Boeing 757-225, G-JALC

AAIB Bulletin No: 7/98 Ref: EW/C97/8/10 Category: 1.1

Aircraft Type and Registration:	Boeing 757-225, G-JALC
No & Type of Engines:	2 Rolls-Royce RB211-535E4 turbofan engines
Year of Manufacture:	1983
Date & Time (UTC):	24 August 1997 at 0708 hrs
Location:	London Gatwick Airport
Type of Flight:	Public Transport
Persons on Board:	Crew - 9 - Passengers - 184
Injuries:	Crew - None - Passengers - Several minor evacuation injuries
Nature of Damage:	Left main landing gear downlock hydraulic hose ruptured
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	38 years
Commander's Flying Experience:	7,037 hours (of which 1,500 were on type)
	Last 90 days - 221 hours
	Last 28 days - 80 hours
Information Source:	AAIB Field Investigation

History of flight

The flight crew reported for duty at 0500 hrs to operate a holiday charter flight from London Gatwick to Palma de Mallorca (Spain). The return sector was scheduled to operate to Manchester Airport. Both flight deck crew members were correctly licensed, medically fit and adequately rested to operate the flight. The cabin crew complement was correctly constituted and was adequately rested for duty.

The aircraft pushed back from stand 16 on schedule at 0600 hrs and taxied for take off from Runway 26L. The take-off weight was 94,371 kg and there was 18,700 kg of fuel on board (this was to be a fuel tankering sector, with a minimum sector fuel requirement of 11,000 kg). The maximum allowable take-off weight was 104,326 kg.

The aircraft was being operated with the Autothrottle system inoperative, in accordance with the operator's Minimum Equipment List. Thrust settings were adjusted manually throughout the flight. The departure was uneventful using Flap 15° at 0622 hrs. A normal retraction of gear and flaps occurred in accordance with the company standard operating procedures. The aircraft then flew on ATC radar headings during the initial climb phase. At 0624:51, with a speed of 265 kt and passing 5,700 feet, a Left Hydraulic (Hyd) Low Quantity alert occurred on the aircraft's Engine Indication and Crew Alerting System (EICAS). At 0625:12, the first officer (as handling pilot) engaged the Right Autopilot system when passing 6,300 feet. At 0627:28, a Left Hyd Low Pressure EICAS alert occurred at 300 kt passing FL120.

The aircraft continued its climb to FL230, reaching this flight level at 0632 hrs. The commander informed company operations, the engineering contractor and the handling agency of the nature of the problem and that the aircraft would be returning to land at Gatwick. ATC were then informed that the commander had decided to return to Gatwick. Initially the aircraft was given radar vectors, then cleared to the TIMBA inbound holding fix. Descent instructions followed in due course and the aircraft entered the hold while descending to FL100 at a descent speed of 300 kt.

During the descent, the crew carried out the company Hydraulic System Pressure (Single System Failure) checklist from the aircraft's Quick Reference Handbook (QRH). Initially, the commander was reading the checklist items which contained a tabulated System Condition Chart (Figure 1, card 09-02). Having noted the systems that would be available the commander informed ATC that the aircraft would require to be towed off the runway after landing, but that otherwise no emergency procedures would be required. However, on being informed that the inbound aircraft had a hydraulic problem, the ATC Watch Manager at Gatwick initiated a full airfield emergency alert.

On approaching the holding fix, the commander took over as handling pilot and passed the checklist responsibility to the first officer. The crew were aware that the hydraulic failure may require the selection of the landing gear and flaps using the Alternate systems. Believing the Hydraulic System Pressure (Single System Failure) checklist to have been completed, the first officer referred to the Alternate Flap Operation and Alternate Gear Extension parts of the Hyd Systems Press checklist (Figure 1, card 09-04). The aircraft descended in sequence in the hold and was then radar vectored towards the final approach area. The flaps and landing gear were deployed using the Alternate systems.

The actual landing weight was about 92,000 kg and the normal maximum permitted landing weight was 89,811 kg. The crew elected to land with 30° flap and a selected VREF of 134 kt.

