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Boeing 737 Pilot Flying Selects Incorrect Altitude in Holding Pattern, Causes Dangerous Loss of Separation with MD-81

The B-737 pilot correctly read back an ATC clearance, but set the wrong flight level in the autopilot mode control panel. Separation between the B-737 and a McDonnell Douglas MD-81 in the same holding stack was reduced to less than one-half mile (0.8 kilometer) horizontally and 100 feet (30.5 meters) vertically at their closest.

FSF Editorial Staff

A Boeing 737-400 and a McDonnell Douglas MD-81, both inbound to Heathrow Airport, London, England, lost the required separation when the B-737 pilot flying (PF) set an incorrect altitude in the autopilot mode control panel (MCP). As a result, the aircraft came within a recorded separation of between 2,231 feet and 2,690 feet (680 meters and 820 meters) horizontally and 100 feet vertically.

There were no injuries among the eight crewmembers and 69 passengers aboard the B-737, or the seven crewmembers and 70 passengers aboard the MD-81, in the Nov. 12, 1996, incident.

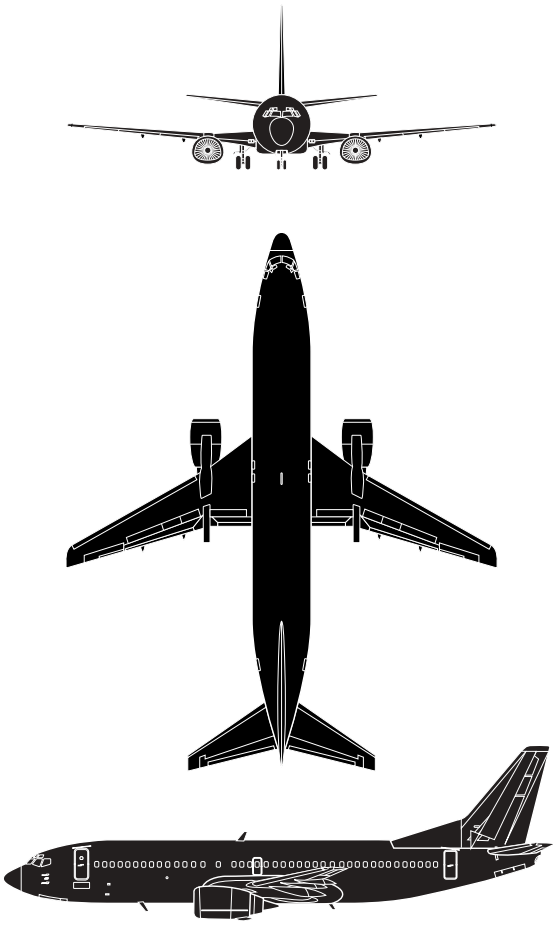
The U.K. Civil Aviation Authority (CAA) Joint AIRPROX Assessment Panel (JAAP), which reviews controller-reported loss-of-separation incidents in U.K. airspace, assigned the incident an "A" classification, defined as "an aircraft proximity in which actual risk of collision has existed."

[The United Kingdom has adopted the International Civil Aviation Organization (ICAO) global code word AIRPROX to replace the British term "airmiss." An AIRPROX is defined as "a situation in which, in the opinion of a pilot or a controller, the distance between aircraft, as well as their respective positions and speeds, have been such that the safety of the aircraft involved was or may have been compromised."]

The incident report by the U.K. Air Accidents Investigation Branch (AAIB) did not include a formal statement of probable cause. But the report said, "It was apparent during this investigation that the principal cause … lay in human factors, where the information-processing task for the pilot had broken down after a correct readback of the clearance to ATC [air traffic control]."

The B-737 was flying to London from Amsterdam, Netherlands, and the MD-81 was flying to London from Aarhus, Denmark.

The B-737 flight crew had begun their duty day at 0940 (all times Universal Coordinated Time [UTC]) in Stockholm, Sweden, and had flown one segment to Amsterdam, arriving at about 1350. Their next segment, the flight to London, was delayed for an hour, and takeoff occurred at 1607. The first officer, with 2,200 hours in type, was the PF; the captain, with 5,880 hours of flight time, of which 2,570 were in type, was the pilot not flying (PNF).



