Botched landing, Accident to Boeing 757-200 G-BYAG at Girona Airport on 14 september 1999

Micro-summary: **Foul weather and airfield lighting yield a botched landing for this Boeing 757-200.**

Event Date: **1999-09-14 at 2147 UTC**

Investigative Body: **Civil Aviation Accident and Incident Investigation Commission (CIAIAC), Spain**

Investigative Body's Web Site: **http://www.fomento.es**

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CIAIAC
Comisión de Investigación
de Accidentes e Incidentes
de Aviación Civil

TECHNICAL REPORT
A-054/1999

Accident to Boeing
757-200 G-BYAG
at Girona Airport
on 14 september 1999

MINISTERIO
DE FOMENTO

Technical report

A-054/1999

Accident to Boeing 757-200 G-BYAG at Girona Airport, on 14 September 1999

MINISTERIO DE FOMENTO

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Foreword

This report is a technical document that reflects the point of view of the Civil Aviation Accident and Incident Investigation Commission (CIAIAC) regarding the circumstances of the accident and its causes and consequences.

In accordance with the provisions of Law 21/2003 and Annex 13 to the Convention on International Civil Aviation, the investigation has exclusively a technical nature, without having been targeted at the declaration or assignment of blame or liability. The investigation has been carried out without having necessarily used legal evidence procedures and with no other basic aim than preventing future accidents.

Consequently, any use of this report for purposes other than that of preventing future accidents may lead to erroneous conclusions or interpretations.

This report has originally been issued in the Spanish language. This English translation is provided for information purposes only.

Table of contents

Abbreviations

00 °C	Degrees Celsius
00° 00’ 00”	Degrees, minutes, seconds
000° M	Degrees of magnetic heading
AAIB	Air Accidents Investigation Branch
aal	Above aerodrome level
ACC	Area Control Centre
ACMP	Alternating Current Motorised Pump
ADF	Automatic Direction Finder
ADI	Attitude Director Indicator
AEC	Aft Equipment Centre
agl	above ground level
AIP	Aeronautical Information Publication
amsl	above mean sea level
AOC	Air Operator’s Certificate
APP	Approach
APU	Auxiliary Power Unit
ARO	Aircraft Reporting Office
ATC	Air traffic Control
ATIS	Automatic Terminal Information Service
ATPL	Airline Transport Pilot’s Licence
BKN	Broken
C	Celsius
CAP	Civil Aviation Publication
CB	Cumulo-nimbus or circuit breaker
CG	Centre of Gravity
cm	centimeter(s)
CRM	Cockpit Resource Management
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
DME	Distance Measuring Equipment
EASA	European Aviation Safety Agency
EDP	Engine Driven Pump
EFI	Electronic Flight Instruments
EICAS	Engine Indication and Crew Alerting System
EPR	Engine Pressure ratio
ETA	Estimated Time of Arrival
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FDR	Flight Data Recorder
FEC	Forward Equipment Centre
FIR	Flight Information Region
FMC	Flight Management Computer
FMU	Fuel Metering unit
FO	First Officer
FOM	Flight Operations Manual
fpm	feet/minute
ft	foot
g	Gravitational acceleration
GCU	Generator Control Unit
GPWS	Ground Proximity Warning System
GRN	Girona Airport
Hpa	Hecto pascals
hrs	hours minutes
HSI	Horizontal Situation Indicator
IAP	Initial Approach Point
ICAO	International Civil Aviation Authority

Abbreviations

ILS	Instrument Landing System
ISA	International Standard Atmosphere
JAR	Joint Airworthiness Requirements
kg	kilogram(s)
km	kilometre(s)
kt	knot(s)
lb	pound(s)
LDR	Landing Distance Required
LEGE	ICAO designator for Girona Airport
ltr	litre(s)
M	Magnetic
MAC	Mean Aerodynamic Chord
MAPT	Missed Approach Point
MEC	Main Equipment Centre
METAR	Meteorological Report
MHz	Mega Herz
MLG	Main Landing Gear
MM	Middle Marker
NDB	Non-Directional Beacon
NLG	Nose Landing Gear
nm	nautical mile(s)
NOTAM	Notice to Airmen
OM	Operations Manual
OM	Outer Marker
OMA	Airport Meteorological Division
PAPI	Precision Approach Path Indication
PF	Pilot Flying
PNF	Pilot Not Flying
psig	pounds per square inch gauge
PSU	Passenger Service Unit
QAR	Quick Access Recorder
QNH	A code for ambient pressure related to mean sea level
RA	Radio Altimeter
RVR	Runway Visual Range
SCT	Scattered
sec	second
SEI	Airport Fire Service
SOP	Standard Operating Procedures
Sta	Fuselage Station
TAF	Terminal Area Forecast
TMA	Terminal Manoeuvring Area
TWR	Tower
UTC	Universal Co-ordinated Time
VHF	Very High Frequency
VOLMET	Meteorological Transmission
VOR	VHF Omni Range

Synopsis

The aircraft made an approach and landing at Girona Airport, Spain, at night through heavy thunderstorms with rain. At a late stage of the approach the airfield lighting failed for a few seconds. The aircraft touched down hard simultaneously on the nose and mainwheels and bounced. A second harder touchdown on the nosewheel displaced the nose landing gear and its support structure. Resultant aircraft systems damage caused the loss of virtually all electrical power, interference with controls and uncommanded forward thrust increase.

The aircraft ran off the side of the runway at high speed around 1,000 metres after the second touchdown. After crossing a number of obstacles it landed heavily in a field outside the airfield boundary and came to rest after having travelled almost 1,900 metres from the second touchdown. The fuselage had been fractured in two places and there was considerable disruption to the cabin. There was no fire. Evacuation of all the occupants, initiated by the cabin crew, was completed rapidly. Emergency services had difficulty in locating the aircraft in the adverse conditions and arrived on the scene after evacuation had been completed.

Under the provisions of Annex 13 to the Convention on International Civil Aviation, Accredited Representatives of the United Kingdom and of the United States of America participated in the investigation. Technical assistance was provided by the manufacturer and the operator.

1. FACTUAL INFORMATION

1.1. History of the flight

1.1.1. *Pre-departure and en-route*

On 14 September 1999 at 1940 hrs,[1] Britannia Airways Boeing 757 (B757) registration G-BYAG, flight number BAL226A, departed Cardiff Airport, United Kingdom, for a flight to Girona Airport, Spain. On board were two flight deck crew members, seven cabin crew members and 236 passengers.

