Boeing 757-2T7, G-MONC

AAIB Bulletin No: 1/2003	**Ref: EW/C2002/05/06**	**Category: 1.1**
Aircraft Type and Registration:	Boeing 757-2T7, G-MONC	
No & Type of Engines:	2 Rolls-Royce RB211-535E4-37 turbofan engines	
Year of Manufacture:	1983	
Date & Time (UTC):	22 May 2002 at 1630 hrs	
Location:	Gibraltar Airport	
Type of Flight:	Public Transport	
Persons on Board:	Crew - 10	Passengers - 165
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Structural damage to forward fuselage in area of nose landing gear	
Commander's Licence:	Airline Transport Pilots Licence (Aeroplanes)	
Commander's Age:	44 years	
Commander's Flying Experience:	11,100 hours (of which 5,000 were on type) Last 90 days - 79 hours Last 28 days - 36 hours	
Information Source:	AAIB Field Investigation	

History of the flight

The aircraft was scheduled to operate a passenger service from Luton Airport, Bedfordshire to Gibraltar. Reverse thrust on number one engine was inoperative, but there were no other significant deferred defects and the aircraft departed Luton on schedule at 1346 hrs with the commander as handling pilot.

The weather was fine and the flight progressed without incident until the arrival in Gibraltar. Conditions for the landing were given as wind 260°/23 kt, nil weather, few clouds at 4,500 feet, and ATC gave the aircraft radar vectors for a visual approach to Runway 27. The commander disconnected the autopilot and established the aircraft on final approach at five miles from touchdown with landing gear down, flaps at 30° and the autobrake selected to level 4. The Digital Flight Data Recorder (DFDR) showed the speed stabilised at the calculated approach speed of 143 kt. In accordance with normal procedures, the first officer announced the headwind and crosswind components from the Flight Management Computer. The Cockpit Voice Recorder (CVR) recorded three announcements giving headwinds of 25-26 kt and a stable crosswind of 5 kt from the right.

The flare and touchdown were normal and the commander selected the reverse thrust levers to the REVERSE IDLE position. However, almost immediately after mainwheel touchdown the nose of the aircraft pitched down rapidly and the nosewheel impacted the runway. Thereafter the landing roll proceeded without further event, and the aircraft vacated the runway and taxied to parking. Subsequent inspection of the aircraft revealed significant damage to the forward fuselage in the area of the nosewheel.

Flight Recorders

Introduction

The solid-state CVR was of two hours recording duration with the landing occurring one hour before the recording ceased. The design of the CVR was such that, for the period of the recording, crew speech and incoming radio transmissions were recorded on one channel. Upon replay it was found that the signal level of the incoming radio traffic was excessively high and masked crew conversation. This problem, however, did not hinder the investigation but the operator was advised to take corrective action.

The sequence of events was determined from the CVR, solid state DFDR (see figure 1 *(jpg 76kb)*) and optical Quick Access Recorder (QAR). The QAR, which was replayed by the operator, contained the same parameter set as the DFDR and hence provided no additional data.

Recording of elevator position

Early Boeing 767 and Boeing 757 DFDRs used EICAS data as the source for recording elevator position. Unfortunately these values had been filtered and smoothed and were not representative of the actual position during changes in surface deflection. This anomaly, highlighted in previous NTSB and AAIB reports, resulted in the development of a modification that provided raw surface position to the FDR whilst retaining the smoothed / filtered values for EICAS presentation. This modification had been effected on G-MONC with the result that the elevator positions stated are correctly correlated with timings of other recorded events.

Landing

The landing flare was initiated just below 70 feet agl at an airspeed of 137 kt. Pitch attitude increased from 0.5° to 3.3° nose up at touchdown over a period of 9 seconds. Touchdown was with wings level at 132 kt and a resultant normal acceleration of +1.34g and a maximum nose up elevator deflection of 15.6? (full elevator travel is +30.5° up to -20.5° down). The speedbrake handle moved from the armed to the deployed position as the air / ground logic changed state.

Over the ensuing 1.125 seconds, the elevator position changed from 15.6? nose up at touchdown to full nose down (20?) and the pitch attitude began to reduce rapidly. The aircraft became light on the main landing gear oleos but not enough to register a change of state of the air / ground logic. The right reverser indicated in transit just before the (almost simultaneous) main landing gear re-compression and nose gear ground contact. A normal acceleration of +1.6g was recorded during the re-compression of the main landing gear. The rate of derotation at nose gear oleo compression was calculated to be 10?/second. This figure was confirmed by the aircraft manufacturer who also stated the design limit value to be 7°/second.