The aircraft flew an uneventful ILS approach to Runway 26L, during which the crew carried out the items from the normal landing checklist. On responding to the 'Speedbrake' prompt, the commander commented that it was armed, but that it may not work. No special brief was given on this aspect and the company standard procedures called for the non handling pilot to monitor the deployment of the speedbrake lever and the selection of reverse thrust. There were no specific crew callouts required for normal speedbrake deployment.

The weather prevailing at the time of the landing was a surface wind from 190°M at 6 kt, visibility 5,000 metres in mist, scattered cloud base 200 feet, broken cloud base 300 feet, temperature +19°C, dew point +18°C, mean sea level pressure 1013 mb. The landing threshold elevation of Runway 26L is 195 feet amsl. The crew became visual with the runway at about 400 feet agl and the commander disconnected the autopilot at this stage.

On touchdown, the commander commented that the aircraft appeared to wallow and pitch up and down twice before nosewheel touchdown. After touchdown, reverse thrust was applied on the right engine only, as expected. The speedbrake was not deployed and this was not noted by either pilot. The aircraft began to yaw to the right and left rudder was applied to stop this trend. However, a large swing to the right developed and the first officer also applied left rudder pedal in an attempt to assist the commander. The aircraft regained the runway heading but by this time had left the paved area onto the grass to the right side of the runway. It came to rest between the first and second Runway 26L Rapid Exit Taxiways with no damage.

The cabin staff, who had been briefed about the return to Gatwick, but told that it would be a normal landing apart from the subsequent towing requirement, realised that something was amiss when the swing to the right developed and the aircraft began to roll across the grass surface. The passengers were not in the 'brace' position but suffered no immediately apparent injuries from the deceleration, which had peaked at less than -0.35 g during the deceleration on the grass. Once the aircraft had stopped, the commander, having no flight deck indications of any further abnormalities, made a Passenger Address (PA) announcement to the cabin crew and passengers to remain seated.

On seeing the aircraft on the grass, the Airport Fire Service informed the ATC Tower controller that the aircraft had left the paved area. Shortly after the aircraft had stopped, the Fire Service informed the Tower that there was heavy smoke apparent from the left mainwheel area and that an evacuation of passengers was recommended. This was heard by the crew on the ATC frequency and reiterated by the controller. At this point, the commander initiated an immediate evacuation by use of the aircraft PA system.

The evacuation was completed within 90 seconds. The only abnormality reported was that the door 3R would not open (aft of the right wing trailing edge). Passengers in this area were encouraged to use the alternate 3L door by the cabin staff member in this location. Passengers were grouped ahead of and behind the aircraft by the emergency services and the aircraft's crew and a satisfactory evacuee count was completed.

The landing was filmed by the airport operator using a camera mounted at the terminal end of the airport and by a police mobile unit at the Rendezvous Point (RVP) North.

Analysis of the Flight Data Recorder (FDR) information showed that the aircraft touched down at 133 kt. The speedbrake had been armed during the approach sequence but was not deployed. Reverse thrust was selected on the right engine at 128 kt, up to 75% N1 by 116 kt. The aircraft attained a maximum roll angle of 4° right wing down with reverse thrust applied, this being confirmed by reference to the video coverage. Left rudder input was initiated at the time of the reverse thrust selection, the amount increasing slowly to achieve 15° (47%) left deflection over 9 seconds. At this stage, the aircraft began to swing to the right. The rudder input was reduced for a period of about 3 seconds, then a rapid left rudder input occurred over the next two seconds to achieve full left rudder deflection by about 85 kt. This had the effect of stopping the right turn and brought the aircraft back onto the runway heading (262°M), then correcting a further 5° left. The right roll angle had reduced to zero by 60 kt, reverse thrust was reduced at 36 kt and subsequently cancelled. The company standard operating procedures specify that, after 60 kt, reverse thrust lever movement should be initiated to reach the reverse idle detent by taxi speed. The lever(s) should be positioned fully down once the engine(s) have decelerated to reverse idle.

The recorded data indicated that the aircraft left the paved surface at a speed of about 83 kt on a heading of 270°M, although the heading variation had previously reached a maximum of 276°M. From this, it is apparent that the corrective action to reduce the heading excursion was already effective by the time the aircraft left the paved surface, but that the application of full left rudder came too late to prevent the aircraft leaving the side of the runway.

