the berm off the end of Runway 24, causing the tail to separate from the aircraft and rendering the aircraft uncontrollable. Also, there are no specific standards or recommended practices regarding the construction and risk assessment of berms or similar immovable objects in the runway overrun/undershoot areas beyond the established runway end safety area.

The Board is concerned that, because man-made objects, such as the berms off the ends of runways 06 and 24 at Halifax International Airport, are not evaluated in terms of their potential risk to aircraft landing or taking off, there is the potential that an unnecessary hazard may be allowed to exist when mitigation for such risk may be reasonably undertaken.

4.3.2 Persons and Dangerous Goods on Board

Air traffic controllers were unable to get timely information on the number of persons and dangerous goods on board the aircraft. Although MK Airlines Limited was able to provide information regarding the number of persons on board about one hour after the accident, it was not until 10 hours after the accident that rescue and fire-fighting personnel received a listing of the dangerous goods that had been loaded at the previous stop. While there is a requirement for aircraft operators to record both dangerous goods and persons on board, this information is frequently not accessible in a timely manner.

The National Transportation Safety Board (NTSB) has made recommendations for regulatory authorities and operators to address this deficiency, as follows:

1. Recommendation A-90-105, issued 03 September 1990

   The NTSB recommends that the Federal Aviation Administration: require airlines to provide airport crash/fire rescue personnel accurate and timely numbers of all persons aboard an accident/incident aircraft, and to provide assistance in determining the disposition of persons who have been recovered from the scene of an accident.

2. Recommendation A-98-080, issued 12 August 1998

   The NTSB recommends that the Federal Aviation Administration: require, within 2 years, that air carriers transporting hazardous materials have the means, 24 hours per day, to quickly retrieve & provide consolidated specific info about the identity (including proper shipping name), hazard class, quantity, number of packages, & location of all hazardous materials on an airplane in a timely manner to emergency responders.

3. Recommendation A-05-017, issued 31 May 2005

   The NTSB recommends that the Federal Aviation Administration: inform all air traffic control tower controllers of the circumstances of this accident, including the need to ensure that aircraft rescue and firefighting (ARFF) vehicles are not delayed without good cause when en route to an emergency and the need to relay the number of airplane occupants to ARFF responders.

On 13 January 1999, a Douglas DC-3C aircraft crashed on Mayne Island, British Columbia. The accident aircraft was transporting a small amount of dangerous goods. Although personnel involved in the transportation industry were aware of the items, the first responders to the accident site were not. The TSB investigation report contained the Finding as to Risk, "First responders were not aware of the presence of the dangerous goods and were therefore at increased risk during their response activities on the site." (TSB Investigation Report A99P0006)

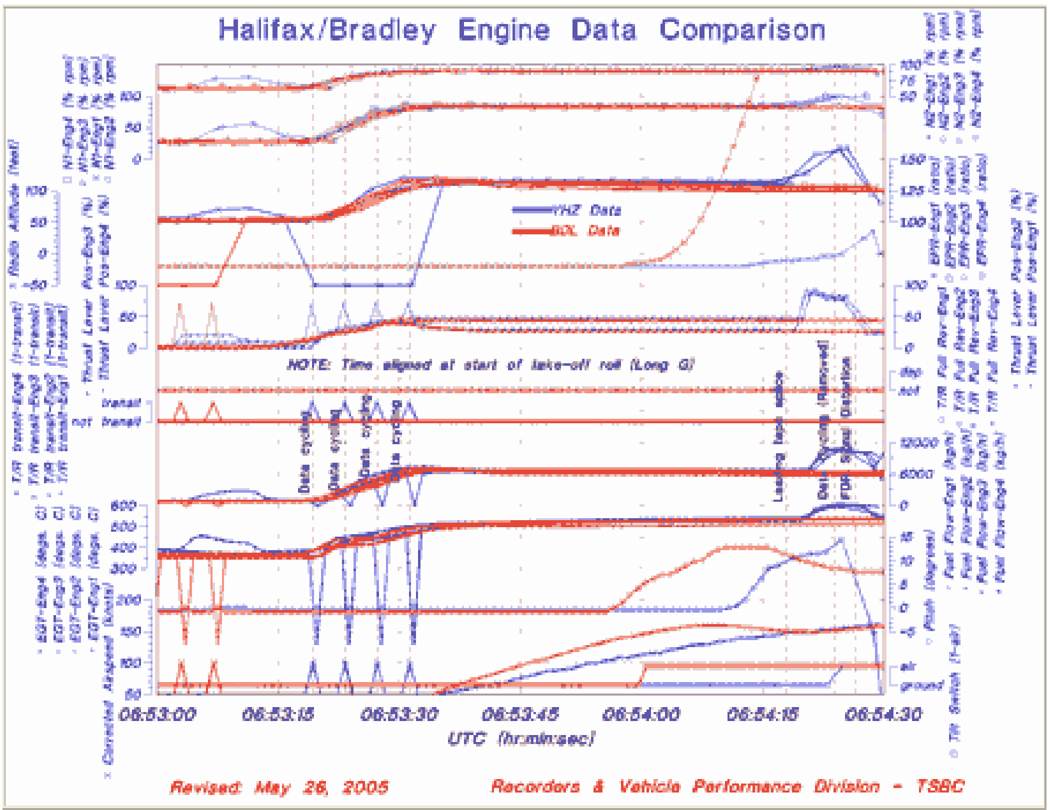
On 15 September 2000, a Boeing 727 aircraft landed at Ottawa, Ontario, and overran the runway. There was no damage to the aircraft or injury to the nine crew members. There were no passengers on board. The TSB investigation report contained the Finding as to Risk, "The emergency response services (ERS) vehicles approached the aircraft with no knowledge of the number of passengers, the amount of fuel on board, or whether any dangerous goods were on board. The tower controller did not have that information to pass on to the ERS personnel, potentially delaying or slowing ERS operations and therefore jeopardizing ERS and passenger safety." (TSB Investigation Report A00H0004)