The pilots reported for duty at 1845 hrs. The Terminal Area Forecast (TAF) for Girona, valid from 1900 hrs on 14th until 0400 hrs on 15th, indicated a «temporary» (TEMPO) condition of thunderstorms and rain with a visibility of 2,000 metres.

The forecasts for the selected alternate airports, Barcelona, Reus and Toulouse were similar. In Barcelona and Reus the actual situation was one of storms with forecast period the same as for Girona. At the third alternate, Toulouse, storms were forecast for between 0000 hrs on 15th and 0300 hrs on 15th, outside the scheduled flight time. The SIGMET issued on 14th for the Flight Information Region (FIR) of Barcelona indicated that storms were observed through the day.

Prior to departure the crew discussed the weather forecasts and the commander loaded an extra 15 minutes of holding fuel to allow for possible delays. The First Officer (FO) was designated to be the pilot flying (PF) for the outbound sector.

The departure and en-route phases of the flight were uneventful. The FO gave a briefing for the Instrument Landing System (ILS) approach for Runway 20 before the aircraft commenced a descent towards Girona.

When within radio range of Girona, at 2114 hrs, the crew requested the latest weather information from Girona Air Traffic Control (ATC) and were given the following: «THE WIND IS NORTH, 10 KT, QNH 1010, VISIBILITY 5 KM, THUNDERSTORM AND RAIN, SCATTERED 1,800, FEW 3,500 FEET CB, QNH 1010, TEMPERATURE 20, DEWPOINT 20.» The controller added that the storm was to the south-west of the airfield.

The controller offered the option of an ILS approach to Runway 20, but the crew decided to land on Runway 02 considering the prevailing conditions of wet runway, downslope and tailwind, and requested the GRN (Girona) VOR/DME 02 approach. In view of the greater complexity of the approach the commander now assumed the PF role. On communicating with the Girona Tower again, the crew was authorised for the GRN VOR/DME 02 approach.

[1] All time references in this Report are given in UTC, unless specifically stated to the contrary. Two hours must be added to obtain local time in Girona.

The FO asked the cabin crew to secure the cabin early and advised them and the passengers that the approach would be turbulent. The pilots were able to see thunderstorm activity on the weather radar to the west and southwest of the airfield. The senior cabin crew member noted, and later advised the commander, that the aircraft had been hit by lightning on the port side during the descent.

1.1.2. *The first approach*

At 2118 hrs, 16 nautical miles (nm) inbound to the GRN VOR, the commander deployed the speedbrake. The aircraft arrived overhead the VOR at 2122 hrs descending through 7,200 feet above mean sea level (amsl) and commenced the VOR/DME 02 approach procedure (Figures 1 and 16 of Appendix A).

One minute after passing over the GRN at 7,200 ft the crew observed that there was 4,200 kg of fuel remaining. While in the right turn back to the VOR the commander's approach chart was dislodged from its holder by turbulence and he asked the FO to read out details from his chart as required. At 2126 hrs the aircraft passed over the GRN VOR again, now at 5,000 feet amsl. Flap 1° and then flap 5° were selected during the outbound turn and at 2129 hrs the aircraft levelled at 3,400 feet amsl. The tower passed the aircraft the following weather information: «VISIBILITY NOW IS 4 KILOMETRES, SCATTERED AT 1500 AND FEW 3000, CB BROKEN 4000. THE THUNDERSTORM IS NOW OVER THE FIELD».

After having received this information the commander checked the fuel contents at 3,600 kg, having previously noted the company minimum requirement of 2,800 kg and advised the FO that in the event of a missed approach they would divert to their alternate airport. From this time until the missed approach was carried out there were three separate calls of «BUG MINUS TEN» from the FO, indicating that the airspeed was 10 kt below the target speed.

At 2132 hrs, with the aircraft established inbound to the VOR on the 197 radial at 10 DME, the aircraft was fully configured for landing (flap 30°) and the speedbrake was re-stowed when its position was noted during the completion of the landing checklist. At 2133 hrs the tower controller advised a change of wind to 200/12 kt and offered the crew to turn to the right when reaching minimum and to enter the left downwind circuit to Runway 20. The commander acquired visual reference with the airfield lights but was not in a position to land or to accept a circling approach so he commenced a missed approach at 2136 hrs. The minimum altitude of the aircraft during the missed approach was 820 feet amsl (351 feet above aerodrome level (aal)). The crew notified ATC, followed the missed approach procedure and were asked to report when they reached the non-directional beacon of Girona (GRN NDB) at 5,000 feet.

The crew confirmed the fuel available at 3,100 kg, and the FO noted a low pressure caution indication for a forward fuel pump, a situation which would be expected with the quantity of fuel in the tanks and the attitude of the aircraft in the missed approach.

At 2137 hrs ATC passed the crew the following weather information for Barcelona, at the request of the crew: wind 360/10 kt, scattered 3,000 feet, temperature 18 °C, dewpoint 17 °C and QNH 1010 Hpa (hecto pascal).

1.1.3. *The second approach*

At 2138 hrs the crew requested an Instrument Landing System (ILS) 20 procedure. They were cleared for an approach and advised that the wind was 190/15 kt with a Runway Visual Range (RVR) of 1,500 metres (Figures 2 and 17 in Appendix A). The commander did not carry out another approach briefing with the FO but the crew agreed a single further approach, to be followed by diversion to the alternate Barcelona, if unsuccessful.

Subsequently the Flight Management Computer (FMC) generated an «INSUFFICIENT FUEL» message which the FO advised to the commander, who acknowledged. Established on the localiser, the commander ordered the weather radar to be turned off and reviewed the missed approach procedure. Just before capturing the glideslope, the commander noted that they had 2,800 kg of fuel, the operator minimum required for diversion taking into account the alternate fuel and final reserve fuel (30 minutes) and that, in the case of proceeding to Barcelona, they would have a shortfall of approximately 200 kg in accordance with such company's requirements. The crew re-confirmed between themselves that the commander would be looking for external visual reference while the FO would be monitoring the instruments for the approach.

At 2145 hrs the aircraft was fully configured for a flap 30° landing, had received landing clearance and was advised of the surface wind of 150/9 kt. The commander said «Lights in sight» at 2146:32 h, when the aircraft was approximately at 1,000 feet (530 feet aal). At 2146:47 hrs the commander said «Contact» and the aircraft landing lights were switched on and then the ATC advised the crew that the aircraft was in sight and passed the latest wind of 150/6 kt.

