INCIDENT

Aircraft Type and Registration:	Boeing 747-132, N481EV
No & Type of Engines:	4 Pratt & Whitney JT9D-7F Series turbofan engines
Category:	1.1
Year of Manufacture:	1970
Date & Time (UTC):	24 April 2004 at 1048 hrs
Location:	Airborne near the Compton VOR beacon
Type of Flight:	Public Transport (Cargo)
Persons on Board:	Crew - 4 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	None
Commander's Licence:	Air Transport Pilot's Licence
Commander's Age:	57 years
Commander's Flying Experience:	About 16,000 hours (of which 4,000 were on type) Last 90 days - 116 hours Last 28 days - 53 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was carrying out a cargo flight from Ramstein in Germany to Wright Field in New York State. Shortly after reaching a cruising level of FL360, the left outboard engine ran down and could not be restarted. It was decided to return to Ramstein and the aircraft descended to FL210 and took up an easterly heading. The crew determined that the three remaining engines were not producing the selected thrust and declared an emergency requesting a diversion to London Heathrow Airport. The aircraft was radar vectored onto the final approach track for Runway 27R and the commander completed a successful approach to a safe landing. Significant thrust was available and used during the final stages of the approach and the aircraft was taxied under its own power. Three safety recommendations were made and one was re-iterated.

History of the flight

The crew of two pilots and a flight engineer travelled from their hotel by taxi to Ramstein airport on the morning of the flight. The journey took approximately 25 minutes and followed a rest period of 24 hours. On arrival at the aircraft, a ground engineer who had carried out the pre-flight inspection and had signed the technical log met the crew. There were no deferred defects and the aircraft was loaded with cargo, which had been distributed and secured in the cargo bay.

The flight engineer (FE) performed an external inspection and checked the security and loading of the cargo. A second flight engineer was being re-positioned back to the USA and was being carried as a passenger. Having completed the refuel, the FE ensured the doors were secure and then joined the pilots, who had been carrying out their cockpit checks.

For the climb and the transit across northern Europe the weather was good with clear skies and no forecast precipitation. Engine start and taxi were normal and the aircraft departed from Runway 27 at Ramstein on schedule at 0905 hrs with the aircraft commander as the Pilot Flying (PF) and the co-pilot performing the role of Pilot Not Flying (PNF). Whilst the initial climb seemed normal, as altitude increased the rate of climb appeared to be slower than would be expected for the gross mass of the aircraft of 290 tonnes. No cloud was encountered and two of the three air conditioning packs were supplying the pressurisation as normal. The cruising level of FL360 was reached 33 minutes after takeoff and all engine parameters were normal with the autopilot engaged. A cruise speed of 0.84 Mach was selected and the crew prepared to obtain their Oceanic clearance when something, which was not identified by the crew members, made all three of them look at the Engine Instrument Display System (EIDS). The No 1 engine EPR (Engine Pressure Ratio) started to reduce and the co-pilot saw it initially stagnate in the mid-range before reducing further. The fuel flow increased although the figure could not be recalled.

In accordance with the operator's Standard Operating Procedures (SOPs), the commander instructed the FE to check the engine indications, from which he confirmed that the engine had failed and the engine shut down drill was performed in accordance with the abnormal check list. Air Traffic Control at the London Area Control Centre (LACC) was informed of the engine failure and a descent to FL310 was requested and approved. When level at FL310 and when instructed by the commander, the FE attempted to re-start the No 1 engine, but this was not successful. The FE then contacted the operator's Maintenance Control and was instructed to return to Ramstein where maintenance support was available. The co-pilot advised the LACC of the intended change in routing and a 180º left turn was approved with a descent to FL210. The commander carried out the descent using the autopilot in the vertical speed mode during which he became aware that the thrust levers were positioned in the "number six position", well forward of the normal position for such a descent, yet the EPR indications were at idle. When the aircraft was levelled at FL210, the air speed began to decrease significantly which the co-pilot drew to the attention of the commander. The crew discussed the anomaly of the forward thrust lever position and low engine power indications and recorded the engine EPRs as: '#1 eng 0.704, #2eng 1.124, #3eng 1.206 and #4eng 1.149'. The commander asked the FE to check that the igniters and fuel heat were on. He confirmed that they were and that the fuel temperature was normal. The FE then sought advice from Maintenance Control regarding what the problem might be and what action could be taken. Maintenance Control was unable to offer any solutions and the crew agreed that if normal thrust were not available, an immediate diversion to London Heathrow would be the safest option.

The LACC was informed that the crew were declaring an 'emergency', and requesting an immediate diversion to London Heathrow. The controller asked the co-pilot to confirm they were declaring a 'MAYDAY', to which she responded "YES WE ARE DECLARING AN EMERGENCY". Transponder code 7700 was allocated and set and the LACC began planning the routing and vertical profile for the aircraft to land at Heathrow.

The commander was seen by the co-pilot to advance the Nos 2 and 4 thrust levers one at a time but the EPRs remained the same with the EGTs increasing to approximately 890ºC with no detectable corresponding forward acceleration. Further operation of the thrust levers was considered but the commander did not wish to compound his problems by possibly flaming out the remaining engines. He decided that from the aircraft's current position, he would be able visually to manage the descent of the aircraft to Heathrow. The crew had clearly seen Heathrow as they passed abeam it and it was clear of cloud. They were not familiar with the location of the major UK airports but having seen Heathrow, they had noted its size and could visually locate its position. The LACC allocated a discreet frequency for the sole use of the aircraft and radar vectored it in a continuous descending right turn back towards Heathrow. Although initially the crew were concerned that the radar headings to the south were taking them away from Heathrow, the controller continued their turn back towards the airport. As the aircraft progressed on a northerly track, it was clear that it would be too high to join on a left base for Runway 27R which had been allocated. The controller informed the crew that the aircraft was still too high for the approach to which the co-pilot informed the controller "WE'RE JUST NOT SURE WE'RE GONNA GET ENOUGH POWER TO LAND". As the aircraft approached the point at which a left turn would normally be given to intercept the localiser, a descending 270º right turn was given by ATC which brought the aircraft onto an intercept heading for the ILS approach for Runway 27R from the north. The crew did not have available to them the approach charts for London Heathrow so the ILS frequency for and the length of Runway 27R were obtained from ATC.

