

# Spiral Dive

BY MARK LACAGNINA

An overwater departure on a dark, stormy night ends in the Mediterranean.



Following a night takeoff from Beirut, Lebanon, the flight crew of Ethiopian Airlines Flight 409 acknowledged an air traffic controller's assignment of a heading to keep the Boeing 737-800 away from isolated thunderstorms over the Mediterranean. The instruction was repeated — and acknowledged — several times, but the crew never established the aircraft on the assigned heading. Ground radar showed that the 737 flew a meandering path for about five minutes before entering a steep turn and descending rapidly to the sea, killing all 90 people aboard.

Based on the findings of an investigation team commissioned by the Lebanese Ministry of Public Works and Transport, the final report concluded that the probable causes of the Jan. 25, 2010, accident were “the flight crew’s

mismanagement of the aircraft’s speed, altitude, headings and attitude through inconsistent flight control inputs, resulting in a loss of control.” The report also faulted the flight crew for “their failure to abide by CRM [crew resource management] principles of mutual support and calling deviations.”

Contributing factors were “the increased workload and stress levels that ... most likely led to the captain’s reaching a situation of loss of situational awareness similar to subtle incapacitation and the [first officer’s] failure to recognize it or to intervene accordingly,” the report said.

## Unfamiliar Airport

Flight 409 was bound for Addis Ababa, Ethiopia, with 82 passengers, a flight security officer, five cabin crewmembers and the two pilots. The



Investigators determined that the captain likely experienced spatial disorientation and lost control of this 737.

flight crew had flown to Beirut the previous day and had 25 hours of rest.

The captain, 45, held type ratings for the 737-700/800 and the Fokker 50. His 10,233 flight hours included 188 hours as pilot-in-command (PIC) of 737s and 1,042 hours as a Fokker PIC. He was hired by Ethiopian Airlines in 1989 and flew agricultural aircraft for nine years before being assigned as a first officer in de Havilland Twin Otters, 737s and 757s. He was promoted to a Fokker captain in 2008 and completed training as a 737 captain less than two months before the accident.

The captain's most recent training in CRM and upset prevention and recovery had been completed in December 2007.

"Interviews conducted with the captain's superiors, trainers and next of kin revealed that he had a nice personality, was very polite, open to take criticism, healthy, did not smoke or drink alcohol, [and] was keen on reading and sports," the report said.

The first officer, 24, had 673 flight hours, including 350 hours as a 737 first officer. He had been transferred to the operations division of Ethiopian Airlines after graduating from its flight academy in January 2009. He completed CRM and upset prevention and recovery training in March 2009 and was endorsed as a 737 first officer in August.

"Interviews with the first officer's superiors, trainers and friends revealed that he had a nice personality and was a good student, who [had] graduated among the best six in the flight academy," the report said.

Weather conditions at Beirut Rafic Hariri International Airport at the time of the accident were described as fair, with calm winds and no precipitation, but there was significant thunderstorm activity west and southwest of the airport, over the Mediterranean.

"During the preflight preparation phase, the crew was heard on the CVR [cockpit voice recorder] discussing various operational issues ... and conducting the appropriate briefing and checklists," the report said. "In addition ... the crew was heard discussing their layover in

Beirut and a meal which could have affected the quality of their sleep prior to ... the flight. However, their tone of voice and discussions were normal during that phase. The captain was also heard confirming that this was his first flight into Beirut."

### Clearance Changes

After the passengers were boarded, the crew obtained their instrument flight rules clearance to Addis Ababa. The clearance included a standard instrument departure that initially called for a slight right turn after takeoff from Runway 21 to intercept the 220-degree radial of a VOR (VHF omnidirectional radio) located on the airport; the initial altitude was 3,000 ft.

The crew was taxiing the aircraft to Runway 21 when the airport traffic controller told them to line up on the runway and report ready for takeoff. The first officer, the pilot monitoring, reported ready for takeoff at 0235 local time. The controller cleared the crew for takeoff and issued a revised departure procedure that called for an "immediate" right turn toward CHEKA, a VOR located 31 nm (57 km) north of the airport.

The 737 was lifting off the runway when the controller again revised the clearance, instructing the crew to turn right to an initial heading of 315 degrees (Figure 1, p. 14). The first officer acknowledged the instruction and set the assigned heading on the aircraft's mode control panel (MCP).