At 2146:58 hrs, at 250 feet above ground level (agl) and on the correct glidepath, the commander disconnected the autopilot and autothrottle. The aircraft began to deviate above the glidepath.

At 2147:10 hrs, 110 feet agl and co-incident with the FO calling out «FULL SCALE FLY DOWN» (informing the commander that the aircraft was above the ILS glidepath) the commander briefly pushed the control column almost fully forward before returning it to an approximately neutral position. The aircraft pitched down to –4.5° nose down attitude and then back up to –2.5° nose down attitude. During this period the commander lost his visual reference with the runway.

1.1.4. *The landing*

At 2147:13 hrs, between 80 and 54 feet agl, there was a Ground Proximity Warning System (GPWS) Mode One (Excessive descent rate) «SINK RATE» audio caution. One second later the FO called out «THOUSAND DOWN» (indicating a 1,000 ft/min rate of descent) and there was a second «SINK RATE» audio caution. There was an automatic radio altimeter callout of «TEN» feet followed immediately by the thrust levers being retarded to idle.

At 2147:17 hrs the aircraft touched down in a –2° pitch attitude with wings level at an airspeed of 141 kt and a recorded peak normal (vertical) acceleration of 3.11g. The aircraft bounced, the nose pitched up to +3.3°, a roll to the right commenced, both the thrust levers advanced and the power on both engines increased to 1.18 EPR (Engine Pressure Ratio). Full nose down elevator was applied and held until a second touchdown, resulting in a rapid pitch down. The aircraft made the second touchdown 1.9 seconds after the first at –0.5° pitch attitude (nose down), with a pitch rate of 7°/sec nose down and 4.2° of right roll and a roll rate of 2.2°/sec to the right. The control column returned to neutral and the recorded data ceased half a second later.

The aircraft electrical power failed and the emergency cabin lighting activated. The FO called out «AUTOBRAKE» (informing the commander that the system was not working) and the commander applied the brakes manually. The evidence found indicated that spoilers and thrust reversers probably did not deploy. After travelling along the runway the aircraft veered to the right and left the paved surface 1000 metres from the second touchdown point (Figure 20, Appendix A).

1.1.5. *Evacuation*

The aircraft came to rest, with the fuselage broken in two places, in a field outside the airport boundary and lying approximately 10 metres below the runway surface elevation. The commander was unconscious when the aircraft first came to a halt; he recovered consciousness shortly thereafter. The FO carried out the recall actions for a passenger evacuation. His seat had been displaced as a result of cockpit floor deformation and he had some difficulty in locating the required switches in the darkness.

The passenger evacuation was initiated separately in each of the three cabin sections by the cabin crew members. Passengers left the aircraft rapidly by available exits, followed by the cabin crew. By the time that the flight crew had completed their evacuation drills most of the passengers had vacated the aircraft.

1.1.6. *Search and rescue*

The tower controller perceived that something untoward had occurred during the landing and selected the emergency alarm shortly after the aircraft touched down. The emergency bell did not ring in any of the connected airport areas. The Airport Fire Service (SEI) was informed by means of a dedicated telephone line and mobilised immediately.

The SEI vehicles went to the end of Runway 20 and then drove along the runway trying to locate the aircraft, without success. In view of the absence of contact with the aircraft, the search was extended along the sides of the runway and into the overshoot area.

Some 18 minutes after the accident, the passengers and the main part of the aircraft were located, on the right side of Runway 20, outside the airport perimeter fence. After a further delay in gaining access, rescue of the passengers and assistance for those who had been injured started.

The passengers were transported to the terminal by bus. The transfer to the terminal building was completed approximately one hour and ten minutes after the accident.

1.2. Injuries to persons

Injuries	Crew	Passenger	Total in the aircraft	Others
Fatal		1*	1	
Serious		2	2	
Minor	1	40	41	Not applicable
None	8	193	201	Not applicable
Total	9	236	245	

* Note: One passenger who was initially admitted to hospital with apparently minor injuries was discharged the following day. He died five days later as a result of unsuspected internal injuries.

1.3. Damage to aircraft

The aircraft was damaged beyond economical repair and following examination was sold for salvage by the owner's insurer. The fuselage suffered two almost complete circumferential breaks and extensive undersurface damage and the nose landing gear and its support structure detached. Both main landing gears collapsed, both powerplants detached and the wings received severe local damage.

1.4. Other damage

The runway surface was scored in a number of places. Several runway edge lights were broken. The aircraft destroyed a section of the airport perimeter fence and caused damage to trees and a field outside the airfield boundary.

1.5. Personnel information

1.5.1. *Commander*

Age:	57 years
Sex:	Male
Nationality:	British
Licence:	Airline Transport Pilot's Licence (ATPL)
Validity:	To 14/7/2008
Aircraft ratings:	B737-200, B757 and B767, Piper Pa 23, 34 and 44
Instrument Rating:	Valid to 27-8-2000
Proficiency Check:	Valid to 27-2-2000
Line Check:	Valid to 03-12-1999
Medical Certificate:	Class One issued 17/8/1999. Valid to 17-2-2000
Flying experience:	
— Total:	16,700 hours
— On type:	3,562 hours
— Last 90 days:	195 hours
— Last 28 days:	65 hours
— Last 24 hours:	9 hours
Previous rest period:	14:50 hours

Crew Resource Management refresher training had been conducted on 14-10-1998.

1.5.2. *First officer*

Age:	33 years
Sex:	Male
Nationality:	British
Licence:	Commercial Pilot's Licence valid to 3-6-2001
Aircraft ratings:	Boeing 757
Instrument Rating:	Valid to 9-10-1999
Proficiency Check:	Valid to 17-10-1999
Line Check:	Valid to 11 january 2000
Medical Certificate:	Class 1 issued 14-1-1999. Valid to 13-1-2000

Flying experience:

— Total:	1,494 hours
— On type:	1,145 hours
— Last 90 days:	160 hours
— Last 28 days:	60 hours
— Last 24 hours:	9 hours
Previous rest period:	14:50 hrs

Crew Resource Management training had been completed on 5-1-1999.

1.5.3. *Flight crew duty periods*

The pilots had been rostered to fly together for a sequence of three night flights. On 12 September 1999 they operated a flight from Cardiff to Tenerife, Canary Islands, and return, with duty commencing at 1635 hrs and finishing at 0325 hrs on 13 September. They then reported for duty at 1655 hrs on 13 September, operated from Cardiff to Bodrum, Turkey, and return, finishing their duty period at 0355 hrs on 14 September. The pilots stated during the post accident debrief that they felt well rested and did not consider that fatigue had affected their performance.

