AIRCRAFT ACCIDENT REPORT 3/93

Air Accidents Investigation Branch

Department of Transport

Report on the accident to Lockheed 1011 Tristar, 9Y-TGJ, near 'KIRN' VOR, Germany, on 9 March 1992

This investigation was carried out in accordance with
The Civil Aviation (Investigation of Air Accidents) Regulations 1989

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Department of Transport
Air Accidents Investigation Branch
Defence Research Agency
Farnborough
Hampshire GU14 6TD

11 May 1993

The Right Honourable John MacGregor
Secretary of State for Transport

Sir,

I have the honour to submit the report by Mr D F King, an Inspector of Air Accidents, on the circumstances of the accident to Lockheed 1011 Tristar, 9Y-TGJ, near 'KIRN' VOR, Germany, on 9 March 1992.

I have the honour to be
Sir
Your obedient servant

K P R Smart
Chief Inspector of Air Accidents

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GLOSSARY OF ABBREVIATIONS USED IN THIS REPORT

AAIB	-	Air Accidents Investigation Branch
agl	-	above ground level
ATC	-	Air Traffic Control
BAA	-	British Airports Authority
CAA	-	Civil Aviation Authority
CAP	-	Civil Aviation Publication
CAS	-	Calibrated airspeed
CDL	-	Configuration Deviation List
CVR	-	Cockpit Voice Recorder
DDG	-	Dispatch Deviations Procedures Guide
DFDR	-	Digital Flight Data Recorder
EPR	-	Engine Pressure Ratio
FDR	-	Flight Data Recorder
FL	-	Flight Level
ft	-	Feet
hrs	-	Hours
kt	-	Knots
LATCC	-	London Air Traffic Control Centre
lb	-	Pounds
lb/min	-	pounds per minute
mb	-	millibars
MHz	-	Megahertz
MMEL	-	Master Minimum Equipment List
N_1	-	Fan speed
nm	-	nautical miles
PRSOV	-	Pressure Regulating and Shut-off Valve
RPM	-	Revolutions per minute
UK	-	United Kingdom
UTC	-	Co-ordinated Universal Time
VOR	-	Very high frequency omnidirectional radio range
V_{REF}	-	Reference landing airspeed

Air Accidents Investigation Branch

Aircraft Accident Report No: 3/92 (EW/C92/3/1)

Registered Owner:	Credit Lyonnais/PK Airfinance
Registered Operator:	Trinidad and Tobago (BWIA International) Airways Corporation
Aircraft Type and Model:	Lockheed L1011-385-3 Tristar (Series 500)
Nationality:	Trinidad and Tobago
Registration:	9Y-TGJ
Place of accident:	Near 'KIRN' VOR, Germany Latitude: 49° 51' N Longitude: 007° 22' E
Date and Time:	9 March 1992 at 1450 hrs

All times in this report are UTC, unless otherwise stated

Synopsis

The accident was notified to the Air Accidents Investigation Branch (AAIB) by Heathrow Police on Monday 9 March 1992 and, following agreement with the German authorities, the investigation began the same day.

The following AAIB personnel participated in the investigation:

Mr D F King, Principal Inspector (Engineering)	Investigator in Charge
Mr C I Coghill, Senior Inspector (Engineering)	Engineering Matters
Mr P N Giles, Senior Inspector (Operations)	Operational Matters
Mr P F Sheppard, Assistant Principal Inspector (Engineering)	Flight Recorders

The accident occurred when, on departure from Frankfurt Airport, the translating cowl of the No 1 engine thrust reverser became detached, struck the leading edge of the left horizontal stabiliser and fell to the ground. The commander subsequently shut down the engine and diverted to London Heathrow Airport where an uneventful overweight landing was made. The aircraft had had two previous malfunctions of the No 1 engine thrust reverser system.

Two Safety Recommendations have been made.

1 Factual Information

1.1 History of the Flight

The aircraft was scheduled for a flight from Frankfurt to St Lucia. When the flight engineer checked the aircraft Technical Log he noted that the No 1 engine thrust reverser had been 'locked-out' in order to inhibit its use. During his subsequent check of the aircraft he was told, by the ground engineer, that a thrust reverser blocker door on the No 1 engine had come loose and would have to be removed prior to the flight. The resulting deficiency was permitted by the Configuration Deviation List (CDL). When the work had been completed the flight engineer checked that all of the screws which connected the thrust reverser translating cowl to its leading edge ring were in place.

The aircraft, call sign 'West Indian 981', took off from Frankfurt at 1435 hrs. As it climbed through Flight Level (FL) 100 there was a thud, accompanied by what appeared to be a compressor stall, and the aircraft shuddered. The first officer was the handling pilot and called "engine failure No 1 engine". The commander noted that it had not failed because, although it had initially fallen, the fan RPM (N_1) was now returning to normal. The Engine Pressure Ratio (EPR) had, however, stabilised at 1.20 compared with 1.55-1.60 on the other two engines. There was a slight vibration and a passenger reported having seen '...something come off the engine'. About four minutes after the initial incident, the commander shut down the No 1 engine.

As about 106,000 lb of fuel would have to be jettisoned to reduce the aircraft's weight to the maximum permitted for landing, a procedure which he estimated would take at least 30 minutes, the commander decided to divert to London Heathrow Airport, as this was the company's main European maintenance base. He elected to remain at FL140. The flight engineer, and subsequently the commander, carried out a visual inspection of the No 1 engine and concluded that the thrust reverser translating cowl had become detached; no other damage was identified at this time.

At 1520 hrs, 'West Indian 981' called London, Dover Sector, and informed the controller of the requirement to jettison fuel and that the time required was estimated to be 30 minutes. As the aircraft was above 10,000 ft and over the sea, the controller cleared 'West Indian 981' to "...commence your dumping now. I'll run you towards Dover and if necessary run you down the channel before taking you into Biggin." This was acknowledged and, having ascertained that the No 1 engine had been shut down, the controller asked if the commander wished to declare an emergency. The reply was "No I don't think so. We'll be alright." Flight deck discussion recorded on the Cockpit Voice Recorder (CVR) about this time indicated that the commander's decision not to declare a emergency was largely based on the inconvenience which would consequently be experienced by him and his crew after they had landed, rather than the condition of the aircraft.

The fuel jettison was initiated but one of the two fuel pumps in the No 1 fuel tank was unserviceable and, consequently, the jettison rate from that tank was reduced. A short time afterwards, the commander became concerned about a lateral fuel asymmetry which had developed and the jettison was stopped; both engines were then fed from the No 1 tank. Some time later the jettison was recommenced.

At 1528 hrs, 'West Indian 981' was transferred to London, Lydd sector. The controller asked how long the jettison would take and, having been given an estimate of 20 minutes, gave the aircraft radar headings.

At some point after this, a passenger reported that there was damage to the left horizontal stabiliser. He had noticed it at the time of occurrence but was now concerned that the damage appeared to be getting worse. This information, coupled with the length of time it was taking to jettison the fuel, convinced the commander that an overweight landing should be made. At 1551 hrs the request for an immediate approach was made. The controller asked for confirmation that the fuel jettison had finished and was told that "...we haven't finished the dumping we've just got a report that there is some damage to the stabiliser so we think we'd better just come straight in". Clearance was given direct to Biggin Hill VOR. 'West Indian 981' was cleared to descend to FL120 and, at 1554 hrs, requested to change frequency to 128.4 MHz. Communication was not established on this frequency until just before 1600 hrs when the aircraft was recleared to FL80.