Despite the actions taken by the NTSB and the TSB's prompting of regulators to address the safety deficiency, the unsafe condition continues to persist. The Board is concerned that all air carriers do not have a reliable system to provide, in a timely manner, specific information about the number of persons on board an aircraft and the identity, number, and location of all hazardous materials loaded on their aircraft. This lack of accurate information can compromise the effectiveness of the response and potentially put rescue personnel and the aircraft occupants at greater risk than is necessary.

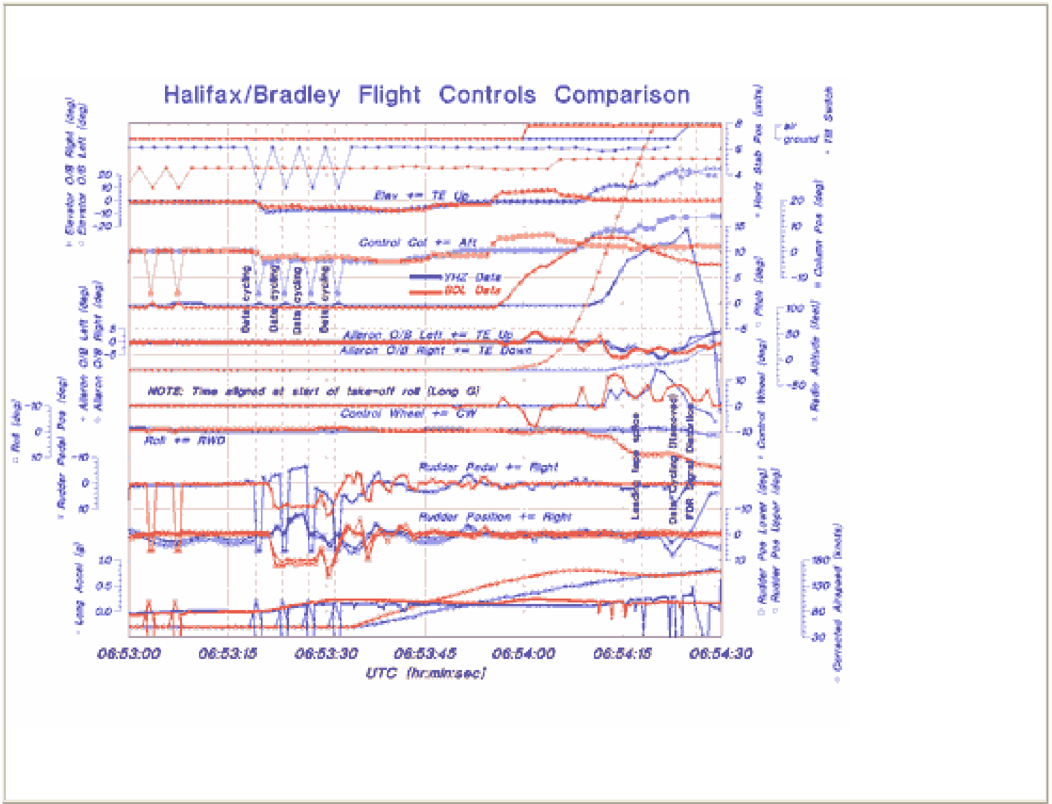
This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 06 April 2006.

