POOR PERFORMANCE

The Transportation Safety Board of Canada has released its final investigation report into a fatal Boeing 747 cargo crash in Halifax. The findings reveal how a simple error in calculating takeoff performance was a key factor leading to the crash.

Operating a converted Boeing 747 as MK Airlines flight 1602, the crew of seven – all with Ghanaian licences – were scheduled to depart Luxembourg at 10:00 UTC on October 14, 2004 for Bradley International Airport, Connecticut, USA, with a cargo made up mainly of lawn tractors. Actual departure was delayed until 15:56 UTC because the loadmaster decided that dirt needed to be cleaned from the tractors if the cargo was to be accepted by US authorities.

The flight arrived at Bradley at 23:22 UTC where the lawn tractors were unloaded and new cargo taken on board. Due to problems with the loading system, the departure from Bradley for Halifax International Airport, Nova Scotia, Canada, was delayed until 04:03 UTC. Flight 1602 arrived at Halifax at 05:12 UTC. Some cargo was unloaded and 53,000kg of lobster and fish taken on.

The first officer took a much-needed nap in the upper deck while the loading was proceeding. After fuelling was complete, the crew began taxiing the aircraft to position on runway 24, and at 06:53 UTC (02:53 local time) the aircraft began its takeoff roll. At this time the crew had been on duty for nearly 22 hours.

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 – this time with considerably more force. The aircraft remained in contact with the ground to a point 825ft beyond the end of the runway, where it became airborne and flew briefly for 325ft before the lower aft fuselage struck an earthen mound supporting an instrument landing system (ILS) localiser antenna and the tail snapped off. The rest of the aircraft continued in the air for another 1,200ft before it hit the ground and burst into flames killing all on board.

Two eye witnesses reported that the takeoff seemed normal to them until the very last minute when they saw the 747's tail hit the earthen mound supporting the ILS and the aircraft's tail break off. One reported that the 747 sparked into a huge orange fireball as the fuel ignited when it hit the ground in thick scrub.

Initially, the investigation involved the Royal Canadian Mounted Police's major crimes unit, which remained in charge in a 24-hour a day effort until foul play was ruled out.

The Canadian Transportation Safety Board investigation was initially hampered by the loss of the cockpit voice recordings. Prolonged exposure to the intense post-accident fire had melted the tape.

> The aircraft … flew briefly for 325ft before the lower aft fuselage struck an earthen mound supporting an instrument landing system (ILS) localiser antenna, and the tail snapped off.

Takeoff data: The flight data recorder (FDR), while slightly damaged, contained good data for the accident flight. It showed the thrust levers were advanced and a rolling takeoff was commenced at 06:53:22. At the start of the takeoff roll, with the aircraft weighing nearly 354,000kg, the thrust levers were smoothly advanced from ground idle thrust (an engine takeoff power setting of 1.0 engine pressure ratio, or EPR) to takeoff power with all final EPR settings indicating between 1.3 and 1.33 (derated). Full thrust EPR was 1.60. The aircraft accelerated through 80kt (calibrated) about 1,800ft from the threshold.

The FDR showed that the control column was moved aft to 8.4° to initiate rotation as the aircraft passed the 5,500-ft mark of runway 24, with 3,300ft of runway remaining. The initial rotation rate was approximately 2.2° per second, and the pitch attitude stabilised briefly at approximately 9° nose-up, with airspeed at 144kt. The tilt switch on the FDR continued to record GROUND. The control column was then moved further aft to 10°, and the aircraft responded with a further pitch up to approximately 11°, when initial contact of the lower aft fuselage with the runway happened. At this time the aircraft was approximately at the 8,000ft mark and slightly left of the centreline. The control column was then relaxed slightly, to 9° aft.

