FATAL Calculation

Failure of the flight crew to detect a computer programming error led to inadequate takeoff performance by their 747.

BY LINDA WERFELMAN

The accident airplane had been converted to a full freighter in 1995.

An MK Airlines Boeing 747-200SF failed to gain altitude on takeoff from Halifax, Nova Scotia, Canada, and struck rising ground beyond the runway end because the flight crew unknowingly used an incorrect aircraft weight to calculate takeoff speeds and thrust settings. Contributing to the Oct. 14, 2004, accident were crew fatigue and a dark takeoff environment that restricted the crew's ability to gauge the aircraft's progress in the takeoff, the Transportation Safety Board of Canada (TSB) said in the final report on the accident.[1]

The airplane was destroyed by the impact and subsequent fire, and all seven crewmembers were killed.

Investigators said that the crew probably used the takeoff weight from the previous flight to calculate performance data for the Halifax takeoff using the Boeing Laptop Tool (BLT)[2]; the resulting V speeds[3] and thrust settings were "too low to enable the aircraft to take off safely for the actual weight of the aircraft," the report said.

The flight crewmember who used the BLT likely did not recognize that the data were incorrect for the takeoff in Halifax, and the crew likely did not perform checks in accordance with the operator's standard operating procedures (SOPs) that would have detected the errors, the report said.

"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," the report said.

The report identified two additional contributing factors:

- "Crew fatigue likely increased the probability of error during calculation of the

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takeoff performance data and degraded the flight crew's ability to detect this error"; and,

- "Crew fatigue, combined with the dark takeoff environment [at 0354 local time], likely contributed to a loss of situational awareness during the takeoff roll. Consequently, the crew did not recognize the inadequate takeoff performance until the aircraft was beyond the point where the takeoff could be safely conducted or safely abandoned."

The accident occurred at the beginning of a flight to Zaragoza, Spain — the third in a series of four flights being conducted by a "heavy," or augmented, flight crew of two captains, one first officer and two flight engineers. A loadmaster and a maintenance technician also were aboard.

The series of flights originated Oct. 13 in Luxembourg, when Flight 1601 departed at 1556 coordinated universal time (UTC) — after a six-hour delay — for Bradley International Airport in Windsor Locks, Connecticut, U.S.

At Bradley, after 4.5 hours on the ground for cargo unloading and loading, and a captain and flight engineer crew change, Flight 1602 departed for Halifax at 0403 UTC Oct. 14.

After landing in Halifax at 0512 UTC, more cargo was loaded into the airplane. Two crewmembers — not identified in the report — were observed sleeping in passenger seats during the loading.

At 0653 UTC, the crew began the takeoff roll on Runway 24. The airplane's lower aft fuselage struck the runway during rotation and again several seconds later; the airplane remained in contact with the ground until it was 825 ft (252 m) beyond the end of the runway. It then flew 325 ft (99 m) before the lower aft fuselage struck an earthen berm supporting an instrument landing system localizer antenna. The airplane's tail separated on impact, and the rest of the airplane continued in the air for 1,200 ft (366 m), then struck the ground and burned (Figure 1, page 20).