For operational reasons, the British Airports Authority (BAA) would have preferred the aircraft to land at Stansted Airport. The controller told 'West Indian 981' that "There's a request from BAA at Heathrow that you divert to Stansted." The commander replied that he would prefer to continue to Heathrow. This was agreed and the aircraft was recleared to FL70 and transferred to Heathrow Approach control. Recorded flight deck conversation indicated that the commander thought that the reason for the request was because the aircraft had lost part of its engine structure and the BAA was concerned about it overflying a large built up area.

The Heathrow approach controller instructed 'West Indian 981' to "...leave Biggin heading three four zero your landing runway is two seven right." After this had been repeated back to him, the controller asked what speed the aircraft would be able to maintain; 'West Indian 981' replied "We'd like to stay clean as long as possible we can do that at about two fifteen." At 1604 hrs, 'West Indian 981' was cleared to 4,000 ft and transferred to Heathrow Radar with 18 nm to go to touchdown. The landing gear was selected down at this stage and the aircraft was set up for the approach; the landing weight was estimated to be 400,000 lb and a V_{REF} of 155 kt was determined. At 1605 hrs the aircraft was recleared to 3,000 ft and was given a heading of 300° to establish on the localiser on runway 27R. Shortly after this the flight engineer reported that there was "No nose gear". The approach checks were actioned but the landing gear position indicator still showed a green light for each main landing gear and a red 'IN TRANS' light for the nose landing gear. A lights check had been carried out when, at 1607 hrs, 'West Indian 981' was cleared to descend with the Instrument Landing System and transferred to Heathrow Tower. The commander instructed the flight engineer to pull the nose gear Manual Landing Gear Uplock Release Handle and, shortly afterwards, the green nose landing gear position light illuminated. The 'LANDING' check-list was actioned. The crew had, while dealing with the landing gear problem, overlooked the frequency change and, at 1609 hrs, Heathrow Radar cleared 'West Indian 981' to land; the surface wind was passed as south westerly/11 kt.

Following a frequency change to Heathrow Tower, 'West Indian 981' called "Inside the marker."; the landing clearance was confirmed with a surface wind of 210°/10 kt. Coincident with the flight engineer calling "Stopping the dump" the controller asked "...are you aware that you're still dumping fuel". The commander, who had apparently not heard the flight engineers call, immediately instructed him to "Stop the dump" and replied "I'm afraid yes sir we were beg your pardon for that we just stopped it." A wind check of 250°/9 kt was passed and the aircraft landed just after 1610 hrs.

After touchdown both 'DLC AUTO SPLR' fail lights illuminated and the speed brake lever remained in the 0° position; the spoilers were selected manually. As the aircraft vacated the runway the flight engineer reported that the 'C' system hydraulic reservoir 'HI TEMP' light had illuminated and the quantity had fallen to ¼ full. The engine driven pump was switched off.

The Airport had been brought to a state of Full Emergency and the emergency services attended the aircraft as it landed. Contact was established with the Airport Fire Service and, when the aircraft was brought to a halt, an inspection was carried out of the No 1 engine and the area around it. A report was given to the commander and the aircraft was cleared to taxi to the stand.

1.2 Injuries to persons

	Crew	Passengers	Others
Fatal	-	-	-
Serious	-	-	-
Minor/None	13	173	-

1.3 Damage to aircraft

The No 1 engine thrust reverser translating cowl was missing apart from its leading edge ring structure, most of which was still attached. There were score marks and indentations on the under surface of the wing immediately inboard of the No 1 pylon and also some score marks on the wing leading edge above the pylon. Stabiliser damage was restricted to the No 3 structural segment of the left leading edge but that had been disrupted leaving a large ragged hole.

1.4 Other damage

There was no reported damage to any ground installations or persons.

1.5 Personnel information

1.5.1 Commander:	Male, aged 47 years		
Licence:	Airline Transport Pilot's Licence (Republic of Trinidad & Tobago); valid until 22 May 1992		
Aircraft ratings:	Lockheed L1011 Tristar, 500 Series		
Medical certificate:	Class 1; no limitations; valid until 22 may 1992		
Instrument rating:	Valid until 15 June 1992		
Last base check:	30 November 1991		
Last line check:	5 December 1991		
Flying experience:	Total all Types:	12,903 hours	
	Total on accident type:	4,000 hours	
	Preceding 90 days:	90 hours	
	Preceding 24 hours:	2 hours	
Duty time:	6 hours 40 minutes to the time of the accident		
Rest period prior to duty:	72 hours		

1.5.2	First Officer:	Male, aged 51 years	
	Licence:	Commercial Pilot's Licence (Republic of Trinidad & Tobago); valid until 21 June 1992	
	Aircraft ratings:	Lockheed L1011 Tristar, 500 Series	
	Medical certificate:	Class 1; with the limitation that corrective lenses must be worn; valid until 21 June 1992	
	Instrument rating:	Valid until 19 October 1992	
	Last base check:	29 September 1991	
	Last line check:	29 October 1991	
	Flying experience:	Total all Types:	10,100 hours
		Total on accident type:	3,000 hours
		Preceding 90 days:	100 hours
		Preceding 24 hours:	2 hours
	Duty time:	6 hours 40 minutes to the time of the accident	
	Rest period prior to duty:	72 hours	
1.5.3	Flight Engineer:	Male, aged 37 years	
	Licence:	Flight Engineer's Licence and Commercial Pilot's Licence (Republic of Trinidad & Tobago); valid until 12 January 1993	
	Aircraft ratings:	Lockheed L1011 Tristar, 500 Series	
	Medical certificate:	Class 1; no limitations; valid until 21 June 1992	
	Last base check:	29 September 1991	
	Last line check:	29 October 1991	
	Flying experience:	Total all Types:	3,338 hours
		Total on accident type:	2,061 hours
		Preceding 90 days:	76 hours
		Preceding 24 hours:	2 hours
	Duty time:	6 hours 40 minutes to the time of the accident	
	Rest period prior to duty:	72 hours	

1.5.4	Ground Engineer:	Male, aged 29 years
	Licence:	Aircraft Maintenance Engineer's Licence issued by the United Kingdom (U K) Civil Aviation Authority (CAA) for Category A (Aeroplanes 2) and Category C (Jet Turbine Engines); valid until 19 February 1995
	Authorisation:	Authorised by Trinidad and Tobago (BWIA International) Airways to certify work in Category A1 (Airframe, L-1011); Category B1 (Engine, RB211) and Category K1 (Black Box Change, L1011)
	Experience:	12 years (including 4 year apprenticeship). British Airways company approval previously held on L1011 airframe and RB211
	Type Training:	1986, British Airways, Heathrow L1011 airframe course and RB211 engine course

The Aircraft Maintenance Engineer mentioned in this report and referred to as the 'ground engineer' was employed by the Operator as a 'technical representative' responsible for providing or acquiring engineering support for the airline's aircraft during turn-arounds at destinations in the UK and Europe. Normally based at Heathrow, he would position himself at the European airports served by the airline on the evening before a given flight, to receive the incoming aircraft and provide any required maintenance or rectification. At Heathrow, Air Canada was contracted to provide manpower or assistance and at other locations the engineer would do the work himself or acquire an appropriate local contractor. The engineer was technically responsible to the airline's Chief Inspector and, as a condition of his company approval, was required to notify the Chief Inspector of any unusual occurrences or defects affecting the aircraft.

On 7 March the engineer had completed two days off, but the work on 9Y-TGJ required a twelve and a half hour shift that day. He worked a five hour morning shift on 8 March and flew to Frankfurt that evening, where he completed a nine and a half hour shift, servicing and carrying out rectification work (removal of the blocker door on No 1 reverser) on 9Y-TGJ.