The pitch attitude stabilised in the 11° range for the next four seconds, and the lower aft fuselage contact with the runway ended briefly. With 600ft of runway remaining, FDR data showed that the thrust levers were advanced to 92 per cent and the EPRs increased to 1.60. With 420ft remaining, the lower aft fuselage hit the runway a second time. As the aircraft passed the end of the runway, the control column was 13.5 aft, pitch attitude was 11.9° nose-up, and airspeed was 152kt. The highest recorded nose-up pitch of 14.5° was recorded after the aircraft passed the end of the runway at a speed of 155kt. The aircraft became airborne approximately 670ft beyond the paved surface.

The flight data showed that when the recorded tilt switch position changed to AIR, the airspeed was about 155kt, consistent with the Vmu of 150±2kt, indicating that there was sufficient lift to fly. At this point in the FDR data there were some gaps in the recorded information; however two additional pitch samples were recorded indicating rapid nose-down pitching to -20° consistent with impact with the mound of earth supporting the localiser and loss of the tail section.

Calculations: Analysis by investigators revealed that the flight crew's takeoff performance calculations resulted in an error that remained undetected until the aircraft reached a point where the crew response was too late to avert the accident. The investigation team initially paid a lot of attention to the

DISASTER SCENE

AAP/Andrew Vaughan

Break up: Emergency workers look over the broken up remains of Mk Airlines flight 1602 at the accident site near Halifax, Nova Scotia, Canada. Eye witnesses said that the takeoff seemed normal until the last minute when they saw the 747's tail hit the earthen mound supporting the ILS and the aircraft's tail break off.

calculation of the aircraft's weight.

The 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 weighing 80kg. The aircraft also carried approximately 50kg of catering for the crews. MK Airlines used standard weights for the weight of the flight crew in the cockpit, totalling 270kg. None of these three weights, which totalled 1,120kg, had been included in the operating empty weight or the mass and balance sheet that was used to calculate the aircraft weight for takeoff.

When the weight of the wooden skids used with the seafood pallets (2,000kg) and the combined weight of the fly-away kit, catering, and the flight crew (1,120kg) were added to the 350,698kg weight calculated by the crew, the actual aircraft weight would have been approximately 353,800kg.

Failure to detect an error in the load weight could result in adverse aircraft performance and, potentially, an accident. However, the investigation found that the aircraft was still within the allowable weight and balance limits for the takeoff at Halifax.

Various scenarios that could have led the crew to use a low EPR setting and low rotation speed were examined. Investigators assumed that if the crew entered the correct airport, runway, and atmospheric information into the Boeing laptop computer used for calculations, then the only factor that would determine the V speeds and the EPR settings would be the weight of the aircraft used in the "planned weight" field of the software.

If the crew mistakenly used the zero fuel weight (262,000kg) or landing weight (281,000kg), the resulting rotation speeds would be too high compared to what investigators found on the FDR. If the user input 253,800kg instead of 353,800kg by mistake the result still would not match the FDR data. The only weight that that investigators found would generate the same rotation speed and EPR settings found in Halifax FDR was the weight calculated for takeoff from Bradley International Airport – 240,000kg. But how could this occur?

The investigation then turned to a close examination of the operation of the Boeing laptop computer. When the calculation program was launched, all previous settings, data, and information from the last use – Bradley International Airport – would have populated all data fields. Presumably the user would have changed all the fields to data for the Halifax International Airport, runway and ATIS. But the investigation found that after that, if the user opened the weight and balance page, for whatever reason, and returned to the takeoff performance page, the planned weight dialogue box would be populated with the takeoff weight from the weight and balance page, that is Bradley. If the user did not know about this reversion feature of the software, or did not notice the change and selected “calculate”, the takeoff (V) speeds and EPR setting would have been identical to those for takeoff from Bradley.

The investigation found that a more comprehensive training program for use of the Boeing laptop computer that emphasised 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.

Fatigue: When investigators looked at duty and roster times, they found that the crew performance may have been impaired by fatigue and stress.

Although the company’s operations manual said that flights would not be planned beyond 24 hours, the crewing department at MK Airlines routinely scheduled flights in excess of that limit. And there was no effective program in place to monitor how frequently this occurred. Interviews established that crews napped in flight and while on the ground to accommodate the longer scheduled duty days.