Boeing 757 hydraulic systems

The aircraft is equipped with three separate and independent hydraulic systems titled Left, Centre and Right. The services operated by each system, or combination of systems, are shown in Figure 2. The design is such that the aircraft operation is not significantly impaired by the loss of a single system in flight. However, of the three systems, the loss of the Left system causes the greatest degree of change to the operating procedures prior to, and during, the landing phase. It is not permitted to dispatch the aircraft for flight with one hydraulic system inoperative.

In the event of a loss of Left system pressure, the aircraft systems which become unavailable are left autopilot and left thrust reverser. Additionally, if the Left system fluid contents fall to zero, the flaps and slats must be deployed using the Alternate (electrically powered) systems and the landing gear lowered using the Alternate system. In these circumstances, the nosewheel steering system and the automatic deployment-on-landing function of the speedbrake system (lift dump spoilers) are also lost. Spoiler panels No 3 and No 5 (left wing) and No 8 and No 10 (right wing) are rendered inoperative by the loss of Left system pressure.

A standpipe is fitted in the Left system reservoir which, under certain specific leakage cases, preserves a quantity of hydraulic fluid for use by the Power Transfer Unit. However, in this case, there was a total loss of hydraulic fluid from a ruptured left main landing gear downlock actuator flexible hose, an area in which system leakage protection is not provided.

Standard crew action in event of a left hydraulic system pressure loss

The relevant section of the manufacturer's expanded checklist for crews requiring to deal with this type of failure is shown in Figure 2. The initial requirement is to switch off the hydraulic pump switches for the affected system. The left autopilot is inoperative, but crews may use the centre or right autopilot normally. The left thrust reverser is inoperative, but the right thrust reverser will operate normally. The auto brake function (automatic symmetric brake application to the selected deceleration setting after landing) is not to be used, as this may adversely affect the ability to apply differential braking in order to keep the aircraft on runway heading during the landing roll.

There are also four functions which MAY be unavailable, dependant upon whether or not there is any residual hydraulic fluid in the system. These are the automatic speedbrake function (speedbrakes may require manual deployment after touchdown, before the application of right thrust reverser), nosewheel steering function (may require the aircraft to be towed off the runway after stopping), and the Alternate deployment systems for flaps, slats and landing gear. The checklist refers the crews to the correct procedures in the QRH, namely TRAILING EDGE FLAP DISAGREE and GEAR DISAGREE, corresponding to the actual EICAS messages generated in the event of these systems not operating normally on selection. The Trailing Edge Flap Disagree checklist specifies a maximum landing flap setting of 20° (for possible go-around considerations), although the Alternate Flaps selector switch provides for the selection of the normal maximum of 30°. The flaps and slats Power Drive Units are driven by electric motors at a slower rate than is achieved by the normal hydraulically powered system, taking about 2 minutes to move from 0° to 20° flap.

Crew actions during the incident flight

At the time the commander took control of the aircraft, it had been cleared by ATC direct to the TIMBA holding fix to take up the hold as part of the normal sequence of inbound traffic to Gatwick. No emergency had been declared and no additional holding time was requested by the crew. At this stage, the commander took control of the aircraft handling, passing responsibility for the radio transmissions, weather updates, checklist actions and remaining QRH actions to the first officer in the normal way. However, even after the change of handling pilot, the commander continued to handle the QRH on occasions during the remainder of the flight, somewhat diluting the usual division of flight deck duties. Although it was understandable that the commander wished to be the handling pilot for the landing phase, there was no reason for him to take control at such an early stage.

At the time of the change of handling pilot, the holding pattern at TIMBA had not been entered into the Flight Management Computer (FMC). It was therefore not possible for the commander to conduct the hold entry using the autopilot coupled to the Lateral Navigation (LNAV) function of the FMC. The first officer did enter the holding pattern and the approach procedure for the ILS approach to Runway 26L at this time but the commander flew the aircraft on autopilot in Heading mode for the hold entry, changing to LNAV mode for the subsequent holding pattern. The hold entry, coupled with the slight additional workload of manual thrust settings, the reduction in speed from 300 kt to a holding speed of 214 kt on reaching FL100 and during the subsequent descent when cleared to FL80, occupied the commander's attention for a period of about 4 minutes. During this period, he noted that the aircraft had sufficient fuel on board to hold for at least one hour, he attempted to commence the approach briefing for the ILS approach and he referred once more to the QRH tabulation of systems affected by the failure.

