Spatial disorientation was the primary cause of the Sept. 13, 2008, crash of a Boeing 737-500 at Perm, Russia, according to the final report by the Russian Air Accident Investigation Commission (AAIC). Contributing factors were inadequate crew resource management (CRM), a lack of proficiency in basic aircraft handling and a lack of skills associated with the use of a "Western-type" attitude indicator for recovery from an upset.

During the approach to Perm's Bolshoye Savino Airport, the flight crew was challenged by night instrument meteorological conditions, as well as by a navigation programming error and a "throttle stagger" that made manual engine management difficult and led to control problems caused by asymmetric thrust. The copilot, the pilot flying, abruptly handed over control to the captain when the aircraft was in a steep climbing left turn. The captain, whose spatial disorientation was exacerbated by alcohol and fatigue, was unable to recover. The aircraft rolled nearly inverted, entered a steep descent and fragmented when it struck terrain at high

BY MARK LACAGNINA

Misgauged Recovery

An unfamiliar, Western-type attitude indicator was little help to the disoriented Russian captain when an upset occurred.

The accident aircraft landing at Perm in happier days.

speed. All 82 passengers and six crewmembers were killed.

The aircraft was operated by Aeroflot-Nord, which was rapidly adding 737s to its fleet and training pilots to fly them. The report said that there were "serious drawbacks" in the transition training that the accident pilots had received, and it faulted the airline for pairing a captain with limited experience as a pilot-in-command with a copilot with limited experience in type.

The captain, 35, had more than 3,900 flight hours, including 90 hours in an Antonov 2 during his primary training and about 2,700 hours as a Tupolev 134 copilot. His experience in 737s comprised 1,190 hours, with 477 hours as captain. The copilot, 43, had more than 8,900 flight hours, including about 7,000 hours in An-2s and 1,600 hours as a Tu-134 copilot. He had logged 236 hours in 737s.

The aircraft that the pilots had flown before transitioning to the 737 — the An-2, a large utility biplane, and the Tu-134, which has fuselage-mounted turbofan engines and a flight deck accommodating two pilots and a navigator — have "Eastern-type" attitude indicators, in which the horizon remains fixed horizontally and the aircraft symbol tilts to show bank angle (Figure 1). Conversely, the horizon line in the 737's Western-type attitude indicator tilts while the aircraft symbol remains fixed horizontally.

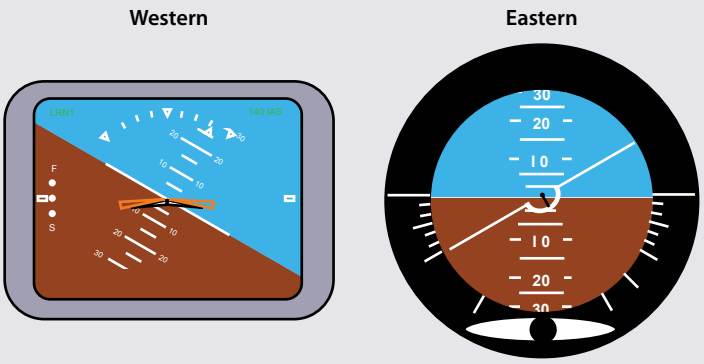
Neither pilot had any experience with two-pilot flight crew operations or modern "glass" flight decks when they began their 737 transition training. The captain was trained in 2006 at a U.S. facility that was not approved by Russian authorities. The report said that an adequate assessment of the training was not possible because the captain's file did not contain all the pertinent documents. The copilot was trained in 2007–2008 at an approved facility in Russia. His records reflected inattention to standard operating procedures and CRM practices, and substandard proficiency in flying with a thrust asymmetry. Instructors' notes recommended that the copilot pay more attention to controlling airspeed and attitude during approach.

Both pilots had received English language instruction at the airline's training center. Although they were not engaged in international flight operations, the training was necessary because all the documentation for the 737 was in English. Both pilots received passing grades. However, the report said that the relatively large amount of material included in the training syllabus and the relatively short period of training made it highly doubtful that the pilots assimilated all the instruction. Moreover, analysis of recorded statements by the copilot during the accident flight indicated that his English proficiency was not suitable for operating the 737, especially the flight management system (FMS) and autoflight systems.

