A navigation problem distracted the AdamAir pilots from flying the aircraft.

OFF-COURSE *Confusion*

BY MARK LACAGNINA

The flight crew's attention was focused on troubleshooting an inertial reference system (IRS) problem, and neither pilot was monitoring the flight instruments when the autopilot disengaged and the Boeing 737-400 began to roll and pitch nose-down, said the Indonesian National Transportation Safety Committee (NTSC). The pilots apparently became spatially disoriented and did not conduct the appropriate procedures to recover from the upset. The 737 descended into the Makassar Strait, near Sulawesi, Indonesia; all 102 people aboard were killed.

The accident occurred Jan. 1, 2007, during a scheduled flight from Surabaya, East Java, to Manado, Sulawesi, with 96 passengers and six crewmembers. The flight was operated by Adam SkyConnection Airlines as AdamAir Flight 574.

Both pilots were Indonesian. The pilot-in-command (PIC), 47, was the pilot flying. He had 13,356 flight hours, including 3,856 flight hours as a 737 PIC, and was hired by AdamAir in July 2006. The copilot, 36, had 4,200 flight hours, including 998 flight hours as a 737 copilot. He joined the airline in September 2005.

"There was no evidence that the PIC [or the copilot were] not fit for duty, nor was there any evidence of physiological or psychological problems in the days preceding the accident," said the NTSC's final report on the accident.

The 737 was manufactured in 1989 and had accumulated 45,371 flight hours and 26,725 cycles. The report said that the aircraft had "many previous owners and operators" before AdamAir leased it from a holding company.

Position Unknown

The aircraft departed from Surabaya's Djuanda Airport at 0559 coordinated universal time — 1359 local time. The crew established the 737 on Airway W32, which extends east-northeast from Surabaya over the Java Sea to the Makassar VOR (VHF omnidirectional radio) on the southwest coast of Sulawesi, then north-northeast to Manado, which is on the northern tip of the island (Figure 1).

The 737 was nearing the KASOL waypoint at 0614 when the crew was cleared by air traffic control (ATC) to fly directly to the DIOLA waypoint. About five minutes later, the copilot

reported that the aircraft was reaching the assigned cruise altitude, Flight Level 350 (approximately 35,000 ft), and was told by ATC to report abeam the ENDOG waypoint.

About 10 minutes after the copilot acknowledged the instruction to report abeam ENDOG, the air traffic controller who had been handling the flight exclaimed, "Where is Adam direct to? My God, he is flying north." By this time, however, the flight had been handed off to a different sector controller.

The aircraft was north of the GUANO waypoint (see Figure 1) at 0637 when the new controller told the crew to fly directly to DIOLA. A few minutes later, the controller asked the crew for their heading, and the copilot replied that they were heading 046 degrees, direct to DIOLA. The controller told the crew to fly a heading of 070 degrees to track directly to the waypoint.

At 0655, the copilot asked the controller for their radar position. The controller said that the aircraft was 125 nm (232 km) from the Makassar VOR and crossing the 307-degree radial.

ATC radar and radio contact with the aircraft were lost at 0658. "The controllers asked a number of aircraft … to help them make contact with AdamAir 574," the report said. "They were unable to establish contact with the aircraft."

ATC alerted search and rescue authorities at 0815, which was the flight's estimated time of arrival at Manado. The search for the aircraft began in the vicinity of the last recorded ATC radar return and was conducted by Indonesian military units, the country's search and rescue organization, the NTSC, the Air Accident Investigation Bureau of Singapore, Singapore navy divers and other resources. On Jan. 10, wreckage was found in the water and spread along the western shore of Sulawesi, from Baru to Pare-Pare.

A towed, submersible sonic detector sent by the U.S. Navy to aid the search detected locator beacon signals from the cockpit voice recorder (CVR) and digital flight data recorder (DFDR). Searchers determined that the recorders and the main wreckage were 2,000 m (6,562 ft) below the surface of Makassar Strait. The recorders were recovered by a Phoenix remotely operated vehicle in August 2007. The U.S. National Transportation Safety Board assisted in the recovery of the recorders.