1.6 Aircraft information

1.6.1 Leading particulars:

Type:	Lockheed L1011-385-3 Tristar (500 Series)
Constructor's number:	193G-1179
Date of manufacture:	1979
Certificate of registration:	Registered in Trinidad and Tobago in the names of Credit Lyonnais/PK Airfinance, Paris, France
Certificate of airworthiness:	Renewed on 28 January 1992 in the Public Transport/Passenger/Cargo categories and valid until 27 January 1993
Total airframe hours:	33,556 (at landing)
Engines:	3 Rolls-Royce RB211-524 B4 02 No 1 Engine Serial No 14814
Maximum Authorised weight for take-off:	504,000 lbs
Actual take-off weight:	475,642 lbs
Maximum Authorised weight for landing:	368,000 lbs
Estimated actual landing weight:	396,260 lbs

1.6.2 Structure and Operation of the Thrust Reverser Translating Cowl

The subject thrust reverser was of the Rolls-Royce 'standard weight' type driven by an air motor through a closed loop flexible drive system connecting the six gearboxes and screwjacks (see Appendix A, Figures 1 to 4).

Reverse thrust is obtained by diverting the cold, bypass air stream only; the hot, core efflux, is not affected. Part of the bypass duct's outer casing, the translating cowl, can be moved aft to expose vents (cascade vanes) which allow bypass duct air to flow radially outwards from the duct and divert it forwards to create reverse thrust. As the translating cowl moves aft articulated panels (blocker doors) are folded rearwards to block the bypass duct nozzle. The structure of the translating cowl comprises a leading edge ring beam (interrupted by the pylon) which is attached through ball nuts to the screwjacks which transport the cowl and also transfer the cowl loads to the engine. A double skin structure is attached to the ring and provides the sealing of the bypass duct when the engine is in the forward thrust condition. Finger brackets attach the front, translating end of the blocker doors to the cowl ring. When reverse is selected the screwjacks open the cowl which, in turn, folds the blocker doors rearwards to block the cold nozzle. The blocker doors do not seal the periphery of the bypass duct when the reverser is stowed and so it is the cowl which sustains the duct pressure loads.

When the cowl is in the fully forward position mechanical latches engage in Nos 2 and 5 gearboxes. If the reverser is to be 'locked-out', ie stowed and made inoperative, locking pins are installed in the Nos 2 and 5 gearboxes and a de-activation key is inserted into the system's Pressure Regulating and Shut-off Valve (PRSOV).

The condition of the thrust reverser on each engine is indicated in the cockpit by three illuminating captions; 'REVERSER PRESS', 'TRANSIT' and 'REVERSE'. Translating cowl position is detected by two sensors at the base of the pylon which detect targets mounted on the cowl; a forward position device at the cowl's leading edge (when stowed) adjacent to the left side of the pylon and an aft position device at the cowl's leading edge (when deployed) on the right side of the pylon. The design of the indication system is such that the 'TRANSIT' caption will illuminate if the forward position detector is uncovered, even if reverse thrust has not been selected.

1.6.3 The fuel jettison system

Each wing tank contains two pumps which supply fuel under pressure to the associated dump valve. When the dump valve is opened fuel passes into the refuel/defuel/jettison gallery and flows overboard, via a jettison nozzle valve, through jettison masts, one in each wing. Fuel from each of the centre tanks is fed through a gravity transfer valve into its associated wing tank. The galleries on each side of the system are linked by a cross-ship isolation valve. The total flow rate with all pumps working should be about 4,500 lb/min; this would be reduced by about 600 lb/min if an inner tank pump failed and 300 lb/min if an outer tank pump failed.

Latching in the Master Jettison switch opens the cross-ship isolation valve, both jettison nozzle valves and both centre tank gravity transfer valves; it also arms the four dump valve switches, which in turn energise the motors which open the dump valves. If the tank pumps are providing pressure, fuel will be jettisoned. Unlatching the Master Jettison switch closes all the valves automatically. If the latter action is not taken, automatic shut-off sensors terminate jettison when a nominal preset fuel level is reached.

1.7 Meteorological information

The weather was not significant in this accident.

1.8 Aids to navigation

Aids to navigation were not significant in this accident.

1.9 Communications

Communications were conducted on the normal London Air Traffic Control Centre (LATCC) and Heathrow Airport radio frequencies. Recorded speech transcripts were made of all communication between Air Traffic Control (ATC) and 'West Indian 981' whilst in UK Airspace.

No communications problems were experienced which affected the outcome of the accident.

1.10 Aerodrome information

The aircraft landed safely at Heathrow Airport. The airport characteristics were not relevant to the accident.

1.11 Flight Recorders

1.11.1 Cockpit Voice Recorder

The aircraft was fitted with a Fairchild A100 CVR, which records 4 parallel tracks of information on an endless loop of tape with a recording duration of 30 minutes. The CVR was installed to the UK CAA standard, which requires that the crew microphones are live to the recorder at all times. The track allocation was as follows:

Track 1	First officer's live microphone & headset audio
Track 2	Cockpit area microphone
Track 3	Flight engineer's live microphone & headset audio
Track 4	Commander's live microphone & headset audio

The tape was removed from the recorder and a satisfactory replay obtained. Signals on the first officer's track were distorted and the live microphone signals were not audible. His conversation was deciphered using the area microphone and pick-up through the commander's microphone. Information commenced just before the aircraft left the racetrack pattern, determined by ATC for fuel jettison, for vectoring to Heathrow Airport.

1.11.2 Flight Data Recorder

The aircraft was fitted with a Lockheed model 209 Digital Flight Data Recorder (DFDR). This recorded a total of 33 variable parameters plus 55 discrete (switch position) parameters. A satisfactory replay was obtained.

A plot of selected parameters is shown at Appendix B, which covers the area of the cowl detachment and engine shut-down. A second plot, at Appendix C, shows selected parameters for the approach and landing.

1.11.3 Sequence of Events

The aircraft appeared to be climbing out normally when at 10,300 ft and a speed of 348 kt Calibrated airspeed (CAS) the autopilot disengaged. Between 6 and 7 seconds later, at 10,500 ft and 350 kt CAS, the EPR on No 1 engine dropped from 1.48 to 1.36 over a period of 1 to 2 seconds. It dropped further 6 to 7 seconds later to 1.32 over a 1 to 2 second period; at the same time the autopilot was re-engaged. About 8 seconds after this, the autothrottle was disengaged and the EPR on all three engines reduced. During the initial changes in EPR on No 1 engine, the EPR on engine Nos 2 and 3 had remained constant at 1.5. After a further 130 seconds the autopilot was disconnected again and the EPR on all three engines increased, with autothrottle being engaged after about 5 seconds. 75 seconds later the autopilot was once more engaged and about 10 seconds after that the No 1 engine was apparently shut down. During the 3 minutes 50 seconds between the initial EPR reduction and the engine shut down the EPR on No 1 engine remained 0.1 to 0.2 below the level of the other two. The reason for the autopilot disengagement before the EPR reduction is not clear from the DFDR, but it should be noted that the EPR is the only engine parameter recorded.

There was no discrete signal for No 1 reverser in transit at the time of the cowl detachment or subsequently during the flight. It was not possible to confirm correct signalling of this discrete to the DFDR from the received record as the last normal operation of the reverser had been more than 25 hrs before the incident and had been over-written but the airline did later confirm the 'TRANSIT' function was signalling to the DFDR on 9Y-TGJ.

No information from the CVR was available during this period as it occurred prior to the earliest information on the 30 minute duration recording.