Boeing 737-400

The Boeing 737-400, a twin-turbofan airliner, is a stretched version of the Boeing 737-300. The variant first flew in February 1988, with the first customer delivery in September 1988.

The B-737-400, available in a basic model or long-range option, is powered by two CFM56-3C-1 engines. Maximum takeoff weight for the basic model is 138,500 pounds (62,820 kilograms), or 150,000 pounds (68,040 kilograms) for the long-range option. The long-range option, with 136 passengers and maximum takeoff weight, has a maximum cruising speed of Mach 0.82 and an initial cruising altitude of 31,700 feet (9,662 meters).

The aircraft is flown by a two-pilot crew. Depending on seating layout, the B-737-400 can carry 146 to 168 passengers. At maximum passenger capacity, range is 2,405 miles (3,870 kilometers).

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

During the incident, the aircraft were being controlled by the Lambourne (LAM) sector of the London Air Traffic Control Centre (LATCC).

"The controller at the time was a trainee on the sector, being supervised by a qualified mentor controller," said the report.

The LAM holding pattern is based on a very high frequency omnidirectional radio (VOR) near Romford, Essex. The required minimum vertical separation in the pattern is 1,000 feet.

Because of delays caused by single-runway operations at Heathrow, there was extensive holding for arriving flights. The MD-81 already had entered the LAM holding pattern when it was handed off to the LAM sector ATC at 1638. The flight was instructed to maintain flight level (FL) 170 (17,000 feet).

"Two minutes later, at 1640 hours, the B-737 came onto the [LAM] frequency, routing inbound to LAM, descending to FL 170," said the report. "It was instructed to enter the hold at LAM. Meanwhile, the MD-81 had been stepped down progressively until, at 1641 hours, it was instructed to descend to FL 140 (14,000 feet) and to expedite descent."

The MD-81 reported reaching FL 140 at 1641:45. The controller then cleared the B-737 to descend to FL 150 (15,000 feet). At 1641:55, the B-737 first officer, the PF, read back correctly the clearance to FL 150.

"At 1642:07 hours, the B-737 had about five nm [nautical miles; 9.3 kilometers] to run the LAM VOR and the MD-81 was turning back westward inbound to LAM and was 0.6 nm [1.11 kilometers) north of the B-737," said the report. "At this time, the B-737 was some 1,800 feet above the MD-81. From this point, the LATCC radar-display data blocks associated with each aircraft (i.e., flight number, destination and altitude data) became overlapped and could not be deciphered by the controller. This is not an unusual occurrence when aircraft are adjacent in holding stacks and did not cause concern to the controller at that stage."

At 1643:18, when the B-737 reported entering the hold at LAM, it was 700 feet directly above the MD-81. The two aircraft turned left together in the holding pattern (Figure 1, page 3).

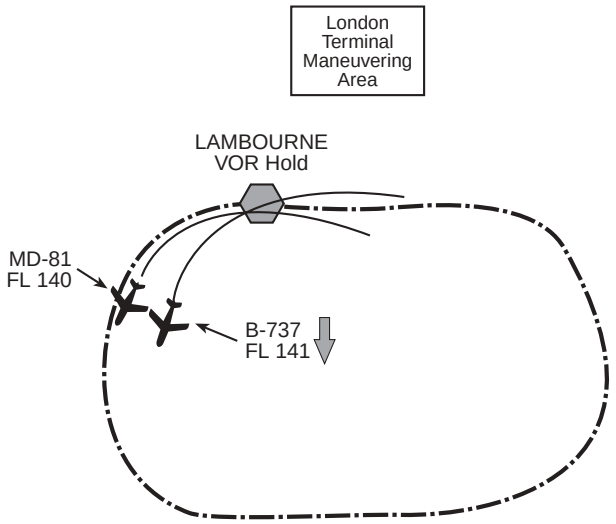
A short-term conflict alert (STCA) system was operational at LATCC.