Examination of the occurrence crew’s work/rest/sleep and duty history indicated that they would have been at their lowest levels of performance because of fatigue at around the time of their arrival in Halifax. This state of fatigue would have tempted them to take procedural shortcuts and would probably have reduced their situational awareness. Their impaired performance would have been present when they were calculating takeoff performance data and during the takeoff when they failed to recognise inadequate takeoff performance.

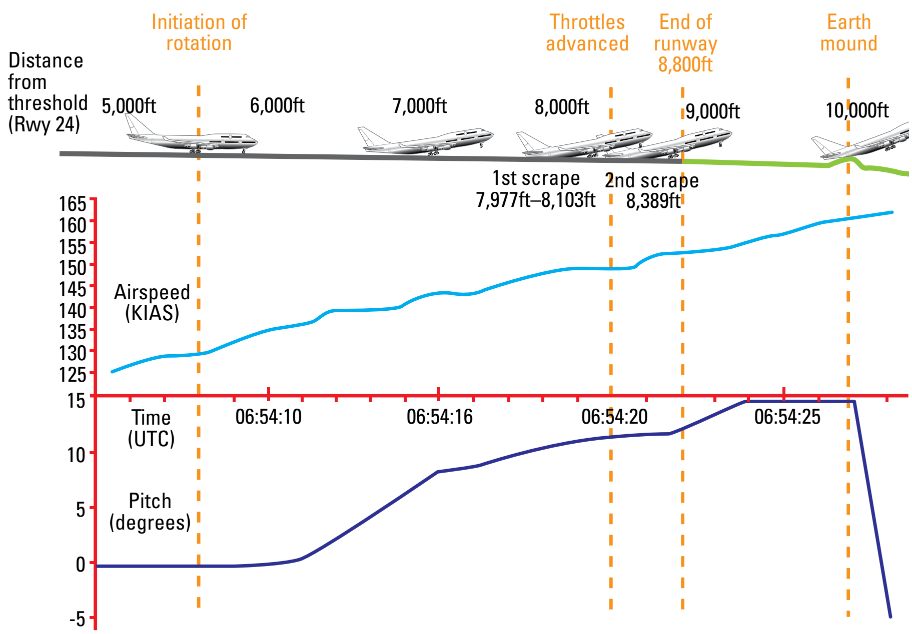
The aircraft was on the ground at Halifax International Airport for 1 hour 42 minutes. Twice during this time ground personnel noted that the first officer was not in the cockpit; it was common for flight crew to nap or rest if the turnaround time was long enough. It is likely that he took a nap between the time the takeoff 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, degrading his performance for 10 to 15 minutes after waking up.

If the first officer had been sleeping while the aircraft was on the ground in Halifax, he would have been susceptible to sleep inertia, degrading his performance for at least 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 takeoff 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.

Conclusions: The investigation found that crew fatigue, combined with the dark takeoff

ACCIDENT SEQUENCE



Tail scrape: The 747’s tail scraped the runway twice before the aircraft hit an earth mound at the end of the runway after failing to achieve takeoff performance.

KEY FINDINGS

1. The Bradley takeoff weight of 240,000kg was likely used to generate the Halifax takeoff performance data.
2. V speeds and thust settings were too low.
3. It is likely that the crew member who used the Boeing laptop tool to generate takeoff performance data did not recognise that the data were incorrect. It is unlikely that the crew adhered to procedures calling for an independent check of the takeoff data card.
4. The pilot did not carry out the gross error check in accordance with standard operating procedures.
5. Crew fatigue, combined with a dark takeoff environment probably contributed to a loss of situational awareness.
6. The aircraft’s lower aft fuselage struck an earthen mound supporting a localiser antenna, resulting in the tail separating from the aircraft.
7. The company did not have a formal training and testing program for the Boeing laptop computer, and it is likely likely that the user of the laptop was not fully conversant with the software.

Takeoff accidents

A review by the Transportation Safety Board of Canada of large (above 5,700kg), turbine-powered aircraft accident and incident data has shown that there have been at least 12 major accidents where takeoff performance was significantly different from scheduled performance. Four of the aircraft involved were destroyed and there were 297 fatalities.