Appendices

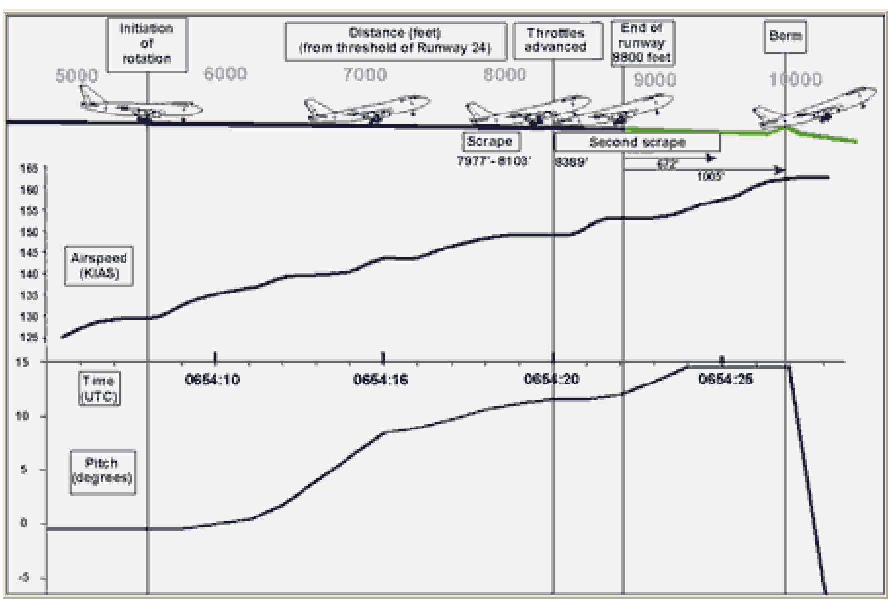
Appendix A -Flight Data Recorder Engine Data Comparison Between Bradley and Halifax



Appendix B -Flight Data Recorder Flight Controls Comparison Between Bradley and Halifax



Appendix C - Take-off Sequence



Appendix D - Sequence of Events

Time (UTC)	Sequence of Events Summary	Indicated Airspeed (knots)	Pitch (degrees)	Distance from Runway 24 threshold (feet)
0647:06	Flight data recorder (FDR) powers on. All engines are running, parking brake is on, flaps are retracted, horizontal stabilizer is at 3.3 trim units, heading is 337ºM, static air temperature is 7.7ºC	50	-0.9	
0648:36	Thrust levers are advanced	50	-0.9	
0648:40	Aircraft begins to taxi	50	-0.9	
0648:58	Flap handle position set to 20º. Horizontal stabilizer position briefly moves from 3.28 trim units to 4.9, then briefly decreases to 4.6, followed by further increase to 6.1 trim units (and remains at 6.1 trim units to end of flight)	50	-0.4	
0649:05	Leading edge flaps extended	50	-0.4	
0649:48	Aileron control check performed	50	-0.4	
0650:03	Elevator control check performed	50	-0.4	
0650:14	Rudder control check performed	50	-0.4	
0651:13	Starts onto runway	50	0	
0651:51	Backtracks Runway 24	50	-0.9	
0652:49	Starts right turn at threshold, to line up for take-off Runway 24	50	-0.9	
0653:18	Stops right turn on heading 240º, aligned with runway centreline	50	-0.4	194
0653:19	Thrust levers are advanced for rolling take-off	?	-0.4	205
0653:31	Split occurs in throttle lever angles	?	-0.4	474
0653:35	Recorded airspeed begins to record data above 50 knots indicated airspeed (KIAS)	51	-0.5	725
0653:36	Engines stabilize at take-off power (engine pressure ratios at 1.32 to 1.34; engines 2 & 3 thrust lever angles (TLAs) at 47 per cent and 43 per cent, while engines 1 & 4 TLAs at 30 per cent)	53	-0.5	801
0654:08	Control column moves aft to initiate rotation	130	-0.5	5483
0654:10	Nose-up rotation commences; elevator data mirrors control column movement	135	-0.4	5907
0654:13	Control wheel moves clockwise to 6.1º (6º to 7º clockwise input for next 6 seconds); control column moves aft to 8.4º	140	2.3	6571
0654:15	Rudder (lower) deflects right to 2.5º	143	6.7	7026
0654:16	Control column moves to 8.3º aft; pitch briefly stabilizes at 9º; pitch rate approximately 2.2 degrees per second	143	8.5	7257
0654:17	Control column moves further aft to 10º (data loss due to tape splice)	145	?	7490
0654:18	Control column moves to 9.1º aft; pitch reaches 10.6º (next 4 samples indicate pitch stabilizing in 11º range, consistent with lower aft fuselage/ground contact)	?	?	7726
0654:19	Control column at 9.0º aft; pitch reaches	?	10.7	7965