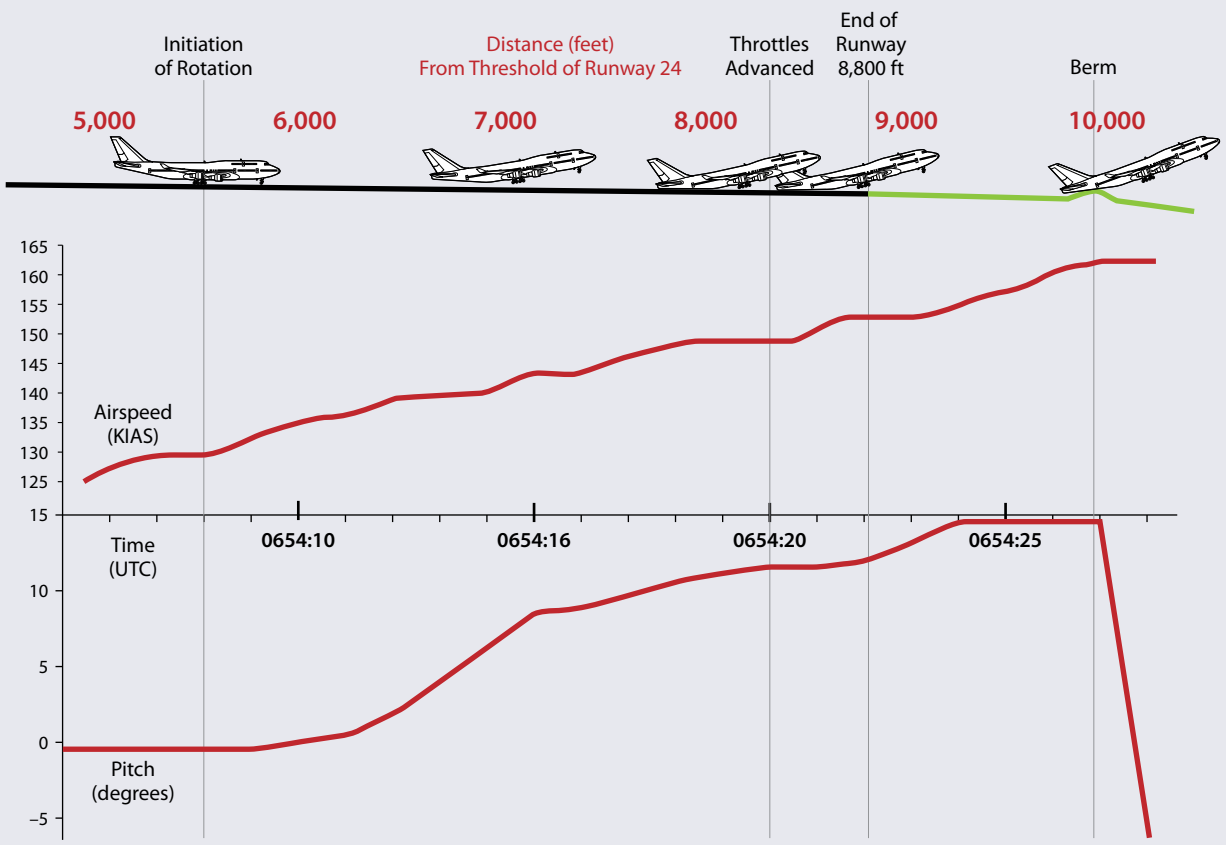
Airport weather conditions at 0700 UTC included wind from 260 degrees at six knots, visibility of 15 mi (24 km), overcast ceiling at 1,800 ft above ground level and a temperature of 10 degrees C (50 degrees F).

The airplane's cockpit voice recorder (CVR) tape was damaged beyond use by the post-impact fire. Its flight data recorder (FDR) yielded data that enabled comparisons of flight

The Boeing Co.

The Boeing Laptop Tool is used in calculating takeoff and landing performance data.

Takeoff Sequence



UTC= Coordinated universal time KIAS = Knots indicated airspeed

Source: Transportation Safety Board of Canada

Figure 1

performance during the takeoffs at Bradley and Halifax.

SOP 'Difficulties'

The captain of Flight 1602 had a Ghanaian airline transport pilot license (ATPL) and a current medical certificate. He had 23,200 flight hours, including 254 flight hours in type in the 90 days preceding the accident and 4,000 flight hours in 747s, and had been off duty for 29 hours before reporting to work for the series of flights that began Oct. 13. He had worked for MK Airlines since its inception in 1990.

In 2000, when the company changed its 747 SOPs and required all 747 pilots and flight engineers to undergo additional training, the captain "had some difficulties adjusting to the new SOPs," the report said; after a two-week review period, he completed the training "without further difficulty."

The report said that records showed "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 was "not comfortable using personal computers and software" such as the BLT and preferred to refer to paper charts and manuals in calculating performance data, the report said. Colleagues generally considered him "competent flying the aircraft," the report said. "He was respected and exercised adequate command authority in the aircraft, although he preferred to work in a casual manner."

