Boeing 737-4Q8, G-BSNW

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Aircraft Type and Registration:	Boeing 737-4Q8, G-BSNW
No & Type of Engines:	2 CFM56-3C1 turbofan engines
Year of Manufacture:	1992
Date & Time (UTC):	18 September 1996 at 1029 hrs
Location:	Near Florence, Italy
Type of Flight:	Public Transport
Persons on Board:	Crew - 7 - Passengers - 116
Injuries:	Crew - 1 Minor - Passengers - Nil
Nature of Damage:	Nil
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	49 years
Commander's Flying Experience:	10,000 hours (of which 2,500 hours were on type)
	Last 90 days - 183 hours
	Last 28 days - 44 hours
Information Source:	AAIB Field Investigation and Company Investigation

History of the flight

The aircraft departed from London Gatwick for a scheduled flightto Athens with the first officer as handling pilot. A fuel loadof 13,200 kg had been selected by the commander and this resultedin full wing tanks and 4,000 kg in the centre tank. In accordancewith standard operating procedures, all 6 booster pumps (twoin each of the three fuel tanks) were selected on prior to start. With these switch positions, pressure differentials within thefuel system would mean that the centre tank fuel would be usedbefore the fuel in the two wing tanks. A fuel schematic diagramis shown at Figure 1.

The take off and climb were uneventful and the first officer engagedAutopilot 'B' as G-BSNW climbed through FL 140. Towards the topof the climb, the commander noticed a small imbalance of fuel;the left wing was indicating approximately 150 kg more than theright wing. He mentioned this imbalance to the first officerand advised him of his intention to balance the fuel. By now,the

aircraft was level at FL 290 and the crew were advised byATC that FL 290 would be the final cruising level rather thanthe planned FL 330. At approximately 0912 hrs, the commanderthen selected the left centre booster pump to off; no other fuelswitches were moved. His intention was that the left wing tankwould supply fuel to the left engine and the centre tank wouldsupply fuel to the right engine, thereby balancing the fuel betweenthe two wing tanks. The commander annotated his SWORD (Flightlog) with "Fuel Bal" and drew an 'attention line' downthe right side to a point approximately 27 minutes later; thecommander also made a mental note to check the balance after fiveminutes. Subsequently, fuel check figures were entered on theSWORD by the commander at 0921 hrs, 0942 hrs, 0954 hrs and1008 hrs.

As the flight continued over Northern Italy, the aircraft enteredcloud and encountered some light turbulence. Some time laterat 1029 hrs, while the commander was consulting the Flight ManagementComputer (FMC), the first officer noted that G-BSNW had continuedpast a 'waypoint' without following the required track to theleft; at the time, the Mode Control Panel (MCP) was in LateralNavigation ('L Nav') mode. Additionally, the 'trend vector' startedto show a turn to the right. The first officer's initial impressionwas that there was a problem with the FMC and selected 'Heading'on the MCP. However, this had no apparent effect and the aircraftwas now banking increasingly to the right. With a bank angleapproaching 30_ to 35°, the first officer's thought was thatthe autopilot had malfunctioned as the bank angle limit set onthe MCP was 25°. He disconnected the autopilot by usingthe switch on the control wheel and the aircraft immediately bankedfurther right. As the first officer countered this movement bymoving the control wheel to the left, he was also aware of thecommander manoeuvring the control wheel. The commander had heardthe first officer say "selecting heading select" andhad looked up. Almost immediately, he heard the first officersay "taking the autopilot out". The commander couldsee that they were IMC, with a large angle of bank and that thecontrol wheel was in a left bank attitude. He can recall statingthat he had control and remembers applying back pressure and alarge left roll input to the control wheel. The aircraft rolledwings level and began to climb; the first officer was now justfollowing through on the controls and giving the commander attitudeinformation. The crew were aware that the aircraft had divergedfrom its assigned level by at least 800 feet and also from itsassigned track. By now, ATC were concerned with the manoeuvringof the aircraft and there was some confusion until the aircraftwas re-established at FL 290 on the required track.

