Boeing 737-406, PH-BTG and McDonnell Douglas DC-9-81, SE-DMB

AAIB Bulletin No: 5/97 Ref: EW/C96/11/4Category: 1.1

Aircraft Type and Registration:	i)	Boeing 737-406, PH-BTG
	ii)	McDonnell Douglas DC-9-81, SE-DMB
No & Type of Engines:	i)	2 CFM56-3C1 turbofan engines
	ii)	2 Pratt & Whitney JT-8D turbofan engines
Year of Manufacture:	i)	1994
	ii)	1991
Date & Time (UTC):		12 November 1996 at 1644 hrs
Location:		Lambourne VOR Holding Pattern
		Near Romford, Essex
Type of Flight:		Public Transport
Persons on Board:	(i)	Crew - 8 - Passengers - 69
	(ii)	Crew - 7 - Passengers - 70
Injuries:		None
Nature of Damage:		None
Commander's Licence:	i)	Airline Transport Pilot's Licence (Netherlands)
	ii)	Airline Transport Pilot's Licence (Norway)
Commander's Age:	i)	34 years
	ii)	51 years
Commander's Flying Experience:	i)	5,880 hours (of which 2,570 were on type)
	ii)	8,327 hours (of which 337 were on type)
Information Source:		AAIB Field Investigation

The Boeing 737 (B737) and DC-9-81 (MD81) were inbound to LondonHeathrow from Amsterdam (Netherlands) and Aarhus (Denmark) respectively.The incident occurred while both aircraft were under the controlof the Lambourne (LAM) Sector Control (frequency 121.225 MHz)at the London Air Traffic Control Centre (LATCC), West Drayton.The controller at the time was a trainee on the sector, beingsupervised by a qualified mentor controller.

The LAM holding facilityis based upon the LAM VOR, ground track 267°M inbound withleft turns and outbound leg timing of 1 minute up to and includingFL140 (maximum speed 220 kt), or 1.5 minutes at FL150 and above(maximum speed 240 kt).

Due to single runway operations, therewas extensive holding in progress for Heathrow arrivals and theMD81 had already entered the LAM holding pattern at FL170 whenit was transferred to the control of this sector at 1638 hrs.It was instructed to maintain FL170 and was passed an ExpectedApproach Time (EAT) of 1649 hrs. Two minutes later, at 1640 hrs,the B737 came onto the frequency, routing inbound to LAM descendingto FL170. It was instructed to enter the hold at LAM. Meanwhile,the MD81 had been stepped down progressively until, at 1641 hrs,it was instructed to descend to FL140 and to expedite descent.At 1641:45 hrs the MD81 was requested to report reaching FL140,but replied that it was already at that level. Accordingly thecontroller then cleared the B737 to descend to FL150**.** At1641:55 hrs, this instruction was correctly acknowledged by theB737 crew, including the correct cleared flight level 150.

At1642:07 hrs, the B737 had about 5 nm to run to the LAM VOR andthe MD81 was turning back westward inbound to LAM and was 0.6nm north of the B737. At this time, the B737 was some 1,800 feetabove the MD81. From this point, the LATCC radar display datablocks associated with each aircraft (*ie* flight number,destination and altitude data) became overlapped and could notbe deciphered by the controller. This is not an unusual occurrencewhen aircraft are adjacent in holding stacks and did not causeconcern to the controller at that stage.

At 1643:18, the B737reported that it was taking up the hold at LAM. At this time,it was directly overhead the MD81, 700 feet above it. The aircraftthen turned left together in the holding pattern. At this stage,the LATCC Short Term Conflict Alert (STCA) system operated indicatingthat the B737 and the MD81 had lost the required separation. TheSTCA system indicated the callsigns of the conflicting aircraftto the controller, but not the respective flight levels. The controllertherefore requested each aircraft in turn to confirm its FlightLevel. The MD81 was questioned first and responded level at FL140.Immediately following this at 1643:30 hrs, the B737 was questionedand replied that it was 'out of FL143'. The aircraft was theninformed that its previously cleared level was FL150 and was instructedto climb immediately back to that level as there was traffic immediatelybelow it and to expedite the climb. Both aircraft were in cloudand neither crew saw the other aircraft. At 1644:30 hrs, the B737reported level at FL150. The minimum permitted vertical separationin the holding stacks is 1,000 feet.

There was no further communicationwith either aircraft regarding the incident and each was descendedfurther and handed over in the correct sequence to Heathrow IntermediateDirector (North East) Control.