The first officer, who had a Ghanaian ATPL and a current medical certificate, had 8,537 flight

hours, including 245 flight hours in the 90 days before the accident, and had been off duty for 17 hours before reporting to work Oct. 13. He was "a competent pilot, and comfortable using personal computers," the report said. "As the only first officer for the series of flights, he would have had to be an active crewmember on duty on the flight deck for all takeoffs, departures, arrivals and landings for the series of flights."

The flight engineer was qualified and certified in accordance with Ghanaian Civil Aviation Regulations (GCARs) and had a current medical certificate, the report said.

Roots in Ghana

MK Airlines, which had a Ghanaian air operator certificate (AOC), began operations as Cargo d'Or, using one Douglas DC-8. An office was established near London Gatwick Airport to facilitate sales. After investing in another Ghanaian airline in 1993, the company's name was changed to MK Airlines. Expansion continued throughout the 1990s, and at the time of the accident, the company operated six DC-8s and six 747s. The company employed about 450 people; several flight crewmembers told accident investigators that there were crew shortages, especially in 747s.

The report said that MK Airlines had a "familial approach" to business, which resulted in both a "strong sense of loyalty and commitment to the success of the company" and a working environment in which managers and supervisors "could have had difficulty ensuring that their 'friends' adhered to company procedures and policies."

Company managers said that they had an "open approach" to flight safety and that they wanted a flight operations quality and flight safety program that was developed in-house to reflect the company culture. The program was developed slowly and, at the time of the accident, was so new that some components described in the company operations manual (OM) had not been fully implemented.

Many MK Airlines flight crewmembers lived in southern Africa and were separated from their families for weeks at a time while on duty, the report said.

"With the political and social unrest in some of these areas, there was the potential for harm to come to their families when the employees were away," the report said. "There were several examples cited where employees' families had experienced incidents of home invasion and/or personal attack. This was identified as a source of stress within the company."

Not long before the accident, the captain of Flight 1602 — at the request of the company's managing director — had submitted a letter to the company in which he expressed concern about the increasing number of pilots leaving the company, indicated that there were not enough crews for the aircraft and suggested a new compensation package to provide more financial stability for flight crewmembers.

Records showed that the Ghanaian Civil Aviation Authority (GCAA) had decreased the frequency of its inspections of MK Airlines and that the actual inspections performed in the two years before the accident were "below the minimum frequency of about 20 inspections indicated in the inspector's handbook," the report said.

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Excluded Weight

The accident airplane, which was manufactured in 1980 as a passenger-cargo combination freighter and converted in 1995 to a full freighter, had 80,619 operating hours and 16,368 cycles. The airplane's maximum allowable takeoff weight was 377,842 kg (832,990 lb).

The takeoff weight when the airplane departed from Bradley was 239,783 kg (528,626 lb). The weight-and-balance information left at Halifax by the Flight 1602 crew indicated that the takeoff weight was 350,698 kg (773,149 lb), with the center of gravity within limits. The actual weight was about 353,800 kg (779,987 lb) — higher than recorded because the weight of several items was inadvertently excluded — but still within limits.

'Self-Study' of BLT

Training on new technology equipment and software, such as the BLT, was conducted through "self-study and hands-on experience,

using training material developed from the manufacturer's manual," the report said. "The information was distributed through notices to flight crews but had not been incorporated into the OM. There was no formal documentation to record an assessment of the individual's knowledge and competency using the equipment."

The BLT included a weight-and-balance summary page on which the computer's user could enter passenger weights, cargo zone weights and fuel; using this data, the BLT updated the takeoff weight at the bottom of the summary page. The updated weight was then "passed back to the planned weight field on the main input dialogue screen, and would automatically overwrite any entry in the planned weight field, without any notification to the user."

The report said that this feature was "believed to be a key element in how the incorrect takeoff performance data were generated."

In February 2004, 747 flight crewmembers received a 46-page manual on how to use the BLT to calculate performance data, along with a notice from the company's 747 chief training pilot asking crewmembers to study the information "for when the BLT program is put onto onboard computers." Some crewmembers received instructions for using the BLT during regular recurrent training, but most received no formal training on the BLT, the report said.