1.5.4. *Flight crew evidence*

The pilots co-operated fully with the investigation. Interviews were conducted initially ten days after the accident and further interviews were carried out by a specialist in human factors in the succeeding days. The commander had a good recall of the events leading up to the final stages of the approach.

The commander reported that the weather radar was in use throughout the descent and approach and they could see thunderstorm activity to the south and west of the airfield when inbound to the GRN VOR. He also recalled having been advised by the senior cabin crew member that the aircraft had been struck by lightning during the intermediate descent, but noted that there was no apparent effect on the aircraft systems. After the missed approach to Runway 02 he noted that the flight conditions were smoother and that when established inbound to Runway 20 the weather radar showed no significant weather on the approach ahead.

Following the first approach and go-around he calculated that the remaining fuel was sufficient to carry out the ILS approach and to then divert to Barcelona if required. He did not consider that the fuel state was a significant pressure on the operation as he had enough to fulfil the company requirements and following any go-around from the ILS approach he would already be heading in the direction of the alternate airport, Barcelona, where weather conditions were good.

The commander reported that he obtained visual contact with the runway at about 500 feet agl but that he did not see approach lighting or PAPI (Precision Approach Path Indication) lights. He maintained the glidepath by reference to the ILS glideslope and by the visual aspect of the runway lights. Later in the approach after having disconnected the autopilot the aircraft became high on the glideslope and he made a power and pitch correction. As he did so he felt the aircraft sinking and at the same time he lost all the visual cues from outside the aircraft. Knowing the aircraft was very close to the runway the commander stated that his initial response was shock and without visual cues all he was able to do was attempt to maintain the last «sensed» pitch attitude and wings level. The aircraft landed hard and bounced and made a second hard landing. Still lacking visual reference the commander was unsure of his position on the runway but applied full braking and then, feeling the aircraft going to the right, tried to prevent the aircraft from leaving the runway by using left rudder. He did not recall hearing any cautions or warnings during the approach.

The FO was monitoring the final stages of the approach on the flight instruments. He recalled seeing runway lights on the approach but no approach lights or PAPIs. He did recollect hearing the GPWS «SINK RATE» caution at a very late stage before contacting the runway.

1.5.5. *Cabin crew*

There were seven cabin crew members operating on the flight. Their seating positions were as follows: Senior crew member at the forward left entry door (L1), two crew members at the L2 entry door, one crew member at each of the L3 and R3 emergency exit doors and one at each of the L4 and R4 rear entry doors. The crew members had all undergone the airline's emergency procedures initial and, where required, recurrent training.

1.5.6. *ATC personnel*

1.5.6.1. Tower controller

Age:	34 years
Sex:	Female
Licence:	Air Traffic Control
Date of Issue:	17-07-1997. 30-10-1997 started work at Girona Airport Tower
Qualifications:	Aerodrome controller
Validity:	Expires 22-05-2000

Last medical certificate:	Class 3 on 21-04-1999 valid to 21-04-2000
Time on duty that day:	1.40 hours
Rest period:	12 hours
Recurrent training	MFAENT (module of base for adapting to procedural and technological development) course, annually.

1.5.7. *Controller evidence*

According to the report from the controller, shortly after authorising the landing on Runway 20, the airport lights went out. She then saw the aircraft on its final approach; saw it touch the runway and then suddenly could not see it any more. She sought hard to find it and saw it rolling along the runway without lights. She also saw flashes and/or sparks from the left side of the aircraft before it passed the tower. Visibility was reduced by torrential rain. After selecting the emergency alarm the airport lights went out several more times.

The controller stated later on that she was absolutely sure that the approach and PAPI lights of Runway 20 were on after the first missed approach. She also stated that the pilots never told her that those lights were off.

1.6. Aircraft information

1.6.1. *Aircraft details*

Manufacturer:	Boeing
Aircraft type:	757-204
Constructor's serial number:	26965
Date of manufacture:	1992
Registration:	G-BYAG
Registered Owner and Operator:	Britannia Airways Limited
Certificate of Airworthiness:	UK Transport Category (Passenger)
Certificate of Airworthiness Expiry:	22 february 2001

Maintenance particulars

Total airframe hours at time of accident:	26,429 hours / 9,816 cycles

Certificate of Maintenance Review:	Issued 1-9-1999, valid to 31-12-1999
Certificate of Release to Service:	Issued 17-8-1999
Last major «C» check:	2-4-1998
Hours from «C» check at time of accident:	5,784 hours / 2,164 cycles

Engines

Manufacturer:	Rolls-Royce
Model:	RB211-535E4 turbofan

1.6.2. *Weight and balance*

Take-Off Weight:	90,489 kg (Maximum allowable 113,398 kg)
Zero Fuel Weight:	80,589 kg (Maximum allowable 83,500 kg)
Fuel load:	10,200 kg
Landing Weight:	83,389 kg (Maximum allowable 90,000 kg)
Centre of Gravity at takeoff:	23.5% Mean Aerodynamic Chord (MAC)
Centre of Gravity at landing:	22.0% MAC

1.6.3. *Aircraft description*

1.6.3.1. General

The Boeing 757 is a twin-engine aircraft of conventional layout with a low, swept-wing. The 757-200 version has an overall length of 155.3 feet (47.3 metres) and a wingspan of 124.5 feet (37.9 metres). The general layout and the positions of the main fuselage longitudinal stations (Sta) are shown in Appendix A Figure 4.

The aircraft has three hydraulic systems, Left, Centre and Right. The Left and Right systems are each pressurised to 3,000 psig (nominal) by one engine-driven pump (EDP) on the respective engine and by one electric alternating current motorised pump (ACMP).

The majority of the aircraft's electrical power control components and electronic units are housed in the main equipment centre (MEC), an underfloor bay immediately aft of the nose landing gear (NLG) doghouse (Figure 10). Power control panels for both engine generators and for the auxiliary power unit (APU) generator are mounted on the forward wall of the MEC. The main aircraft battery and static inverter are housed in a forward equipment centre (FEC) beneath the flight deck. A small number of electronic units, including the recorders, were housed in two aft equipment centres located in the rear fuselage.

The aircraft is fitted with conventional electrically powered air data instruments together with Electronic Flight Instruments (EFI). The EFI displays consist of two Attitude Director Indicators (ADI) and two Horizontal Situation Indicators (HSI). Together with attitude and flight mode information the ADI also shows deviation from localiser and glideslope. If a deviation of more than one dot for one second is detected the glideslope scale changes colour from white to amber and the pointer flashes.