The QRH requirement to land with 20° flap was noted while the commander was referring to the checklist, but the go-around procedure was not discussed at that stage and the landing data 'bug' card had already been completed for a 30° flap landing using the VREF speed appropriate to the actual landing weight, which was in excess of the normal maximum. The QRH reference to the system availability and procedures that MAY be required led the crew to believe that normal operation of the landing gear and flaps was possible, even though they had noted the EICAS hydraulic quantity indication showing the system contents to be completely empty. The commander requested that the aircraft be positioned for a ten mile final approach in case it was necessary to configure the flaps and landing gear earlier in the arrival pattern than usual.

After entry, the aircraft carried out one further holding pattern, taking a further six minutes to complete. The commander briefed the passengers on the situation at this stage, then discussed the landing with the senior cabin crew member, reiterating the belief that it would be a normal landing apart from the subsequent towing requirement. Further descent was given by ATC followed by radar vectors to position it for the ILS approach. The commander did not request additional holding time in order to allow the aircraft to be correctly configured prior to the commencement of the approach.

While the aircraft was being vectored on the downwind leg, the commander requested the selection of flap 1° in order to commence the configuration procedure. On selection, the flaps did not move and an EICAS Trailing Edge Flap Disagree alert was generated. This confirmed to the flight crew that the alternate systems would indeed be required. For reasons that he could not subsequently explain, the first officer referred to the Alternate Flaps and Alternate Gear section of the QRH procedure appropriate to a Dual Systems Failure (Figure 1, card 09-04) instead of the Trailing Edge Flap Disagree and Landing Gear Disagree procedures (Figure 3, cards 07-08 and 11-02), as referred to in the Hydraulic Single System Failure procedure (Figure 1, card 09-02). Nevertheless, the landing gear and flaps were deployed successfully using the Alternate systems. The crew overlooked the QRH procedure requirement to land with 20° flap which would have resulted in a VREF of 145 kt, appropriate to the actual landing weight. The additional landing flap is unlikely to have significantly influenced the tendency of the aircraft to yaw to the right during the landing roll. The aircraft manufacturer indicated that the selection of the Reserve Brakes Switch would not have adversely affected the operation of the Normal brakes or anti-skid systems in this case.

The speedbrake did not deploy automatically on touchdown; neither pilot noted this and it was not manually deployed. The lift dumping action of the wing spoilers therefore did not occur. The application of full reverse thrust on the right engine only is likely to have caused a lift dumping effect on the right wing only, resulting in the marked right wing down attitude during the landing roll. Sufficient left rudder pedal input was not applied to prevent the aircraft from yawing to the right initially. The first officer then assisted in the application of full left rudder, which had the effect of turning the aircraft to regain the runway heading, but not before the aircraft had departed from the right side of the runway. Neither pilot could recall whether any differential braking was applied and there are no recorded parameters on the FDR which could confirm this.

Once the aircraft had stopped on the grass, there were no abnormal aircraft status indications apparent on the flight deck. The commander therefore initially advised the cabin crew and passengers to remain seated. However, in response the radio message from the Airport Fire Service, a full evacuation was immediately initiated.

Given that the hydraulic fluid from the left system had been deposited over the left main landing gear and brake units, it is likely that, even if the aircraft had been brought to a halt on the paved surface, smoke would have been produced by the effect of the hydraulic fluid on the hot brakes. This would probably have been of sufficient intensity for the Airport Fire Service to recommend a passenger evacuation, as was the case when another operator's Boeing 757, with a left hydraulic system failure, landed at Geneva Airport (Switzerland) on 23 September 1997 (reported in AAIB Bulletin 1/98).

Crew training and experience

The First Officer had a total of 3,400 hours flying experience, of which 270 hours were on type. He had completed his training course on the Boeing 757 in May 1997. He had occasion to practice the hydraulic failure procedures during a simulator training session on 25 April 1997.

The commander had previously carried out hydraulic failure procedures during simulator training sessions in February 1995, July 1995 and most recently on 25 August 1996.

