

No: 11/90

Ref: EW/C1174

Category: 1a

Aircraft Type and Registration: Boeing 747-200, N303TW

No & Type of Engines: 4 Pratt & Whitney JT9D-7AH turbofan engines

Year of Manufacture: 1972

Date and Time (UTC): 7 August 1990 at 1012 hrs

Location: London Gatwick Airport

Type of Flight: Public Transport (Charter)

Persons on Board: Crew - 17 Passengers - 439

Injuries: Crew - None Passengers - 26 (minor) Others - 2 (minor)

Nature of Damage: Tail pipe fires in Nos 2, 3 & 4 engines - minor scorching of underside of right wing

Commander's Licence: Canadian Airline Transport Pilot's Licence with FAA endorsement

Commander's Age: 48 years

Commander's Total Flying Experience: 13,000 hours (of which 300 hours were on type)

Information Source: AAIB Field Investigation

Following an uneventful flight from Montreal the aircraft made an ILS approach and landing on runway 08R at London Gatwick Airport. After touch down reverse thrust was selected and operated normally on all four engines. However, as reverse thrust was cancelled Nos 2, 3 and 4 engines' compressors appeared to stall. When the aircraft turned off the runway, tail pipe fires were observed on these three engines and, shortly after the aircraft was stopped an emergency evacuation was ordered by the commander. During the evacuation 26 passengers and 2 firemen suffered minor injuries.

History of the Flight

The aircraft was scheduled to fly an international public transport charter flight from Montreal to Toulouse, via London Gatwick. It was operated by a crew of 17, comprising 3 flight deck members and 14 cabin attendants. Prior to reporting for duty at Montreal all crew members had completed rest periods in excess of 24 hours. All of the flight crew members were properly licenced and possessed the required ratings. All of the cabin attendants had completed 'recurrent training' and 'evacuation slide jumps' during the previous eight months.

At 0410 hrs the aircraft commenced taxiing at Montreal Mirabel Airport. As it was moving towards the runway the Flight Director (Flight Attendant in charge) carried out the normal pre-take off passenger briefing. It is the operating company's policy that all passenger briefings are read out using a standard format in both English and French. The briefing includes instruction on the location of the emergency

exits, but does not include the advice that, in the event of an emergency evacuation, all hand baggage should be left on board.

The aircraft took off from Montreal at 0420 hrs and the sector was uneventful, except that, shortly after take off, the cabin PA system went totally unserviceable at all main cabin stations. However, it did remain serviceable at the upper cabin deck and flight deck positions. All flight attendants were briefed on a modified internal communications procedure. Following descent the aircraft was cleared for an ILS approach to runway 08R at Gatwick Airport. This was commenced at 1006 hrs with the aircraft commander as the handling pilot flying a manual approach. A stable approach was flown in good weather conditions and light winds, with a target threshold speed (V_{ref}) of 142 knots. At 1009 hrs Gatwick Tower cleared a departing B747 aircraft to line up on runway 08R and shortly afterwards cleared it for take off. The subject aircraft then contacted Gatwick Tower and was cleared to continue the approach. Both pilots reported that they could see the departing 'heavy' aircraft and were satisfied with the separation. At 1010.30 hrs Gatwick Tower cleared the aircraft to land. The final stages of the approach were smooth and as the aircraft was flared, the pilots report that there was light turbulence which they attributed to residual wake turbulence from the departing Boeing 747. (Radar recordings show that at this moment the departing B747 was about 4 nm from the 08R threshold and climbing through 800 feet).

The landing was normal and reverse thrust was selected on all four engines. The aircraft decelerated normally and, as the co-pilot called '70 knots' the cancellation of reverse power was initiated. As the aircraft approached the high speed turn off there were three loud bangs, within the space of about one second, and the co-pilot called 'EGT, EGT, EGT' as the exhaust gas temperatures of Nos 2, 3 and 4 engines rose rapidly above maximum and the three over temperature lights on those engines illuminated. As the aircraft was brought to a halt the Gatwick Ground Controller informed the crew that the No.4 engine was on fire. The flight engineer shut down the No. 4 engine. Almost immediately another departing aircraft, that was taxiing past the nose, transmitted that Nos 2 and 3 engines were also on fire. The flight engineer shut down these engines but, on instructions from the commander, left No. 1 running as the Auxiliary Power Unit (APU) was unserviceable. After receiving further advice from the rescue services the commander ordered the No. 1 engine to be shut down and an emergency evacuation from the left side.