The flight apparently progressed uneventfully with a decision made to divert to Heathrow and to enter the hold to jettison fuel. It was not possible to identify, from the recorders, when fuel jettison commenced.

The CVR information commenced as the crew were deciding to jettison fuel to the outer marker. Some damage to the tailplane had been reported, and they decided to ask for clearance to start the approach immediately. Just after they were given clearance to leave the hold, at 19 minutes before touchdown, a comment was made that they were only 'dumping' out of one half. The commander then remarked that not only were they 'dumping' out of one half, they were only 'dumping' from one pump out of one side. About three minutes later there was a discussion about the aircraft trim being effected by the 'wing imbalance'. The commander suggested that it would be better to use aileron trim rather than rudder trim to counteract this.

The crew decided not to declare an emergency because they believed they would have to undergo medical checks and would not be able to operate the following day. About 10 minutes prior to touchdown BAA requested that the aircraft divert to Stansted. The commander requested that they be allowed to proceed to Heathrow as all of their facilities were there. Meanwhile the flight engineer consulted Air Canada, the handling agent, who were adamant that the aircraft should come to Heathrow. ATC cleared the aircraft to Heathrow before the flight engineer had finished this discussion. Subsequently the commander intimated to the crew that he thought that the request had arisen because the authorities did not want aircraft to fly over crowded area if bits were likely to fall off.

At about 6½ minutes before touchdown the commander commented that the speed was high and should be reduced. The first officer suggested using flap but the commander indicated that the landing gear should be used. Just after the first officer called for the landing gear there was an increase in background noise on the CVR which indicated that it had unlocked and projected into the air stream. The DFDR at this point indicated that the landing gear became unlocked at a speed of 239 kt at 5,800 ft above runway level. The crew were aware that the gear deployed lights were not illuminated and carried out a light test on the system, which appeared to be satisfactory. The captain asked for the alternate landing gear release to be pulled and a short time later, during the landing checks, a 'down and three greens' call was made. The DFDR indicated that the landing gear remained unlocked for a period of 3 minutes 27 seconds and locked down 2 minutes 40 seconds before touchdown, when the speed was 172 kt and the aircraft was 2,100 ft above the runway. Landing clearance was confirmed with a surface wind of 210°/10 kt. The aircraft touched down apparently normally at about 156 kt and, during the deceleration, spoilers and reverse thrust on engines two and three were used.

After landing the aircraft was asked to hold when clear of the runway. Shortly after this, the DFDR indicated a hydraulic low power warning on the 'A' system followed 54 seconds later by a similar warning on the 'C' system. On the CVR it was apparent that the flight engineer noticed a warning and reported that they had a high temperature light and loss of fluid from the 'C' system. No mention of the 'A' system could be detected. As the aircraft taxied back to the stand the commander remarked on a loss of nosewheel steering, and observed that he could only steer to the right. This was apparently rectified by resetting the 'Nose and by-pass handle'.

1.12 Wreckage and impact information

The engine and aircraft were first examined at Heathrow and then the engine was removed to a Rolls-Royce facility for some more detailed examination under AAIB direction and subsequent repair. The German authorities recovered wreckage in the locality of Kirn, 45 nautical miles west south west of Frankfurt Airport, and made arrangements for it to be sent to the UK where it was examined with the rest of the engine (see Appendix D).

All of the cowl surface had detached exposing the cascade vanes (see Appendix E, Figure 1) but most of the ring structure within the cowl's leading edge, which is the principal load transfer element of the cowl, was still attached to the screwjack ball nuts through which it transmits cowl loads to the engine. The trackway which is engaged by the cowl edge where it abuts the pylon outboard surface had suffered a tearing failure along its whole length.

All but two of the blocker door attachment fingers were still secured to the remaining ring section and as the ring was in the stowed position and the locking latches were engaged, these blocker doors were in the stowed, forward thrust position. A portion of the ring structure was, however, missing from the outboard edge of the cowl (where it normally abuts the outboard side of the pylon) round to the point of attachment of blocker door No 13, adjacent to the ring's support at the ball nut of screwjack No 5. Screwjack No 5 contained one of the two cowl latches; the other being in screwjack No 2. The failure of the ring at this location was in overload with indications of outward and rearward bending. As found, No 14 blocker door was free to move between its stowed position and the folded position which it adopts to block the bypass duct when the reverser is deployed. Its attachment finger had broken free from the cowl ring through overload failure of its attachment flanges but sufficient of the flanges remained to retain the finger in its slot between the cascade vane segments. No 15 blocker door was absent, having been removed at Frankfurt. It was calculated that progressive bracket failures would result in step increases of the maximum bending moment in the unsupported end of the cowl by a factor of approximately 6 with the failure of the first finger bracket, [found at Frankfurt] and 16 with the failure of the second. The ball nut of the No 6 screwjack was positioned near its fully forward position (see Appendix E, Figure 2). Its cowl attachment foot with its four captive nuts was undamaged. The ball nut of No 4 screwjack was also positioned close to its forward position near to its attachment location on the ring beam but not bolted to it. The No 20 cascade vane box (adjacent to the No 6 screwjack) was found to be retained by only one bolt (of two) at its forward end.

The cowl skin was recovered in two major parts together with a number of smaller fragments and separated panels. Nothing was found of the missing portion of the leading edge ring beam. Though the ring had separated at its point of collapse the double skin assembly had continued to detach around the reverser's whole periphery. The skin assembly had also broken at a position below the ring failure and had probably left the aircraft as two main pieces together with the smaller fragments found on the ground. Score marks and punctures on the fixed cowling aft of the reverser showed that the upper outboard section of the translating cowl had hinged rearwards and downwards as it detached, probably pivoting about the position of the skin assembly break. At either end of the cowl outer skin some heavy abrasion and impact damage was found which probably corresponded to the impacts with the wing and stabiliser, though the two areas of cowl damage could not be positively identified with these areas of airframe damage.

An examination of the thrust reverser drive system at Rolls-Royce confirmed the report by the airline ground engineer on the condition of the system as it had been left after the work at Heathrow on 7 March and Frankfurt on 9 March (see Paragraph 1.17.1), and identified the failures within the system. The flexible drive between Nos 5 and 6 gearboxes had failed, one drive shaft from the air motor had failed and the other had suffered overload damage. The No 4 gearbox and screwjack mating splines were found to be stripped and this was determined to be the original cause of the reverser jam on 7 March; the failure of No 4 to translate with the other jacks causing the cowl to distort and jam and the flexible drives to fail in overload. Such damage to the splines can develop if a gearbox and screwjack are installed with excessive endfloat in the jack. Some damage on the fixed part of the reverser adjacent to the jack, consistent with movement of the jack, indicated that had occurred in this case. The relevant section of the Maintenance Manual (78-31-19) contains a cautionary note on the importance of the endfloat dimension.

Crew and DFDR evidence indicated that the No 1 thrust reverser 'TRANSIT' light did not illuminate when the cowl detached even though the stowed position detector had been uncovered. Rolls-Royce confirmed that under the circumstances of the cowl detachment the 'TRANSIT' light ought to have illuminated. No fault was discovered in the engine mounted part of the indication system when it was tested at Rolls-Royce and neither was any fault in the aircraft system recorded when the aircraft was prepared for service. No defect or damage was found, therefore, to explain this anomaly. However, the airline reported that about two weeks after the aircraft had been returned to service a fault did arise in the No 1 reverser indication system when the 'TRANSIT' light illuminated inappropriately and two electrical circuit cards were replaced during rectification.