The commander was now flying the aircraft manually and neededa considerable left control wheel deflection to maintain straightand level flight. The crew checked the aircraft systems but couldfind no reason to explain the situation. After discussing thepredicament, the commander declared a 'PAN' and requested a diversionto Rome. Once the aircraft was heading for Rome, the first officersuggested that he take the handling duties, thereby enabling thecommander to properly review the situation. This was agreed and,shortly afterwards, the commander noticed the fuel imbalance. With the first officer monitoring his actions, the commanderreconfigured the fuel system to resolve the imbalance. Then,once the crew were satisfied that there was no further problemwith the aircraft and that they still had the required fuel, theycancelled both the emergency and the diversion. A normal landingwas subsequently carried out at Athens at 1211 hrs.

At the time of the incident, the cabin staff were setting up theduty free trolley and some passengers were queuing for the toilets. As the commander was recovering the aircraft from the uncommandedroll, cabin crew members experienced a violent rolling manoeuvreand a sensation of being pressed to the floor; the purser andtwo passengers fell to the floor. Afterwards, once the cabinstaff had ensured that all the passengers were in their seatswith their seatbelts fastened, the purser went to the flight deck. The commander informed her that the incident was under controlbut that they would be diverting to Rome; she returned to thecabin to prepare for the landing and to

reassure the passengers. Shortly afterwards the commander advised her of the cause ofthe incident and subsequently made a Public Address (PA) to thepassengers; thereafter, once the imbalance had been corrected,he visited the cabin to further reassure the passengers.

Operating instructions

Relevant information contained within the company operating manualsare detailed below:

1. The maximum fuel imbalance between the two wing tanks is 453kg.

2. With 1,000 kg or more fuel loaded in the centre tank, all pumpsmust be on and the crossfeed selector closed.

3. Both pilots must monitor selections made to restore fuel balance. "THE TIME AT WHICH BALANCING WILL BE COMPLETED MUST BE CALCULATEDAND EITHER NOTED DOWN BY BOTH PILOTS OR A TIMER SET OR SUITABLEWAYPOINTS INSERTED IN THE FMC."

4. To balance the fuel loads between tanks No 1 (left wing) andNo 2 (right wing), "With fuel in the centre tank, turn centretank fuel pumps OFF, then balance fuel between tanks No 1 andNo 2. When tanks are balanced turn centre tank pumps ON."

5. "A minimum of once per sector and at least once per hourin the cruise, record on SWORD a fuel check from the PDCS/FMS,or by calculation using tanks fuel and SWORD "REQ" fuel. If the calculated fuel differs significantly from the plannedfigure on SWORD this must be investigated." There is a requirementto check the FMC fuel figure against the tanks fuel prior to start.

Aircraft information

The aircraft involved in the incident is one of 27 similar typesoperated by the company at this base. However, it is one of 8which came from another company and, at the time of the incident,none of these aircraft had a timer, with an associated audiblebell, fitted on the flight deck; these are referred to as 'eggtimers'. All other company similar types at all bases were fittedwith 'egg timers'.

Personnel information

The commander had recently completed his command training whichwas carried out at another base and on aircraft which all had'egg timers'. He passed his final line check on 4 February 1996. During the investigation, he made the point that the 'egg timer'was routinely used during his line command training for variousactivities including fuel balancing. He also acknowledged thatthe way he attempted to balance the fuel on this occasion is notin accordance with company procedures and that none of the trainingstaff had mentioned this method of fuel transfer.

The first officer had a total of 609 hours flying experience ofwhich 205 hours were on type. His training had been carried outat another base and he passed his final line check on 17 July1996. He stated that the only way he had been shown to balancethe fuel was in conjunction with the 'egg timer'.

Boeing information

During the investigation, Boeing Commercial Aeroplane Group wereasked if there were any technical reasons why the system of fuelbalancing used by the commander should not be used. They confirmedthat the Boeing standard procedure is as described in the companymanuals but that there is no purely technical reason why the procedureused in the incident should not be used.