Flight Recorders

The Flight Data Recorder (FDR) fitted was a Sundstrand Digital Flight Data Recorder (DFDR) which has 39 analogue parameters and 60 discrete events. This was removed and returned to AAIB for replay where a satisfactory readout was obtained.

The attached figure (figure 2) shows selected parameters from the FDR from about 20 seconds before touchdown. The aircraft touched down at speed for 146 kts CAS, 12 seconds later the EPR increases as reverse thrust is selected on all engines. This is also shown by the reverse thrust operating discretely (RTOP) which show the transition from the stowed position to the operating position. These discretely are only recorded once per four seconds so there may be a delay of up to four seconds from the operation to this being recorded by the FDR. There is also a discrete recording reverse thrust in transit (RTTR) which again is recorded only once per four seconds. Because of this low sampling rate the discrete only shows the No. 3 engine in transit as reverse thrust is selected, the transition on the other three engines is within the four second sampling period.

The EPRs remained at around 1.02 on all engines for 25 seconds before EPR No. 4 engine reduces first, followed in the next second by the EPR on Nos 2 and 3. The run down of the three engines occurred at an airspeed recorded by the FDR as 48 kts CAS. However, at speeds below 50 kts the pitot/static system cannot be used to give reliable speed information. At about this time it can be seen from the Magnetic Heading recording that the aircraft began a left turn off the runway heading. No. 1 engine EPR also reduced, but, as can be seen from the figure, reduced at a lower rate to the other three engines which ran down immediately to around 0.7 EPR. The reverse thrust was cancelled on No. 1 engine as shown by RTOP 1, reverse thrust remained in transit on the other three engines as shown by the RTTR discretes.

The Cockpit Voice Recorder was a Fairchild A100 model, with the area microphone channel recording crew conversation and the other three channels recording captain's, co-pilot's and flight engineer's RTF transmissions. A satisfactory replay was obtained. The recording showed that the flight crew had carried out the approach and landing in accordance with the procedures laid down by the operating company. Three loud bangs were clearly audible on the area microphone channel which coincided with the reduction in EPR shown on the FDR.

The Emergency Evacuation

When the Gatwick Ground Controller first noticed and informed the aircraft of an engine fire he initiated an Aircraft Ground Incident and the fire and rescue services were alerted. The flight deck crew could see no signs of fire and had no fire warning indications except the over-temperature exhaust gas warning lights on Nos 2, 3 and 4 engines. The main engine fire warning system lights remained out. The flight engineer initially shut down No. 4 engine only, and subsequently shut down Nos 2 and 3 engines after the commander had received further information of the situation from outside the aircraft. The engines were shut down using the overheat drill which requires that the engine fire handles are pulled, thus arming but not discharging the fire bottles. The fire bottles are normally discharged only when the fire handle lights are illuminated.

Fire and Rescue services had arrived at the scene within one minute of the alarm call. The aircraft was requested to contact them on the discreet frequency of 121.6MHz. There was some delay in achieving two way contact between the ground and the flight deck due to the amount of radio traffic and flight deck workload. When two way contact was achieved the Fire Control Officer advised an evacuation from the forward doors only. Unfortunately this message was transmitted co-incidentally with the shut down of No. 1 engine when all electrical power was also lost. Thus this message was not received on the flight deck.

With no evidence of fire visible from the flight deck, the commander had to rely on information from outside sources. As soon as it became apparent that an emergency evacuation was advisable he ordered the remaining engine to be shut down and, using the code 'Easy Victor Left' over the PA system (which was serviceable from the flight deck), ordered an emergency evacuation via the left side doors.