The aircraft is powered by two high-bypass ratio turbofan engines, fitted with thrust reversers, each mounted on an underwing pylon. Rated sea level, static take-off thrust is 40,100 lb.

Fuel is carried in an integral tank in each wing and in an integral wing centre section tank located beneath the cabin floor and extending into the wing roots.

The seat shoulder strap selectors of the pilot and co-pilot have two positions: lock or manual, and automatic. According to the information provided by the manufacturer, the B757 Flight Crew Operating Manual describes that the manual position is typically used as an option to help restrain an incapacitated pilot. The automatic position is the normal setting for aircraft operation and allows the crew member to have unrestricted movement during flight and landing but locks in the event of extreme deceleration conditions. When the shoulder restrain inertia reels lock, the pilot's head path should remain clear of the glare shield and post at the left side of the windscreen.

1.6.3.2. Passenger cabin

G-BYAG's cabin was divided by toilet and galley units into a forward, centre and aft section, each with a single central aisle (Figure 5). The cabin was fitted with a total of 235 passenger seats, predominately as triple seat units. Each seat unit has two pairs of legs with fore/aft cross bracing and is mounted on two longitudinal seat rails fastened to lateral cabin floor beams. The seats had been certificated to withstand the following static decelerations (measured in g (acceleration due to gravity)); the «Federal Aviation Administration» (FAA) standards for seats and for the floor structure on which they were mounted applicable to new aircraft certification at the time of G-BYAG's accident are also given:

Requirements	Downwards	Forward	Lateral
G-BYAG Certification	4.5	9	1.5
New Certification	6	9	4

Note: Other conditions included in FAR (Federal Aviation Regulation) 25.785 (f), applicable to G-BYAG's certification, required loads of 6.5g downwards and 2.0g laterally.

Current certification also requires dynamic testing up to a maximum combined forward and lateral deceleration of 16g.

Television monitors are mounted above the aisle at intervals from a central conditioned air duct in the ceiling. Cabin baggage lockers along either side of the cabin are mounted on the fuselage upper sidewalls. The lockers are of composite sandwich construction, generally around 150 centimeters (cm) (59 inches) long, 71 cm (28 inches) deep and 33 cm (13 inches) high with a placarded contents weight of 180 lb/80 kg. Mounting brackets attached to the locker endwalls by inserts are attached by mounting rods to fuselage frames. A passenger service unit (PSU) is installed above each seat unit in the base of the lockers. The PSU contains reading lights, oxygen masks, an oxygen generator and a loudspeaker, measure around 71 cm (28 inches) long, 56 cm (22 inches deep) and 8 cm (3 inches) high and weigh 4 kg.

Each PSU is hinged to a horizontal rail at the fuselage sidewall by means of composite hinges and latched to a rail fitted in the base of the locker; when unlatched it is restrained by a 19 cm (7.5 inch) long lanyard at its inboard side.

The passenger cabin is provided with eight exits, each equipped with an inflatable emergency escape slide. The exits are accessed by three entry/service doors (L1/R1, L2/R2, L4/R4) and one emergency exit door (L3/R3) on each side of the fuselage. Each entry/service door is equipped with a pneumatic system activated by the first outward movement of the door to provide power assist for door opening when armed. To open the door in the armed condition the interior handle must be fully rotated (180°) and then the door pushed outboard with an assist handle a further 20-30° (door position relative to the fuselage) to initiate the power assist. The first 140° of handle rotation puts the forward end of the door into the most inward position, known as the «cocked» position, from there the aft end of the door continues to rotate outwards. Should the door jam in the «cocked» position then the actuator pressure bleeds down.

Emergency exit doors are a plug type, hinged at the bottom and opened by pulling up on a door handle at the side. With the doors armed, each escape slide is designed to deploy as the door opens; after dropping approximately 1.5 metres a lanyard becomes taut and causes the slide to inflate automatically.

During the certification testing process successful door opening trials were carried out with the aircraft in a 14.8° roll and 4° nose down pitch attitude.

1.6.3.3. Landing gear

The aircraft is fitted with conventional tricycle landing gear. Main landing gears (MLG) each have a 4-wheeled truck pivoted at the base of a shock strut (oleo) forming the leg.

The wheels and tyres are numbered (1-8) across the aircraft from left to right, front wheels first. The leg is trunnion mounted to the wing rear spar and to a main landing gear support beam behind the spar. It is supported on its forward side by a drag strut and on its inboard side by a side strut. Lower strength parts of the mounting structure load paths are designed to form structural fuses that would fail first and thus protect the wing structure from damage in the event of overload on the landing gear truck.

The nose landing gear (NLG) has two wheels carried on an axle mounted at the base of a shock strut forming the leg. The top of the leg is attached to the aircraft by trunnions mounted on either sidewall of the NLG mounting structure at Sta 389. The leg is braced fore and aft by a folding drag strut that is trunnion-mounted to the bay sidewalls at Sta 350. On retraction, the drag strut folds from its overcentre position and the NLG leg retracts forwards.

1.6.3.4. Nose landing gear mounting structure

The NLG mounting structure consists of a box structure, open on its underside, built into the lower part of the forward fuselage (Figures 6 and 7). In this report the forward part of the box, between Sta 263-324, is referred to as the «wheelwell» and the aft part, between Sta 324-395, as the «doghouse».

The box is rectangular in section, with a step decrease in width towards the rear at the Sta 324 Frame. The NLG bay is unpressurised and the wheelwell/doghouse structure is thus subjected to cabin pressure loads, in addition to NLG loads, and is a relatively robust structure with multiple external beams. It is joined along its entire lower perimeter to the fuselage structure, but the primary structural connection with the fuselage is via two deep-section fuselage frames, at Sta 324 and 395 respectively.

The lateral beams reinforcing the doghouse roof have a vertical separation from the underside of the cabin floor beams of around 11-13 cm (4.3-5.1 inch).

Two pairs of NLG doors, hinged to the bottom of each wheelwell/doghouse sidewall, close over the open bottom of the landing gear bay when the NLG is retracted. When the NLG is down the two forward doors are closed and the two aft doors open.

1.6.3.5. Control systems

The demand signals from the flight deck for the principal flight and engine controls are transmitted by tensioned cable/pulley systems, with the exception of the speedbrakes which are electrically controlled.