In March 2004, 747 flight crews received a two-page notice — one page for pilots and one page for loadmasters — that said the BLT software had been installed on all aircraft computers and approved for calculating performance data. The notice asked crewmembers to use the accompanying procedure to complete takeoff data cards.

On the loadmasters' page, the notice said, "When closing the weight-and-balance page,

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the takeoff weight as listed in the weight-and-balance page will now appear in the planned takeoff weight block." This comment was not included in the instructions for pilots.

The notice also asked flight crewmembers to read the instructions in the BLT manual.

"It could not be determined if the occurrence crew read the BLT manual issued in February or the simplified instructions issued in March," the report said. "Reports from other MK Airlines Limited flight crews indicated that the operating captain was not comfortable using the BLT, while the first officer had been observed using it."

The report said that, without the CVR tape, it was difficult to determine exactly why the flight crew used low engine pressure ratio (EPR) settings and a low rotation speed; nevertheless, it described this as the most likely scenario:

> The takeoff data card was most likely completed using performance data from the BLT. The FDR data for the Halifax takeoff was nearly identical to that of the Bradley takeoff, indicating that the Bradley takeoff 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 takeoff performance data containing incorrect V speeds and thrust setting for Halifax. The flight crew used the incorrect V speeds and thrust setting during the takeoff attempt; however, the settings were too low, especially the thrust setting, to enable the aircraft to take off safely.

24-Hour Duty Day

A 2002 revision of the OM established a maximum duty time of 24 hours — and 18 flight hours — for an augmented crew flying one to four sectors. The Flight 1602 crew was scheduled for a 24.5-hour duty day. At the time of the accident, they had been on duty nearly 19 hours; had they completed their flight schedule, delays experienced in Luxembourg and at Bradley would have resulted in a 30-hour duty day. Voyage reports indicated that the flight's loadmaster and ground engineer had been on duty 45.5 hours.

The report quoted the OM as saying that all flights were "planned in accordance with the limitations of the company's approved rest, duty and flight time schemes." Nevertheless, a review of planned duty periods for MK Airlines Flights 1601/1602 showed that about 71 percent of the flights were planned for longer than 24 hours; the average was 24.37 hours. Airline management and GCAA officials said that they were unaware of this.

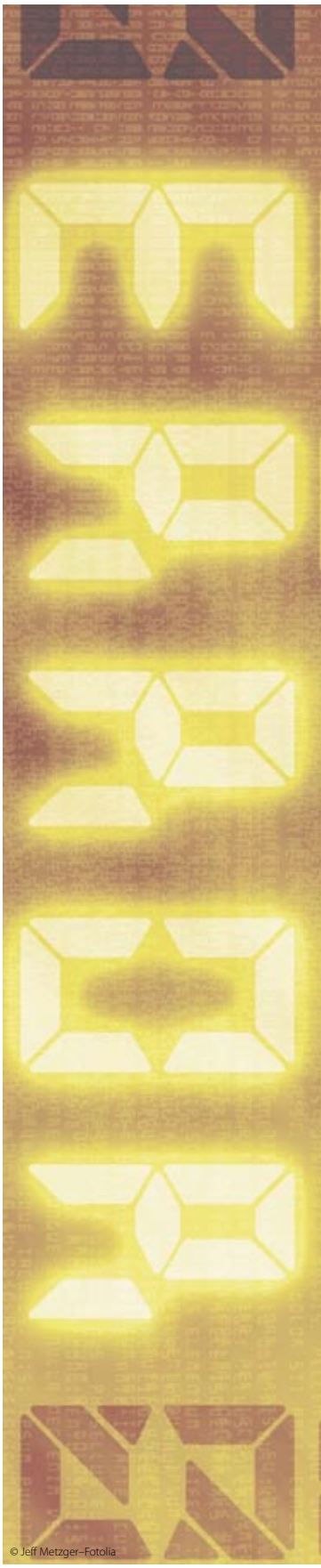
Actual duty periods for Flights 1601/1602 exceeded 24 hours 95 percent of the time; the average was 26.85 hours. Company management was aware of this; GCAA was not.