Recorded information

The Cockpit Voice Recorder (CVR) continued to operate after theincident and the record of the event was subsequently overwritten. The Flight Data Recorder (FDR) was replayed by both the companyand by the AAIB.

The data showed that, initially G-BSNW was level at FL 290 andsteady on a heading of 120°M. With the autopilot engaged,the left aileron began a slow but progressive deflection whilethe aircraft remained wings level. This movement continued untilthe aileron was at the maximum authority allowed by the autopilot. For the next five minutes, the left aileron maintained this positionat 4.5° deflection and the aircraft remained wings level. Thereafter, for an additional 2 1/2 minutes,the aircraft rolled to the right with a corresponding change inheading. As the roll reached 45° of right bank, the autopilotwas disengaged and a substantial left roll demanded. However,almost immediately, the roll demand was reversed resulting inthe aircraft going to a maximum of 54° of right bank beforea large left roll was again demanded. Simultaneously, a substantialelevator demand was applied to climb the aircraft. Over the nexttwo and one half seconds, G-BSNW climbed 1,000 feet and a maximumnormal acceleration of 1.9g was recorded. By now, the aircrafthad changed heading by approximately 100° to the right.Then, G-BSNW descended to FL 286 before climbing to and levellingat FL 290. Four and one half minutes after the autopilot wasdisengaged, the aircraft was re-established at FL 290 and on asteady heading of 120°. There was no indication of any rudderinput during the flight, prior to the disengagement of the autopilot.

Subsequent information

The maximum aileron deflection with the autopilot engaged is approximately4.5°, corresponding to a control wheel deflection of 20°. In manual flight, the aileron can be deflected up to 20°and this corresponds to a control wheel displacement of about82°. The autopilot has no authority over the rudder.

Calculations suggest that the probable extent of the fuel imbalanceat the time of autopilot disengagement would have been approximately1,600 kg.

Incident discussion

The aircraft was fully serviceable throughout the flight. Thefirst abnormal event occurred when the commander decided to balancethe fuel as G-BSNW reached cruising level. He decided to do thiswith an imbalance of approximately 150 kg, while the engines werebeing supplied from the centre tank. This imbalance is well withinthe maximum allowable of 453 kg. He then used a non standardprocedure to balance the fuel. Although the manufacturer confirmedthat there is no purely technical reason why this particular fuelbalancing procedure could not be used, one disadvantage is thatthe balance correction would take approximately twice as longas the normal procedure. Furthermore, it is not a procedure detailedin any of the aircraft manuals or one which had been demonstratedby the training staff. The initial decision to balance the fuelwas premature and possibly unnecessary, and the subsequent balancingprocedure used was non-standard.

As he started to balance the fuel, the commander noted down atiming reminder on his SWORD but the first officer did not. Furthermore,although the commander informed the first officer that he wasgoing to balance the fuel, the commander did not then fully involvehim in the procedure. The company regulations require that bothpilots are involved in any procedure involving the fuel system;additionally, for any fuel balancing, they should both note downa reminder on their SWORDs or set a timer or insert a suitablewaypoint in the FMC. The fact that the first officer was notfully involved in the switch selection would mean that he wasless likely to monitor the fuel situation, confident that thecommander was doing so. Effectively, there was only one pilot'in the loop'.

Over the next one hour and 17 minutes, the commander made fourfuel checks but completed them without specific reference to theaircraft fuel gauges. There is a requirement for the pilot tomake a comparison between the fuel gauges and the FMC prior toengine start; this was done and was satisfactory. In flight,the company procedures are for the pilot to compare the requiredfuel from the SWORD with the 'established fuel on board'; witha satisfactory pre-flight cross check between the fuel gaugesand FMC, it is acceptable for the FMC fuel figure to be used. However, the existing fuel check does not cover the fuel distribution. The company report of the incident highlighted this aspect andrecommended a review of the in-flight fuel checks. Although acomprehensive fuel check should be considered as 'Airmanship',the review is sensible.