The elevator was briefly relaxed to 1.4? nose down for 0.5 seconds before full nose down elevator was reapplied and maintained until the aircraft had slowed to below 119 kt. From that time, until airspeed had reduced to below 90 kt, between 3? and 7? of nose down elevator was applied. A significant nose up elevator of 17.5? was applied as the aircraft slowed through 80kt before becoming predominantly neutral for the remainder of the rollout. Thrust reverse was cancelled at about 70 kt. The deceleration recorded during the landing roll was consistent with autobrake level 4 operation and left rudder had been applied to counteract the asymmetric retardation resulting from the use of only one thrust reverser.

During the post-landing crew discussion the commander stated that he believed that he had been holding the stick back.

Previous landings

The DFDR recording comprised 74 complete flight sectors, of which at least 18 terminated in a landing at Gibraltar. The commander involved in this accident had performed three of these 18 landings and one at Luton. A characteristic of all of these landings was that full nose down elevator was applied and maintained shortly after touchdown. This characteristic was not evident in the other 70 landings recorded.

Examination of the aircraft

Structures

The nose landing gear on the Boeing 757 is contained within a rectangular box, sometimes referred to as the dog house, which is built into the underside of the forward fuselage structure. It was apparent that considerable wrinkling of the fuselage skin had occurred on either side of the nose gear bay. The damage was rather more severe on the left than the right, with several rivets having been pulled through the skin. The structure of the dog house, ie the walls and roof of the nose gear bay, had sustained little visible distortion, and the nose leg was similarly undamaged.

The longitudinal station of the rear wall of the dog house was coincident with a bulkhead at Station 395. (Note: the fuselage frame stations are referenced, in inches, to a datum in front of the nose of the aircraft). This had sustained considerable buckling damage and was associated with the most severe damage visible from outside the aircraft. Less severe damage had occurred to a similar bulkhead further forward at Station 324, and the intervening frames had suffered varying degrees of buckling.

The electrical power distribution panels are located in cabinets immediately aft of Station 395. It was apparent, from witness marks on the upper edges of the cabinets, that these had been driven upwards into the floor beams during the impact, although they had subsequently recoiled such that a gap had been restored. As with the fuselage frames, the damage was more pronounced on the left side, thus reinforcing the view that the dog house had rotated slightly, relative to the fuselage, in a counter-clockwise direction when viewed from the front.

Many cables, including those for the flying controls, engine and braking system, run either side of the floor beams to the flight deck. The upwards deflection of the cabinets had not been large enough to contact the cables on this occasion. However, in at least one accident involving a severe impact on the nose landing gear (Boeing 757 G-BYAG at Gerona, Spain, on 14 September 1999), cables were severed or jammed, resulting in the engines being rendered uncontrollable. It should be noted that nose landing gears are not subject to the provisions of JAR25.721a; these apply to the main landing gears and deal with fuse pins that allow the gears to break away in the event of a heavy impact so that damage to fuel tanks is minimised.

Elsewhere on the aircraft, the fuselage crown was examined for evidence of compression wrinkles; none was found. Inside the cabin, it was noted that a piece of trim under an oven in the forward galley was buckled, and that the flight deck door was binding on the floor.

Flying controls

Despite the fact that the DFDR data suggested that no faults had occurred in the hydraulic, flying control or braking systems, it was considered appropriate to perform a function check on them in order to establish confidence in their integrity.

A ground power unit was connected to the aircraft and the hydraulic systems were pressurised. The flying controls, including the horizontal stabiliser, were exercised, with no problem being found.

Six spoiler panels on each wing, four outboard and two inboard, provide secondary roll control as well as flight and ground speedbrakes. The spoilers are commanded electrically by six spoiler control modules (SCMs), with actuation via hydraulic power control units. A failure of one SCM will result in the non-deployment of a symmetrical pair of spoiler panels, together with associated flight deck annunciations.

The system was function tested by moving the speedbrake lever to ARM and retarding the thrust levers to the idle position. All the spoiler panels were observed to deploy normally.

Braking system

The potential for a nose down pitching moment brought about by abnormal or early operation of the Autobrake system was also considered. This is controlled by an antiskid/autobrake control unit located in the aft equipment bay by the rear cargo door. After selecting the required deceleration level on the flight deck, brake pressure is applied to the wheels when weight on wheels is sensed, the thrust levers are at idle and the pitch attitude, as measured by the inertial reference system (IRS), reduces below 1°.

A full test of the system was conducted in accordance with procedures contained in the aircraft maintenance manual; this involved activating the IRS and the hydraulic system. No problems were found and interrogation of the control fault register showed no previous faults.