'C' hydraulic system failed to operate fully when the aircraft was on approach to Heathrow and the landing gear was selected 'DOWN'. A low quantity indication was noticed by the crew and later, after landing, a high temperature indication occurred. While the aircraft was being prepared for its return to service, the nose gear was successfully cycled six times once 'C' system had been replenished and bled, but subsequently, the Cartridge Solenoid Valve in the Landing Gear Control Module was suspected as faulty and was replaced. A loss of hydraulic pressure caused by a malfunction of this valve could have resulted in the landing gear and spoiler problems experienced on the accident flight.

The problem with the 'C' system, and the indication of an 'A' system pressure loss after landing, were not pursued further by AAIB for the purposes of this investigation.

1.13 Medical and pathological information

There was no medical or pathological information.

1.14 Fire

There was no fire.

1.15 Survival aspects

There were no survival aspects.

1.16 Tests and Research

No additional tests or research were carried out.

1.17 Additional information

1.17.1 Maintenance History

During landing at London Heathrow on 7 March, two days before the accident, it was found that reverse thrust could not be obtained on No 1 engine; the thrust reverser 'TRANSIT' light illuminated and would not extinguish. The airline's duty ground engineer found the reverser's translating cowl to be jammed about mid-way in its traverse and distorted. He informed his airline's operations control that the aircraft would not be ready for its next scheduled departure and, supervising the assistance of engineering staff from another airline which was under contract to provide servicing support, he began a systematic process to free the cowl and achieve a safe stowed and locked condition.

In the process of investigating and manipulating the cowl the team disconnected the dual flexible drives from the air motor and found that the drive from the left-hand output of the air motor was broken. Attempting to move the cowl through its manual drives at jacks Nos 2 and 5, they observed that jacks Nos 4 and 6 appeared to be jammed. They disconnected the drive at No 6 gearbox and found that it had failed. They also isolated No 4 gearbox by disconnecting its associated drives on either side at Nos 5 and 3 gearboxes. At Nos 4 and 6 screwjacks they also detached the ball nuts, which translate along the screws, from the cowl itself whereupon the distortion in the cowl straightened out and they were able to wind the cowl manually to the fully deployed position. The ball nut on No 6 jack was still not free to move on the screw and so a cascade vane box was removed to give access and the flexible drive on the inboard side of No 6 gearbox was disconnected (there was later found to be a failure at the air motor end of the drive). It then proved possible to wind No 6 ball nut and also No 4 ball nut to their fully forward positions and the vane box was refitted. When an attempt was made to wind the cowl forward for stowing and locking its movement became stiff and it jammed again. A cascade vane box was again removed for access and the drive into No 1 gearbox was disconnected. The cascade vane box was re-installed and the reverser was successfully wound to the fully forward position where both latches engaged.

The procedure for 'locking out' the thrust reverser was then completed; locking pins were inserted at Nos 2 and 5 gearboxes, the PRSOV was de-activated and, additionally, a baulk was installed on the primary (inboard) pneumatic lock actuator. In the cockpit the No 1 thrust reverser lever was wire locked down and the thrust reverser lever and the 'REVERSER PRESSURE' light on the flight engineer's panel were labelled 'DE-ACTIVATED'. The aircraft was declared serviceable, a description of the work carried out was entered in the Technical Log and an entry made in the 'Deferred Defects Control Sheet'. The entry made in the Deferred Defects contained a specified time limit for rectification of 10 days from the time of the entry. This was derived from the Master Minimum Equipment List (MMEL) Procedures Manual for the case where a thrust reverser is locked stowed and is unusable (Repair Interval - Category C). The engineer made a telephone call to the airline's Maintenance Control Centre in Trinidad to inform them of the actions taken. In addition to the standard aircraft departure telex he sent a separate signal describing in all relevant detail the actions taken, stating that there was 'no other damage apparent' and asking for a 'more thorough inspection' of the reverser to be carried out when the aircraft arrived at Port of Spain. Though the local ground engineer referred to the MMEL Procedures Manual and the Rolls-Royce Maintenance Manual, neither he nor the engineering staff at the Maintenance Control Centre recognised the structural significance of the disconnections made, particularly that of the No 6 ball nut from the cowl, or that the actions taken were outside those permitted by the MMEL.

The aircraft departed from London Heathrow on 7 March at 1725 hrs and arrived at Port of Spain, Trinidad at 2333 hrs Local Time after routing through Barbados. An engineering team had been assembled to deal with the inoperative thrust reverser but, immediately prior to 9Y-TGJ's arrival at Port of Spain, a double engine tail pipe fire occurred in another of the airline's Tristar aircraft while it was parked and the available manpower was diverted to work on that aircraft. 9Y-TGJ was then rescheduled to replace that aircraft on a service to New York at 0400 hrs Local on 8 March and, although an inspection was carried out, it was limited to a visual inspection and a confirmation of correct reverser de-activation and lock-out. This inspection was not recorded in the Technical Log. It was known, and noted on the Deferred Defects Control Sheet, that the MMEL allowed 10 days operation before a locked-out reverser need be repaired and so the aircraft was released to service. During this stop at Port of Spain a routine review of the aircraft's maintenance status, known as 'Log Book Posting', was carried out and each deferred defect would have been re-examined by supervisory staff.

The aircraft returned to Port of Spain at 1940 hrs Local on the 8 March. The fire damaged aircraft was still undergoing extensive inspections and a double engine change, with consequent demands on manpower and on the availability of other aircraft in the fleet. As no further problem had been encountered with the reverser on No 1 engine, 9Y-TGJ was released to service with no further actions on the reverser and departed for Frankfurt at 2300 hrs Local. When it arrived at Frankfurt on 9 March it had completed a total of 6 sectors and 30 flying hours since the reverser had been locked-out at Heathrow.

On his post-flight inspection at Frankfurt the ground engineer observed that the thrust reverser was still locked-out. He further noted that a blocker door in the top left-hand side of the reverser, adjacent to the disconnection between the translating cowl and the No 6 screwjack ball nut, was unattached at its forward end. He found that the front attachment finger between the blocker door and the cowl had fractured and assumed that this failure was the result of damage dating from the prior jamming incident, when the cowl had suffered visible distortion. By this time the crew were on board and he informed the commander that the aircraft would not be available at the 'slot time'. The ground engineer removed the blocker door as permitted by the CDL in the Flight Manual. He inspected the other blocker doors and the translating cowl and made appropriate entries in the Technical Log and the Deferred Defects Control Sheet. It was on the following flight out of Frankfurt that the cowl detached.

The ground engineer stated that, in the work that he carried out on 9Y-TGJ's reverser, he was mindful of the recent accident to a Lauda Air Boeing 767 in which a thrust reverser reportedly deployed in flight. Consequently, he was concerned to ensure that the reverser could not deploy and was securely locked-out. (The Boeing 767 in question was fitted with a different type of engine with a different design of operation of its thrust reverser).

1.17.2 Thrust Reverser Maintenance and Operational Procedures

The Lockheed MMEL Procedures Manual is the manufacturer's document which advises operators of procedures which will enable them to operate the aircraft within the constraints of the mandatory, Federal Aviation Administration MMEL. The MMEL Procedures Manual permitted one thrust reverser to be inoperative provided it was 'locked-out' (stowed and secured) according to the procedures laid down in the Lockheed or Rolls-Royce Maintenance Manuals, and certain operational procedures were observed as stipulated in the Flight Manual. The locking out procedure in the Rolls-Royce Manual (and also the powerplant section of the Lockheed manual which was derived from it) dealt with an intact reverser.