	11.1º			
	Start of initial runway scrape mark number 1			7977
	End of scrape mark number 1			8103
0654:20	Control wheel moves clockwise to 14.2º; control column moves aft to 12.0º; pitch reaches 11.5º; thrust levers are advanced	149	11.2	8207
	Start of second runway scrape mark number 2			8389
0654:21	Control column moves aft to 12.6º; pitch at 11.5º; engine pressure ratios of engines 2 & 3 reach 1.6 (maximum commanded thrust); engine pressure ratios of engines 1 & 4 are no longer recorded	149	11.5	8449
0654:22	Control column moves further aft to 13.5º; rudder (lower) deflects right to peak 8º; pitch reaches 11.9º (data loss likely due to lower aft fuselage contact with runway)	152	11.6	8692
	End of useable runway			8800
0654:23	FDR data loss	?	?	8939
0654:24	Control column at 13.4º aft; pitch reaches 14.5º; first tilt switch sample indicating "Air"	?	14.5	9188
0654:25	Data loss likely due to lower aft fuselage impact with localizer berm; localizer berm at 9955 feet; therefore, position discrepancy equates to an error of approximately 5 per cent	155	?	9438
	End of scrape mark number 2 in grass			9622
0654:26	Data loss due to localizer berm strike continues for another second	?	?	9691
0654:27	Data loss	?	?	9947
	Localizer berm position			9955
0654:28	Maximum recorded radio altitude is 36 feet; pitch decreases to -5.4º	?	?	10 206
0654:29	Final recorded sample of radio altitude at 0 feet; pitch further decreases to -20.9º; horizontal stabilizer position records spurious value of -72.8 trim units following localizer berm impact; FDR stops recording	R	-8.8	10 468

Appendix E - Glossary

AC	Advisory Circular
A/C	aircraft
AFM	aircraft flight manual
agl	above ground level
AOC	air operating certificate
ARFF	Aircraft Rescue and Fire Fighting
ASI	airspeed indicator
asl	above sea level
ATC	air traffic control
ATIS	automatic terminal information service

ATPL	airline transport pilot licence
B747	Boeing 747-200
BLT	Boeing Laptop Tool
BSI	British Standards Institution
CAA	Civil Aviation Authority
CAP	Civil Air Publication
CAP 371	United Kingdom Civil Aviation Authority publication entitled *Avoidance of Fatigue in Air Crews*
CRMI	Crew Resource Management Instructor
CVR	cockpit voice recorder
EASA	European Aviation Safety Agency
EFB	electronic flight bag
EGPWS	enhanced ground proximity warning system
EPR	engine pressure ratio
ERS	emergency response services
FAA	Federal Aviation Administration (United States)
FARs	*Federal Aviation Regulations*
FCL	flight crew licensing
FDR	flight data recorder
FL	flight level
FSO	Flight Safety Officer
GCAA	Ghana Civil Aviation Authority
GCARs	*Ghana Civil Aviation Regulations*
GMF	Garuda Maintenance Facilities
HIAA	Halifax International Airport Authority
HRM	Halifax Regional Municipality
IASA	International Aviation Safety Assessments
ICAO	International Civil Aviation Organization
ILS	instrument landing system
in Hg	inches of mercury
JARs	*Joint Aviation Requirements*
KCAS	knots calibrated airspeed
kg	kilograms
KIAS	knots indicated airspeed
LUX	Luxembourg
m	metres
MAC	mean aerodynamic chord
MKA1601	MK Airlines Limited Flight 1601
MKA1602	MK Airlines Limited Flight 1602
N	north
N/A	not applicable
NOTAM	Notice to Airmen
NTSB	National Transportation Safety Board (United States)
OM	operations manual
PDUs	power drive units
PF	pilot flying
QRH	quick reference handbook
RCMP	Royal Canadian Mounted Police

