BY MARK LACAGNINA

MISSED

The pilots did not notice a misset pressurization mode selector and misidentified a warning about cabin altitude. After hypoxia struck, autoflight systems kept the 737 flying until the fuel ran out.

opportunities

The Helios Airways Boeing 737-300 was climbing through 16,000 ft after departing from Larnaca, Cyprus, on Aug. 14, 2005, when the captain reported a takeoff configuration warning to operations personnel. The warning horn that the captain heard was actually for a problem with the cabin-pressurization system, according to the Hellenic Air Accident Investigation and Aviation Safety Board in Greece. Unaware of the problem, the pilots were incapacitated by hypoxia, and the aircraft, on automatic control, continued toward Athens, entered a holding pattern and plunged to the ground after the engines flamed out. None of the 121 occupants survived.

In its final report, the board said that the direct causes of the accident were:

- "Nonrecognition that the cabin pressurization mode selector was in the 'MAN' (manual) position during the performance of the 'Preflight' [checklist] procedure, the 'Before Start' checklist and the 'After Takeoff' checklist;
- "Nonidentification of the warnings and the reasons for the activation of the warnings (cabin altitude warning horn, passenger oxygen masks deployment indication, master caution); [and,]
- "Incapacitation of the flight crew due to hypoxia, resulting in the continuation of the flight via the flight management computer and the autopilot, depletion of the fuel and engine flameout, and the impact of the aircraft with the ground."

The 737-300 pressurization system was designed to maintain a cabin altitude of 8,000 ft at the aircraft's maximum certified ceiling, 37,000 ft. The mode selector, which is in an overhead panel above the first officer's seat, has three positions: "AUTO" (automatic), "ALTN" (alternate) and "MAN" (photo, page 21). With the system in automatic mode, which normally is selected for flight, the crew selects the planned cruise altitude and destination altitude in the appropriate windows on the mode selector, and a cabin pressure controller positions the outflow valve to maintain a programmed cabin-pressure schedule. The alternate mode is selected to change from one cabin pressure controller to the other. With the system in manual mode, the flight crew has "direct" control of pressurization, using a toggle switch to position the outflow valve. "Manual control is primarily used as a backup to automatic control," the report said.

There are four annunciator lights above the pressurization control panel. An amber "AUTO FAIL" light indicates a failure of the automatic mode. An amber "OFF SCHED DESCENT" light illuminates if the aircraft descends before reaching the planned cruise altitude set in the "FLT ALT" window. A green "ALTN" light indicates that the system is in the alternate mode. A green "MANUAL" light indicates that the system is in the manual mode.

Unscheduled Leak Check

The mode selector had been set to manual for a pressurization-system check the morning before the accident. The unscheduled maintenance was performed in response to a technical log entry by the flight crew that had landed the aircraft in Larnaca at 0425 after a flight from London. The technical log entry stated that an inspection of the aft galley service door was required because the door seal "freezes, and hard bangs are heard during flight."

After conducting a visual inspection of the door and the pressurization check, a ground engineer (maintenance technician) wrote in the technical log that no defects were found and that no leaks or abnormal noises occurred. The report said that although the airplane maintenance manual included no specific requirement to return the mode selector to "AUTO" after the check, it would have been prudent for the ground engineer to have done so.

The report also noted that a rapid decompression of the accident aircraft's cabin had occurred during a flight from Warsaw, Poland, to Larnaca on Dec. 16, 2004. The decompression occurred when the aircraft was at Flight Level (FL) 350 (approximately 35,000 ft) and near the point at which

the flight crew had planned to begin descent. The crew conducted an emergency descent and landed the aircraft at the destination. The Cyprus Air Accident and Incident Investigation Board, which investigated the incident, concluded that the decompression likely occurred either because the outflow valve opened due to an electrical malfunction or the aft galley service door opened due to an improperly positioned handle. Maintenance actions included adjustment and rigging of the door and replacement of the no. 2 cabin pressure controller and the chemical oxygen-generator cylinders in the passenger service units. Technical log entries indicated that no abnormalities were found during a cabin pressure leak check and outflow valve test.

Boeing 737-300

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The Boeing 737 was designed to use many components and assemblies from the 727. Deliveries of the first production model, the 737-200, which has Pratt & Whitney JT8D engines, began in 1967. The larger 737-300 was introduced in 1984 with quieter and more fuel-efficient CFM International CFM56 engines, rated at 20,000 lb (9,072 kg) thrust.