At the instant that they heard emergency evacuation code, the flight attendants began their emergency drills. In the passenger cabin the evacuation was ordered by shouted commands in both English and French. Escape slides were initially deployed at doors L1, L2 and L4 only (figure 1). Subsequently the slide at R5 was also deployed but not utilised for passenger evacuation. The flight attendants' reports indicated that the first reaction by passengers to the emergency evacuation order suggested an unawareness of the presence of fire, and in some cases an impression that the aircraft was parked for disembarkation. Overall there was some confusion and misunderstanding of the necessity to evacuate

the aircraft as quickly as possible. There were reports of passengers attempting to carry their hand baggage to the emergency exits and, when challenged, or when they reacted to the shouted commands of the flight attendants that no hand baggage was to be taken off the aircraft, they next attempted to return to their seat positions and re-stow it in the over-head lockers. There were also recorded cases of passengers carrying packages with them down the escape slides. Nevertheless, in spite of the problems of communication and control, the evacuation was completed without serious injury to any person. The total time taken to complete the evacuation could not be accurately established, however it was in excess of 90 seconds. There was also evidence that the aircraft's cabin crew carried out their emergency drills efficiently and in accordance with their operating company's procedures.

Fire and Rescue services

Following the call out to an Aircraft Ground Incident, the Fire and Rescue Services' response, which included 5 fire fighting appliances, resulted in their arrival at the site within one minute of the alert. They saw a large amount of black smoke coming from Nos 2 and 3 engines. Closer inspection revealed deep seated fires developing in the rear end (tail pipes) of both engines. The order was given to apply BCF(100 kgs) as well as Foam liquid(65 litres). Subsequently 7000 litres of water was also applied. At the same time the Fire Control Radio operator was attempting to establish radio contact with the flight deck crew. This proved to be difficult but, when two-way contact was finally established, the Fire Control Officer advised an emergency evacuation via the front doors. For reasons already stated this advice was not received or acknowledged from the flight deck. The emergency evacuation started from the left side doors.

When the emergency evacuation started and the aircraft's escape slides were deployed, fire and rescue personnel were already in position around the aircraft. There was therefore no requirement for flight attendants to be positioned at the bottom of escape slides in order to assist passengers. There were already sufficient rescue personnel available to cope with this duty. This had a significant effect on the speed of the evacuation and probably kept the number of passenger injuries to a minimum. During the emergency operation two firemen sustained minor injuries due to the inhalation of BCF fumes.

Examination of the aircraft

(i) Engines

After the evacuation had been completed the aircraft was towed clear of the runway for examination. The No. 1 engine was apparently unaffected and the the translating cowl was in the stowed, *ie* forward thrust position. The translating cowls on the other engines were close to being fully deployed. External damage appeared to be limited to wrinkling on the underside of the exhaust collector (which is aft of the core engine cowl) on No. 3 engine, and to a lesser extent on No. 4 engine. This was ascribed to the rapid cooling that occurred when water was discharged into the engines by the fire services. The rotating assemblies of the engines had been subjected to a similar thermal shock as well as high EGT. This dictated that the three affected engines were replaced before the aircraft was returned to service. A boroscopic examination revealed no internal mechanical damage. It was noted however that the No. 2 engine fan was difficult to rotate by hand.

The engine fires had resulted in the underside of the wing becoming smoke blackened and it was noteworthy that in each case the blackening was predominantly to the right of the engine, indicating the presence of a right-to-left air movement relative to the aircraft at the time of the fire.

On the flight deck it was observed that all the thrust levers were at the forward idle positions and that the start levers were at the cut-off positions (thereby operating the high and low pressure fuel shut-off valves). Additionally all the engine fire handles had been pulled, arming but not discharging the fire bottles. Other functions performed by moving the fire handles to this position include shutting down electrical generation, the pylon air valve and the hydraulic shut-off valve. The thrust reverser "transit" lights were illuminated for engines 2, 3 and 4, showing that the reversers had begun to stow as the engines shut down since each reverser mechanism is driven by an air motor.