"The system software is designed to take radar-track and altitude data and make linear extrapolations looking forward for a two-minute period … to predict possible conflicts between aircraft pairs when the appropriate separation standards could be lost," said the report. The system could generate two levels of alert — low and high — depending on the severity of the projected loss of separation.

The STCA indicated a low-level alert when the vertical separation between the aircraft became less than 900 feet, and then a high-level alert when separation decayed to less than 600 feet. The system supplied the controller with the call signs of the B-737 and the MD-81, but not their respective flight levels.

The controller then questioned the flight crews of the two aircraft to confirm the flight levels.

AIRPROX, Lambourne Sector, London Air Traffic Control Centre, Nov. 12, 1996



VOR = Very high frequency omnidirectional range
MD-81 = McDonnell Douglas MD-81
B-737 = Boeing 737 FL = Flight level

Source: U.K. Air Accidents Investigation Branch

Figure 1

"The MD-81 was questioned first and responded level at FL 140," said the report. "Immediately following this, at 1643:30 hours, the B-737 was questioned and replied that it was 'out of FL 143 [14,300 feet].' The aircraft was then informed that its previously cleared level was FL 150 and was instructed to climb immediately back to that level, as there was traffic immediately below it, and to expedite the climb. Both aircraft were in cloud and neither crew saw the other aircraft."

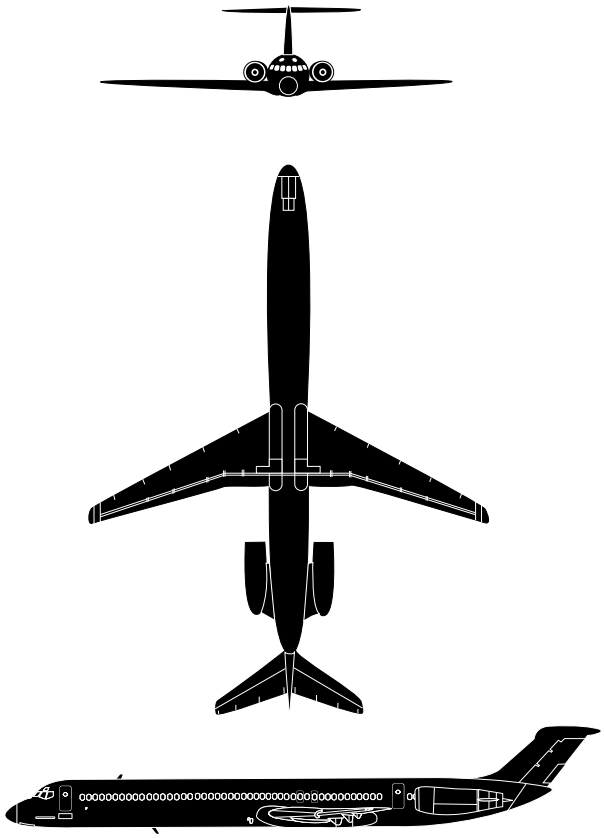
In response, the B-737 PF began a climb using the autopilot and autothrottle systems, and reported reaching FL 150 at 1644:30. No further ATC communication was made concerning the altitude deviation, and the two aircraft were handed off in sequence to Heathrow Intermediate Director (North East) Control.

The LATCC Separation Monitoring Function (SMF) continuously monitors the separation of aircraft with transponders in the LATCC coverage area, and creates postevent documentation for analysis when it detects a violation of predefined separation criteria. The system provides information in the form of a listing, a radar-replay simulation and a printed diagram of the event.

Alerted by the SMF, the controllers involved later filed a report about the incident.

Investigators determined from ground-based radar records that the B-737 and the MD-81 had come within 100 feet vertically and between 2,231 feet and 2,690 feet horizontally, from 1643:54 to 1643:59.

"The B-737 had executed a slightly smaller-radius turn than the MD-81, which resulted in the B-737 being slightly ahead and to the left of the MD-81 at the time of the closest proximity, with both aircraft having left bank applied for the turn, about 25 degrees in the case of the B-737," said the report.