The cable system for the elevator left control system runs in the fuselage roof and the system for NLG steering runs alongside the NLG bay. The cables for the other systems are routed back along the fuselage underfloor, generally through cut-outs in the webs of the cabin floor beams (Figure 7.2). The forward parts of these runs are thus located above the NLG doghouse and in most cases also above the NLG wheelwell. This routing applies to the cable runs for the following systems:

System	Cable Designation		
	No. 1	No. 2	No. 3
Rudder	RA/RB		
Aileron	A1A/A1B	A2A/A2B	
Elevator (No. 2 system)		E2A/E2B	
Stabiliser	SP1A/SP1B	SP2A/SP2B	SP3A/SP3B
Flaps	WFA/WFB		
Slaps	LESA/LESB		
Wheelbrakes	LGB2A/LGB2B	LGB4ALGB4B	
Powerplants	TLA/TLB	TRA/TRB	

There are thus 13 cable pairs in these routes.

1.6.3.6. Powerplant controls

Pilots' forward thrust demands for each engine are made by rotation of a forward thrust lever mounted on the flight deck centre console. Reverse thrust is demanded by rotation of a reverse thrust lever piggybacked on the forward thrust lever. Mechanical interlocks prevent movement of either lever when the other is not at idle. Mechanical linkages within the console convert the rotation of each pair of forward and reverse thrust levers into rotation of a single pulley mounted below the flight deck floor (referred to as the forward pulley). Full anticlockwise rotation (viewed from the left) of the forward pulley from its null position provides maximum forward thrust and full clockwise rotation provides maximum reverse thrust (Figure 8.2).

Each of the two forward pulleys is connected to a pulley mounted in the respective powerplant pylon (referred to as the pylon pulley) by a tensioned cable loop passing over a series of idler pulleys (Figure 8.1). Mechanical linkages driven by the pylon pulley operate a hydro-mechanical fuel metering unit (FMU) mounted on the engine to regulate the engine fuel supply and also operate thrust reverser selectors.

The control cables between the flight deck and the powerplants are routed through fuselage floor beam cut-outs (Figure 9) and thence through the wing leading edge to the respective powerplant pylon. The designations of the powerplant control cables, together with their lateral distance from the aircraft centreline where they pass above the NLG doghouse are:

Powerplant	Cable designation	Distance fron centreline
No. 1	TLA and TLB	51 cm (20 inch) left
No. 2	TRA and TRB	76 cm (30 inch) left

Pulling on the «A» cable (with the pylon pulley in its null position) increases forward thrust and pulling on the «B» cable increases reverse thrust. Forward thrust increase from idle to maximum requires an approximately 4.0 inches (10.2 cm) forward movement of the «A» cable. Reverse thrust increase from idle to maximum requires an approximately 1.7 inches (4.3 cm) forward movement of the «B» cable.

1.6.3.7. Aircraft warning and information systems

The Boeing 757-200 is equipped with an «Engine Indication and Crew Alerting System» (EICAS). This system displays the engine parameters, provides the crew with centralised information in respect of abnormalities in the onboard systems and shows the status of the aircraft for flight despatch. The indications are displayed on two screens on the flight deck forward panel.

In the event of a failure, or if any system light comes on, the EICAS shows an alert message to the crew on the upper screen. There are also other alerts through audio tones and the Master Warning/Caution Lights.

The audio alerts are only used to draw the attention to caution and warning situations. Amongst these are the automatic voices for the Ground Proximity Warning System (GPWS) fitted. Mode One of the GPWS, «Excessive Descent Rate», has two boundaries and is independent of aircraft configuration. Penetration of the first boundary generates a repeated aural caution of «SINK RATE» and of the second boundary an aural warning of «WHOOP WHOOP PULL UP», with an associated light for each case. At 100 feet Radio Altimeter (RA) height the first boundary is penetrated at a descent rate of 1,000 feet per minute (fpm) or greater. The Mode One envelope is active from 2,450 feet RA to 30 feet RA height (effectively height agl). The GPWS also provides for an automated voice callout of height, linked to the radio altimeter system. These audio callouts were set to operate at 2,500, 1,000, 50, 40, 30, 20 and 10 feet RA height. There is a priority system should more than one alert occur at the same time. In this case the automated height callouts had a lower priority than the Mode One «SINK RATE» alert.

The aircraft manufacturer informed after the accident that they considered that the «SINK RATE» warning provides a higher level of excessive vertical rate awareness for the crew rather than the perceived timing between individual automatic height callouts, and that such callouts were advisory in nature (not mandatory) in accordance with the regulations in force.

The aircraft is equipped with Flight Management Computers (FMC). These utilise information from the flight plan entered by the pilots, various systems and stored memory to compute flight profile and progress data. The message «INSUFFICIENT FUEL» is generated by the Flight Management Computer and displayed to the crew when «Estimated fuel at destination is less than entered reserves value».

1.6.3.8. Braking system

Normal and Alternate main landing gear wheelbraking systems are provided, powered by the Right and Left hydraulic systems respectively. Each system incorporates an electrically operated antiskid facility. Brakes could be applied by pilot brake pedal inputs or by inputs to the Normal system from an electrically operated autobraking system.

With the autobrake system armed, automatic braking initiates after touchdown when all of the following conditions are met:

— Electrical power available.
— Both forward thrust levers are at less than 10° above idle.
— No tilt detected on both MLG trucks.
— Mainwheel spinup detected.

Loss of any of these conditions would cause deactivation of the autobraking system.

1.6.3.9. Speedbrake

The speedbrake system deploys spoiler panels on the upper surfaces of the wings. The spoilers are electrically signalled and each panel is actuated by one of the three hydraulic systems. System arming and operation is by a lever located on the left side of the flight deck centre console. When in the «UP» (extended) position the lever is not in the pilot's normal field of view. A caution is generated if the speedbrake is extended when the aircraft is between 800 and 15 feet agl or landing flap is set. There was no system on the aircraft to alert flight crew if engine thrust and speedbrake were being used at the same time. To prevent the inadvertent use of speedbrake when not required, Boeing recommend a procedure whereby the pilot flying should keep a hand on the selection lever at all times when speedbrake is deployed in flight. This procedure was also in the operator's Flight Operations Manual (FOM).

The system is also used to provide ground spoiler after landing. With the speedbrake lever in the «Armed» position, the lever moves to the «UP» position and all 12 spoiler panels are signalled to deploy automatically after landing when all of the following conditions are met:

— Electrical power available.
— Both forward thrust levers are at less than 10° above idle.
— No tilt detected on both MLG trucks.
— Hydraulic pressure to both MLG truck tilt actuators.

Loss of any of these conditions would cause spoilers to retract, if hydraulic pressure were available. Loss of hydraulic pressure would allow spoilers to gradually retract under the effects of gravity and air loads.