(ii) Escape slides

Three of the four slides used to evacuate the passengers and crew functioned normally. The exception was the slide at L2, which was found in a position such that the top was at an angle relative to the door sill. This meant that the slide was above the sill level at the aft end of the door aperture although the slide was still useable and no adverse comment was made by any of the cabin crew. It was not clear whether the slide deployed in this position or adopted it during the course of the evacuation. All the slides were removed from the aircraft before it was towed clear of the runway and this action may have removed any evidence that could have revealed the reason why the L2 slide was twisted. The slide grips the side of the aircraft as it inflates and is not normally easily displaced once inflation is complete. Although a small rip in the girt (the sheet of material joining the slide with the girt bar in the door sill) was found, it is considered unlikely that this would have resulted in a loss of tension sufficient to cause the slide to move.

(iii) PA system

Shortly after take off from Montreal the PA system went unserviceable everywhere apart from the upper deck, from where all subsequent announcements had to be made. The cabin interphone system was similarly affected. When the aircraft was examined on the ground at Gatwick it was found that only one PA station (at door 4R) was completely dead although a number of defects were noted on some of the remaining stations. It was also found that the gain on two out of the three PA amplifiers was rather low. Reference to the cabin log revealed that a number of problems, some of an intermittent nature, had affected the PA system over the preceding five days. Whilst the engines were being replaced at Gatwick, one of the amplifiers and three PA handsets were replaced in order to rectify the PA system.

Use of reverse power

Under certain conditions the JT9D engine may be prone to stall or surge. Because the circumstances of this accident apparently resulted in engine stalls whilst reverse thrust was being cancelled, it was considered important to request advice from both the aircraft and engine manufacturers. Advice was requested concerning the recommended operating procedures that should reduce this problem.

The aircraft manufacturer's Operations Manual reverse thrust procedures call for application of reverse thrust to a maximum of 85% N_1 . "Thrust should then be modulated as required based on the available runway remaining. The desired level of reverse thrust, up to the maximum, should be maintained until the airspeed approaches 60 knots. Approaching 60 knots, thrust should be reduced so that a thrust level of 60% N_1 is reached by 40 knots. Below 40 knots idle should be selected." The manufacturer's Flight Crew Training Manual advised that the use of high levels of reverse thrust at low speed might cause engine stalls.

The engine manufacturer's Operating Instruction No. 190 emphasised that, upon landing, reverse thrust was most effective at high speeds. The use of reverse thrust at low speeds (normally below 60 knots) was not recommended except in an emergency. "In addition to the lack of effectiveness of reverse thrust at low speeds, there are other adverse effects that should be recognised. First, the recirculation of hot exhaust gas into the inlet at low speeds can induce engine surge and, at worst, destructive engine over-temperature." An additional caution stated that "Reverse thrust should not be used in high speed ground turns...."

The operating company's Operations Manual contained the following advice on the normal procedures for the use of reverse thrust:-

The immediate application of reverse thrust cannot be overemphasised as reverse thrust is most effective at high speed. Also, the prompt application of reverse thrust before the engines have decelerated to ground idle will provide the most effective acceleration response. Pull all reverse thrust levers simultaneously to the interlock position regardless of the number of reversers to be used. Maintain pressure on the reverse thrust levers and after the interlock release, pull reverse symmetrical levers to full aft position and then forward to achieve no more than 70% N₁. At 70 knots Ground Speed (INS) begin reducing reverse thrust to remain within the normal operating range as shown in the following table.

NOTE:- Maximum Reverse Thrust 85% N₁ may be used under critical conditions.

N ₁ %	INS G/S
	100 kts
70%	70 kts
60%	60 kts
50%	50 kts

When required, a reverse thrust setting of 50% N₁ may be used at speed less than 50 knots, but this should only be necessary during slippery runway conditions. Normally, at speeds less than 50 knots, the reverse thrust levers should be positioned at IDLE FORWARD.

Summary

It is apparent that the danger of JT9D engines surging is widely recognised and operating procedures have been designed to reduce this danger to a minimum. Whilst there are minor differences in the recommended criteria, it is noted that the operating company's procedures are generally the most restrictive. There is no doubt that, on the accident flight, the Nos 2, 3 and 4 engines surged almost simultaneously. There is also no doubt from the evidence on both the CVR and FDR that the flight crew operated the aircraft in accordance with their company's recommended procedures, except that the cancellation of reverse might have been at a slightly lower speed than that recommended. There were however two other co-incidental factors at the moment of the engine surges. Firstly, the aircraft was turning left onto the high speed turn-off, and secondly, there was possibly an adverse effect on the engine intake airflow due to residual wake turbulence from a departing B747. The surface wind at the time was variable between 3 and 6 knots.