McDonnell Douglas MD-81

The McDonnell Douglas MD-81 is the basic version of the MD-80 series, a higher-capacity variant of the McDonnell Douglas DC-9 twin-turbofan airliner. It has the same cabin size as the MD-82 and MD-83, but different performance characteristics. An aircraft of the MD-80 series, then known as the Super 80, first flew in October 1979 and was first delivered to a customer in September 1980.

The MD-81 is powered by two Pratt & Whitney JT8D-209 engines, mounted on pods on each side of the rear fuselage. Maximum takeoff weight is 140,000 pounds (63,505 kilograms), and maximum level cruising speed is 575 miles per hour (925 kilometers per hour).

The aircraft is flown by a two-pilot crew. Passenger capacity varies with seating layout; maximum is 172. With a typical mixed-class capacity of 155 passengers, the MD-81 has a range of 1,800 miles (2,897 kilometers).

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

Digital flight data recorder data from the B-737 revealed that the aircraft had descended as low as 14,052 feet, and had descended at a rate of about 1,000 feet per minute (305 meters per minute) while below FL 150, with the autopilot and autothrottles engaged.

The AAIB considered the factors that had been involved in the loss of separation.

The B-737 PNF was responsible for communications with ATC, for obtaining broadcast weather information and for maintaining contact with airline operations personnel on the company frequency. The PNF also was designated, according to the airline policy, to make passenger-address system (PAS) announcements.

"With regard to the altitude/flight level selections on the [MCP], whenever the autopilot and autothrottle systems are engaged, it is the responsibility of the [PF] to select the new cleared level in the MCP altitude window," said the report. "The selector operates in increments of 100 feet and has a tactile 'click' mechanism for each increment. The new cleared level is required to be confirmed by the [PNF] before the change is executed. The [PNF] will have acknowledged the new cleared level to ATC. Thus, for normal operations, both pilots have been 'in the loop' and have both confirmed their understanding of the ATC clearance."

But in the LAM incident, at the time of the ATC clearance to FL 150, the captain — the PNF — was making a PAS announcement about the delay caused by the hold.

"The clearance readback to ATC was done correctly by the first officer, but the incorrect FL 140 was entered on the MCP," said the report. "When the [captain] returned to the monitoring of the ATC channel, he was briefed by the first officer that the cleared level was FL 140. Thus, only one pilot had been involved in the change of cleared flight level process, and the two-crew cross-checking did not occur. Therefore, the discrepancy between the cleared level and the MCP-selected level went undetected by the crew.

"After the event, the B-737 crew remained unaware that the situation had resulted from their deviation from ATC clearance, as both pilots were convinced that they had been correctly cleared to FL 140."

The controller's radar display was unable to show flight-level information about the aircraft involved in the incident because the data blocks overlapped. The STCA system provided alerts about the loss of separation beginning 44 seconds before the closest proximity occurred, but it, too, could provide no altitude data.

"Several seconds were then lost while the controller verified each aircraft's level," said the report. "Work is currently under way to analyze the effects of garbling on the accuracy of Mode C [transponder altitude] data to determine if it is appropriate to include it in the STCA [display]."

Neither aircraft was fitted with a traffic-alert and collision avoidance (TCAS) system, nor was either required to be so equipped. The B-737 operator said that its wide-body types were already equipped with TCAS and that it was studying proposals to institute TCAS throughout its fleet. The MD-81 operator planned to introduce TCAS into its fleet the following year.

Had the two aircraft been equipped with TCAS II, the incident would have been unlikely, according to the AAIB. [There are two levels of TCAS technology. TCAS I generates traffic advisories only. TCAS II generates both traffic advisories and resolution advisories (RAs), which give the flight crew visual and aural guidance for vertical maneuvering to avoid a collision. TCAS II also can generate preventative commands such as "Do not descend" where a descent would create a conflict with traffic.]

"To ascertain whether TCAS II would have been effective in this case, the available ground radar data was used in a computer simulation of a TCAS II system … ," said the report. "Two simulations were carried out, from the viewpoint of each aircraft involved.