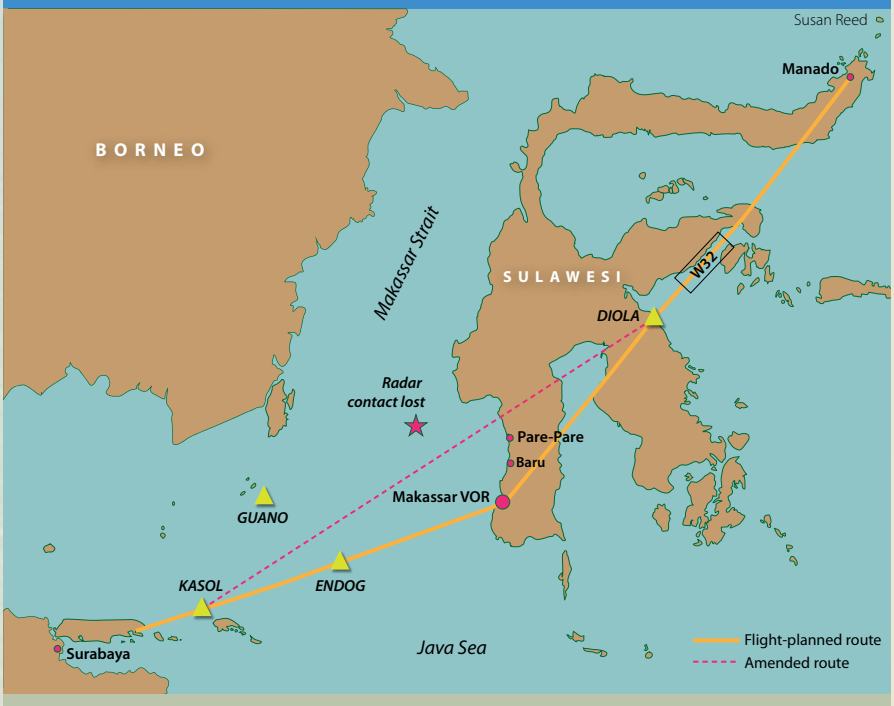
Concerned and Confused

Analysis of the DFDR data showed that the autopilot's heading and altitude-hold modes had been selected. The aircraft was slightly out of trim, and the autopilot was counteracting its tendency to turn right; the control wheels were displaced five degrees left.

The report said that the CVR recording — which began at 0628, or about 30 minutes before the upset occurred — indicated that the crew was "concerned and confused" about discrepancies in their IRS data.

A brief description of the IRS serves to explain the navigation problem that confronted the crew and their attempts to resolve it. An IRS — also called an inertial navigation system (INS) — is a self-contained system that receives no external navigation signals.[1] The major components of the 737's IRS are two inertial reference units (IRUs), each having three sets of laser gyroscopes and accelerometers that independently determine flight data parameters such as position, heading, groundspeed, vertical speed, altitude, attitude, wind

AdamAir 574 Route of Flight

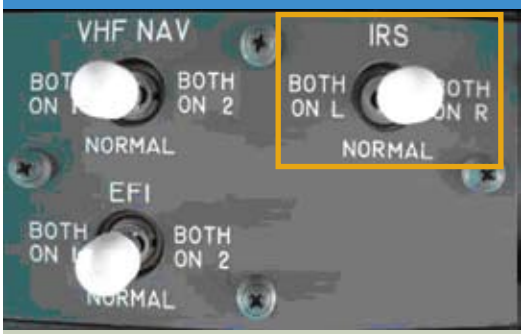


VOR = VHF omnidirectional radio

Source: National Transportation Safety Committee, Indonesia

Figure 1

IRS Transfer Switch

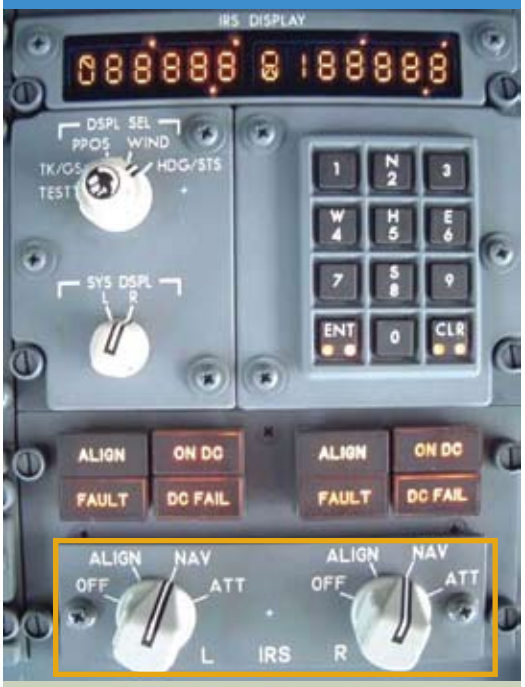


IRS = inertial reference system

Source: National Transportation Safety Committee, Indonesia

Figure 2

IRU Mode Selector Switches



IRU = inertial reference unit

Source: National Transportation Safety Committee, Indonesia

Figure 3

speed and wind direction by sensing changes in the aircraft's movement. IRS data are provided to the flight instruments, flight management system, autopilot and other systems.