The aircraft appeared to the radar controller to be establishing on the extended centre line for Runway 27L which he queried with the co-pilot. He was informed that they were going to carry out a series of 'S' turns in order to lose height and manoeuvre for the runway. Whilst the aircraft was high for a conventional approach, the commander used his knowledge of the aircraft's handling qualities and performance, in the configurations into which it would be placed, to judge an approach path such that if no thrust was available, the aircraft would touch down on the runway.

Throughout the approach, the co-pilot and FE assisted the commander by providing relevant information. Landing speeds had been calculated and the airspeed indicator bugs set. Maintaining the visual aspect envisaged by the commander, in order to achieve the necessary glide angle to reach the runway, was something that he was not able to communicate as it was a judgement exercise and not a promulgated procedure with known heights or associated speeds. A prompt from the FE for lowering the landing gear was relevant but the commander wanted to delay the action until he judged the correct point for it to be selected 'DOWN'. He used turning manoeuvres, flap and gear selections to reduce speed whilst conserving height. Only in the final stages of the approach with flaps set at 30º was thrust instinctively added to which the engines responded and the forward acceleration was detected by the crew.

The aircraft touched down at 145 kt CAS (Calibrated Air Speed) within the normal touchdown zone. Medium autobrake, spoilers and reverse thrust were used to reduce speed on the runway. After a discussion between the aircraft commander and the airport Rescue and Fire Fighting Service, the aircraft was taxied under its own power to a parking stand.

Air Traffic Control

Control of the aircraft was initially being carried out by the LACC controller who, following the run down of the

No 1 engine, managed the initial descent clearances from FL360 to FL310 and then to FL210 with the associated 180º left turn to return to Ramstein. When the controller was made aware of the problems with the remaining three engines and the fact that the pilot was declaring an emergency, she contacted the London Terminal Control Centre (LTCC) Radar Coordinator and informed him of the situation. The emergency transponder code of 7700 was allocated to the aircraft and a Radar Controller was assigned to control the aircraft using a discreet frequency. The co-pilot, who was managing the aircraft's radio telephony, was instructed to make contact on that frequency which she did and control was then passed to the LTCC.

The assigned controller took up a radar console adjacent to the TMA controller who was managing all the other aircraft in or transiting that area of the London TMA below FL200. This permitted close dialogue between the two controllers when trying to sequence the air traffic.

The Group Supervisor (GS) decided that a London Heathrow Approach Controller would be needed to handle the final vectoring of the aircraft for the landing runway, which was Runway 27R. The allocated approach controller made his way to where the TMA controller was sat and occupied the adjacent console. Shortly afterwards the approach controller was joined by the Terminal Control Watch Manager.

Having created a controlling team co-located at adjacent terminals, ATC's intention was to use 35 track miles from when the aircraft was heading 315º to radar vector it from the left base position onto the final approach. At that stage the controllers believed that the aircraft was capable of reduced thrust and not suffering a total loss of thrust on the three remaining engines. It was only when the co-pilot transmitted the warning that there may not be enough power to make the landing did the full extent of the problem become known.

At that point the aircraft appeared to stop its rate of descent and even climb slightly before continuing the descent. Given the height of the aircraft and its close proximity to Heathrow, the radar controller instructed that a 270º turn to the right should be executed to lose the excess height and speed. The flight crew accepted this instruction and the manoeuvre was flown, rolling out on an intercept heading of 305º for the extended centreline of Runway 27R. This manoeuvre took the aircraft over the centre of London.

The Heathrow Approach controller took over control of the aircraft using the same discreet frequency to avoid the flight crew having to make a frequency change. He wanted the aircraft to slow down in order to improve the accuracy of his control but also to reduce the radius of the turns being made which were large due to the aircraft's high speed. He discussed the track miles required by the flight crew to lose their height and his offer of 18 nm was agreed.

The Approach controller was still concerned at the height and speed of the aircraft in relation to the reducing track miles to run and so he verified with the co-pilot that they were making their approach to Runway 27R as it appeared on the radar display that they were aligning with 27L. The crew confirmed that they were visual with Runway 27R and were going to make 'S' turns to lose the height. The controller monitored the progress of the flight confirming several times during the final approach that the pilot was able to lose the height, which still appeared too great for the distance to run. The controller obtained a landing clearance from the tower and passed it to the crew. He also knew that the last opportunity for an orbit was at about six miles from touchdown and after that, with no thrust, the aircraft would be committed. As the aircraft rolled out of the left turn onto the final approach track at 2 nm, the controller could see that the aircraft's height and speed were reasonable and he attempted to re-assure the crew by confirming this to them and re-confirming their clearance to land.

During the handling of the emergency, there was some speculation within ATC concerning the nature of the cargo onboard the aircraft. The airline was conducting flights in support of the US military and it was not known if there were Dangerous Goods onboard.

Meteorological conditions

The synoptic situation at 1200 hrs UTC on the day of the incident showed an area of high pressure covering western Europe with generally thin Cirrus cloud over south-eastern parts of the British Isles. The area forecast gave a few shallow cumulus clouds, base 4,500 ft and scattered or broken, mainly thin cirrus clouds, in layers between 26,000 ft and 43,000 ft. The forecast surface visibility was between 20 and 30 km with no weather.