Underlying most of these occurrences was a combination of the failure or absence of procedural defences to detect an error in the takeoff performance data and the failure of the crews to recognise abnormal performance once the takeoff had commenced. Some key examples:

- On March 12, 2003, a Boeing 747-412 suffered a tail strike on takeoff in Auckland, New Zealand, and became airborne just above the stall speed. The aft pressure bulkhead was severely damaged, but the crew managed to land safely. The cause of the tail strike was a result of the flight crew entering a takeoff weight 100 tonnes less than the actual weight into the flight management system resulting in low takeoff speeds being generated. There was no crew cross-checking of the speeds.
- On March 11, 2003, a Boeing 747-300 in Johannesburg, South Africa, had a tail strike on takeoff. The flight engineer had entered the zero fuel weight of 203,580kg instead of the takeoff weight of 324,456kg into the hand-held performance computer, and then transferred the incorrect computed takeoff speeds onto the takeoff cards.
- On June 14, 2002, an Airbus A330 had a tail strike on takeoff in Frankfurt, Germany, because incorrect take-off data were entered into the FMS. The crew did not detect the tail strike, and only became aware of it when they were notified by air traffic services during the climb-out. The aircraft sustained substantial structural damage to the underside of the tail.
- On December 28, 2001, a B747-200 cargo aircraft suffered a tail strike on takeoff in Anchorage, Alaska, and sustained substantial damage. The crew did not account for the weight of the additional fuel (about 45,360kg) taken on board in Anchorage, and inadvertently used the same performance cards that were used for the previous landing. The crew members were unaware that the tail had struck the runway until after they arrived at their destination.
- On January 13, 1982, a Boeing 737-222 was on a scheduled flight from Washington, DC, to Fort Lauderdale, Florida. During takeoff, the engine pressure ratios (EPRs) were set for 2.04, and on the takeoff run, anomalous engine instrument readings were noted; the captain elected to continue the takeoff. Approximately 2,000ft and 15 seconds past the normal takeoff point, the aircraft became airborne. The aircraft initially climbed, but failed to accelerate. The stall warning stick shaker activated shortly after takeoff and continued until the aircraft settled, hit the 14th Street Bridge and several vehicles, then plunged into the frozen Potomac River. The investigation revealed that the engine inlet pressure probes had become blocked with ice, resulting in high EPR indications. Of the 79 persons on board, 74 perished, and there were four ground fatalities.

WRONG EPR SETTING ON TAKEOFF

Pressure problem: Ice blocked the engine inlet pressure probes giving the flight crew of Air Florida flight 90 incorrect readings. The 737-222 hit a bridge shortly after takeoff and plunged into Washington's Potomac River. Left to right: the aircraft at Miami, Florida; US coast guard vessels help with recovery; salvage operations begin.

environment probably contributed to a loss of situational awareness during the takeoff roll. As a result, the crew did not recognise the inadequate takeoff performance until the aircraft was beyond the point where the takeoff could be safely conducted or safely abandoned.

The investigation also found that the Boeing laptop tool was introduced by MK Airlines 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 in March 2004 did not specifically remind pilots that, when returning from the weight and balance page, the takeoff weight as listed in that page would appear in the planned takeoff weight field on the performance page. It is unknown if the user of the Boeing laptop tool in this accident was fully conversant with the software, in particular this feature.

Since the accident the company has changed its rostering practices, introduced new weight and balance calculation procedures, improved training and introduced a safety management system. Boeing has released new guidelines to all users of the Boeing laptop computer.

The message urged all operators to ensure that their crews were properly trained on the software feature that automatically overwrites any entry in the planned weight field on the main screen when a user views the weight and balance summary page. The overwriting and the calculation of performance data will be based on the information in the weight and balance summary field.

The investigation report stressed the need for crew to follow standard operational procedures, and recommended that better systems be introduced to ensure correct takeoff speed and thrust.

Adapted from the Transportation Safety Board of Canada aviation investigation report number AO4H0004, "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".