An IRS transfer switch and two IRU mode-selector switches are located on the 737's overhead panel (Figure 2). The transfer switch has three positions: "BOTH ON L"; "NORMAL"; and "BOTH ON R." When "NORMAL" is selected, the PIC's electronic attitude director indicator (EADI) and electronic horizontal situation indicator (EHSI) receive data from the left IRU, and the copilot's EADI and EHSI receive data from the right IRU. The other two switch positions are used to channel data either from the left IRU or the right IRU to both pilots' instruments. The accident aircraft's IRU transfer switch was selected to "NORMAL."

Each IRU has a mode-selector switch with three positions (Figure 3): "ALIGN," which is used before departure for position initialization, using the latitude/longitude coordinates for the gate or an airport reference point, and to align the gyros vertically and with true north; "NAV," for normal navigation; and "ATT," the attitude mode, which is used if alignment is lost in flight. When the attitude mode is selected, there is a brief transition period in which the autopilot disengages and several flight data parameters are replaced with failure warnings on the pilots' flight instruments. The 737's quick reference handbook (QRH) says that during this period, the aircraft should be hand-flown straight and level, with no power or configuration changes, until valid pitch and roll parameters are displayed. The QRH notes that the transition period is approximately 30 seconds.

'Bad Weather'

After the crew initially was cleared to fly directly to DIOLA, the aircraft entered an area of convective activity conducive to the formation of severe icing conditions, hail, lightning and severe turbulence. One of the pilots advised the passengers that the aircraft was entering "bad weather" and told them to return to their seats and fasten their seat belts.

About this time, the navigation problem apparently worsened. "The pilots believed they were off track and were concerned and confused but did not raise any concerns with ATC," the report said. Among pertinent statements recorded by the CVR were: "We will get lost"; "Crazy, it's crazy"; "This is really bad"; "The IRS is erroneous"; "But the left one is good"; "This is messed up"; "It's starting to fly like a bamboo ship."

The statement "but the left one is good" and other statements indicated that the crew suspected that the right IRU was malfunctioning but were confused by the absence of a failure warning. Nevertheless, the PIC eventually decided to use the IRS fault procedure in the QRH to realign the right IRU. He told the copilot to change the mode for the right IRU from navigation to attitude.

"However, after moving the IRU mode selector switch to 'ATT,' they did not comply with the QRH requirement to fly the aircraft straight and level at a constant airspeed for 30 seconds," the report said. Consequently, when the autopilot disengaged, the aircraft began to roll right 1 to 2 degrees per second. The roll rate subsequently increased to 4 to 5 degrees per second. During

the IRU realignment, the roll indication, horizon scale, pitch scale and sky/ground shading disappeared from the copilot's EADI.

The investigation verified that the right IRU was malfunctioning. The PIC's EADI therefore continued to receive valid data from the left IRU. The standby attitude indicator and magnetic compass also were operational. Nevertheless, the PIC did not take positive action to level the wings.

"For about 46 seconds after the autopilot disengaged, the pilots were completely occupied with troubleshooting," the report said. The roll rate was arrested twice within 15 seconds by manual control input. "But the wheel inputs were momentary, and the aircraft continued to roll to the right," the report said.

'Critically Uncontrollable'

The ground-proximity warning system (GPWS) generated an aural "BANK ANGLE" warning when the bank angle reached 35 degrees. "This is an indication that the left IRU was operational and providing attitude data to the GPWS at this time," the report said. The roll rate again was arrested by manual control input but only momentarily; the 737 continued to roll right and also began to pitch nose-down.

The report said that the pilots likely had become spatially disoriented. They did not follow standard procedures for recovering from a nose-low unusual attitude. The procedure listed in the QRH requires the pilot flying to roll in the shortest direction to wings-level *before* applying nose-up elevator.

The aircraft was banked 100 degrees right and pitched 60 degrees nose-down when one of the pilots pulled back on the control column, causing aerodynamic loading to increase to 2.0 g — that is, two times standard gravitational acceleration. The crew then began to roll the aircraft left at a rate of approximately 4 degrees per second. "During this roll, nose-up elevator in excess of 2.0 g of force was commanded," the report said. "Nose-up elevator input continued, resulting in a 3.0-g force … with 42 degrees of bank."