The wind at FL360 was 300º/20 kt with temperature -59ºC, dew point -66ºC and relative humidity 40%.

The weather observations for the relevant period at London Heathrow at shown in Table 1 below.

Engineering

Since the operator did not have any engineering presence in the UK, the aircraft was examined at Heathrow by an engineer from another company. Being aware of rumours that the aircraft had been parked in the Middle East during a sandstorm, one of his first priorities was to take fuel samples from all six fuel tanks. The samples were sent to the US Air Force facility at RAF Mildenhall where subsequent tests found the fuel to be to the correct specification with no abnormalities.

The engineer then inspected the engines externally and opened the cowls to check for leaks; none were found and no visible anomalies were apparent. No exceedences had been recorded by the Engine Instrument Display System so he performed a 'wet cycle' on the No 1 engine. During this he noted that there were no indications of Low Pressure Spool Speed (N_1) or Fuel Flow (FF) for this engine on the EID.

Having noted that the No 1 igniter system was inoperative, the engineer then tried to start the engine using igniter system No 2. The start was successful but there were still no indications of N_1 or FF. He replaced the N_1 tacho generator but there were still no N_1 indications so he cleaned the 'Cannon' plugs associated with N_1 and FF. During this activity, the engineer found a BITE (Built-In Test Equipment) fault on the EIDS which led

Time Hrs UTC	Mean wind direction & speed (kt)	Visibility	Clouds	Air Temp	Dew Point	QNH mb	Trend
1020	240º/02	>10 km	No significant	17º C	09ºC	1027	No change
1050	230º/05 direction variable between 150º & 280º	>10 km	Few at 4,000 ft Scattered at 30,000 ft	19º C	06ºC	1027	No change

Table 1

him to change the right-hand display unit and clean the 'Cannon' plugs for the EIDS system.

The engineer then removed the fuel filters from all four engines, despatching them to the operator's headquarters for analysis. Before despatch, he had noted that there was some particulate contamination of the No 1 engine filter, but the other three appeared clean. He did not consider that the contamination of the No 1 filter was particularly heavy (this was later confirmed by the operator's engineering department). As a precaution he checked the additional filters on the fuel control unit from this engine and found them clean. The engine was then started and run at idle, during which N_1 and FF indications were observed to be normal.

In the presence of the crew, all four engines were started and run-up to take-off power, with instrument readings being taken which were relayed to the operator's main maintenance base. Since the readings indicated normal operation and performance by all four, clearance was given for the aircraft to continue with its planned journey.

Subsequent information from the operator is that nothing in the aircraft's operating history since the incident has caused any concern over performance of any of the engines.

High altitude engine acceleration characteristics

The operator's Boeing 747 Operations Manual contains the following information regarding engine behaviour and management:

> *"Slow engine acceleration and/or slow EPR response at high altitude could be misinterpreted as lack of engine response to thrust lever movement. Due to the engine inlet air spillage at low thrust settings near idle and the possibility of false EPR indications, other engine parameters should be monitored. If engine thrust appears to be unresponsive in terms of EPR, advance the thrust lever and monitor N1, EGT and Fuel Flow increase; normally EPR should respond in approximately 15 to 20 seconds. Engine acceleration time up to one minute may be experienced. If N1, EGT and Fuel Flow do not respond normally, or if the engine has flamed out, refer to Abnormal Procedures".*

An additional note on the subject is included on the same page:

> *"NOTE: During high altitude and low gross weight cruise, the engine bleed valve may open when setting cruise thrust. When this occurs, the EPR drops .10 to .15 with an associated decrease in N1 and Fuel Flow. Moving the thrust lever two or three knobs forward of the others can normally schedule the valves closed. Once the bleed valves have closed and thrust has increased, retard the thrust lever slowly to establish desired EPR setting".*

Abnormal engine procedure

An abnormal procedure covers the *"Unscheduled thrust loss or abnormal response to thrust lever advancement"*. The procedure applies when abnormal engine indications occur with low EPR/N_1 and high EGT following thrust lever advancement from a low thrust level or when an unscheduled thrust loss occurs. The abnormal procedure is set out in the Quick Reference Handbook (QRH) and is read by the FE; allocated actions are performed by the PF and FE whilst the PNF monitors the crew actions.

When an engine enters a surge or non recoverable stall condition, the procedure requires the engine to be shut down and restarted in order to regain control of the engine. This is performed in a set sequence or flow. When at high level and adjusting thrust at cruising level or when commencing a descent the Flight Operations Manual states:

> *"If engine surge occurs during steady-stage at high altitude operation, reduce flight altitude to 35,000 feet or below (if possible)".*
>
> *"NOTE: Thrust lever movement above 35,000 feet should be made very slowly (approx .02 EPR/SEC".*

Manual of Air Traffic Services (MATS) Part 1

MATS Part 1 contains guidance on the two main issues of relevance to this incident. It addresses the manoeuvring, over a densely populated area such as central London, of an aircraft in an unsafe condition and diversion from the flight planned route whilst carrying dangerous goods.