The captain was hand flying the aircraft. Company procedure called for engaging the autopilot at 400 ft above ground level on departure but allowed for hand flying with flight director guidance below 10,000 ft in good weather and low traffic activity to maintain proficiency. Noting that the flight crew was aware of the convective activity in the area, the report said, "The captain's decision to fly manually was a major contributor toward the degradation of the situation."

The first officer did not call for the "After Takeoff" checklist, as required by standard operating procedure, and there was no indication



29,000 ft). The first officer acknowledged the instruction and set the assigned altitude in the MCP.

The controller then said, "Sir, I suggest for you, due to weather, to follow heading two seven zero to be in the clear for fifteen to twenty miles, then go to CHEKA."

The captain asked the first officer, "Two one, say again?" The first officer relayed the question to the controller, saying, "Confirm heading two one zero?" The controller replied, "Ethiopian 409, sir, negative. To proceed direct CHEKA, sir, turn left now, heading two seven zero." The captain asked, "Left heading two seven zero?" as the first officer was acknowledging the instruction, saying, "Roger, left heading two seven zero." The captain asked, "OK,

on the cockpit voice recording that the pilots accomplished the checklist items.

### 'What Heading?'

The aircraft was in a right turn and climbing through 2,000 ft at 0238, when the first officer established radio communication with Beirut Control. The controller cleared the crew to climb to Flight Level 290 (approximately

what heading did he say?" As the first officer set the assigned heading on the MCP, he told the captain, "Two seven zero is set."

During this exchange, the captain had continued the right turn through the selected heading of 315 degrees, and the bank angle had increased beyond 35 degrees, triggering two enhanced ground-proximity warning system "BANK ANGLE" warnings.

About 54 seconds after confirming the assigned heading, the controller said, “Ethiopian 409, follow heading two seven zero, sir. Follow heading two seven zero. Turn right heading two seven zero now.”

“This was associated with a sharp left [control] wheel input ... which resulted in a roll angle of 45 degrees, reaching a maximum of 64 degrees left [bank] and triggering five automatic ‘BANK ANGLE’ calls,” the report said.

### Out of Trim

The captain apparently was not following the flight director commands on his primary flight display and “was most likely unaware of the bank angle he was himself generating,” the report said. Moreover, despite almost constant manual flight control inputs, the captain did not trim the controls. “That surely increased [his] workload and was surely not compatible with basic flying skills requiring the aircraft to be continuously in trim when flying manually in order to relieve the pressure on the control column, allowing the pilot to focus on managing the flight.”

The 737 was turning left through 237 degrees when the captain rolled right and eased forward pressure on the control column. The aircraft began to pitch nose-up, and the indicated airspeed, which had reached 243 kt, began to decrease.

The report said that the flight crew likely became preoccupied at this point with a sudden onset of heavy rain, the sound of which was recorded by the CVR. The captain told the first officer to engage the autopilot, which indicated that he “felt uncomfortable with manually controlling the aircraft and that he was looking for a solution,” the report said. There was no reply from the first officer, who may not have heard the command. In addition, the captain continued to make manual flight control inputs, which would have prevented the autopilot from engaging.

At 0239, the controller again said, “Ethiopian 409, follow heading two seven zero. Turn right heading two seven zero.”

The first officer replied, “Right heading two seven zero, roger,” and told the captain, “Two seven zero set.”

The aircraft was climbing through 7,250 ft when indicated airspeed decreased from 159 kt to 141 kt and the stick shaker (stall warning) activated. The stick shaker remained on for 27 seconds. The 737’s angle-of-attack reached 18 degrees, and two more “BANK ANGLE” warnings were generated.

“What is that?” the captain asked. He repeated the question two more times in a louder voice. The report said that the question likely did not refer to a single item, such as the stick shaker or bank angle warnings, but to “the global situation, indicating that he didn’t understand why the situation was degrading in such a way.”

### ‘Go Around’

Indicated airspeed had decreased to 120 kt when the aircraft stalled at about 7,700 ft, pitched nose-down and rolled left, reaching a bank angle of 68 degrees. The captain “reacted by significantly pulling the control column back and bringing the wheel to the right, while putting some pressure on the right rudder pedal,” the report said. “Those actions did not completely match what was expected as a reaction to a stall” — that is, to apply nose-down elevator control.