Throttle Stagger

The accident aircraft was among 12 737s operated by Aeroflot-Nord. The aircraft was owned by a Bermudan company, previously operated in China and had accumulated about 43,491 flight

Attitude Indicator Display Differences



Source: Daniel W. Knecht

Figure 1

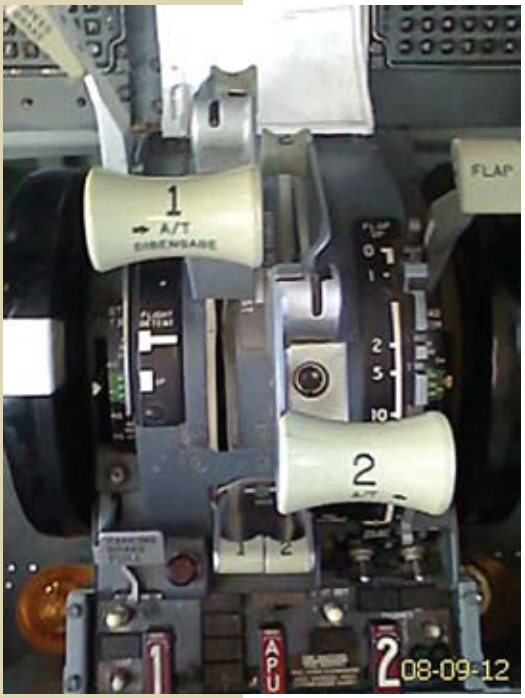


Photo taken on a previous flight shows throttle stagger required to maintain 83 percent fan speed on both engines.

hours when the airline began flying it about four months before the accident.

The aircraft had a throttle-stagger condition that exceeded the limits specified in the aircraft maintenance manual (AMM). This condition requires the throttles to be placed in different positions to match engine settings. Recorded flight data showed that during partial-power operations, engine fan speeds varied up to 20 percent with the throttles in the same position. Setting the engines to produce identical fan speeds resulted in a throttle stagger of up to 15 degrees, with the left throttle ahead of the right throttle. The report noted, however, that there was no throttle stagger at idle and "almost none" at takeoff power.

The report said that the airline's maintenance personnel did not follow the procedures recommended by the AMM to correct the problem, which initially was identified more than a month before the accident.

Maintenance documents indicated that the 737 was being operated with an inoperative traffic-alert and collision avoidance system and an inoperative autothrottle. The autothrottle was designated as inoperative because it had disengaged several times during a previous flight. However, maintenance personnel had not complied with minimum equipment list provisions requiring the circuit breakers to be pulled and "collared" to prevent them from being reset, and the autothrottle switch to be placarded as inoperative.

Investigators found that the autothrottle actually was functioning properly and that the uncommanded disengagements were related to the throttle stagger. Despite its designation as inoperative, the autothrottle was used during seven subsequent flights, including the accident flight.

'Totally Drunk'

The captain and copilot were conducting their third flight together. The scheduled departure time from Moscow's Sheremetyevo Airport was 2112 coordinated universal time (0312 local time). Both pilots had received 15 hours of rest before reporting for duty and had passed medical examinations before the flight. However, the report said that the captain's schedule during the previous three days did not comply with national regulations and was conducive to fatigue; he had conducted six flights, including two night flights, and had taken almost no rest at night.

Before starting the engines, the captain made a public address announcement to the passengers. The report said that one passenger sent a text message to a friend in England, saying that he was frightened because the captain sounded "like he is totally drunk." He said that other passengers were worried but had been assured by flight attendants that everything was all right.

While completing the initialization of the inertial reference system (IRS), the copilot made two slight errors in entering the stand's geographical coordinates in the FMS. The immediate result was a misposition of 1 minute, or approximately 1 nm (2 km). The captain, who was supposed to be monitoring the copilot's preflight actions, did not catch the error.

The 737 departed from Moscow at 2113. The captain flew the takeoff and then transferred control to the copilot. The copilot flew the aircraft with the autopilot and autothrottle engaged. Perm is about 675 nm (1,250 km) east of Moscow. The cruise altitude was 9,100 m (about 29,900 ft).

