Boeing 737-500, G-OBMX

AAIB Bulletin No: 2/97 Ref: EW/C96/9/3 Category: 1.1

Aircraft Type and Registration:	Boeing 737-500, G-OBMX
No & Type of Engines:	2 CFM56-3C1 turbofan engines
Year of Manufacture:	1991
Date & Time (UTC):	5 September 1996 at 0851 hrs
Location:	Near Lambourne
Type of Flight:	Public Transport
Persons on Board:	Crew - 6 - Passengers - 64
Injuries:	Crew - Nil - Passengers - Nil
Nature of Damage:	Nil
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	55 years
Commander's Flying Experience:	13,640 hours (of which 5,525 hours were on type)
	Last 90 days - 214 hours
	Last 28 days - 74 hours
Information Source:	AAIB Field Investigation

History of flight

The crew had flown an uneventful flight from London Heathrow toBrussels during which the aircraft had been fully serviceable. After a normal turnround, the same crew took-off for the returnflight. The commander was the handling pilot and he engaged AutoPilot 'A' soon after establishing the aircraft on the departurefrom Brussels; in accordance with his company procedures, he hadused auto-throttle from the beginning of his take-off roll. Theclimb and cruise were normal and the automatic control systemswere operating correctly. During the descent, the crew were advisedthat there was a delay going into Heathrow, and were instructedto enter the 'Hold' at Lambourne. After approximately 15 minutesin the 'Hold', ATC instructed the crew to leave Lambourne at FL80 on a heading of 270°(M) at 220 kt IAS. The commanderselected 'HDG SELECT' and '270°' on the Mode Control Panel(MCP) and, as the aircraft crossed Lambourne, it rolled out onthe required heading.

With the aircraft still level at FL 80 and clear of any cloud,the crew were not visually aware of any other aircraft in theirvicinity. Neither crew member had their feet on the rudder pedalsbut the commander had his hands lightly on the control wheel. The crew were then cleared to descend to FL 70 and the commanderselected the new altitude, Vertical Speed ('V/S') and a descentrate of 1,000 feet per minute on the MCP. As the aircraftstarted the programmed descent, the Flight Service Manager (FSM)entered the cockpit. Both crew members turned in their seatsto talk to the FSM and the commander took his hands off the controlwheel as he turned. Shortly afterwards, both of the flight crewwere aware of the aircraft banking to the left; the bank appearedrapid but smooth. They both turned back and the commander puthis feet on the rudder pedals and his hands on the control wheel. As he did so, his impression was that the wheel and rudder werecentral. The aircraft appeared to be banked at least 30°and the impression of both crew members was that the aircraftwas continuing to roll to the left. The commander immediatelydisconnected the autopilot and applied right rudder and rightcontrol wheel. Response to the control inputs was rapid and accurateand the aircraft was quickly brought back under control**.** After confirming that the rudder and aileron trim were neutraland that there were no system abnormalities, the autopilot wasre-engaged. It operated correctly for the remainder of the flightalthough the commander manually disconnected it very early onthe approach.

The first officer confirmed the commander's account of the incident. He also reached for the controls following the uncommanded roll,which he estimated as 50° bank. He also thought that thecontrol wheel and rudder were central prior to the commander'smanual input. Both crew members had experienced wake turbulencebefore but were not fully convinced that this was a wake encounter. They based this assessment on the fact that it was smoother andmore extreme than their previous experience.

The incident was reported to AAIB and arrangements were made toread and analyse the recorded flight data and for AAIB personnelto be present during an investigative inspection.

Engineering investigation

Following the incident, a full inspection of the aircraft rollcontrol system was conducted with the assistance of the manufacturer. This inspection established that the control system was correctlyrigged, well within the limits required, and functioned normally. The inspection was expanded to ensure that there had been nomoisture ingress into the connectors of the avionics boxes whichaffect flight controls. It also showed that the protective shields,in the E & E bay behind the nose landing gear, were correctlylocated and in good condition. There was no evidence of moistureingress into the bay from any source.

Additionally, a special check on the roll control system was performedto ensure confidence in the calibration and directional senseof the roll control signal to the flight data recorder system. This showed that both aspects were correct.