The seriousness of the incidentwas highlighted when the LATCC Separation Monitoring Function(SMF) data became available a few minutes after the event. TheSMF continuously and automatically monitors the separation betweentransponding aircraft and will detect any breach of pre-definedseparation criteria that takes place within the coverage of theLATCC enroute radar system. The SMF is not a collision avoidancesystem. It provides post event notification to assist in an investigationof the circumstances of the loss of separation. This is producedin a listing, a radar replay simulation and a printed encounterdiagram. Once the SMF notification had been received by the supervisor,the controllers involved then compiled and submitted the appropriateAirprox (C) report about the incident.

The closest distance betweenthe aircraft, derived from recordings of ground based radar facilities,was 100 feet vertically and between 680 and 820 metres horizontally,at 1643:54 to 1643:59 hrs. The B737 had executed a slightly smallerradius turn than the MD81, which resulted in the B737 being slightlyahead and to the left of the MD81 at the time of closest proximity,with both aircraft having left bank applied for the turn, about25° in the case of the B737.

From the B737 DFDR data, itwas determined that the minimum flight level achieved by the aircraftat the time of the incident was 14,052 feet at 1643:46 hrs. (Note:the time base for the B737 DFDR and that for the recorded groundradar facilities were not synchronised). The aircraft was descendingat a rate of about 1,000 feet per minute while below FL150, withautopilot and autothrottle engaged. In response to the call fromATC, an immediate climb was initiated using the autopilot andautothrottle systems. The aircraft reached FL150 again at 1644:24hrs.

Flight Deck Management

The B737 was being operatedin accordance with the company's Standard Operating Procedures.The crew had come on duty that day at 0940 hrs in Stockholm. Theyoperated one sector to Amsterdam, arriving at about 1350 hrs.There was a delay of about one hour at the start of the incidentsector, with the aircraft becoming airborne from Amsterdam forLondon Heathrow at 1607 hrs. The First Officer, who had some2,200 hours on type, was the handling pilot for this sector, withthe commander, as non-handling pilot, being responsible for makingthe ATC radio transmissions and for obtaining updated weatherinformation from the ATIS and VOLMET facilities, as well as contactwith the company on the operations frequency for flight progress/ETApurposes and for special messages. Additionally, within the company,the nonhandling pilot is normally delegated to make thePassenger Address System (PAS) announcements.

With regard to thealtitude/flight level selections on the Mode Control Panel (MCP),whenever the autopilot and autothrottle systems are engaged, itis the responsibility of the handling pilot to select the newcleared level in the MCP altitude window. The selector operatesin increments of 100 feet and has a tactile 'click' mechanismfor each increment. The new cleared level is required to be confirmedby the non-handling pilot before the change is executed. The non-handlingpilot will have acknowledged the new cleared level to ATC. Thus,for normal operations, both pilots have been 'in the loop' andhave both confirmed their understanding of the ATC clearance.The aircraft is also equipped with an altitude deviation alertingaural and visual warning system which operates in the event ofa deviation away from the altitude set on the MCP.

In this case,at the time of the B737 re-clearance to FL150, the commander (non-handling)was not monitoring the ATC channel because he had deselected itin order to make a PAS announcement to the passengers regardingthe holding delay. The clearance readback to ATC was done correctlyby the First Officer, but the incorrect FL140 was entered on theMCP. When the commander returned to the monitoring of the ATCchannel, he was briefed by the First Officer that the clearedlevel was FL140. Thus, only one pilot had been involved in thechange of cleared flight level process and the two crew cross-checkingfunction did not occur. Therefore, the discrepancy between thecleared level and the MCP selected level went undetected by thecrew.

After the event, the B737 crew remained unaware that thesituation had resulted from their deviation from ATC clearanceas both pilots were convinced that they had been correctly clearedto FL140.

Short Term Conflict Alert (STCA) System

The STCAsystem is now operational in the majority of UK controlled airspace.The system software is designed to take radar track and altitudedata and make linear extrapolations looking forward for a twominute period in order to predict possible conflicts between aircraftpairs when the appropriate separation standards could be lost.In the Terminal Control implementation of STCA, two levels ofalert may be issued, dependant upon the predicted proximity ofthe two aircraft and the time before this occurs. In a 'low severityalert' the aircraft symbols change from green to flashing whiteand a white pairing line joins the relevant pair on the radardisplay. A 'list box' also appears, indicating the radar identificationsof the pair involved. This alert level may be 'acknowledged' bythe controller when resolution instructions have been passed asrequired. The high level alert causes a colour change to red andthis cannot be acknowledged by the controller. The alert remainson until the conflict has been resolved and the appropriate separationregained. The system is designed as a safety net and not a separationassurance tool.