By coincidence, the same aircraft, flown by the same commander, had experienced an incident landing in Gibraltar on 11 May 2002, in which wheels Nos 1and 5 (i.e. the left side wheels of the left landing gear) had locked at touchdown, causing smoke and eventual tyre deflation. The antiskid/autobrake control unit was changed and the subsequent strip report indicated that an out of limits voltage problem had occurred on wheelcard 1-5. This referred to one of the four cards within the unit, each of which controls the antiskid function of a pair of wheels; the pairings being 1-5, 2-

6, 3-7 and 4-8. However, the DFDR data did not show any discernible increase in longitudinal deceleration attributable to the locked wheels when compared with the subsequent incident.

Manufacturers comment on nose landing gear

During the course of the investigation, it became apparent that a modification was available for Boeing 767 aircraft, which introduced a revised nosegear metering pin. This device controls the flow of hydraulic fluid within the oleo strut and the reason for the modification was to absorb the energy produced during overderotation events, thereby lowering the load on the nosegear. No similar modification however was available for Boeing 757 aircraft. The manufacturer stated that this was because B767 aircraft were sustaining structural damage within derotation pitch rates at or around the design limit of 7° per second. The Boeing 757 has the same design limit, with no record of structural damage occurring at this figure.

Aircraft operating information

The current Boeing B757 Flight Crew Training Manual provides the following information and recommended technique for operating the aircraft after touchdown and during the landing roll:

> *After main gear touchdown, initiate the landing roll procedure. .. Fly the nose wheel onto the runway smoothly by relaxing aft control column pressure. Control column movement forward of neutral should not be required.* ***CAUTION; Pitch rates sufficient to cause airplane structural damage can occur if large nose down control column movement is made prior to nose wheel touchdown.***

In 1994 'Airliner' magazine published an article on the subject and in January 2002 a CD titled 'Airplane Derotation - a matter of seconds' was distributed by Boeing to its customer base. Boeing also publishes a magazine entitled AERO which is distributed to operators *to provide supplemental technical information and to promote safety and efficiency in daily operations*. The April 2002 issue, which included an article on *Hard Nosegear Touchdowns*, had been distributed to the company training staff. It contained the following information which is not type specific:

> *In recent years, there has been an increase in the incidence of significant structural damage to commercial airplanes from hard nosegear touchdowns. In most cases, the main gear touchdowns were relatively normal. The damage resulted from high nosedown pitch rates generated by full, or nearly full, forward control column application before nosegear touchdown.*
>
> *enough nose-down elevator authority exists to damage the airframe structure if the airplane is rapidly derotated following main gear touchdown .the maximum nosed-down elevator authority is designed to control go-arounds, which require considerably more longitudinal control than the landing maneuver.*
>
> *Forward control column movement should not be applied..in an effort to improve landing performance or directional control. The rudder provides the required directional control until the airplane is at a relatively low speed..Large forward column displacement.may reduce the effectiveness of main-wheel braking because it reduces the amount of weight on the main gear*

Human Factors

The commander was unaware that he had developed the regular use of full nose-down elevator on landing, although he remembers using full forward stick occasionally when landing in wet or slippery conditions in the belief that the technique would improve braking and control effectiveness. It is possible that repetition of the control input sequence in the context of landing had established a habit. An intrinsic feature of such a habit is the possibility of execution without conscious monitoring.

The commander's training records contained no evidence of a non-standard landing technique and the first officer on the accident flight did not notice the use of full nose down elevator. However, training captains and non-handling pilots have duties during touchdown and landing roll procedures that tend to divert their attention away from the control column, and this may explain why the use of the technique had not been noticed earlier.

Having developed an incorrect landing technique, it is possible that it was simply a matter of time before the timing in the application of full nose-down elevator caused an incident. However, although the availability of historic data was limited, it appears that the commander's technique was different in Gibraltar compared to landings elsewhere. The commander stated that the prospect of landing in Gibraltar caused him no disquiet, but each of the four Gibraltar landings recorded on the DFDR showed that full nose-down elevator was being applied very soon after mainwheel touchdown. The difference on the accident flight was that the nose attitude at touchdown was significantly higher than on the three previous landings. During landings at other destinations the rate of derotation was being controlled by aft elevator until the nosewheel was on, or close to, the runway.

Although the commander may not have been consciously concerned about the Gibraltar landing, there are a number of factors that may have had a subconscious effect.

(i) Gibraltar has a reputation for difficult wind conditions, and indeed the Company has imposed limitations on both the experience level of commanders operating into Gibraltar and on the wind directions and strengths in which landings are permitted.

(ii) The runway in Gibraltar is adequate for a B757, but is relatively short with parallel areas of concrete that add to the visual perception of a short runway.