Enquiries of the manufacturer revealed that the maximum roll controldeflection which the autopilot can achieve is, by design, about4.5° of aileron movement (a control wheel movement of about20°), depending on the stimulus. The maximum aileron movementwhich can be achieved by the pilot is about 20°, which requiresa control wheel input of about 82°.

Weather conditions

An aftercast was provided by The Meteorological Office at Bracknell. At 0800 hrs on the day of the incident, there was a ridge ofhigh pressure established over England and Wales with a northeasterly airflow over southern England. There were no forecastsfor turbulence on the day and no subsequent reports of turbulencebeing experienced. Analysis of the upper soundings suggest thatthere was a strong inversion around 5,000 feet amsl in the areaof Lambourne and the wind speed at that level was 060°T/15kt.

Radar information

Recorded radar information was obtained, correlated with the FDR,analysed and is displayed at Figure 2. It showed that G-OBMXwas 1 minute 26 seconds or 6.35 nm behind a B767 aircraft whichwas also approaching Heathrow. A B757 aircraft which had justdeparted from Runway 09 at Heathrow, passed approximately atright angles to the track of the two inbound aircraft. As theB757 was 2,300 feet below G-OBMX, it was not consideredrelevant to the incident.

The tracks of the B767 and G-OBMX are very close and, consideringthe recorded wind and with GOBMX descending geographicallyearlier than the B767, the position of the incident is consistentwith G-OBMX encountering the wake shed by the B767.

FDR information

A time history of the relevant parameters is shown at Figure 3. This shows that G-OBMX was level at FL 80, heading 270°Mand at 220 kt IAS. Wind recorded at that level was 057°T/40kt. At 08:51:10 hrs, G-OBMX started a gentle descent. Shortly afterwards, as the aircraft descended through 7,800 feet,small perturbations appeared on the 'normal g' trace. Withintwo seconds, right roll control was applied; initially this keptthe aircraft wings level. However, over the following three seconds,the aircraft started to roll to the left, albeit against an increasingaileron deflection to counter this movement. With the aileronthen constant at about 5° deflection, G-OBMX continued toroll left at an increasing roll rate. The autopilot disengagedand a large right roll demand was applied to the aircraft. Themaximum left roll rate derived from the data was more than 18°per second and this occurred after the right roll demand was applied. With the sampling intervals associated with the FDR data acquisition,the aircraft may have achieved a greater bank angle than the recorded31°. The aircraft then recovered to wings level within fourseconds. There are no subsequent indications of any further uncommandedflight path excursions.

Information from Boeing Commercial Airplane Group indicated that,from data obtained from a test programme, there are some key characteristicsor attributes of wake encounters. External characteristics includeperturbations in airspeed and in normal g without correspondingchanges in pitch attitude; this can also sometimes be seen inrandom changes in lateral acceleration and angle of attack. Rollcharacteristics can be much more difficult to discern but includea roll angle that leads to a heading change and a roll rate increasingwith time. The G-OBMX FDR data shows these classic characteristics. It also displays similarities with other recorded wake turbulenceevents.

Wake turbulence

Aircraft vortex wake categories and spacing criteria are definedin the Manual of Air Traffic Services (MATS) - Part 1 Chapter3 & Appendix B. The B767 is included in the heavy categoryand both the B757 and B737 are included in the medium category. The spacing required for a medium category aircraft behind aheavy category aircraft is five miles. The spacing between twomedium category aircraft is three miles. However, SupplementaryInstruction No 6 of 1994 to MATS

acknowledged the unique characteristicsof the B757 and raised the spacing requirements of a medium categoryaircraft behind a B757 to four miles. These figures relate specificallyto aircraft on final approach but, within the MATS, there is aninstruction to apply spacing so that "aircraft of a lowerweight category do not fly through the wake of an aircraft ofa higher category within the area of maximum vortices. Whereminimum separation between IFR flights is greater than the vortexwake spacing requirements then the IFR minima shall be applied."