For both pilots, the simulator exercises had been completed using an earlier version of the QRH, prior to the introduction of the tabulated data into the hydraulic failure procedures. Copies of the revised format QRH had been circulated to crews for comment prior to their implementation.

QRH checklist presentation

During this investigation, it was noted that there were differences in the style, layout and content of the QRH checklists provided by the operator in this case (Figure 1) and that produced by the aircraft manufacturer (Figure 2). The operator's training department had produced a new format QRH for company use, with the intention of making the manufacturer's checklist easier to use. It had been introduced onto the aircraft fleet in May 1997.

The manufacturer's reference to the use of differential braking with the left thrust reverser inoperative was omitted from the operator's revised version in use during this incident. During this investigation, the operator revised the single system failure checklist to fully reflect the content of the manufacturer's procedure.

While the operator's version contained page references to further required procedures or continuation of a procedure on a subsequent page, there were no 'End of Procedure' notifications to confirm to crews that all of the items relevant to a particular series of actions/checks had been completed, although there was no clear evidence to suggest that this adversely affected the choice of Alternate Flaps and Gear checklists.

Copies of QRH pages for hydraulic failure procedures were obtained from all major UK operators of the type for comparison purposes. It was noted that each operator had a different style, nomenclature, layout and, in some cases, content. There is currently no requirement for operators to conform to any particular standard, it being the responsibility of each operator's training department to either accept the manufacturer's version or to modify this to produce its own custom design.

In September 1997, the CAA published Guidelines for the Design and Presentation of Emergency and Abnormal Checklists (CAP 676) in order provide advice to operators on the optimum methods of presentation of this type of information to flight crews. None of the current checklists examined met all of the relevant criteria published in CAP 676.

It is therefore recommended that the CAA positively encourage all UK Public Transport Operators to assess their current Emergency and Abnormal Checklists or Quick reference Handbooks with a view to improving their format and content in accordance with the guidelines published in CAP 676.

Engineering investigation

The technical investigation covered three areas, namely; the failure of the left hydraulic system; the failure to open of the overwing emergency exit R3; and the R3 door emergency slide which was subsequently found not to have been armed.

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Left system hydraulic failure

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The loss of hydraulic fluid in the left hydraulic system was caused by the failure of the left hand main landing gear downlock actuator flexible hose. This is a problem known to the aircraft's manufacturer and is caused by bending fatigue.

The manufacturer's records show that up to 1996 almost 500 hydraulic system fluid loss events have occurred since Boeing 757 deliveries began in 1982. Almost 400 of these events have been the loss of the left system. Many of these were associated with individual components that have been the subject of design review, improvement and Service Bulletin (SB) or Service Letter (SL).

The downlock hose which ruptured on this aircraft is of an early design which was determined to have an inadequate service life because of the bending cycles imposed on it during gear retraction and extension. An improved hose was introduced to all Boeing 757 operators in 1994 by Service

Letter (757-SL-29-028) which recommended replacement at a convenient maintenance opportunity. The aircraft has three independent hydraulic systems and, because of the redundancy this design provides for the system, none of the design changes and Service Bulletins have been subject to FAA airworthiness action.

The Service Letter was being incorporated by this operator's contracted maintenance organisation on all Boeing 757 aircraft maintained by them. This was carried out on an attrition basis. At the time of this incident the contracted maintenance organisation were responsible for 17 such aircraft and had completed the embodiment on 13 of them. Following this incident the Service Letter was rapidly embodied on all of the remaining aircraft. In addition it is understood that all UK operators and maintenance organisations of ex-Eastern Airlines Boeing 757 are now aware of this problem.

The manufacturer's records contained details of one previous runway excursion event due to single hydraulic system loss. In February 1989, during a scheduled cargo flight, a 757 Freighter suffered a left system fluid loss during cruise. The pilot elected to continue to the destination of Phoenix, Arizona where the weather conditions at the time of landing (0515 hrs local time) were clear and wind calm, temperature of 12_C. The aircraft departed the runway to the right side some 3000 feet from the threshold and 150 feet from the centreline. The crew had reported the condition to ground operations before landing and indicated that nose wheel steering was inoperative. The right thrust reverser was used; auto speed brakes and auto brakes were also selected.