> ***10.10 Handling Aircraft Emergencies***
>
> *10.10.1 When the pilot has declared an emergency and stated the aerodrome to which he wishes to proceed, the controllers shall acknowledge this message. If the controller is instructed to inform the aircraft that it is required or requested to divert to another aerodrome then the reason for this change should be established. The message together with the reason, shall then be passed to the captain and his intentions requested.*
>
> *10.10.2 It is desirable that aircraft in emergency should not be routed over densely populated areas. If this is inconsistent with providing the most appropriate service to the aircraft, for example when any extended routeing could jeopardise the safety of the aircraft, the most expeditious route is the one which should be given. Where possible, when expeditious routing is not required, suggestions of alternative runways or aerodromes together with the rationale that the routing would avoid densely populated areas and be consistent with safety, shall be passed to the pilot and his intentions requested.*
>
> *10.10.3 The decision to comply with advice or instructions to land at an airport, other than his selected diversion, lies with the captain of the aircraft who has ultimate responsibility for the safety of his aircraft.*
>
> *10.10.4 It is recognised that controllers providing en-route services at ACCs (Area Control Centres) may not be aware of the boundaries of major cities, town or villages. However, controllers providing aerodrome approach or approach radar control services should be familiar with the centres of population within their areas of jurisdiction.*
>
> ***11 Dangerous Goods***
>
> *11.1 When the pilot of an aircraft in an emergency states that he is carrying dangerous goods, the message must be relayed without delay to the air traffic services unit at the aerodrome of intended landing. The senior controller at the*

> *aerodrome must notify the aerodrome authority immediately.*
>
> *11.2 An aircraft carrying dangerous goods which requires special handling is not to be deviated from its flight-planned route except in an emergency. If the aircraft has to divert, the first choice should be a military airfield (RAF or USAF). Stansted and Prestwick also have expertise in handling and parking aircraft with dangerous goods on board. Heathrow and Gatwick are not suitable for diversion.*

ATC guidance for aircraft emergencies

National Air Traffic Services (NATS) have produced a booklet entitled '*Aircraft Emergencies, Considerations for Controllers*'. The document is based upon the original guide produced by the United Kingdom Flight Safety Committee (UKFSC) and the UK Civil Aviation Authority's Safety Regulation Group (SRG). It is aimed at provoking thought about emergencies and increasing the understanding of controllers of the process undertaken by a flight crew handling an emergency. It is also designed to assist controllers during their periodical Training for Unusual Circumstances and Emergencies (TRUCE) exercises.

Regarding flight crew, the booklet emphasises the point that there is a:

> *"reluctance to acknowledge the extent of the problem – there is sometimes a reluctance to declare an emergency when it is appropriate to do so" and "the pilot should be asked to declare a 'PAN' or 'MAYDAY' if priority is required".*

The advice for controllers dealing with an incident comparable to that of N481EV is:

> ***Loss of power from all engines***
>
> - *Acknowledge Mayday and inform flight crew of nearest airfield and consider an initial vector.*
> - *Consider imposing RTF silence for other aircraft.*
> - *Orbiting above an airfield will assist in the planning of a glide approach.*
> - *Accurate range and track distances can aid descent planning.*
> - *Flight crew workload will be high due to engine relight techniques.*
> - *A steeper than normal approach path can be expected.*
> - *When giving turns the rate of descent may double.*

Radar Data

Primary and secondary radar data from the radar heads at Debden and London Heathrow (23cm) were available for the incident flight, with radar returns every 6 and 4 seconds respectively. Both radar tracks (Figure 1) begin over the east of London above the Thames estuary and end at London Heathrow.

Flight Recorders

The aircraft's operator supplied the AAIB with a copy of the flight data from the Flight Data Recorder (FDR) that included the incident flight. Data was available for 23 parameters (including time) of which EPR (Engine Pressure Ratio) for each engine was the only recorded engine parameter. Cockpit Voice Recordings during the incident were unavailable as they had been overwritten with more recent information.

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Figure 1

London Heathrow 23 cm and Debden RADAR tracks for N481EV on 24 April 2004

A time-history of the relevant parameters during the incident is shown in Figure 2 and includes comments and aircrew speech (from ATC) for correlation with the radar tracks given in Figure 1. The figure starts halfway through the flight, 40 minutes before touchdown, with the aircraft level at Flight Level (FL) 360, at an airspeed of 290 knots KCAS (Knots Calibrated Air Speed) and a thrust for each of the engines at about 1.45 EPR.

Three minutes later, the thrust on all engines reduced to about 1.4 EPR where they remained for one minute. The thrust on engine No 1 then fell to just under 1.1 EPR over a 10 second period. As the EPR for Engine No 1 reached 1.3, the EPRs for the remaining engines also began to fall, stabilising at about 1.37. The thrust on engine No 1 continued to fall to 0.85 EPR over a 40 second period, and then more gradually to 0.81 EPR[1]. The aircraft's recorded altitude and pitch attitude remained constant throughout these thrust reductions, however; the airspeed slowed by 20 kt. Also, as the thrust on the No 1 engine reduced, the lateral acceleration and bank angles began to increase: the lateral acceleration in a negative sense and the bank angle right wing down, both from nominal values of zero and both consistent with the aircraft side-slipping to the right. (Angle of yaw was not recorded on the FDR.)

Footnote

[1] 0.81 EPR is the lowest value of EPR that the FDR installation can record, even if the actual EPR is less than 0.81.