If the inoperative reverser was the result of a malfunctioning cowl screwjack then the MMEL Procedures Manual permitted one screwjack only, either No 3 or No 4, to be removed together with the associated gearbox and flexible drives. The referred section of the Rolls-Royce manual described the removal of a screwjack with its gearbox and flexible drives and their replacement with other units to result in a serviceable reverser. If the translating ball nut on a jack is detached from the cowl then, even if the jack is not removed, one of its functions, structural support of the cowl, is removed.

The Rolls-Royce Manual contained advisory troubleshooting and corrective procedures. For the case where the reverser partially extends these procedures led to the replacement of screwjacks or flexible drives where any were found defective.

The Tristar Flight Manual (UK version applies to 9Y-TGJ) contained a CDL which contained additional limitations for operation of the aircraft without certain secondary airframe or engine parts. The CDL allowed one blocker door to be missing on each engine. Up to three doors could be removed if the reverser was locked-out.

1.17.3 Safety Actions

On 10 March Rolls-Royce circulated a telegraphic message to operators giving initial information on the accident and this was repeated by Lockheed. Rolls-Royce subsequently circulated a second telex on 27 March with a fuller description of the circumstances of the cowl detachment and, following on from the technical investigation, carried out a review of their recommended maintenance and dispatch procedures for RB211 engines, with both standard weight and lightweight reversers in Lockheed L1011 and Boeing 747, 757 and 767 aircraft. The resulting amendments, described below, were issued in July to be followed by a related Notice to Operators.

Rolls-Royce amended the 'Description of Operation' in the thrust reverser section of the Maintenance Manuals to include a description of the significance of the attachment of the translating cowl to the ball nut housings. The company also wrote a new Maintenance Manual section specifically for reference by the MMEL and CDL to define procedures by which the configurations allowed by these documents can be achieved. In this section there is reference back to the MMEL and CDL as the authorising documents which describe the allowable configurations. The troubleshooting procedure for a seized cowl mechanism was also revised to give more guidance on locating the point of seizure, to avoid the situation where several items are disconnected at once in an indiscriminate approach to solving the problem.

The permission to allow the removal of No 3 or No 4 screwjack on a standard weight reverser with the associated flexible drives was reviewed and found acceptable. There was considered to be adequate structural support and redundancy in the locking system remaining with these components removed and the reverser locked-out. Though the flexible drives do transmit the locking effect from gearboxes Nos 2 and 5 to the other gearboxes, gearboxes Nos 2 and 5 each contain two mechanically independent locks and so, though the peripheral connection may be interrupted, the two separate parts of the reverser actuating mechanism retain redundancy in their locking system.

On Boeing 747 and 767 aircraft fitted with RB211 engines with the lightweight reverser the Boeing Dispatch Deviations Procedures Guide (DDG) had permitted continued engine operation with any one screwjack removed, the lightweight reverser having four jacks. As a result of the review of procedures following this accident it was concluded that this was no longer acceptable. Operators have been advised by telex and Boeing will amend the DDG at the next revision. RB211 engines on Boeing 757 aircraft have hydraulically actuated reversers and the DDG does not permit dispatch with an actuator removed.

Lockheed report that, together with the other aircraft manufacturers, they are currently carrying out a major review of thrust reverser systems with the Federal Aviation Administration. This work is continuing and no specific recommendations are yet available.

1.17.4 Emergency communications procedures

The two levels of emergency as defined in International Civil Aviation Organisation (ICAO) Annex 10, Aeronautical Telecommunications, are:

Distress	A condition of being threatened by serious and/or imminent danger and of requiring immediate assistance.
Urgency	A condition concerning the safety of an aircraft or other vehicle, or some person on board or within sight, but which does not require immediate assistance.'

The company's Operations Manual does not give any guidance on when and what level of emergency should be declared nor does it lay down the subsequent communications procedures to be used. These decisions are left to the discretion of the commander of the aircraft.

1.17.5 Fuel jettisoning

The Manual of Air Traffic services Part 1 Chapter 1 5-6 states:

> 'Pilots of aircraft in flight are permitted to jettison fuel in an emergency. The decision to jettison rests solely with the pilot but he may request guidance from air traffic control. Controllers are to recommend that jettisoning of fuel should be carried out:
>
> (a) Over the sea, if at all possible, or
>
> (b) Above 10 000 feet above ground level (agl).
>
> Exceptionally, if (a) or (b) is operationally impracticable or inconsistent with safety, fuel may be jettisoned above 7000 feet agl in winter and above 4000 feet agl in summer. For fuel to be jettisoned below these levels the situation must be unavoidable.'

The company's Operations Manual does not give any guidance as to the circumstances when fuel should be jettisoned nor does it contain any altitude by which fuel jettison should be terminated. These decisions are left to the discretion of the commander of the aircraft.

1.18 New investigation techniques

None.

2 Analysis

2.1 General

On the departure from Frankfurt, a part of the No 1 thrust reverser translating cowl became detached and caused damage to the left horizontal stabiliser. It was necessary to jettison fuel to reduce the aircraft weight to the maximum permitted for landing, however, the commander considered it prudent to land before this was completed and an overweight landing was made at Heathrow Airport. This analysis examines the reasons for the loss of the thrust reverser cowl and considers other operational and engineering aspects.

2.2 Sequence of failure

Examination of the engine and the recovered cowl parts showed that the failure and separation of the cowl had begun with the loss of structural support from the No 6 ball nut attachment, which had been disconnected on 7 March. The outboard edge of the cowl, under load from bypass duct pressure, would then have been supported first by its engagement in the trackway at its abutment to the pylon and, when that failed, by the attachment finger bracket of No 15 blocker door; the blocker door itself would have been pulled outwards until it contacted the cascade vanes. It was this finger bracket which was found failed (in overload) at Frankfurt and although the trackway had also probably failed, with part of it being lost, this need not have been evident if the cowl edge was unloaded and simply resting in its normal position. The absence of the blocker door may have been instrumental in promoting the failure of the cowl as, although the stowed blocker doors are not airtight, if the cowl was deflecting outward and leaking then they would restrict airflow from the bypass duct and limit the loads on the cowl. However, once the door was removed, any such restriction would disappear and the airloads on the unsupported end of the cowl would not be so limited.

After the failure of the No 15 blocker door finger bracket the cowl would then be restrained by the next blocker door finger bracket, No 14, which separated from the cowl through failure of its attachment flanges during take-off or climb from Frankfurt. During the progressive bracket failures the maximum bending moment in the unsupported end of the cowl would have been rapidly increasing (by a factor of approximately 6 with the failure of the first finger bracket, [found at Frankfurt] and 16 with the failure of the second). The cowl structure finally collapsed in outward bending at the point of the next finger bracket, just short of No 5 jack whose gearbox contained one of the reverser's two stowing locks. This collapse fortunately resulted in the rest of the ring structure remaining in place and the other blocker doors remaining locked stowed; the one blocker door which had been liberated in the cowl separation sequence was free to slide to any position between its normal stowed position and its bypass blocking position.

Although the cowl's main structural ring broke at the point of collapse the double skin assembly attached to it continued to detach around the reverser's whole periphery. The detaching skin assembly also failed at a position slightly beyond the point of the ring collapse and probably left the aircraft as two main pieces together with smaller fragments. At either end of the cowl outer skin some heavy abrasion and impact damage was found which probably corresponded to the impacts with the wing and stabiliser. These two areas of cowl abrasion could not be individually identified with the wing and stabiliser damage but still indicated that the impacts on the flying surfaces had, fortunately, been with one extremity of the piece of cowl involved and were therefore less severe than they would have been if the debris had been hit centrally.