An associated point is the provision of 'egg timers'. Both crewmembers had recently completed training at another base and bothhad used the 'egg timers' for fuel balancing. However, at theiroperating base, not all aircraft had the 'egg timers' fitted. Airmanship should preclude this degree of fuel imbalance happeningbut, if the crews get used to operating with 'timers', they willbecome reliant on them. A mix of aircraft with and without 'timers'would create more risk of this type of incident than would a fleetof standard fit aircraft, even without 'egg timers'. The companyreport recommended that 'egg timers' be fitted to all their B737aircraft.

During the increasing imbalance, the aileron moved gradually toits maximum autopilot deflection of 4.5° to maintain levelflight. The control wheel would have moved in sympathy with theailerons up to the maximum of 20° and would then have maintainedthis deflection. The FDR shows that the aileron deflection of4.5° was maintained for 5 minutes; this means that the controlwheel was also deflected by 20° for the same length of time. It is surprising that this deflection was not noticed by eitherpilot. Thereafter, this deflection was not sufficient to maintainwings level as the fuel imbalance increased further.

A problem eventually became apparent to the crew when the firstofficer noticed that G-BSNW was not following the required trackto the left. Initially, he attempted to change the autopilotlateral mode but, when there was no improvement in the situation,he then disconnected the autopilot. His manual input was correctand the bank angle decreased but, shortly afterwards, the commanderbecame aware of the situation and reached for and took controlof the control wheel. The aircraft bank then increased momentarilyto 54° as a result of control wheel input before rollingleft to wings level although with a nose high attitude.

There is no doubt that the crew was under some pressure to resolvethe undemanded roll. The commander had been alerted to the situationinitially by the first officer commenting on his selection of'Heading' and then by his statement that he was disengaging theautopilot. Neither crew member is certain of exactly when thecommander called that he had control but both were sure that hehad taken control while the aircraft was banking back left. Thecommander has no specific recollection of applying a brief controlwheel input to the right. At that time the aircraft was

bankedto the right but with the control wheel demanding a roll to theleft. However, with no external references, the commander mayinitially have thought that, with the control wheel demandinga roll to the left, the ADI was showing a roll to the left. Thisinitial misinterpretation may have resulted in him applying theright roll demand for a short period before correctly re-applyingleft roll. This roll demand was accompanied by a positive pitchdemand causing subsequent large excursions in height.

The question of who is best placed to recover an aircraft froman unusual attitude is a command decision. The pilot who is handlingthe aircraft when it begins to depart from the required profileis normally the best one to retain control but this depends onhis experience and handling skills. It would be instinctive forthe commander to take control in any situation where he was unhappyabout the aircraft attitude. This incident shows the value ofall flight crew having experience of unusual attitudes. Whilethis type of incident is fortunately rare, other incidents suchas wake turbulence could result in a similar situation of someonesuddenly needing to interpret the aircraft attitude from the instrumentsand take the appropriate action. The company report includeda recommendation for simulator training to be provided to pilotson recovery from unusual attitudes. Additionally, one other majorUK airline has recently instituted a simulator programme to givetheir flight crew experience in the recognition of and recoveryfrom unusual attitudes. These are sensible and practical traininginitiatives but may not necessarily be addressing the basic problem. Modern aircraft are increasingly designed to be flown by an autopilotand/or flight director. This is normally very efficient but thehuman flying and monitoring skills may be decreasing due to increasinguse of, and trust in, the automatics. This incident involvingG-BSNW may be an indication that the basic pilot skill of instrumentinterpretation, particularly in attitudes beyond those the pilotnormally sees, is being degraded. It would be sensible for theCAA to review this aspect to determine if there is a basic skilldeficiency and the training necessary to rectify it.

Recommendation 97-16

It is recommended that the CAA review the current training requirementsand standards of basic instrument flying skills and, if necessary,mandate appropriate training requirements for Public Transportoperations.