Incident to Nationair B747-100, N303TW, at Gatwick on 7 Aug 1990

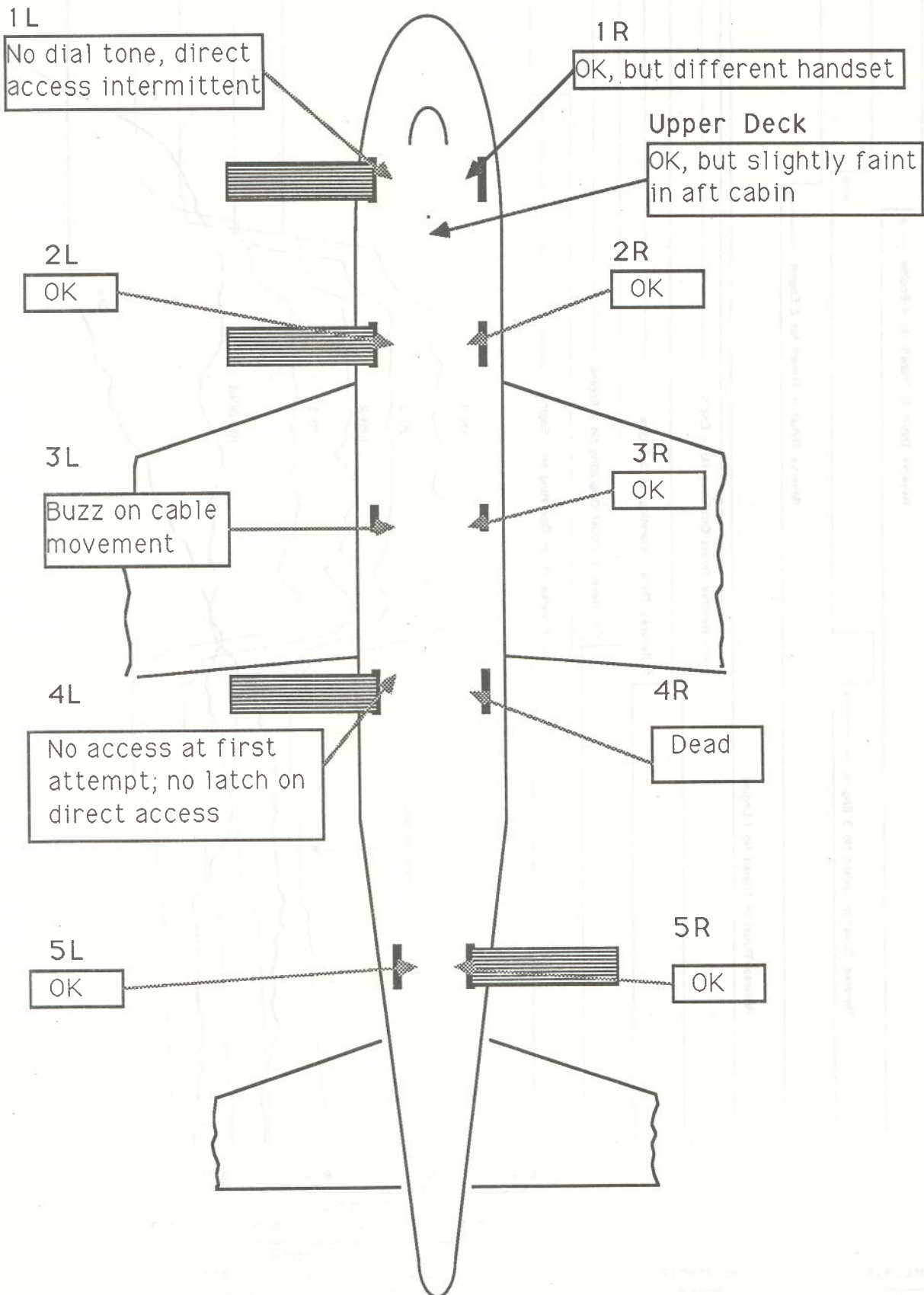


Diagram of escape slides deployed and