2.3 Initial thrust reverser rectification at Heathrow

At Heathrow on 7 March the airline ground engineer and the other contract personnel were faced with an awkward problem in trying to unjam the thrust reverser and restore it to a safe condition. They were aware that the aircraft was undoubtedly going to be delayed for several hours beyond its next scheduled departure and, if they were not successful, that an engine change might be required with even greater delays for the passengers and scheduling difficulties for the airline. This is a common dilemma for first-line maintenance engineers.

The target for the ground engineer and his team appears to have been the achievement of the stowed and locked-out condition for the reverser with all risk removed that the reverser might deploy in flight. In the pursuit of that objective, which was eventually successfully achieved, the other implications of what was being done were not realised. While he was involved in trying to solve the immediate problem of the jammed reverser, it did not occur to the engineer that the translating cowl sustains bypass duct air pressure and that the resulting radial loads are transferred to the engine structure by the ball nuts and screwjacks. There might well be some basis for such a misunderstanding in that the blocker doors very evidently provide a sealing function in the duct in the reverse thrust condition. However, they are incapable of providing the high degree of sealing required in the forward thrust condition and the translating cowl is fitted with seals around its edges and is designed to maintain the sealing under load. As the cowl provides a good seal it inevitably sustains the duct static pressure loads and the blocker doors in the stowed position support virtually no radial air loads.

The local ground engineer did not recognise the structural or procedural significance of the disconnections which the team had made in the reverser, particularly that of the No 6 ball nut from the cowl. Although he referred to the Lockheed MMEL Procedures Manual and the Rolls-Royce Maintenance Manual he did not recognise that these disconnections were outside what was permitted by the MMEL. If the screwjacks' structural function was not recognised and the reverser was locked-out and presumed 'safe', the screwjacks might well have appeared redundant. Again, the MMEL permitted the 'removal' of only No 3 or No 4 screwjack, not its disconnection, and disconnection (albeit of another screwjack) might appear a less significant alteration to the configuration than removal. However, any change of configuration which is not specifically permitted is, for good reason as demonstrated here, not allowable under the Type Approval and its concomitant documents such as the MMEL.

An appropriate action for the ground engineer would have been to consult, before he released the aircraft, either his airline's Maintenance Control Centre or the local Rolls-Royce Heathrow Customer Service Office which is permanently available to give advice in such cases. Such advice might have enabled him to achieve a genuinely safe condition for the reverser or prompted him to declare a further delay.

The disconnections of the flexible drives were also outside what was permitted by the MMEL or CDL but this does not appear to have had any effect on the behaviour of the reverser or on the progress of the cowl failure. The disconnections from the air motor, which has an internal brake, and between No 6 and No 5 gearboxes did reduce redundancy in the security of the system. However, a large measure of redundancy still remained from the double locks in screwjacks No 2 and No 5 along with No 2's remaining connections to No 1 and No 3. The most vulnerable area was at No 5 gearbox which provided the only locking in the outboard side of the reverser, but the locking of No 5 did not degrade during the cowl break-up and detachment. However, it is important when advantage is taken of the operational alleviations in the mandatory MMEL and CDL that they should be followed precisely as any deviations from the prescribed practices may have consequences which are not immediately apparent.

Three of the flexible drives had suffered failure or seizure as a result of the initial reverser defect and a breakage in a flexible drive is effectively a disconnection. Disconnections were not specifically permitted by the MMEL and CDL and even the retention of a failed flexible drive in a (locked-out) reverser was not, therefore, an allowable configuration. The advisory troubleshooting procedures terminated with such defective items being replaced.

Although the ground engineer allowed himself to operate beyond his own knowledge of the aircraft and, because of his misunderstandings, beyond what was permitted in the mandatory procedures, he documented precisely what he had done. He reinforced the statutory record in the Technical Log and the Deferred Defects Record with a comprehensive telegraphic report to the Maintenance Control Centre, asking for an inspection of the reverser when the aircraft arrived there. However, his request for an additional inspection also merited entry in the Technical Log. In retrospect, his allowance of 10 days for rectification of the reverser was inappropriate as the reverser was not in the standard locked-out condition.

2.4 Supervisory maintenance

It might be expected that the supervisory staff at the Maintenance Control Centre, who were not directly involved in the immediate problems of rectifying the aircraft and clearing it for flight, would review the information supplied to them by the engineer and be alert to any conflicts with the MMEL and the CDL if, as reported, configuration changes had been made. They received the information soon after the aircraft's departure from Heathrow but they too did not question the structural or procedural significance of the disconnections described. They considered that as it had been de-activated, it was safe. However, in any case, they prepared to rectify the reverser when the aircraft arrived but at the moment of the aircraft's arrival they suffered the major distraction of a double jet pipe fire in another aircraft at Port of Spain. 9Y-TGJ was then required to replace the damaged aircraft on its next service flight and the inspection that was carried out was simply visual, confirming that the reverser had been correctly locked-out, and not the 'more thorough' inspection requested by the engineer. This inspection was not recorded in the Technical Log but neither did the Log contain the original request, as that had been made in a telex message outside the formal engineering record system. It would have been more proper for the request for inspection and the inspection itself to be recorded in the Technical Log.

When 9Y-TGJ arrived back in Port of Spain later that day, inspection and repair of the other aircraft was still absorbing a large amount of effort and, as no further problems had arisen with the reverser and a locked-out reverser can be legitimately carried for ten days before rectification, no action was taken.

2.5 Rectification at Frankfurt

In all probability, the No 15 blocker door finger bracket failed because it was subjected to excessive loads after the No 6 screwjack had been disconnected from the translating cowl and it was thus an indication that there was something amiss with the reverser. However, when the ground engineer found it broken he appeared to have another obvious reason why it might have failed. The reverser had suffered distortion at Heathrow and he thought that the door attachment might well have taken some damage then which resulted in subsequent failure. There would have been no other obvious signs of distress or unusual operation in the reverser to alert the engineer and the reverser had flown a number of hours in this condition without any evident problem. This sort of damage or failure seems to have been what the engineer had in mind when he asked for a more thorough inspection, but it would have appeared to him that nothing had been discovered in that inspection, which he assumed had been carried out. The aircraft had twice visited its main maintenance base and although there was no indication that his requested inspection had been carried out, he had not entered the request in the Technical Log and might not have been expecting any such notification. Though the actual inspection was not the 'more thorough' inspection sought by the engineer, better communication through the Technical Log in this instance could conceivably have arrested the process which ended with the detachment of the translating cowl. The need to remove the blocker door introduced a delay to the departure of the aircraft which was unwelcome and, of course, the engineer was occupied in carrying out the work. If he had any residual suspicions about the safe condition of the reverser then a telephone call or telex to the Maintenance Control Centre should at least have apprised him of the fact that such an inspection had not been carried out. This could conceivably have aroused suspicions, or at least discussions, about the condition of the reverser or about the legitimacy of the previous actions.

Although the likely significance of the failed No 15 blocker door finger bracket was missed and with it an opportunity to prevent the in-flight failure of the reverser cowl, the action taken at Frankfurt to remove the blocker door was legitimate within the terms of the CDL. It is worth noting, however, that the fact that one of the blocker doors can be removed implies that they do not seal the periphery of the bypass duct when stowed. This means that the translating cowl is exposed to duct pressure loads.