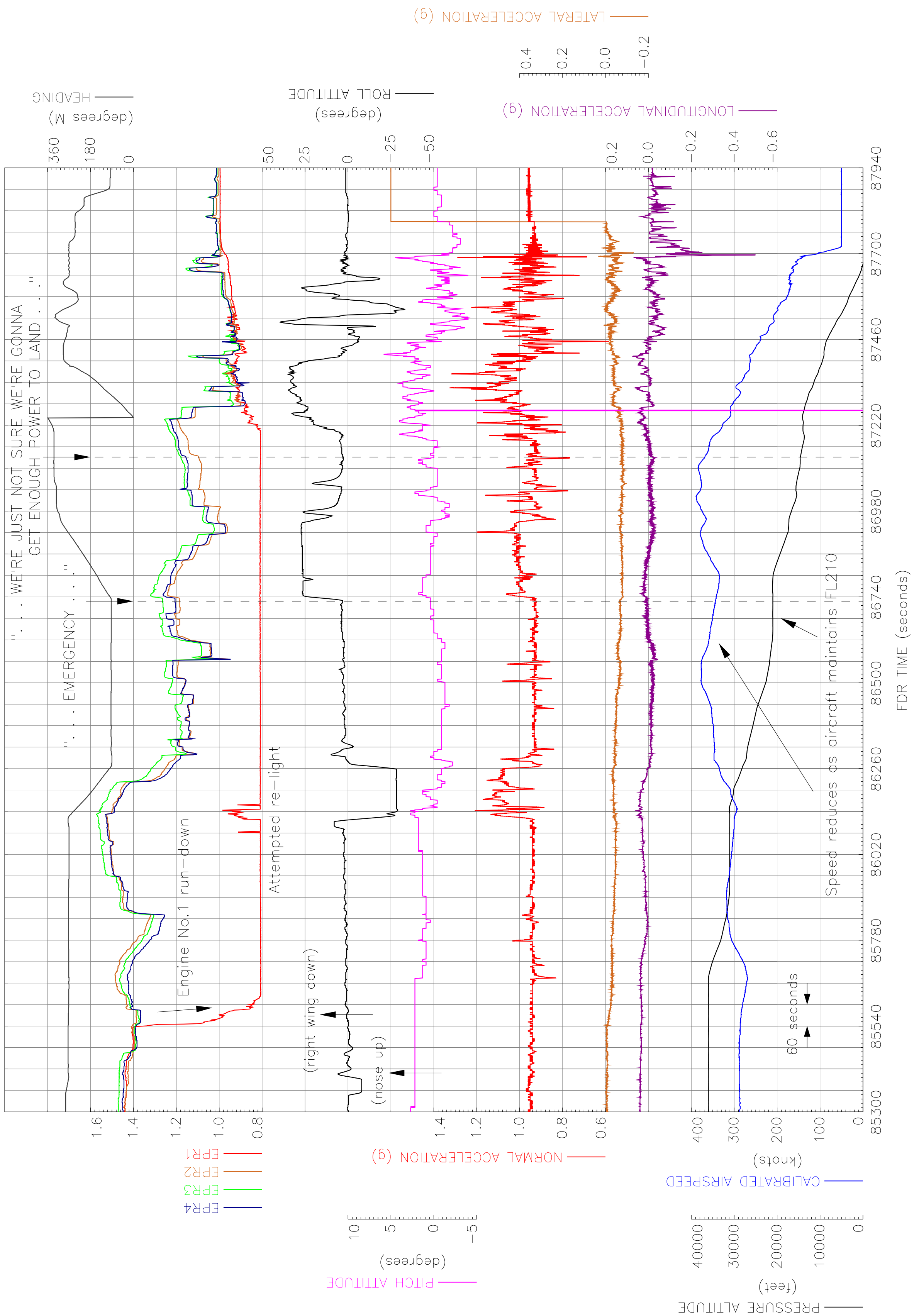

Figure 2

A hime-history of the relevant parameters during the incident

The aircraft then accelerated and descended (with corresponding changes in pitch attitude and altitude), levelling at FL310 for 4 minutes. At the start and end of that period, 3 engines were running at 1.55 EPR (which at that altitude is less than the max continuous of 1.6 EPR). The aircraft then began a descending 180º turn to the left above the Compton VOR, eventually levelling at FL210 just west of Sevenoaks. Small fluctuations in the No 1 engine EPR were evident just before and during the initial stages of the turn, coincident with the stated attempt to re-light the engine. Thereafter the thrust level of the No 1 Engine remained at 0.81 EPR until the aircraft's descent into Heathrow.

The aircraft remained at FL210 for two and a half minutes during which the CAS steadily reduced from 355 kt to 335 kt. Also during this period, the EPR levels on the other three engines were no lower than 1.18 (Engine No 2) and no higher than 1.32 (Engine No 3), each varying (in unison) and by no more than 0.06 (see Figure 3).

Whilst still at FL210 (just south of Maidstone), and coincident with the 0.06 EPR increase of the three engines, the aircraft began a turn to the right before commencing the descent towards Heathrow. The aircraft initially descended at about 2,000 ft/minute before making a 270º right turn (overhead London) on a heading for Heathrow, before continuing to descend at about 2,500 ft/minute until 30 seconds before touchdown. The approach glideslope into Heathrow was calculated at just over 6º, reducing to 2.7º when the aircraft was 1.5 nm from touchdown. The recorded airspeed during the latter stages of the approach was approximately 160 KCAS.

From approximately FL135 (about 8 minutes before touchdown), the indicated thrust levels for the remaining engines reduced below 1.0 to about 0.9 EPR where they remained for the majority of the descent. Also, as the aircraft slowed there was a corresponding increase in the No 1 engine EPR (above 0.8 and eventually reaching 1.0) as the drag produced by the engine reduced towards zero. Thrust on the three operative engines was briefly increased to about 1.15 EPR immediately prior to touchdown. The recorded air speed at touchdown was 145 KCAS.

Performance data

The operator's Operations Manual contained relevant performance data for three-engined cruise flight. The graph of cruise EPR required with one engine inoperative suggested that EPRs of 1.45 would be required to sustain 0.82 Mach (approximately 360 KCAS) at FL210 and 282 tonnes mass. This thrust rating would be above the maximum continuous rating of 1.43 EPR. The Long Range Cruise table, with one engine inoperative with the same conditions, listed a target EPR of 1.31 and a cruise speed of Mach 0.699 (319 KIAS).

There was no information relevant to glide performance, speeds or characteristics.