condition of PA stations

Figure 1

ACCIDENT TO A B747 N303TW AT GATWICK AIRPORT ON 7 AUGUST 1990

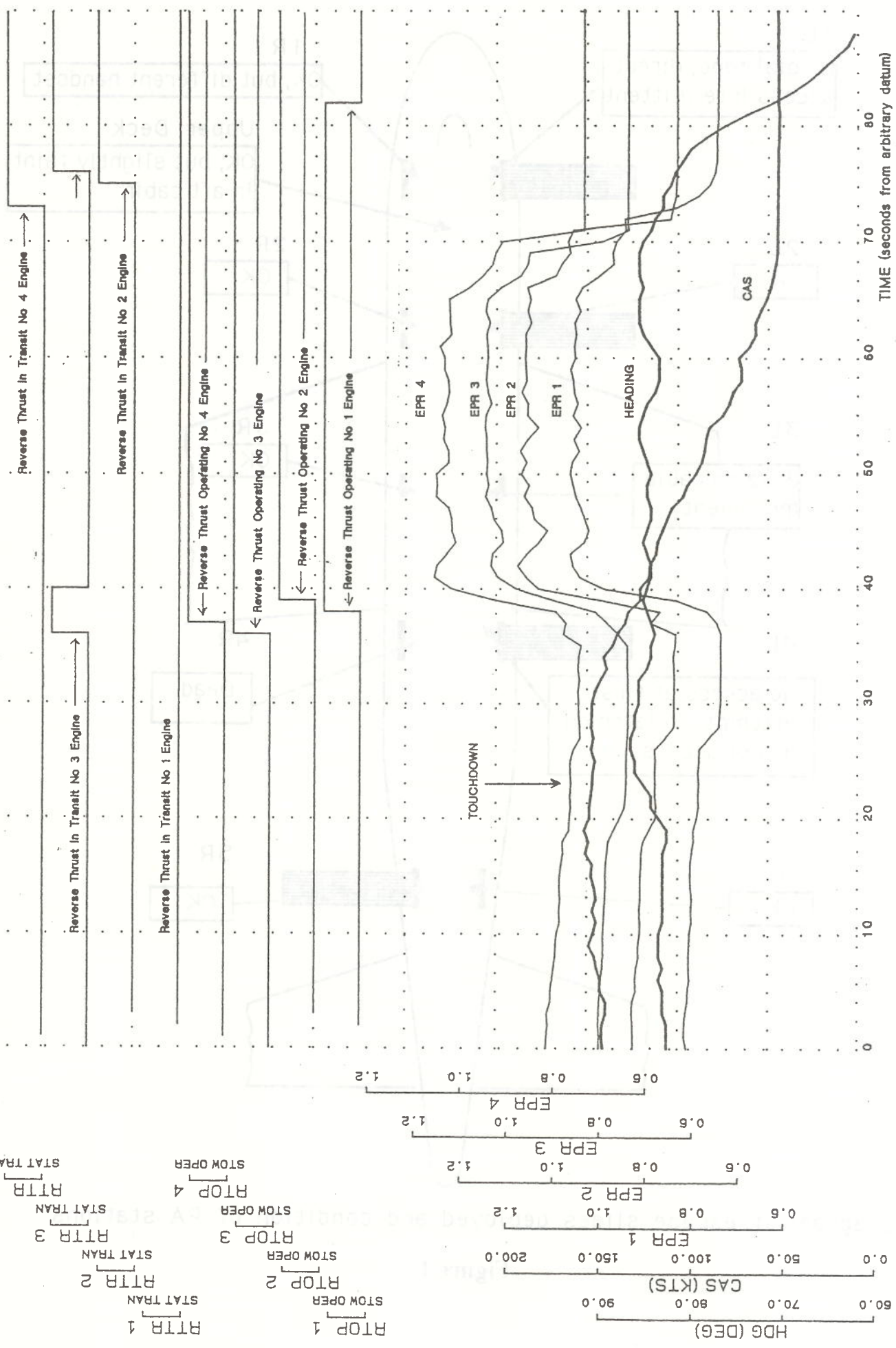


Figure 2