The 737-300 can accommodate 128 to 149 passengers and 1,068 cubic ft (30 cubic m) of cargo. Maximum standard takeoff weight is 124,500 lb (56,473 kg). Maximum landing weight is 114,000 lb (51,710 kg). Maximum operating speed is Mach 0.82. Cruising speed is Mach 0.75.

Production ceased in 2000 after 1,113 737-300s were built.

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

A Mode Overlooked

The accident occurred during a scheduled flight to Prague, Czech Republic, with an en route stop in Athens. The captain, 59, was a native of Germany. He had 16,900 flight hours, including 5,500 flight hours as a 737 captain. He had been employed by Helios Airways from May 2004 to October 2004 and had flown for two other aircraft operators before returning to Helios Airways in May 2005. "According to interviews of his peers at [Helios Airways], during the first period [of employment], he presented a typical 'command' attitude, and his orders to the first officers were in command tone," the report said. "During the second period, his attitude had improved as far as his communication skills were concerned."

The first officer, 51, was a native of Cyprus. He had 7,549 flight hours, including 3,991 flight hours in type. "He had expressed his views several times [to family, colleagues and friends] about the captain's attitude," the report said. "He had also complained about the organizational structure of the operator [and its] flight scheduling, and he was seeking another job." The report said that a review of his training records "disclosed numerous remarks and recommendations made by training and check pilots referring to checklist discipline and procedural (SOP [standard operating procedure]) difficulties."

The flight crew did not reset the pressurization mode selector to automatic before departure. "The fact that the mode selector position was not rectified by the flight crew during the aircraft preflight preparations was crucial in the sequence of events that led to the accident," the report said.

The challenge for the pertinent item on the "Preflight" checklist refers to both the air-conditioning and pressurization systems. The response is: "Pack(s), bleeds on, set." The report said that the pressurization mode selector rarely is positioned to a setting other than automatic, and many pilots interviewed during the investigation said that they typically respond "set"

after checking only that the cruise altitude and landing altitude are set correctly.

The aircraft departed from Larnaca at 0907. The first item on the "After Takeoff" checklist is to check the pressurization system. "This was the second missed opportunity to note and correct an earlier error," the report said.

About 0910, the flight crew was cleared to climb to FL 340 and to fly directly to the Rhodos (Rhodes) VOR (VHF omnidirectional radio). The captain's acknowledgement of the clearance was the last recorded communication between the flight crew and air traffic control (ATC).

Hellenic Air Accident Investigation and Aviation Safety Board

The pressurization system mode selector was in the manual, "MAN," position during the accident flight and was moved beyond that position by impact forces.

Warning Horn

The aircraft was climbing through 12,040 ft, and cabin altitude was slightly below 10,000 ft, at 0912, when the warning horn sounded. Activation of the warning horn in flight indicates a problem with cabin pressurization, the report said. On the ground, the warning horn sounds when the throttles are advanced and the aircraft is not in the correct takeoff configuration — that is, with trim, flaps and/or speed brakes set incorrectly.

According to the quick reference handbook, among the actions that the flight crew should take in response to a cabin altitude warning or rapid depressurization are to don their oxygen masks and stop the climb. That neither action was taken is one indication that the crew reacted to the warning horn as if it were a takeoff configuration warning. The report noted that the crew did not silence the horn, and the loud noise that it produced likely increased their stress.

The captain established radio communication with a dispatcher in Helios Airways' Operations Center about 0914 and reported a "takeoff configuration warning." About one minute later, the "MASTER CAUTION" and "OVERHEAD" lights illuminated on the flight deck annunciator panel. On the overhead panel, the "PASS OXY ON" light, indicating that the passenger oxygen masks had deployed, and the equipment-cooling system "OFF" lights also had illuminated. The report noted that nine technical log entries about the equipment-cooling system had been made in the two months preceding the accident. "The crew became preoccupied with the equipment-cooling-system situation and did not detect the problem with the pressurization system," the report said.

The equipment-cooling system includes fans and ducts that direct cool air to and warm air away from electronic equipment on the flight deck and in the electrical and electronic bay. "Loss of airflow (mass flow) due to failure of an equipment cooling fan or low air density associated with excessive cabin altitude results in illumination of the related equipment cooling 'OFF' light," the report said.