The report cited sleep research that has found that most people begin to require sleep after they have been awake about 15 or 16 hours; the amount of sleep required typically is between 7.5 and 8.5 hours per day.

"A person who does not obtain required sleep will develop a sleep debt and will be subject to performance degradation," the report said. "Fatigue can lead to forgetting or ignoring normal checks and procedures, reversion to old habits and inaccurate recall of operational events. Fatigue can also reduce attention, the effects of which are that people overlook or misplace sequential task elements, become preoccupied with a single task and are less vigilant."

The flight and duty time scheme used by MK Airlines typically resulted in a requirement that a critical crewmember — in this instance, the augmented crew's sole first officer — "be in his or her respective seat for all landings and takeoffs." This disrupts rest/sleep patterns.

Members of other MK Airlines flight crews said that they typically began to feel fatigued



during the stopover in Halifax and tried to nap there. The report described sleeping in the airplane as a routine fatigue-management practice at the company and said this indicated that crews were attempting to mitigate risks associated with fatigue.

Safety Actions

After the accident, numerous safety actions were taken, including the following:

- Transport Canada published a Commercial and Business Aviation Advisory Circular in June 2005 "to reinforce the absolute necessity for accurate load control";
- GCAA told MK Airlines on Nov. 1, 2004, to stop using the BLT "until such time as approval is given by the GCAA" and to comply with rest requirements described in the GCARs for all crewmembers, including loadmasters and ground engineers, until submission of a new company schedule for approval;
- MK Airlines issued a notice on Oct. 20, 2004, discussing required checks on cargo weights. Within two weeks of the accident, the airline issued a notice directing flight crewmembers to immediately stop using the BLT and to use alternate procedures; the airline made a related submission to the U.K. Civil Aviation Authority (CAA) in accordance with CAA guidance on approval of electronic flight bags;
- MK Airlines implemented — with the approval of GCAA and monitoring by U.K. CAA inspectors — a flight time scheme outlined in a U.K. CAA publication, *Avoidance of Fatigue in Air Crews* (CAP 371);
- MK Airlines issued a crew notice about counseling "to reduce fatigue and stress in light of the accident and the continued political and security situation in southern Africa." In addition, a new pay schedule was introduced that "improved the financial security of crewmembers";
- MK Airlines established a safety management system and drafted a new company safety policy. A flight data monitoring program was being implemented;
- At the request of MK Airlines, the U.K. CAA, in cooperation with GCAA, conducted a full audit of the airline for International Civil Aviation Organization compliance. As a result, MK Airlines decided to obtain Joint Aviation Requirements compliance; subsequent revisions were made in the airline's organizational structure, operations, training, maintenance and other areas, and new personnel were hired for new positions;
- The Boeing Co. on Nov. 11, 2004, issued a BLT Operator Message to all BLT users, reviewing the software feature that automatically overwrites entries in the planned weight field on the main screen when a user views the weight-and-balance summary page, reminding users that performance data are calculated using the weight in the planned weight field, and urging operators to ensure proper training for their crews on that feature; and,
- The U.K. CAA in November 2005 audited MK Airlines and found "nothing of an immediate threat to safety." Officials of U.K. CAA and managers of MK Airlines discussed whether the airline should continue to hold an AOC from Ghana; the airline continued operating out of the United Kingdom.

As a result of the accident investigation, TSB recommended that the Canadian Department of Transport, in conjunction with other regulatory authorities, "establish a requirement for transport category aircraft to be equipped with a takeoff performance monitoring system that would provide flight crews with an accurate and timely indication of inadequate takeoff performance." ●

Notes

1. Transportation Safety Board of Canada. *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*, Aviation Investigation Report A04H0004. June 29, 2006.
2. The Boeing Laptop Tool (BLT) is a software application for calculating takeoff performance data, landing data and weight-and-balance information. The 747 performance data in the software are those contained in the approved 747 flight manual.
3. V speeds are defined in the report as follows:
   - V_1 — Takeoff decision speed;
   - V_r — Rotation speed; and,
   - V_2 — Takeoff safety speed.