Simulator evaluation

Having levelled the aircraft at FL210, the commander was unable to maintain 360 KIAS, despite both pilots recalling that the three remaining engine thrust levers were at "position number six". This position is derived from a calibrated arc on the thrust lever quadrant aligned with thrust lever forward and rearward movement. It is used for recording thrust lever position against engine performance, mainly for rigging purposes.

A Boeing 747-200 training simulator was used to assess the thrust developed with the thrust levers at the "number position six" and the ability of the aircraft to

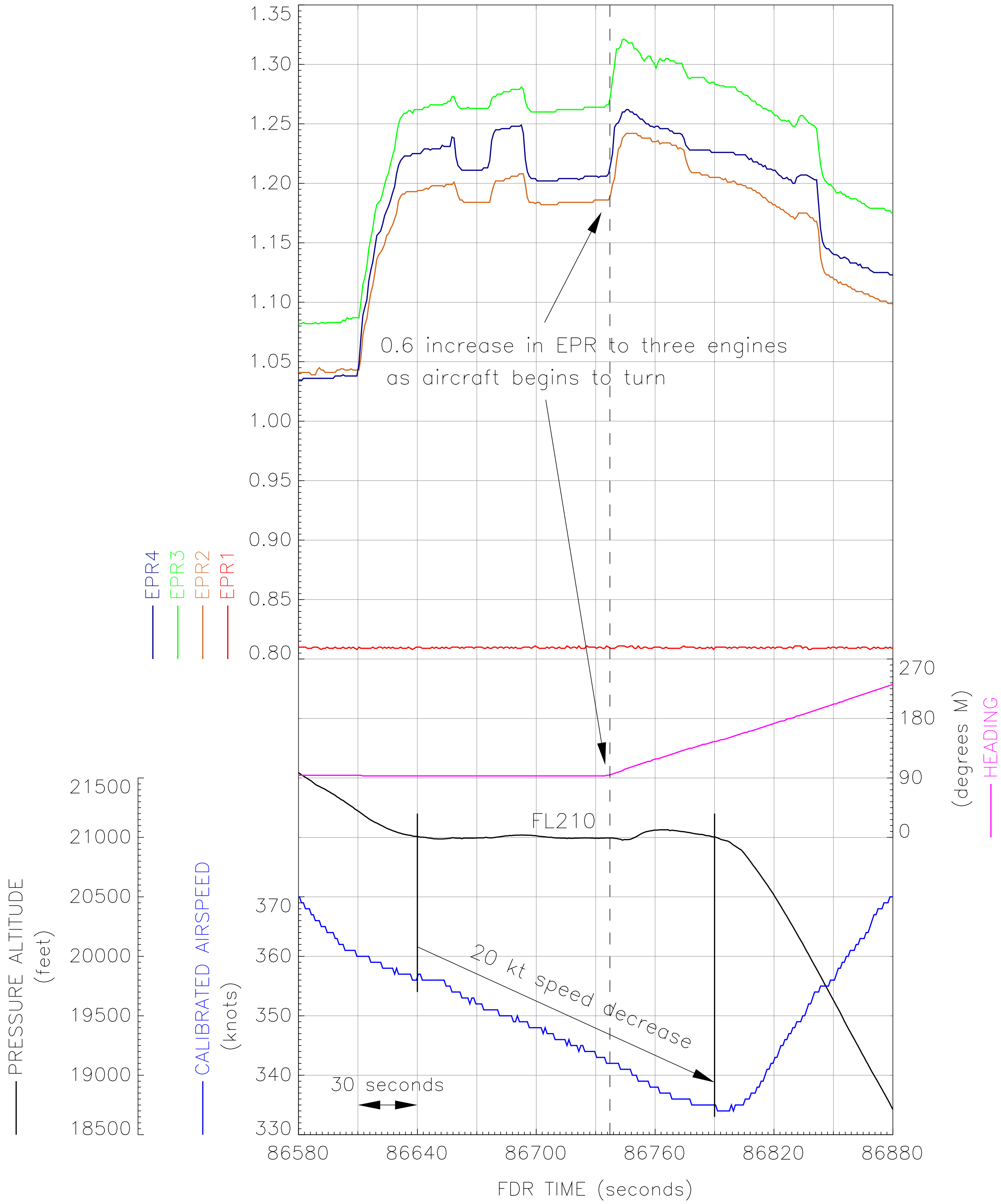

Figure 3

An expanded view time-history of the relevant parameters at FL210 maintain 360 kt using the EPR values recorded by the crew at FL210 and confirmed by the FDR data. The engines represented in the simulator were Pratt and Whitney JT9D-7J series with a max take-off thrust rating of 50,000 lbs. The incident aircraft, N481EV was equipped with Pratt and Whitney JT9D-7F engines producing a maximum take off thrust of 48,000 lbs. The EPR recorded with the thrust lever set at "position number six" was 1.6 EPR. This represented maximum permitted take-off thrust.

The simulator was programmed with an aircraft gross mass of 282 tonnes, a surface temperature of +17°C and a QNH of 1027 which were the conditions prevailing at the time of the incident. A descent was made at 360 KIAS and the simulator levelled at FL210. The EPR recorded by the crew at FL210 were set on the numbers 2, 3 and 4 engines with number 1 engine shut down. The IAS trend was then monitored. The IAS reduced by 8 kt in one minute and 20 kt in three minutes.