Communication Difficulties

The captain told the dispatcher about the equipment-cooling problem, but the dispatcher did not understand what he was saying and suggested that he talk with the on-duty ground engineer — the same person who had conducted the unscheduled maintenance before departure. The dispatcher did not tell the ground engineer what the captain had reported before handing him the microphone.

The ground engineer told investigators that the captain asked for the location of the cooling fan circuit breakers and that he replied that the circuit breakers were behind the captain's seat.

The ground engineer also told investigators that he did not understand the nature of the problem that the captain was experiencing. The report said that the communication difficulties likely arose because "the captain spoke with a

German accent and could not be understood by the British engineer. … Moreover, the communication difficulties could also have been compounded by the onset of the initial effects of hypoxia."

Off the Air

Helios Airways' training program did not specifically require that flight crewmembers and cabin crewmembers be trained to recognize the symptoms of hypoxia. The report said that the lack of this training is "a common situation in the airline industry."

The aircraft was climbing through 28,900 ft about 0920, when the flight data recorder recorded the keying of the no. 2 VHF radio, which was tuned to an ATC frequency. "This marked the last known attempt of radio communication by the flight crew," the report said. Attempts by the airline's Operations Center and ATC to re-establish radio communication with the flight crew were unsuccessful.

The F-16 pilot saw a man who was not wearing an oxygen mask enter the flight deck, sit in the captain's seat and don headphones.

The aircraft continued to climb at an average rate of 3,030 fpm. The pressurization outflow valve remained about 12 percent open during the flight, and the average cabin altitude rate of climb was 2,300 fpm. Cabin altitude reached a maximum of about 24,000 ft.

"The aircraft leveled off at FL 340 [about 0923] and continued on its programmed route," the report said. The aircraft crossed the Kéa VOR about 1021 and "began what appeared to be a standard instrument approach procedure for landing at Athens International Airport, Runway 03L, but remained at FL 340," the report said. The aircraft flew over the airport about 1029 and turned right, toward the Kéa VOR, in accordance with the missed approach procedure (Figure 1). The aircraft crossed the VOR about 1037 and entered the published holding pattern.

F-16 Intercept

Two Greek air force F-16s intercepted the aircraft during its sixth circuit of the holding pattern. The F-16 pilots observed no external structural damage, smoke or fire. "One of the F-16 pilots observed the aircraft at close range and reported at [1132] that the captain's seat was vacant [and] the first officer's seat was occupied by someone who was slumped over the controls," the report said. The captain likely had vacated his seat to check the cooling fan circuit breakers. The F-16 pilot also saw oxygen masks dangling from passenger service units and three passengers sitting motionless, wearing oxygen masks.

The investigation did not determine what actions the cabin crew took or whether they attempted to communicate with the flight crew after the passenger oxygen masks deployed. The cockpit voice recorder (CVR) provided data only for the last 30 minutes of the three-hour flight. The report said that the F-16 pilot's observations indicated that few passengers had donned their masks.

The passenger-oxygen system was designed to supply oxygen for 12 minutes. "In order to retain consciousness after the depletion of the oxygen from the passenger oxygen system, a person on board would have had to make use of one of the [four] portable oxygen bottles," the report said. The valves in three of the bottles were found open. The report said that at least one of the bottles likely had been used by a cabin attendant.