CAA Aeronautical Information Circular (AIC) 178/1993 draws attentionto the dangers associated with turbulence caused by aircraft wakevortices. The AIC makes the point that the separation minimacannot entirely remove the possibility of a wake turbulence encounter. The objectives of the minima are to reduce the probability ofa vortex wake encounter to an acceptably low level, and to minimisethe magnitude of the upset when an encounter does occur.

Wake vortices are present behind every aircraft but are particularlysevere when generated by heavy aircraft. The characteristicsof the wake vortex system generated are determined initially bythe aircraft's gross weight, wing span, airspeed, configurationand attitude. Subsequently, these characteristics are alteredby interaction between the vortices and the ambient atmosphere. Time to total decay can vary from a few seconds to a few minutesafter the passage of the aircraft. For practical purposes, thevortex system in the wake of an aircraft may be regarded as beingmade up of two counter-rotating cylindrical air masses trailingaft from the aircraft, as shown in Figure 1. Studies suggestthat, at medium level, the two vortices are separated by aboutthree quarters of the aircraft's wingspan and, in still air, tendto drift slowly downwards, at a rate of approximately 400 feetper minute, and level off, usually not more than 1,000 feet belowthe flight path of the aircraft. However, their behaviour isnot predictable, particularly in the aspects of their trajectoryand decay.

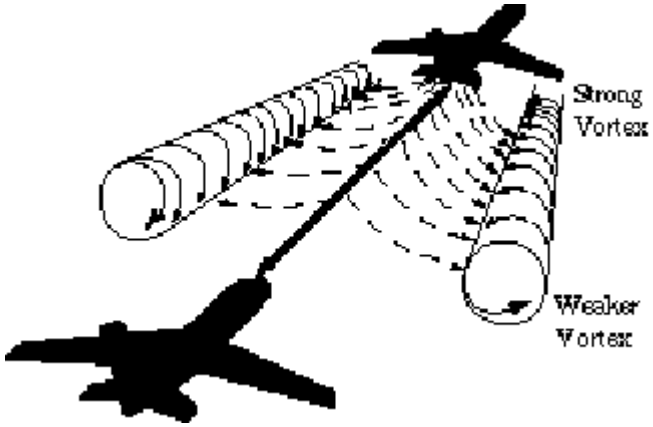

Figure 1

Discussion

The G-OBMX data shows the classic symptoms of a wake turbulenceencounter. A review of the radar trace indicates that G-OBMXwas following a B767, but slightly downwind. The separation,at 6.35 miles, was greater than the required minimum of 5 miles. With G-OBMX starting a descent geographically earlier than theB767, the uncommanded roll started as the B737 was 200 feet verticallybelow the flight path of the B767 at that geographical position(see Figure 2). Within three seconds, the ailerons were at theirmaximum available deflection to the right under autopilot authority(approximately 4.5°) and could no longer prevent the aircraftfrom rolling left. The pilot's response was extremely quick todisengage the autopilot, and exert much greater roll control tocounter the uncommanded roll and restore level flight. However,if he had had his hands on the

control wheel when the autopilotstarted to oppose the uncommanded roll, he would have been immediatelyaware of the control wheel moving.

It is not known what would have happened if the autopilot hadremained in sole control. In these circumstances, the manufacturersstate that there would be no reason for the autopilot to disconnectautomatically. Both pilots considered that the roll would havecontinued and the FDR information indicates that the roll ratewas high and increasing and that the aircraft achieved a bankangle of at least 31°. If G-OBMX had cleared the wake vortexbefore achieving too high a bank angle, it is probable that theautopilot would have recovered the aircraft to level flight.

This incident is an example of a severe wake turbulence encounteroccurring even though the spacing between aircraft was greaterthan the recommended minimum. With the flow rate at major airports,aircraft are highly likely to be at the minimum spacing as theyare being manoeuvred for approach. This incident was controllablewith manual control inputs but doubt remains as to the outcomeif the autopilot had been left to recover the situation. Goodairmanship dictates a 'hands on' monitoring of the autopilot insuch situations. Immediately following this incident, the operatingcompany instituted a flying instruction to their crews to theeffect that the handling pilot must be physically monitoring thecontrols below 10,000 feet agl.