FAA Regulations on chart carriage

Federal Aviation Regulations Section 91.503 specifies the flying equipment and operating information that must be carried on board an aircraft comparable to N481EV. This regulation requires the pilot-in-command of an aeroplane to ensure that:

> *'aeronautical charts and data, in current and appropriate form, are accessible for each flight at the pilot station of the airplane.'*

The detail of the regulation further specifies the carriage of:

> *'Pertinent aeronautical charts' and 'For IFR, VFR over-the-top, or night operations, each pertinent navigational en-route, terminal area, and approach and letdown chart'.*

Analysis

The No 1 engine ran down in flight but the reason why could not be determined. Its failure to relight was explained by the faulty No 1 igniter. The most obvious indication that all was not well with the three operative engines was the commander's recollection that he carried out the descent from FL310 to FL210 using the autopilot in the vertical speed mode during which, he became aware that the thrust levers were positioned in the "number six position", well forward of the normal position for such a descent, yet the EPR indications were at idle. Had the problem simply been one of erroneous EPR indications, the aircraft would probably have exceeded it maximum permitted speed but the FDR data shows that the highest speed achieved in the descent was about 380 KCAS at FL240 which did not exceed the Mach 0.92 speed limit.

The lack of any recorded engine parameters on the DFDR, apart from EPR, made it impossible to verify the crew's impression that the thrust levers had to be placed further forward than they expected to achieve the target EPR. It was also not possible to analyse the nature of the rundown of No 1 engine or the statement that, when two throttles were advanced to check power delivery, the EGT rose without a change in EPR.

Some consideration was given to the possibility that No 1 engine did not actually flame-out but the instrument problems with that engine led the crew to believe that it had; they then shut it down prior to an attempt at restarting which was unsuccessful due to the inoperative No 1 igniter. This is difficult to believe, since other parameters, such as High Pressure spool speed (N2) and EPR would still have informed them that the engine was running. Also, the side-slip to the right recorded by the FDR at the time of the engine rundown suggests a loss of thrust as opposed to a loss of engine indications.

The commander's expectation that his aircraft would sustain 360 KCAS at FL210 was misplaced as the published performance data and simulator trials confirmed. At that level the aircraft required three engines producing 1.31 EPR to sustain the long range cruise speed of 0.699 Mach (equivalent to 319 KIAS) but none of the operative engines were producing this much thrust. The EPRs on the three engines changed in unison but were significantly different: No 2 was lowest, No 4 was greater by 0.03 and No 3 was 0.05 EPR greater than No 2. The average was about 1.23 whilst the aircraft was straight and level at FL210.

The apparent lack of performance of the remaining three engines is perplexing, since, in the absence of any anomalies with the fuel quantity or quality, it is difficult to conceive of any common factor which could affect three (or four) independent systems. One possibility is, of course, atmospheric conditions such as icing but a weather aftercast suggested that the aircraft was flying in conditions that were not conducive to this phenomenon.

The aircraft manufacturer and the AAIB's simulator tests confirmed that the rate of decay in speed at FL210 approximated to the decay in CAS on the incident aircraft from 356 kt to 334 kt in 2 minutes and 29 seconds. Consequently, the rate of speed decay experienced by the crew was consistent with the EPRs they had recorded in flight which in turn suggests that the displayed EPRs were correct.

The level of thrust on three engines at FL210 was not sufficient to maintain the speed at which the aircraft had been flying. Because thrust lever angle was not recorded, it was not possible to correlate the EPRs with thrust lever angles and the recollection of the crew of "position number six" was the only available evidence. Moreover, had the three operative engines' thrust levers been set to the number six position, and if they had been producing thrust equivalent to that lever position, total thrust would have had to be reduced in order to maintain the IAS within safe operating limits.

Whilst the commander considered the possibility that the engines were in a surge condition, he did not want to shut down another engine in case, as with the number 1 engine, he was unable to re-start it. He decided that his best option was to carry out an emergency landing as soon as possible and not to rely on the availability of full thrust from the three operative engines during the diversion. Consequently, the crew committed to carrying out an emergency landing at an airport within gliding range. The identification of the lack of thrust occurred at FL210 which limited the choice of airports to those within gliding range and with adequate runway length available to meet the landing distance required. Within range were London Heathrow and Gatwick airports with Stansted and Luton airports more distant. The crew were not familiar with the location of the major UK airports but they had seen London Heathrow from FL360 with CAVOK conditions and considered it was their best option for carrying out a successful visual approach with reduced thrust on the three operative engines.

Having declared their intention to land at London Heathrow, the crew were radar vectored by ATC towards a left base for Runway 27R. The main function of the controllers was to facilitate the positioning of the aircraft onto the final approach for the commander's nominated airport. When it was recognised that a left base intercept would not be possible, due to the altitude of the aircraft, a 270º right turn was given. This removed the altitude problem and the aircraft was able to make its final approach.

There was no profile or guidance for the commander to follow in conducting the approach without thrust available. His handling of the situation was solely a judgement exercise based on his experience of the aircraft's inertia and the effects on its performance, particularly in the vertical plane, as changes in the flap and gear configurations were made. With continuous visual contact with the runway in the fine weather conditions, the pilot was able to maintain an appropriate approach angle, ensuring the runway was achieved whilst slowing down and configuring the aircraft for landing. This meant a steep approach of 6.5º which caused ATC some concerns regarding the relationship between the aircraft's distance from touch down and its height.

In the final stages of the approach the commander instinctively advanced the thrust levers and all three operative engines responded although it is not known if the thrust developed was consistent with the thrust lever angle selected. Nevertheless, it is probable that even without these thrust selections, the aircraft would still have touched down on the runway but short of the normal touchdown zone.

Conclusions

No reasons were found which could account for either the apparent run-down of No 1 engine or the crew's subsequent perception that the remaining three engines were not delivering selected thrust. Whilst only the engine EPR was recorded on the FDR, it was clear from the evidence given by the crew and the aircraft performance that following the run down of the left outboard engine, the three remaining engines were not producing the thrust expected. This situation appears to have arisen following the descent from FL310 to FL210 and was symptomatic of a problem common to all three operative engines but this could not be proved. The aircraft diverted to the only airport that the flight crew considered suitable and in the process, flew over some of the most congested parts of London in a gliding configuration from which a safe landing was not reasonably assured.