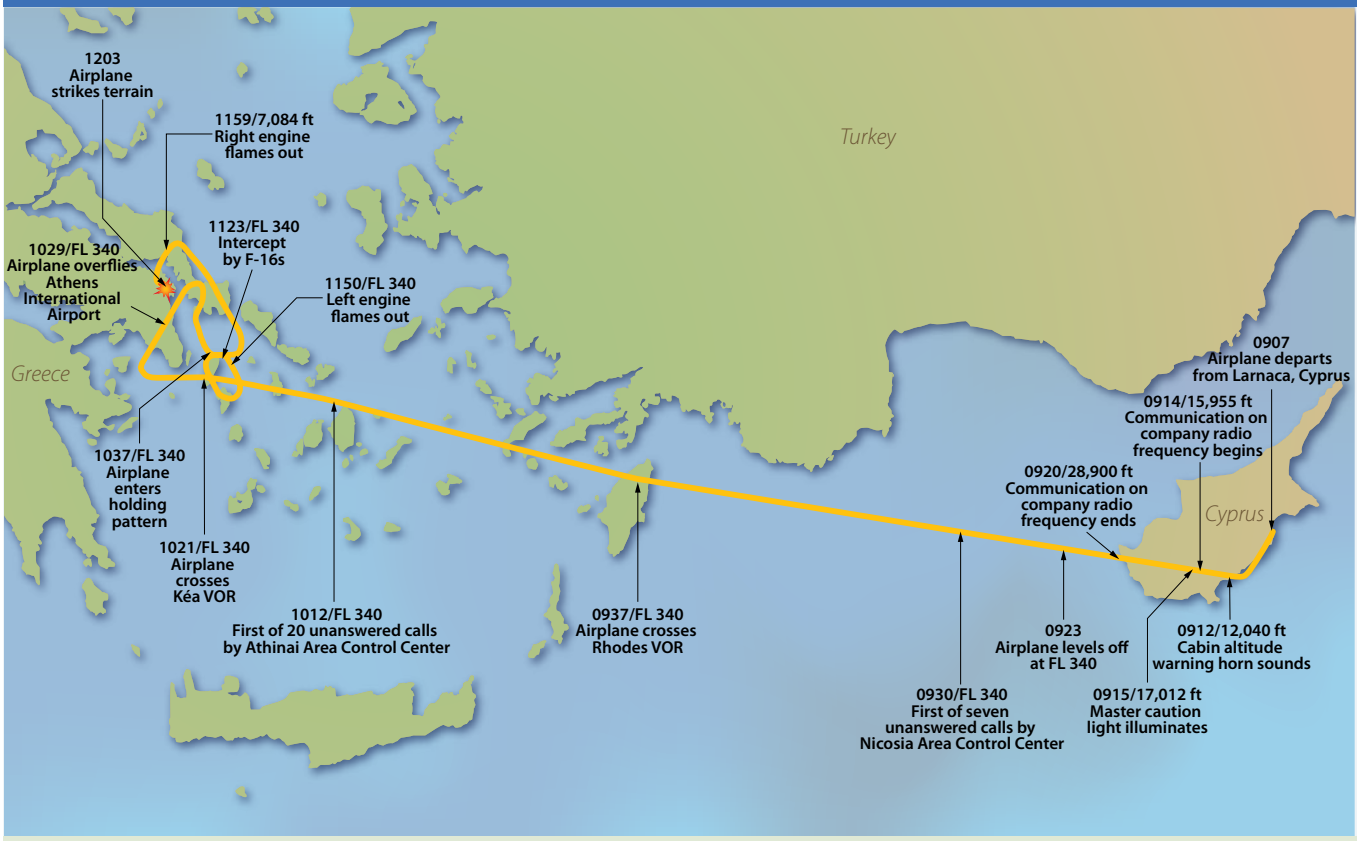
The aircraft was on its tenth circuit of the holding pattern about 1149, when the F-16 pilot saw a man who was not wearing an oxygen mask enter the flight deck, sit in the captain's seat and don headphones. From the F-16 pilot's description of the man's clothing, investigators concluded that the person likely was the cabin attendant who had used one of the portable oxygen bottles. "The F-16 pilot may not have been able to observe an oxygen mask on the person's face because the portable oxygen bottle mask was clear in color," the report said.

The CVR recorded sounds of an oxygen mask being removed from its stowage box and oxygen flowing through the mask. The F-16 pilot tried to attract the cabin attendant's attention, but he did not respond.

Attendant Attempts Control

About 1150, the left engine flamed out due to fuel starvation. The aircraft turned steeply left

Flight Path of Helios Airways Boeing 737, Aug. 14, 2005



FL = Flight level VOR = VHF omnidirectional radio

Times are local.

Source: Hellenic Air Accident Investigation and Aviation Safety Board

Figure 1

to a northerly heading and began to descend. The report said that recorded fluctuations in airspeed and altitude indicated that the cabin attendant, who held a commercial pilot license issued by the United Kingdom, was making an effort to control the aircraft.

CVR data indicated that he attempted to transmit two radio messages about 1154. The first was: "Mayday, mayday, mayday. Helios Airways Flight 522 Athens" followed by an unintelligible word. The second message, spoken a few seconds later in what was described by the report as a very weak voice, was: "Mayday, mayday." Neither message was transmitted, however, because the microphone key had not been depressed.

The 737 was descending through 7,084 ft about 1159, when the right engine flamed out and the heading changed from northerly to southwesterly. About this time, the cabin attendant appeared to acknowledge the presence of the F-16. "He made a hand motion," the report said. "The F-16 pilot responded with a hand signal for the person to follow him on down towards the airport. The [cabin attendant] only pointed downwards but did not follow the F-16."