2.6 Decision to divert to Heathrow Airport

Having shut down the No 1 engine there appeared to be no additional problems which would have necessitated an immediate precautionary landing. The commander considered it prudent to reduce the aircraft weight to below the maximum authorised for landing; this required about 106,000 lb of fuel to be jettisoned and he estimated that this would take at least 30 minutes. As Heathrow Airport was the company's main European maintenance base he reasoned that it would be preferable to divert there; the time airborne would not be significantly longer and he could use some of the excess fuel in the transit. Should the situation deteriorate there were several suitable airfields en route where a precautionary landing could be made. Under the circumstances, given the information available to the commander at the time, the initial decision to divert to Heathrow Airport is considered to be reasonable.

2.7 Declaration of an emergency

The commander made a situation report to LATCC and requested permission to jettison fuel. As no emergency message had been passed the ATC controller asked the commander if he wished to declare an emergency. Although, at that time, the circumstances would have warranted at least a state of Urgency, the commander's reply was in the negative. Even when the situation appeared to have worsened and the commander requested an immediate approach, no formal declaration was made; the aircraft could now be considered to have been in a state of Distress. This presented a quandary to the controller as a state of emergency obviously existed but the crew did not appear to acknowledge it. Under these circumstances, as might normally be expected, the controller took the initiative and the aircraft was handled as it would have been had the commander declared an emergency.

The commander's reasons for not declaring an emergency appeared to have been based on the administrative problems he thought it would create for him and his crew after landing.

2.8 British Airports Authority request

The BAA would have preferred 'West Indian 981' to land at Stansted Airport; the reason was that, had it been necessary to close a runway after the aircraft had landed, there would have been less disruption to traffic flow. The request was a reasonable one for the BAA to make.

The commander was not apprised of the reason for the request but he surmised that it was because the aircraft had lost part of its engine structure and the BAA was concerned about it overflying a large built-up area. Aircraft approaching the westerly runways at Heathrow do spend a significant time over the densely populated area of Greater London and, as 'West Indian 981' was still jettisoning fuel and could possibly suffer further structural detachment, this would, arguably, have been an even better reason to ask the commander to divert to Stansted. Based on this premise the commander decided to continue with an approach to Heathrow when a diversion to Stansted would have been more appropriate.

Notwithstanding, if an aircraft commander is asked to divert to another airfield for whatever purpose, it is considered to be unreasonable to expect him to make the decision whether or not to accept the diversion if he is not apprised of the reason for the request. It is recommended that the CAA require, when an aircraft in an emergency situation is required or requested to divert to an airfield other than that at which the commander has elected to land, he should be apprised of the reason for that requirement or request. [Recommendation 4.1]

It is also recommended that the CAA take action to advise the appropriate agencies that when selecting the route for an aircraft in an emergency the avoidance of densely populated areas should be a primary consideration; when appropriate, and subject to the agreement of the aircraft commander a diversion to an alternate runway or airfield should be considered. [Recommendation 4.2]

2.9 Fuel jettison

When, at 1551 hrs, the commander made the decision to request an immediate approach not enough fuel had been jettisoned for the aircraft to be below maximum landing weight. The situation was aggravated by the loss of the fuel pump which had not only reduced the overall rate of jettison but had produced an asymmetry between tanks. To alleviate this, the jettison was temporarily stopped and both engines were fed from one tank. It was not possible to determine for how long this occurred or whether the system was handled in the most efficient manner. When the decision was made to request an immediate approach, an overweight landing was inevitable. To reduce the weight to as near maximum landing weight as possible and to give the flight engineer more time to balance the fuel the commander decided that the jettison should continue until the aircraft was at the outer marker.

2.10 Nose landing gear

The landing gear is electrically controlled and hydraulically actuated by pressure from the 'C' hydraulic system. Although no fault was apparent at the time the landing gear was selected down, it is probable that the nose landing gear did not unlock because of a fault in that system. The nosewheel steering system would not have functioned normally for the same reason. As a result of the airlines inspections following the accident, the Cartridge Solenoid Valve in the Landing Gear Control Module was suspected as faulty and was replaced. This aspect of the event was not investigated further.

2.11 Autoground spoiler system

The failure of the autoground spoilers to deploy was probably a consequence of the loss of the 'C' hydraulic system. Pressure from this system is used to deactivate an autoground spoiler inhibit circuit and therefore the spoilers will not deploy if pressure is not available in the 'C' system.

3 Conclusions

(a) Findings

(i) The operating crew were properly licensed and adequately experienced to conduct the flight.

(ii) The ground engineer was properly licensed, authorised and experienced to undertake rectification of the thrust reverser.

(iii) Following first-line rectification to free the jammed thrust reverser translating cowl on No 1 engine and lock it out, the cowl was left in a condition in which it was not adequately supported and it suffered a structural failure.

(iv) The whole of the cowl's double skin assembly and a minor segment of its leading edge attachment ring departed from the engine and caused superficial damage to the left wing and severe damage to the No 3 leading edge pocket of the left horizontal stabiliser.

(v) One thrust reverser blocker door had previously been removed and one was freed to translate to the reverse position by the failure of the cowl, but the remaining doors were restrained in the forward thrust position by the major segment of the cowl's leading edge attachment ring which remained in place.

(vi) The condition of the reverser following the rectification work was outside that allowed by the Master Minimum Equipment List but this was neither realised by the ground engineer supervising the work, nor by his supervisory staff to whom he had fully reported his actions through the Technical Log and telex.

(vii) If a telexed request made by the ground engineer to the airline's Maintenance Control Centre for a 'more thorough inspection' of the thrust reverser system at Port of Spain had been recorded in the Technical Log, the fact that, in response, only a limited inspection was implemented would have been available to him on the aircraft's return to London.

(viii) Opportunities for restoration of the reverser to full serviceability were lost when manpower resources were directed to attend to another aircraft major unserviceability in the airline.

(ix) Pre-accident indications of the progressive failure of the cowl were misinterpreted.

(x) Given the information available to the commander at the time, the original decision to divert to Heathrow Airport is considered to have been reasonable.

(xi) The commander did not declare a state of emergency despite the fact that one clearly existed; leaving the controller to take the initiative and handle the aircraft as if an emergency had been declared.

(xii) For traffic flow reasons, the BAA wanted the aircraft to land at Stansted rather than Heathrow. The request was made, through ATC, but the commander was not apprised of the reason for the change of destination.

(xiii) The commander assumed that the reason he had been asked to land at Stansted was because the BAA did not want him to overfly the densely populated area to the east of Heathrow in an aircraft which had suffered significant structural damage. As his decision not to accept the diversion was based on this premise, it was considered to have been inappropriate.

(xiv) In spite of considerable time available to jettison fuel, at landing the aircraft was above the maximum authorised landing weight.

(b) Causes:

(i) The ground engineer took actions which were not supported by his knowledge of the aircraft and, unrealised by him, were not mandated by the Master Minimum Equipment List.

(ii) The ground engineer's supervisors failed to identify that an incorrect procedure had been followed although he had communicated his actions clearly to them.

(iii) Damage became evident which was probably an indication of progressive cowl failure but it was not recognised as such.

4 Safety Recommendations

The following Safety Recommendations are made:

4.1 It is recommended that the CAA require, when an aircraft in an emergency situation is required or requested to divert to an airfield other than that at which the commander has elected to land, he should be apprised of the reason for that requirement or request. [Recommendation 93-39]

4.2 It is recommended that the CAA take action to advise the appropriate agencies that when selecting the route for an aircraft in an emergency the avoidance of densely populated areas should be a primary consideration; when appropriate, and subject to the agreement of the aircraft commander a diversion to an alternate runway or airfield should be considered. [Recommendation 93-40]

D F KING
Principal Inspector of Air Accidents
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