1.6.4. *Required landing distance*

Calculations were made using data from the B757 FAA Airplane Flight Manual to establish the landing distance required (LDR) for a wet runway (115% the distance required for a dry runway) at Girona Airport (LEGE). To provide a comparison, the calculations have been made for the most adverse wind condition and for the conditions on landing in Girona at the time of the accident.

Basic data

Flap configuration:	30°	
Airfield elevation, LEGE:	469 feet	
Runway length:	2,400 metres (7,872 feet)	
Runway state, LEGE:	wet	
Temperature:	ISA + 5 °C	
Landing weight:	83,389 kg	
Wind component:	5 kt headwind	LDR 5,100 feet (1,555 metres)
Wind component:	15 kt tailwind	LDR 6,300 feet (1,920 metres)

As reference, the stopping distance using autobrake has also been calculated. This is the minimum distance required to be able to stop the aircraft from the point of contact with the runway and using the autobrake system. Standard calculations assume that an approach with a glide path of 3° gives a touchdown point 1,000 feet (305 metres) from the threshold. The actual landing conditions specified above together with the following two parameters have been included:

— Approach Speed: 141 kt (based on the landing weight, the aircraft configuration and additions due to the dominant wind).
— Automatic braking mode selected: 4 (the maximum autobrake setting in normal operations).

Calculated stopping distance with 5 kt headwind: 3,160 feet (963 metres).

1.7. Meteorological information

1.7.1. *General situation*

At the time of the accident the weather in the north of Spain was influenced by a slow moving cold front lying from the south coast of the United Kingdom to the central Pyrenees. The Girona area was experiencing extensive cumulus cloud giving rise to rain showers and thunderstorms at the leading edge of the cold front (see Appendix B with meteorological radar images).

At 1800 hrs, locally strong to very strong stormy squalls were recorded in the eastern third of the Iberian Peninsula, with very strong and torrential squalls in Catalonia.

At 2400 hrs, the relative low pressure areas were located in the Mediterranean area, with the lowest being to the East of the Balearic Islands. Convection cores affected the Balearic Islands whilst the low pressure areas were progressing onto the Iberian Peninsula.

1.7.2. *The meteorological situation in the airports in the area*

During the flight the crew had access to meteorological transmission (VOLMET) information from Barcelona which included the meteorological report (METAR) from Girona and Barcelona, amongst other aerodromes.

The meteorological reports from Girona airport between 2100 hrs and 2200 hrs were as follows:

2100 hrs:	Surface wind 010°/8kt, visibility 5,000 metres, light thunderstorm and rain, scattered cloud at 1,800 feet, few cumulonimbus at 3,500 feet, broken clouds at 8,000 feet, temperature 20 °C, dew point 20 °C, pressure at sea level QNH 1,010 Hpa.

2130 hrs:	Surface wind 350°/6kt, visibility 4,000 metres, heavy storm with rain, scattered cloud at 1,500 feet, few cumulonimbus at 3,000 feet, broken clouds at 4,000 feet, temperature 20 °C, dew point 20 °C, QNH 1,010 Hpa. Recent rain.
2200 hrs:	Surface wind 080°/8kt, visibility 2,000 metres, heavy storm with rain, scattered cloud at 1,000 feet, few cumulonimbus at 2,500 feet, broken clouds at 3,000 feet, temperature 18 °C, dew point 18 °C, QNH 1,010 Hpa. Recent rain.

A rainfall of 44.3 litres/square metre was recorded between 2120 hrs and 2200 hrs by the meteorological observation station at Girona Airport. This intensity of rain is defined as torrential.

A total of 307 electrical discharges were counted in the province of Girona and along its coasts between 2120 hrs and 2220 hrs, with none being counted in the province of Barcelona (Appendix B Figure 4).

The wind parameters recorded at Girona Airport, in average speed and direction values for both runways were as follows:

Time	Runway 20	Runway 02
2130 hrs-2135 hrs	250°/08 kt	207°/12 kt
2135 hrs-2140 hrs	201°/09 kt	176°/13 kt Go-around at 2136 hrs
2140 hrs-2145 hrs	177°/09 kt	135°/10 kt
2145 hrs-2150 hrs	109°/07 kt Accident at 2147 hrs	023°/11 kt
2150 hrs-2155 hrs	057°/08 kt	026°/16 kt
2155 hrs-2200 hrs	044°/11 kt	023°/13 kt

The maximum wind speed, averaged over 10 seconds, for each runway was as follows:

Runway 20	at 2155 hrs	15 kt	015°-030°
Runway 02	at 2151 hrs	30 kt	015°-030°

The METARs for Barcelona Airport gave the following stable values between 2100 hrs and 2200 hrs:

Surface wind 360°-340°/10 kt, visibility greater than 10 km, scattered clouds at 3,000 feet, temperature 18 °C-19 °C, dew point 17 °C-18 °C, QNH 1,010-1,009 Hpa.

During the period of time between the aircraft starting the initial approach (2114 hrs) until the moment of contact with the runway (2147 hrs) and during the search and rescue operations (to 2215 hrs) there were storms with heavy rain and electrical activity over Girona Airport and the surrounding area. During this period the storm activity shifted from the south-west of the airport to the north-east, passing over the top of the airport.

1.7.3. *Tower communications on meteorological conditions*

The meteorological information supplied to the pilot as from 2138 hrs, the time at which the ILS approach to Runway 20 was started, was as follows:

Time	Comments	Communication
2138 hrs	Authorised ILS tp Runway 20	Wind 190°/15 KT, RVR 1,500 m, scattered douds at 1400 feet
2143 hrs	Established on the localiser	Wind 170°/12 kt
2143 hrs	At the initiative of the controller At the request of the pilot	Revise QNH to 1,012 Hpa Runway «quite wet»
2144 hrs	Over the beacon and authorised to land	Wind 150°/9 kt
2146 hrs	G-BYAG seen by the controller	Wind 150°/6 kt

1.8. Aids to navigation and landing

1.8.1. *Initial and Runway 02 approach*

The following radio aids were available for navigation and initial approach to Girona Airport:

The Girona NDB, identification GRN and frequency 412 Mega Hertz (MHz). It is situated on the extended centreline of Runway 20 at 7 nm from the airport and has a coverage of 50 nm.

The Girona VOR/DME, identification GRN and emission frequency 114.100 MHz. This is located on the extended centreline of the runway slightly more than 1 nm before the Runway 20 threshold.