While making these control inputs, the captain said “go around” five times. The first officer replied, “Roger, go around.”

“The throttles were pushed full forward for [an] instant, then pulled back a little for a few seconds and then pushed again violently enough [for the sound] to be recorded on the CVR,” the report said.

The CVR again recorded sounds consistent with heavy rain as the controller said, “Ethiopian 409, follow heading two seven zero, sir. Follow heading two seven zero. Turn right heading two seven zero now.” The first officer replied, “Roger, roger.”

One minute before impact, the captain pushed the control column forward, and airspeed increased to 238 kt as the airplane

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descended through 6,000 ft. “The column was then relaxed toward neutral, and the airplane began to pitch up, [climb] and slow down again ... while the left wheel input and right rudder input were maintained,” the report said.

The captain relaxed pressure on the right rudder pedal, and the aircraft rolled left. Airspeed was decreasing through about 200 kt when the first officer said, “The speed is dropping.” The captain replied, “OK, try to do something. Hold this thing.” The report said that the captain’s statement indicated that he needed help but was not able to specify what type of help he needed. The first officer responded only by saying “speed.”

The aircraft’s pitch attitude began to decrease after reaching a maximum of 31 degrees nose-up, but the left bank angle continued to exceed 35 degrees. Two more “BANK ANGLE” warnings were recorded before the captain applied right aileron and right rudder. The stick shaker activated again as angle-of-attack increased, reaching a maximum of 26 degrees as the aircraft stalled for the second time.

The captain again cross-controlled the aircraft, applying full left aileron while holding right rudder. He then applied increasing back pressure on the control column for 17 seconds. Airspeed was 150 kt when the 737 reached 9,000 ft. The captain neutralized the flight controls, but the left bank continued to increase.

### ‘Overwhelmed’

The aircraft was heading east, toward mountainous terrain on shore, when the controller said, “Ethiopian 409, you’re going to the mountain. Turn right now, heading two seven zero.”

The first officer keyed the microphone for about three seconds but made no verbal response. The report said that he likely “was overwhelmed by what was going on, which had left him speechless.”

The left bank angle reached a maximum of 118.5 degrees as the aircraft descended in a spiral dive through 7,300 ft, with airspeed increasing through 228 kt. “Over the next 10 seconds, as the pitch attitude reached 63.1 degrees

nose-down, large left and right wheel inputs were made,” the report said.

Airspeed was more than 7 kt above the aircraft’s maximum certified dive speed of 400 kt and vertical acceleration was 4.76 g (that is, 4.76 times standard gravitational acceleration) when the 737 struck the water about 5 nm (9 km) south of the airport at 0241:30. The impact occurred four minutes and 59 seconds after the initiation of the takeoff roll; the aircraft had been airborne for four minutes and 17 seconds.

The investigation revealed no sign that icing or a mechanical malfunction played a role in the accident, and there was no evidence that the aircraft had been struck by lightning. “The flight profile was the direct result of the flight control inputs and thrust settings,” the report said, noting that post-accident simulations indicated that the upset was recoverable with proper control and power inputs until the last few seconds of the flight.

The report said that the captain’s performance likely had been affected by spatial disorientation, loss of situational awareness and subtle incapacitation that resulted from the high stress and workload induced by the late-night departure in a relatively unfamiliar aircraft and from an unfamiliar airport flanked by high terrain on one side and thunderstorms on the other, with a junior first officer, and possible indigestion and fatigue from the meal that had affected the quality of his sleep.

The “passiveness” of the first officer, evident from the absence of callouts of deviations from flight control parameters and air traffic control instructions, was ascribed to his possible reluctance to challenge the captain. The experience gradient between the pilots “could also explain why [the first officer] did not take over control of the aircraft, even when requested to help,” the report said, noting that the first officer might have asked himself, in effect, “If the experienced captain cannot handle it, will I be able to?” ➤

*This article is based on the Lebanese Ministry of Public Works and Transport “Investigation Report on the Accident to Ethiopian 409, Boeing 737-800, Registration ET-ANB, at Beirut, Lebanon, on 25th January 2010.” ET 409, January 2012.*