(iii) The runways have no overrun as they are bounded by the sea at each end.

(iv) The lack of the number one engine thrust reverser in itself would not have caused any increase in landing roll, but in combination with other factors may have provided a distraction to the commander that could have added a complexity to a normal but slightly more demanding landing.

Flight Data Monitoring

The operator has a Flight Data Monitoring (FDM) programme (previously known as a Flight Operations Quality Assurance (FOQA) programme) which is designed *to measure and improve upon the levels of safety that are being achieved by the Company during actual aircraft operations*. In addition to the statutory DFDR each of the aircraft in the operators fleet is fitted with a QAR. Data on each flight is recorded by the QAR and downloaded for storage on the companys main computer systems during each aircrafts weekly check.

Collected data is processed by a computer programme that searches for specific events that may have occurred during each flight. Two levels of event, detect and alert, are set by defining set values of various parameters that may be further refined by phase of flight, time and defined tolerances. Events are then stored for analysis.

Unfortunately, the use of excessive nose-down elevator during landing had not been programmed as an event in the FDM software programme, and the commander's technique had therefore not been noticed during the FDM analysis process. Nevertheless, the operator was able to retrieve historic FDM data and found that the commander had for some months on occasions been using full nose down elevator after landing and that the frequency of use had increased towards the date of the accident. Further analysis of the data showed that the practice was not evident amongst other company pilots, but the operator has been able to redesign training programmes and improve awareness amongst both line pilots and training personnel.

The establishment of an FDM programme became an ICAO 'Recommended Practice' for operators of all aircraft over 20,000 kg on 1 January 2002. With effect from 1 January 2005 an FDM programme will become an ICAO 'Standard' for operators of aircraft over 27,000 kg. The ICAO initiatives recognise the sensitivities involved in recording and accessing flight data and ICAO Annex 'Standards and Recommended Practices' contains safeguards to ensure that collected data is used only for flight safety purposes and that analysis of the data is non-punitive. In addition, operators are required to establish internal safeguards, and states must determine legal protection for the data.

FDM has been established in some airlines for a number of years, but the availability of QARs has made practical the widespread implementation of FDM programmes. Commercial software is available to analyse collected data, but it will be important for operators to establish customised programmes that suit the aircraft they fly, their Standard Operating Procedures (SOPs) and the airports to which they operate. If the potential of FDM programmes is to be fully exploited, it will be important that they form part of the overall, well established, safety processes, and that they are an adjunct to a healthy safety culture. Manufacturers, operators and regulators will need to consider how FDM can be used to enhance safety whenever changes are proposed or new procedures are developed.

CAA initiatives

The widespread introduction of FDM programmes will be a challenge for all operators and the CAA has in place a number of initiatives to assist. Regular meetings of operators and the CAA have been established to discuss FDM issues and the CAA sponsors an FDM website. The CAA will publish practical advice in the form of an FDM best practice document, and work is already in place to determine how best FDM can be used to detect the causes of problems rather than simple events.

Discussion

Analysis of the DFDR indicated that this accident occurred because full nose-down elevator was applied immediately after main gear touchdown and prior to nose gear touchdown with the aircraft pitch attitude at about 3.5° nose up. As a result, the pitch rate at nose gear touchdown exceeded the design limits and significant damage was caused to the fuselage in the area of the nosewheel. The engineering investigation found no fault with the aircraft that could have accounted either for the applied elevator or which otherwise could have caused the high nose down pitch rate. However, the commander could not recall applying the elevator and neither he nor the first officer had noticed an application of full forward control column.

Evidence indicated that the commander had adopted the habit of using full nose down elevator on landing over a period of time and that it had reached a point where it had become an automatic action. The DFDR showed that the elevator was normally being applied at or after nosewheel touchdown and thus high nose-down pitch rates had not resulted. However, all four of the commander's landings in Gibraltar showed that elevator was being applied very soon after main wheel touchdown.

Although the operators FDM software had not been programmed to detect full nose-down elevator during landing before the accident, the FDM programme data was particularly useful during the investigation of this accident. Use of the data was handled sensitively and constructively by both management and aircrew, and illustrated the positive safety potential of this data source. The operator modified its software to include nose-down elevator on landing as an event immediately after the accident and the CAA has advised other operators to review their FDM programmes accordingly. Furthermore, this accident illustrates the importance of tailoring FDM software to reflect equipment and procedures and that the contribution of FDM overall needs to be considered carefully in a safety management system.

Safety action

CAA initiatives already in place are addressing the challenges brought about by the widespread introduction of FDM programmes and practical advice in the form of a 'best practice' document will soon be published. Consequently the AAIB believe that there is no need to make a safety recommendation as a result of this investigation.