The STCA system uses basic radar data for itscalculations, with no 'aircraft intention' input as to altitudeclearances issued or the expected initiation of turns (such asover holding fixes). Filters have therefore been built into thesoftware in order to minimise the occurrence of 'nuisance' alertswhen separation would be properly maintained, for example, byan aircraft levelling off at a new cleared flight level duringa descent.

In this case, after the 'stack linear prediction filter'criteria had been fulfilled, and the 'close to level off delay'mechanism had confirmed the predicted loss of separation for twoout of three radar sweep cycles (*ie* about 8 seconds) alow level alert was generated when the vertical separation betweenthe two aircraft had reduced below 900 feet (and about 0.11 nmlateral), then changed to a high level alert when the verticalseparation reduced below 600 feet. This alert was generated fora total period of 76 seconds, until the vertical separation againincreased above 600 feet. For both alert levels, the ConflictList box gave the two callsigns of the aircraft involved, butnot the respective flight levels. These flight levels were alsounreadable on the main display because of data block overlap.The alert was triggered some 44 seconds prior to the time of closestproximity. Several seconds were then lost while the controllerverified each aircraft's level. Work is currently underway toanalyse the effects of garbling on the accuracy of mode C altitudedata to determine if it is appropriate to include it in the STCAconflict list boxes.

Traffic Alert and Collision AvoidanceSystem II (TCAS II)

This system, also known as Airborne CollisionAvoidance System II (ACAS II), is based upon the use of aircrafttransponder equipment to provide warnings of possible collisionwith other transponding aircraft. The TCAS equipment scans onceper second and may detect intruding traffic up to 40 nm distantand within 8,700 feet of the subject aircraft. Traffic movementsare assessed and trends are predicted to search for potentialconflicts. Advisory alerts will then be triggered when a particulartarget aircraft becomes a threat, *ie* within a defined volumeof airspace around the aircraft. The lower priority alert is aTraffic Advisory (TA) which produces an aural alert *'Traffic,Traffic'* on the flight deck and a visual cue as tothe location of the target. For closer encounter predictions whenevasive action is required, a Resolution Advisory (RA) is generatedwhich gives both visual and aural cues to the flight crew on thevertical manoeuvre required to avoid a collision. Preventativecommands, such as 'do not descend' can also be generated and displayedto the crew where circumstances are such that level flight willmaintain safe separation.

Neither aircraft involved in this incidentwas fitted with such a system, nor was there any current requirementfor them to be so equipped. However, the B737 operator indicatedthat all of its widebody types were already so equipped and thatit is currently studying proposals to fit the remaining aircraftin its fleet with the system within the next two years. The MD81operator indicated that the programme to incorporate TCAS intothis fleet would commence in Autumn 1997.

In order to ascertainwhether TCAS II would have been effective in this case, the availableground radar data was used in a computer simulation of a TCASII system by the DERA Malvern. Two simulations were carried out,from the viewpoint of each aircraft involved. The simulation showedthe B737 crew would have received a *'Monitor Vertical Speed'*RA when descending through FL146. This would have been accompaniedby preventative 'Do Not Descend' symbology on the flight instruments(Electronic Attitude Display Indicator (EADI) or Vertical SpeedIndicator (VSI), dependant upon the system installation). In addition,the aircraft in close proximity would have been displayed as acolour coded symbol on the Electronic Horizontal Situation IndicatorEHSI, along with the relative height. This RA would have occurredon two occasions while the aircraft were in the turn with lessthan 600 feet vertical separation. In the case of the MD81,the first RA generated would have been 'Monitor Vertical Speed'accompanied by preventative 'Do Not Climb' symbology, followedby 'Descend, Descend' as the B737 came towards its closest pointof approach.

Handling of AIRPROX (C) Reports

An AIRPROXis defined as a situation in which, in the opinion of a pilotor a controller, the distance between aircraft as well as theirrelative positions and speed have been such that the safety ofthe aircraft involved was or may have been compromised.

Reportsgenerated by pilots are classified as AIRPROX (P) reports andare considered by the Joint AIRPROX Working Group (JAWG). Reportsgenerated by Air Traffic Controllers are classified as AIRPROX(C) reports and are considered by the Joint AIRPROX AssessmentPanel (JAAP).