"The simulation showed [that] the B-737 crew would have received a 'Monitor vertical speed' RA when descending through FL 146 [14,600 feet]. This would have been accompanied by preventative 'Do not descend' symbology on the flight instruments (electronic attitude display indicator [EADI] or vertical speed indicator [VSI], dependent upon the system installation). In addition, the aircraft in close proximity would have been displayed as a color-coded symbol on the electronic horizontal situation indicator [EHSI], along with the relative height. This RA would have occurred on two occasions while the aircraft were in the turn with less than 600 feet vertical separation.

"In the case of the MD-81, the first RA generated would have been 'Monitor vertical speed' accompanied by preventative 'Do not climb' symbology, followed by 'Descend, descend' as the B-737 came towards its closest point of approach."

The AAIB noted a CAA safety review of altitude deviations within U.K. airspace during 1994, which included 235 recorded violations. Among those 235, 165 (70 percent) were attributed to pilots who correctly read back clearances but did not comply with them.

In the incident involving the B-737 and the MD-81, the report said, "The transient situation of one pilot being 'out of the loop' on the flight deck was undoubtedly instrumental in the error remaining uncorrected until the STCA system warning was triggered and the controller intervened to prevent both aircraft flying at the same level in close proximity, with the attendant risk of collision."

The AAIB made five recommendations as a result of the incident investigation:

- "**97-17**. It is recommended that [the B-737 operator] review its standard operating procedures to ensure that the monitoring of ATC VHF [very high frequency] communications is carried out by two flight-deck crewmembers with the minimum possible interruption during the climb and descent phases of flight. In particular, interruption of monitoring while PAS announcements are made by flight deck crew should be discouraged during these phases;

- "**97-18**. It is recommended that the CAA publish guidelines for use by crews receiving and [putting into effect ATC] clearances, aiming to ensure that safeguards specified by the operator will minimize the risk of noncompliance. Emphasis should be given to the importance, during the climb and descent phases of flight, of not having just one crewmember monitoring ATC clearances for longer than is absolutely necessary;

- "**97-19**. It is recommended that, where STCA programs are in use, NATS [National Air Traffic Services] ensures that information is provided in such a way that accurate Mode C data for all aircraft is clearly and continuously visible to the controller;

- "**97-20**. It is recommended that NATS investigate improvements to radar displays such that controllers are able to see label information in circumstances, particularly in holding stacks, when the labels would normally overlap; [and,]

- "**97-21**. It is recommended that the CAA make every effort to ensure that the current proposed target dates for the mandatory carriage of TCAS II equipment are implemented by ECAC [European Civil Aviation Conference] and by the JAA, and that such carriage, and use, is made mandatory within U.K. airspace."

The report said, "The CAA has instigated a fresh safety initiative in January 1997 into the cause of these potentially catastrophic occurrences to try and eliminate them."

The JAAP, which reviewed the incident and the AAIB report, endorsed the AAIB recommendations and CAA action.

"From scrutiny of the SMF replay and RTF [radio telephony] recording and transcript, the [JAAP] believed that the controllers' reaction to the STCA alert was subject to some delay," said the JAAP review. "It [is] possible that the initial low-level alert (which lasted for 16 seconds) had been disregarded; this would not have been unusual in a holding-pattern situation where nuisance alerts are not uncommon. The fact that it was a [trainee] controller and mentor might also have imposed some small delay.

"Also, with hindsight, most would agree that the aircraft were challenged in the wrong order; in a holding pattern it is much more likely that it would be the higher of the aircraft which has not conformed to its cleared level.

"It was estimated that the challenge to the MD-81 pilot occurred about eight seconds after the high-level STCA alert commenced, and that [the challenge] to the B-737 pilot [occurred] about five seconds later. These small cumulative delays related to circumstances when the aircraft [was] descending at around 1,000 feet per minute. Nevertheless, although vertical separation decayed to around 300 feet at the time of the controller's challenge to the B-737 pilot (and subsequently decreased to around 100 feet during the recovery), it was quite clear to the JAAP that STCA [was] crucial to the resolution of this dangerous situation. Without STCA, it is unlikely that the controllers would have even known about the severity of the situation and thus [would not have] been able to resolve it."