Safety Recommendations

The service provided by the National Air Traffic Services (NATS) in supporting the crew of N481EV complied with the guidance and procedures in place which were flexible and permitted interpretation. The aircraft had not suffered any damage and the only hazardous material on board was an engine being carried as cargo, although ATC did not know this at the time. Importantly, the stated requirement of the aircraft commander to land at London Heathrow was facilitated.

The commander believed that he was only able to position the aircraft visually and the safe outcome would not have been possible in IMC. There was no guidance available within the Operations Manual on the glide performance of the aircraft or glide approach technique and the commander was fortunate to have an unobscured view of the airport. Had the weather conditions been IMC, forcing the crew to carry out an instrument approach, the aircraft might have landed well short of the runway.

It must be considered where the proper balance of safety rests when considering the plight of persons onboard an aircraft in difficulties in relation to persons on the ground in densely populated and congested areas such as those of central and greater London. The balance between delaying an aircraft's landing by routeing it around a congested area, versus the aircraft's condition deteriorating and possibly leading to an accident outside the congested area, should be considered. Moreover, circumstances under which the condition of the aircraft, through damage or technical failure, may pose an unacceptable danger to persons on the ground requiring non-standard routeing, should be defined.

Although this incident was safely resolved, it raises again the need to review under what circumstances an aircraft in difficulty should be permitted to fly over congested urban areas. Resolution of this issue may require regulatory action. Therefore, it was recommended that:

Safety Recommendation 2005-069

The Civil Aviation Authority (CAA) should review the guidance provided in the Manual of Air Traffic Services (MATS) Part 1 and Civil Aviation Publication (CAP) 475 (The Directory Of CAA Approved Organisations) and consider whether ATC unit Training for Unusual Circumstances and Emergencies (TRUCE) plans adequately prepare controllers to handle aircraft in emergency, and in particular, whether sufficient guidance is provided on the avoidance of built-up areas when vectoring aircraft in emergency. Where considered necessary, this guidance should be amended as soon as practicable.

The investigation team recognised both the professionalism demonstrated by the NATS personnel and the skill of the crew of N481EV, in particular the commander's hand flying of the aircraft, all of which contributed to a safe landing under such difficult circumstances. However, there was no guidance on the gliding performance of the aircraft within the Operations Manual and the commander had to resort to vigorous 'S-Turn' manoeuvres on final approach to manage the aircraft's energy profile. This would not have been practicable in cloudy or poor visibility weather conditions. Therefore it was recommended that:

Safety Recommendation 2005-070

The Federal Aviation Administration of the USA and the European Aviation Safety Agency should require that aircraft Flight Manuals contain guidance relevant to the aircraft's gliding characteristics in the optimum and approach configurations.

The crew of N481EV decided to divert to Heathrow because they had seen the airport. They were not familiar with the range of airport options available to them nor was it obvious to them that their desired destination involved overflying metropolitan London in a configuration that did not assure a safe landing. One reason for their lack of awareness was they were not carrying the requisite charts for likely en-route diversions. This practice appeared to be at variance with the AAIB's interpretation of the requirements specified in FAR 91.503. Therefore, it was recommended that:

Safety Recommendation 2005-071

Evergreen International Airlines should ensure that its flight crews have available onboard their aircraft all the pertinent en-route and approach charts for all the diversion airports applicable to the aircraft type and routes being flown.

The operator responded to this recommendation by stating that a large proportion of its work was in support of the United States military. Consequently, it was more convenient to adopt US Department of Defense charts since these invariably covered their military destinations whilst also covering a good cross-section of civil airports world-wide. London Heathrow is not included in this chart series but Stansted airport is included. Had this not been a severe emergency condition, the flight crew would have diverted to an airport for which they had charts. The operator concluded by stating that it believed the company complied with all regulations.

One of the criteria covered by MATS Part 1 for handling an aircraft that is diverting due to an onboard emergency is whether or not the aircraft is carrying material classified as Dangerous Goods. The International Air Transport Association (IATA) Dangerous Goods Regulations are the globally accepted field source reference for companies shipping hazardous materials by air. These Regulations are based on the International Standards and Recommended Practices developed by the International Civil Aviation Organisation (ICAO) and contained in Annex 18 to the Convention on International Civil Aviation. However the information on what is carried normally resides on board the aircraft and at its airfield of departure. The information is not readily available to Air Traffic Control at the time they might need it and having to ask the crew for the information when they are quite naturally pre-occupied by dealing with an emergency is inappropriate.

A similar problem was identified during the AAIB's investigation into the accident involving a cargo aircraft near Stansted Airport in December 1999 (Aircraft Accident Report 3/2003). Although this recommendation arose from an accident, its intent is equally relevant to the handling of an aircraft emergency. No response has yet been received from the addressee. However, the UK CAA stated that Safety Recommendation 2003-66 was based on the requirements of the 1999-2000 edition of the Technical Instructions. Following discussions between the AAIB and the CAA, proposals to amend the Technical Instructions were accepted by the Dangerous Goods Panel before the Safety Recommendation was published. New requirements included:

a. A copy of the Notification to Captain (NOTOC - detailing dangerous goods on board) or the information on it must be readily available at the airfield of departure and the next scheduled arrival point.
b. If the size of a NOTOC is such that transmission of information to ATC would be impractical, provision is made for the pilot to pass a telephone number to ATC for the use of the Airfield Authorities to obtain a faxed copy.

The possibility of an annotation on the Flight Plan concerning the carriage of dangerous goods was considered by the Dangerous Goods panel but discounted as impractical for several reasons.