The JAAP consists of an independent Chairman plusfour pilots and four controllers. The panel reviews the reportsand assesses the degree of risk inherent in each occurrence. Thecausal factors are determined and, where appropriate, safety recommendationsare made in the interests of flight safety.

Before this incident,a number of Safety Recommendations had been made by JAAP, twoof which were in areas relevant to the circumstances of this AIRPROX.These are detailed below:

J95-6*' The Panel recommended thatthe CAA continue the development of ATC radar Short Term ConflictAlert (STCA) devices especially in TMA airspace, including holdingpatterns.'*

The CAA accepted this recommendation and this systemis now operative in London, Manchester and Scottish Control Centres.

J95-7 *'The panel recommended that the CAA mandate the fittingof TCAS to all commercial air transport aircraft operating inUK controlled airspace as soon as possible.'*

The CAA did notaccept this recommendation. The CAA policy position acknowledgesthe proved safety benefits of TCAS and is pursuing the implementationmandate in accordance with ECAC policy. This policy has proposedthe following mandate to apply to all airspace within ECAC memberstates:

'a. With effect from 1 January 2000, all civil fixedwing turbine-engined aircraft having a maximum take-off mass exceeding15,000 kg or a maximum approved passenger seating configurationof more than 30 will be equipped with ACAS II, and

b. With effectfrom 1 January 2005, all civil fixed wing turbine-engined aircrafthaving a maximum take-off mass exceeding 5,700 kg or a maximumapproved passenger seating configuration of more than 19 willbe equipped with ACAS II.'

A similar mandate has been proposedby the JAA for aircraft registered in JAA states, using slightlydifferent wording but having the same weight categories and targetimplementation dates.

CAA Safety Data Department Survey ofFlight Level Violations

Results of a CAA safety review oflevel violations within UK airspace during 1994 indicated an overalltotal of 235 recorded violations. Of these 165 (70%) were attributedto pilots noncompliance with correctly read-back ATC verticalclearances. Additional analysis of these 'altitude busts' by flightlevel indicated that the majority of occurrences were at and belowFL120 in TMA airspace. It was also found that the majority ofdeviations were in aircraft from foreign operators (68% of theoverall total). Whilst the majority of occurrences occurred duringthe departure and climb phases, the descent phase also figuredprominently as an area of concern.

Safety Recommendations

Itwas apparent during this investigation that the principal causeof the incident lay in human factors, where the information processingtask for the pilot had broken down after a correct read-back ofthe clearance to ATC. The transient situation of one pilot being'out of the loop' on the flight deck was undoubtedly instrumentalin the error remaining uncorrected until the STCA system warningwas triggered and the controller intervened to prevent both aircraftflying at the same level in close proximity, with the attendantrisk of collision.

It was also apparent that the addition of accuratealtitude data to the STCA Conflict Alert List box displaywould have been beneficial in reducing the time interval beforeremedial instructions could be issued by the controller.

It wasalso apparent that the presentation of the data blocks on themain radar displays could be improved in order to reduce the incidenceof data block overlap for adjacent aircraft pairs.

The TCAS IIsimulation showed that such a system, had it been fitted to eitheror both aircraft, would have provided timely warning of theirmutual proximity.

97-17 It is recommended that KLM reviewits Standard Operating Procedures to ensure that the monitoringof ATC VHF communications is carried out by two flight deck crewmembers with the minimum possible interruption during the climband descent phases of flight. In particular, interruption of monitoringwhile PAS announcements are made by flight deck crew should bediscouraged during these phases.

97-18 It is recommendedthat the CAA publish guidelines for use by crews receiving andactioning air traffic control clearances, aiming to ensure thatsafeguards specified by the operator will minimise the risk ofnoncompliance. Emphasis should be given to the importance,during the climb and descent phases of flight, of not having justone crew member monitoring ATC clearances for longer than is absolutelynecessary.

97-19 It is recommended that, where STCA programsare in use, NATS ensures that information is provided in sucha way that accurate Mode C data for all aircraft involved is clearlyand continuously visible to the controller.

97-20 It isrecommended that NATS investigate improvements to radar displayssuch that controllers are able to see label information in circumstances,particularly in holding stacks, when the labels would normallyoverlap.

97-21 It is recommended that the CAA make everyeffort to ensure that the current proposed target dates for themandatory carriage of TCAS II equipment are implemented by ECACand by the JAA and that such carriage, and use, is made mandatorywithin UK airspace.