The event prompted a review of the 757 Operations Manual and changes were implemented for a "Left System Only Inoperative" that included a warning not to use autobrakes and to ensure that the spoilers (speedbrakes) were extended <u>before</u> using the right thrust reverser.

Operation of doors R3 and L3 during the evacuation

The emergency exit doors (door No 3 left and right) are intended for use only during an emergency evacuation. The doors are a plug type, (24" wide and 52" high) and move upward initially, then open outward and down. An emergency escape slide is mounted on each door and is armed by locking a girt bar into a floor mounted fitting. The escape slide is normally left armed to deploy if the door is opened in an emergency. If the door is to be opened for maintenance the slide must be disarmed by removing the slide cover and then removing the girt bar from the floor fitting.

The space into which the door rises during the initial opening sequence is normally closed by a spring loaded hinged panel (**Item A** on Figure 4). The hinged panel is maintained in its closed position by a latch plate (**Item B**) which engages a catch assembly (**Item C**) on the top of the door frame. Raising the interior door operating handle raises the door and releases the catch plate, causing the hinged panel to open and allow the door to move up fully before moving outwards.

Problems have been experienced with the door catch assembly fouling on components on the hinged panel during opening, and a series of Service Bulletins have been issued by the manufacturer since 1987 to remedy the problem.

Neither the R3 door nor the L3 door functioned correctly. The R3 door did not open because the hinged panel assembly above the door jammed, preventing the door from rising. The L3 door opened, but only after the hinged panel assembly had broken away.

The R3 door was forced open after the evacuation, and when it was examined by the AAIB after recovery the central section (**Item D**) of the door catch assembly was missing. This tubular section, which engages in the throat of the latch plate, was not recovered. It has been assumed that the loss of this item was related to the door failing to open. To do so it must have jammed in the latch assembly, preventing the hinged panel from releasing, and thereby causing the door to jam. Both the L3 and R3 catch assemblies were damaged and subsequently replaced.

The problem of the catch assembly jamming in the latch on the hinged panel was recognised by the manufacturer, who issued a Service Bulletin on 9 April 1987; this called for checking for proper release, and adjustment if necessary. This original version of the Service Bulletin was satisfied by the operator of the aircraft at that time (Eastern Airlines), who issued an appropriate company Engineering Order (S25DEE036-1) on 13 May 1987. Some time later Eastern Airlines went out of business and the aircraft was put into storage.

Revision 1 to the Service Bulletin was issued on 9 June 1988 and introduced new parts for both the hinged panel and the catch support on the door. Further work by the manufacturer indicated that the modification to the catch support on the door alone would provide an acceptable solution to the problem. Revision 2, dated 29 June 1989, therefore offered kits for replacing the door catch assembly support (**Item E**) and made the modifications to the hinged panel optional. In January 1991 the FAA mandated the SB with a 60 day compliance period under AD 91-01-05.

This AD was not fully embodied on G-JALC, or three other ex-Eastern Airlines aircraft operated by this operator. These aircraft only had the original version of the SB complied with under the Eastern Engineering Order. Kits to bring the affected aircraft into compliance were to be available and fitted by the end of November 1997.

It is recommended that the FAA inform other Airworthiness Authorities that ex-Eastern Airlines Boeing 757s incorporating Eastern Engineering Order (S25DEE036-1) may not satisfy the FAA AD 91-01-05.

No 3 right emergency slide

The R3 slide would not have deployed if the R3 door had been opened because the girt bar was not fitted into the floor fitting. The girt bar had last been removed for maintenance at a 'C' check in April 1997 and the contracted maintenance organisation accepted that it was not refitted on completion.

Safety recommendations

Recommendation 98-47

It is recommended that the CAA positively encourage all UK Public Transport Operators to assess their current aircraft Emergency and Abnormal Checklists or Quick reference Handbooks with a view to improving their format and content in accordance with the guidelines published in CAP 676.

Recommendation 98-48

It is recommended that the FAA inform other Airworthiness Authorities that ex-Eastern Airlines Boeing 757s incorporating Eastern Engineering Order (S25DEE036-1) may not satisfy the FAA AD 91-01-05.