The JAAP said that the controllers had good luck, because there was a quiet interval on the fairly busy radio communication frequency at the time when they needed to speak with the pilots of the aircraft involved in the incident.

"The [JAAP] has seen several AIRPROX where a controller or pilot has had to wait for a gap on a congested frequency before being able to make an urgent transmission," the JAAP review said.

The JAAP described TCAS as "the ultimate safety net with regard to preventing aircraft colliding" and urged that there be no delay beyond target dates set by the ECAC and the Joint Aviation Authorities (JAA) for mandating TCAS. Those target dates are:

- For all civil fixed-wing, turbine-engine aircraft having a maximum takeoff mass exceeding 15,000 kilograms (33,069 pounds) or a maximum approved passenger-seating configuration of more than 30: Jan. 1, 2000; and,

- For all civil fixed-wing, turbine-engine aircraft having a maximum takeoff mass exceeding 5,700 kilograms (12,566 pounds) or a maximum approved passenger seating configuration of more than 19: Jan. 1, 2005.

[On the same day as this AIRPROX in U.K. airspace, a Boeing 747-100 and an Ilyushin Il-76T collided near Charkhi Dadri, India, at about FL 140. All 23 crewmembers and 289 passengers on the B-747, and all 10 crewmembers and 27 passengers on the Il-76, were killed.]♦

Editorial note: This article was based on U.K. Air Accidents Investigation Branch Bulletin no. 5/97, ref. EW/C96/11/4, and on U.K. Civil Aviation Authority *Aircraft Proximity Reports: AIRPROX (C) — (Controller Reported)*, Volume 12, AIRPROX (C) Report 52/96, Occurrence no. 96/05125.

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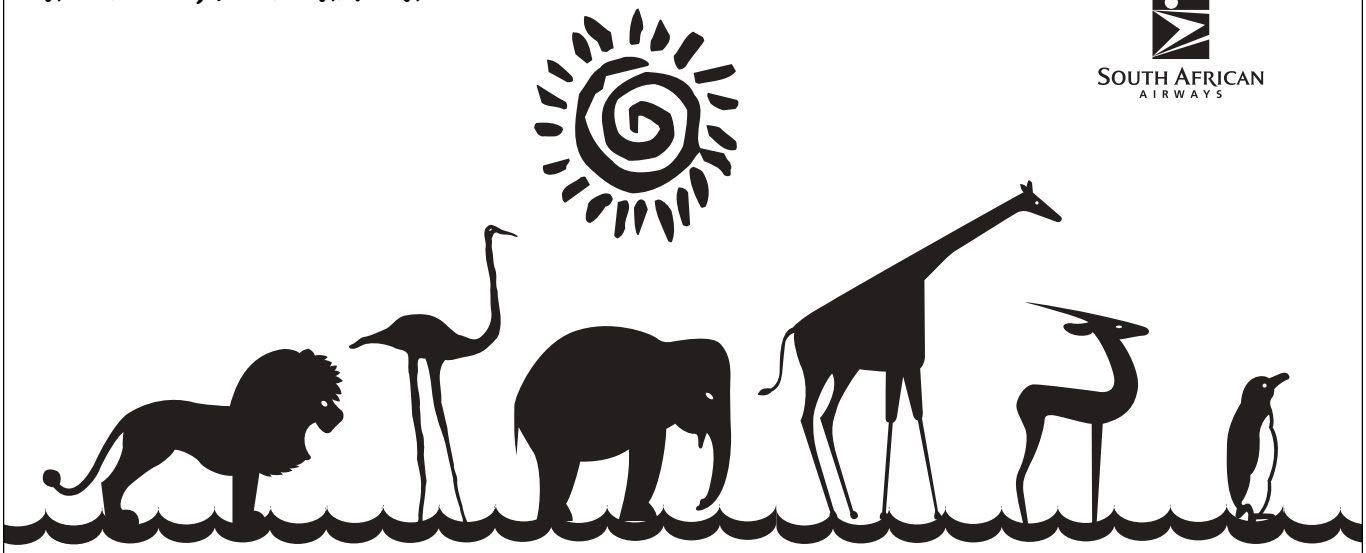

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