Because of the IRS initialization error and normal IRS drift — as well as the inability of the FMS to update its position via the global positioning system (the aircraft did not have a

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GPS receiver) or signals from ground navigational facilities (there were none on the route) — the misposition increased to more than 4.5 nm (8.3 km) as the aircraft neared Perm. The crew began the descent at about 2245.

Confusion Reigns

The automatic terminal information system indicated that surface winds at Perm were from 050 degrees at 6 kt, visibility was 5 km (3 mi) in light rain and mist, the ceiling was overcast at 240 m (787 ft) and the instrument landing system (ILS) approach to Runway 21 was in use.

The report said that analysis of cockpit voice recorder (CVR) data indicated that the captain likely experienced an inordinately high level of stress during the final phases of the flight. Conversation between the pilots often was not related to flight tasks and was replete with expletives and spiteful remarks about the flight attendants and the Airport Control Service. No checklists or mandatory cross-checks were performed, and few required callouts were made during the approach.

The CVR data also showed that the crew was confused by arrival instructions issued by the approach controller to facilitate an aircraft departing from Perm. The instructions differed from the standard arrival route and approach fixes that the copilot had entered in the FMS. After lengthy discussions with the captain, the controller told the crew to navigate directly to the outer marker for the ILS approach. The report said that this instruction annoyed the pilots.

Nearing the airport from the west, the crew relied solely on the inaccurate IRS navigation data rather than tuning the frequency for the outer marker and using the automatic direction finder as a backup. As a result, the aircraft crossed over the runway, rather than the outer marker. The controller did not mention this to the crew.

Following the controller's radar vectors, the copilot maneuvered the 737 onto a right downwind leg for Runway 21 while descending to 2,100 m (about 6,900 ft). The autopilot was in a navigation mode, and the copilot became confused when the aircraft began turning left. "Where's it going?" he said. "I don't understand where it's going." The captain told the copilot to use the autopilot's heading mode.

When power was increased to level the aircraft at 2,100 m, the throttle stagger became so great that the autothrottle automatically disengaged. The captain told the copilot to control the engines manually. Rather than positioning the throttles to match engine fan speed, however, the copilot kept the throttles together. The resulting asymmetric thrust caused a significant left roll moment.

At 2301, the controller issued a further descent clearance to 600 m (about 1,970 ft) and told the crew to maintain 190 kt. The controller then said, "Are you descending? My radar shows 1,800." The report said that the question provoked an "intense reaction" by the captain, who asked "twice emotionally" how low they should descend. The copilot replied that the assigned altitude was 600 m and then said, "Why doesn't it descend? I've pressed heading select." The CVR recording indicated that the captain was annoyed when he told the copilot to select the autopilot's level change mode.

'Take It'

The controller told the crew to turn to the base leg when ready but did not assign a heading. The copilot turned the 737 from the 030-degree downwind heading to a southerly heading to intercept the ILS localizer.

The aircraft was still in the clouds when it reached 600 m. After the copilot advanced the throttles to hold that altitude, the autopilot reached the limits of its control travel in countering the left roll moment, and the aircraft began turning left. The copilot attempted to use the control wheel steering switch to manually level the wings while keeping the autopilot on line but inadvertently pressed the stabilizer-trim switch, causing the autopilot to disengage.

The copilot was unable to maintain control. The aircraft was in a 30-degree left bank and a 20-degree nose-up attitude at 2308, when he told the captain, "Take it. Take it."

The report said that the captain had lost situational awareness during a long discussion with the approach controller. "Take what?" he asked. "I can't do it either." The captain abruptly applied left aileron and did not correct the pitch attitude. The bank angle increased to 76 degrees, and the aircraft made an almost full barrel roll before descending to the ground, the report said.

A postmortem examination of the captain revealed that the level of ethyl alcohol in his body before he died exceeded regulatory limits, the report said. No alcohol was found in the bodies of the other crewmembers.

This article is based on the English translation of AAIC final report no. B737-505 VP-BKO. The official report, in Russian, is available at <www.mak.ru/russian/investigations/2008/vp-bko_report.pdf>. The English translation is available from the U.K. Air Accidents Investigation Branch at <www.aaib.gov.uk/publications/foreign_reports.cfm>.