Although the cabin attendant was a licensed pilot, investigators concluded that anyone with similar flight experience likely would not have been able to control the 737 with both engines inoperative and in the existing conditions of hypoxia and extreme stress. The report said, however, that the cabin attendant apparently attempted to level the aircraft before it struck hilly terrain near Grammatiko, about 33 km (18 nm) northwest of the airport, about 1203.

The remains of 118 occupants were recovered and examined by a forensic pathologist; the bodies of the other three occupants are believed to have been consumed by the post-accident fire. "According to the pathologist's report, the cause of death for all on board was determined to be multiple injuries due to impact, in addition to the extensive burns for 62 of them," the report said. The pathologist's report also said that the occupants likely were "in deep, nonreversible coma due to their prolonged exposure (over 2.5 hours) to the high hypoxic environment" when the impact occurred.

Latent Causes

The report said that the following were latent causes of the accident:

- "Operator's deficiencies in the organization, quality management and safety culture;
- "Regulatory authority's … inadequate execution of its safety oversight responsibilities;
- "Inadequate application of crew resource management principles; [and,]
- "Ineffectiveness of measures taken by the manufacturer in response to previous pressurization incidents in the particular type of aircraft."

Helios Airways was established in 1999 and had begun operating the accident aircraft in May 2004. At the time of the accident, the airline also was operating two 737-800s and an Airbus A319 from Cyprus to 28 destinations in 11 countries. The airline had 228 employees, about one-third of whom were part-time, seasonal employees.

Cyprus contracted with the U.K. Civil Aviation Authority (CAA) to assist in overseeing three airlines in the country. CAA audits of Helios Airways had found several deficiencies. "Management pilots appeared to be insufficiently involved in their managerial duties," the report said. "Training and duty records were found to be incomplete. Manuals were found to be [partially] deficient; they did not always adhere to regulations, and on some issues they were out of date. In the two months before the initiation of the first flight operations with the [accident aircraft], the airline appeared to be effectively scrambling to piece together manuals and paperwork. This suggested that an underlying pressure was prevalent to proceed with little regard for the required formalities." Moreover, flight crew training records indicated that no follow-up action had been taken in response to the first officer's record of insufficient checklist discipline and ineffective performance in abnormal situations.

The report said that the Cyprus Department of Civil Aviation (DCA) appeared to be completely dependent on the U.K. CAA for safety oversight and that the DCA's Safety Regulation Unit was understaffed and lacked leadership and oversight. There was no record that the DCA took action to ensure that airlines responded to deficiencies and issues considered by CAA auditors to require urgent attention.

Previous Problems

Investigators reviewed several previous occurrences worldwide involving aircraft pressurization problems. "Of interest and relevance to the [Helios Airways accident were] nine reports of pressurization problems directly attributed to the crews' failure to set and verify the proper position of the pressurization mode selector to 'AUTO,'" the report said. "Seven of these concerned Boeing 737 aircraft, while the other two events concerned McDonnell Douglas aircraft. These nine reports all referred to aircraft that took off with the pressurization selector inadvertently set to 'MAN.'"

The report said that Boeing had taken or was in the process of taking several actions before the accident to reduce the likelihood of 737 pressurization incidents. Among actions underway was a revision of the *B737 Flight Crew Training Manual* to include information on distinguishing between a cabin altitude warning and a takeoff configuration warning. "A number of remedial actions had been taken by the manufacturer since 2000, but the measures taken had been inadequate and ineffective in preventing further similar incidents and accidents," the report said.

Among actions taken in response to the findings of the accident investigation was Airworthiness Directive (AD) 2006-13-13, issued in June 2006 by the U.S. Federal Aviation Administration. The AD required revision of the 737 airplane flight manual (AFM) "to advise the flight crew of improved procedures for preflight setup of the cabin pressurization system, as well as improved procedures for interpreting and responding to the cabin altitude/configuration warning horn," the report said. The AD also required that the following message be inserted in the AFM: "For normal operations, the pressurization mode selector should be in 'AUTO' prior to takeoff." ●

This article is based on Hellenic Air Accident Investigation and Aviation Safety Board Aircraft Accident Report 11/2006, "Helios Airways Flight HCY522, Boeing 737-31S, at Grammatiko, Hellas, on 14 August 2005." The 198-page report contains illustrations and appendixes.