RESA	runway end safety area
RTG II	Rating II
SARPs	standards and recommended practices
SITA	*Société Internationale de Télécommunications Aéronautiques*
sm	statute miles
SOPs	standard operating procedures
STAS	Standard Take-off Analysis Software
TAT/EPRL	true air temperature/engine pressure ratio limit
TC	Transport Canada
TLAs	thrust lever angles
TODAs	take-off distances available
TP	Transport Publication
TP 312	Transport Canada Publication entitled *Aerodrome Standards and Recommended Practices*
TRE	Type Rating Examiner
TRI	Type Rating Instructor
TRTO	Type Rating Training Organization
TSB	Transportation Safety Board of Canada
UTC	coordinated universal time
VAR	visual-aural range
V1	take-off decision speed
V2	take-off safety speed
Vmcg	minimum control speed, ground
Vmu	expected minimum unstick speed
Vr	rotation speed
Vref	landing reference speed
W	west
Z	Zulu time (equivalent to UTC)
'	minutes
"	seconds
º	degrees
ºC	degrees Celsius
ºM	degrees magnetic
ºT	degrees true

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1. See Glossary at Appendix E for all abbreviations and acronyms.

2. The term "augmented" flight crew is more commonly used in international organizations and regulations.

3. All times are UTC.

4. Runway analysis charts are paper-based references carried on board the aircraft and are used to calculate take-off performance for a specific runway at a particular airport. They allow the pilot to obtain take-off data and take into account atmospheric conditions, the runway condition, and obstacles in the take-off flight path.

5. Volume 2 contains graphs, tables, and charts used to calculate aircraft performance data. It also contains a one-page, quick reference table for the calculation of take-off speeds. This table does not provide information relative to obstacle clearance.

6. The aircraft was originally constructed as a B747BC (passenger/cargo combination) freighter and was subsequently converted to a B747SF (full freighter) in 1995.

7. The *BLT Administrator's Guide*, page 40, defines operating empty weight as the weight typically found on the aircraft during normal operations, such as flight crew plus the weight derived from an aircraft weighing.

8. When water injection is used, the cooling effects of the water on the engine enable longer engine component life and thereby permit the operator to increase the thrust.

9. The thrust produced by the JT9D engines is indicated in the cockpit as EPR. The EPR is a ratio of the pressure of the air entering the engine air inlet to the discharge pressure at the engine jet nozzle.

10. MK Airlines Limited procedures required that "max thrust" be called for all take-offs, even if a de-rated or reduced thrust setting was to be used.

11. Vmu is the calibrated airspeed at and above which the aircraft can safely lift off the ground and continue the take-off.

12. Rotation speed is the speed at which the pilot starts to pull back on the yoke to rotate the aircraft in pitch.

13. NAV CANADA is responsible for providing aeronautical information services for Canada, including runway slope information.

14. SITA - *Société Internationale de Télécommunications Aéronautiques*

15. Zulu is equivalent to UTC.

16. These are FDR indicated data.

17. The air/ground logic of the FDR recorded "tilt switch discrete" is determined by the main landing gear tilt indication on at least one wing or body gear on each side of the aircraft. The tilt indication is satisfied when the wing gear and body gear tilt 53 and 8 , respectively, with respect to the oleos.

18. FDR data indicated 6.1 units and the mass and balance sheet indicated 5.8 units. Differences in values are considered to be within reasonable tolerances to be consistent with a cockpit setting of 5.8 units.

19. A beta version is a version of the software to be used for operational testing before official release.

20. For clarity and consistency, the report uses the term "runway analysis charts" rather than "airport analysis charts."

21. Vref is the minimum speed at the 50-foot height in a normal landing. This speed is equal to 1.3 times the stall speed in the full-flap landing configuration.

22. TAT/EPRL computes the EPR limit for engine rating and mode selected.

23. The date April 2002 was in the document. It was, inadvertently, not updated.

24. The MK Airlines Limited SOPs were to call "MAX thrust" for all take-offs, regardless of the thrust setting being used.

25. The term "acute fatigue" is more commonly used by the TSB.

26. In accordance with the MK Airlines Limited OM, the duty period commences one hour before scheduled departure and ends 15 minutes after arrival at the ramp.

27. Professor James Reason is one of the world's leading academics in the field of understanding human error.

28. In rare cases, when the aircraft is very light, the V1 and Vr bugs can be touching because the speeds are so close. However, in this case, since the crew changed the EPR bugs, it would have been natural to change the ASI bugs.