DFDR data showed that the 737 descended from 35,000 ft to 9,920 ft in 75 seconds. Aerodynamic loading reached 3.5 g, and airspeed increased to Mach 0.926 — 495 kt calibrated airspeed. "This g force and airspeed are beyond the design limitations of the aircraft," the report said. U.S. certification standards require transport aircraft structures to withstand a maximum of 2.5 g at the design dive speed. The 737's design dive speed is 400 kt.

The report said that the aircraft was in "a critically uncontrollable state" when the CVR recorded two thumps and the DFDR recorded a sudden and rapid change in aerodynamic loading from 3.5 g to negative 2.8 g, which indicates that a significant structural failure had occurred. "It is likely that the empennage sustained a significant structural failure during this sudden and rapid flight load reversal," the report said.

The aircraft was descending through 12,000 ft when the structural failure occurred. The DFDR continued to record some parameters until the aircraft descended through about 9,000 ft, when the recording ceased. "The aircraft impacted the water at high speed and a steep descent angle and disintegrated," the report said.

The aircraft was banked 100 degrees right and pitched 60 degrees nose-down when one of the pilots pulled back on the control column.

Boeing 737-400

The 737-400 was produced from 1988 to 2000. It is 10 ft (3 m) longer than the 737-300, has stronger landing gear and can accommodate 146 to 168 passengers. The aircraft has CFM 56-3B2 or -3C engines. Maximum operating speed is Mach 0.82, and maximum range is 2,808 nm (5,200 km). Maximum standard weights are 138,500 lb (62,823 kg) for takeoff and 121,000 lb (54,8865 kg) for landing.

Source: *Jane's All the World's Aircraft*

No Training Provided

"This accident resulted from a combination of factors, including the failure of the pilots to adequately monitor the flight instruments, particularly during the final two minutes of the flight," the report said. "Preoccupation with a malfunction of the [IRS] diverted both pilots' attention from the flight instruments and allowed the increasing descent and bank angle to go unnoticed. The pilots did not detect and appropriately arrest the descent soon enough to prevent loss of control."

The report said that the pilots did not know the IRS well enough to troubleshoot the navigation problem promptly and correctly, and "their actions to rectify the problem resulted in a number of decision errors."

AdamAir did not provide simulator training in correcting IRS malfunctions or in recovering from aircraft upsets. "In accordance with Civil Aviation Safety Regulations, Indonesian operators are required to provide training in emergency or abnormal situations or procedures," the report said. "However, at the time of the accident, the Indonesian regulations did not specifically require upset recovery to be included in their flight operations training."

An engineering simulation conducted by Boeing indicated that recovery from the upset "with a minimum amount of overspeed" could have been made if the crew had leveled the wings before making nose-up elevator control input.

Entries in the aircraft's technical log and maintenance records during the three months preceding the accident included 154 recurring IRS faults — most involving the left IRU. "Line maintenance rectification action was limited to re-racking and swapping IRU components, resetting circuit breakers and cleaning connections when the faults became repetitive," the report said, noting that airline managers apparently were not aware of "the seriousness of the unresolved and recurring defects" which warranted replacement of the IRU.

The report said that the airline had a working environment that tolerated continued operation of the aircraft with known IRS faults. "The fact that AdamAir was still having fleetwide recurring [IRS] defects 11 months after the accident (November 2007), clearly shows that the engineering supervision and oversight changes that were put in place after the accident, to resolve the recurring problems, were not effective," the report said.[2]

Based on the findings of the investigation, NTSC made several recommendations to the Indonesian Directorate General of Civil Aviation (DGAC). Among the actions taken by the DGAC were the establishment of requirements for air operator certificate holders to provide instruction to pilots on IRS and autopilot failures in approved training devices, and to provide ground, simulator and flight training in upset recovery procedures. The DGAC also established navigation system training and qualification standards for maintenance engineers, and requirements to rectify a navigational system problem that is reported more than twice in a 30-day period. ●

This article, except where noted, is based on NTSC Aircraft Accident Investigation Report KNKT/07.01/08.01.36: "Boeing 737-4Q8, PK-KKW; Makassar Strait, Sulawesi, Republic of Indonesia; 1 January 2007."

An NTSB representative flushes debris off a flight recorder recovered from the seabed by a remotely operated vehicle.

Notes

1. Tooley, Mike; Wyatt, David. *Aircraft Communications and Navigation Systems: Principles, Operation and Maintenance*. Oxford, England: Elsevier, 2007.

2. Media reports said that the Indonesian Ministry of Transportation revoked AdamAir's air operator certificate on April 9, 2008, because the airline had failed to operate for 21 days.