Runway 02 is not equipped with an ILS and the instrument approach to this runway uses the GRN VOR/DME, with a final approach inbound on the 197° VOR radial, a decision altitude/height of 850/447 feet and an MAPT (Missed Approach Point) located at 3 DME (See Figure 1 of Appendix A).

1.8.2. *Runway 20*

Runway 20 was equipped with a Category 1 ILS. The decision altitude/height published in the Jeppesen chart for a Category C aircraft was 720/251 feet with a visibility requirement of 800 metres with approach lights operational, or 1,200 metres without approach lights.

The localiser is operational for a +30°/–35° sector around a magnetic bearing of 197° and the antenna is located 291 metres from the Runway 02 threshold. The glide path has a nominal angle of 3° and is located 330 metres from the Runway 20 threshold and 90 metres to the right of the runway centreline in the direction of approach.

The ILS includes two 75 MHz beacons on the extended runway centreline; the outer (OM, outer marker) is located 12,611 metres from the threshold of Runway 20 and the middle (MM, middle marker) is located 1,232 metres from the same threshold. It also has a 330 KHz, LM beacon, identification G, located at the same position as the MM.

The approach plate in the Aeronautical Information Publication (AIP) included an accompanying note indicating that the glideslope must not be used below a height of 720 ft (260 feet agl). The pilots each had a copy of Jeppesen ILS Chart 11-1 dated 13 Dec 1996 (See Figure 2 of Appendix A). The chart contained a note that the ILS could not be used for an autopilot coupled approach below 251 feet agl, but did not contain the AIP note that the glideslope was unusable below 260 ft agl.

1.8.3. *Post accident flight test reports*

A flight to check the status of the ILS for Runway 20 took place on 18 October 1999, with the following result:

Performance satisfactory and with the following observations: the localiser provides coverage over a ±35° sector centred on the approach path, it is recommended that the OM should be narrowed as it is too broad, and flying on the glideslope (GS) the 3rd light of the PAPI (numbered from left to right in the approach direction) appears to be changing from red to white when it should be seen as red. On the approach the NDB indicated «GRN» and the locator compass indicated «G» with satisfactory result.

The reason given by the Airports Operator AENA for the restriction on the use of the glideslope below the decision altitude/height, shown as a Note on the ILS Instrument Approach Chart for Girona Runway 20, was as follows:

Irregularities encountered in the calibration of the aid which, whilst not affecting the operation of the path, gave rise to the inclusion of a permanent NOTAM (Notice to Airmen). This does not signify any loss in the accuracy of the radio aid.

1.9. Communications

1.9.1. *General and en-route*

The crew maintained radio communications with the Barcelona Area Control Centre (ACC) from entry into the Barcelona FIR and Terminal Manoeuvring Area (TMA) until shortly before 2120 hrs when the aircraft was transferred to Girona approach.

1.9.2. *Communications with Girona Airport*

The first radio communication between the aircraft and Girona control tower was at 2114 hrs on the approach (APP) frequency (120.900 MHz) before being transferred by Barcelona ACC and in this communication the crew requested the most recent meteorological information on Girona Airport as it is not equipped with Automatic Terminal Information Service (ATIS).

The controller provided information on the meteorological conditions at the airport, including the location of storms to the south-west of the field, without specifying their movement.

When the flight had been passed on by Barcelona ACC to Girona APP, radio communications were started and maintained, without interference, between the aircraft and this Control Unit. The sequence of communications and the information transmitted was as follows (UTC time is provided as a reference of the start of each communication):

Time UTC	Summary of the Communication
2119:46	The crew advised that they were descending from flight level 210 to flight level 90, at DME 11 from Girona VOR. The flight was authorised to continue for a VOR/DME approach to Runway 02 and the wind information was up-dated.
2122:18	The crew reported overhead the Girona VOR, as had been requested. The controller asked for information on altitude and asked the crew to advise when they were established on final approach at 8 nm, she also gave up-dated information on the wind at runway level.
2125:31	The crew asked for information on the surface wind. The controller reported the current wind.
2129:02	The controller requested information. The aircraft was at 6 DME outbound. The controller supplied meteorological information from the up-dated METAR, including the information that the storm was then over the airfield.
2133:07	The crew notified arrival at 8.5 DME on final approach for Runway 02. Approximately 20 seconds later the controller asked them to revise their QNH as there had been an increase from 1,010 to 1,011 Hpa. She advised the crew of a surface wind change to 200/12 kt and offered a visual circling approach to Runway 20.
2135:53	The crew advised that it was executing a go-around.

Time UTC	Summary of the Communication *(continuation)*
2135:55	The controller asked that they should notify over the Girona NDB at 5,000 feet.
2136:52	The crew asked for the meteorological information on Barcelona. Some 20 seconds later the controller gave them the Barcelona METAR. A little later the crew asked for the meteorological information to the north of the field. They did not obtain this meteorological information. The controller said «standby» but never provided the information.
2138:22	The crew notified over Girona NDB and requested an ILS approach to Runway 20. The controller authorised the approach and advised the crew of the wind, horizontal visibility and cloud base.
2139:20	The controller asked the crew to notify on final over the OM.
2141:48	The crew advised that they were established on the localiser. The controller reminded them to communicate at 6 nm, i.e. over the OM, and gave an up-date of the wind information.
2143:24	The controller advised the aircraft to revise the QNH to 1,012 Hpa. The crew read back the information and enquired whether the runway was wet. The controller informed them that it was «quite wet»
2144:31	The crew reported over the OM. The controller informed them that they were cleared to land on Runway 20 and gave the current surface wind information. The crew read back the clearance.
2146:55	The controller notified the crew that the aircraft was in sight and informed them of the current wind.

There were no further communications between the aircraft and the tower.

1.9.3. Search and rescue communications

At 2147:20 hrs the controller called the aircraft but received no reply. A little later, at 2148:04 hrs, she communicated with the Aircraft Reporting Office (ARO) to advise that «it appeared that the aircraft had crashed». At 2148:23 hrs she called the Airport Fire Service (SEI) to advise that «the aircraft had crashed to the south of the airfield». In response to the SEI question «Where is the aircraft?» she replied «to the south, at the end of the runway, I can't see it».

A transcription of the communications between the Tower and the various airport sections (Traffic Office, ARO, Meteorology, Tower Crew/Equipment Room, Barcelona ACC, SEI and SEI vehicles) by telephone and by radio on 121.700 MHz was prepared. This showed that while G-BYAG was being handled by Girona there was frequent communication between the Tower and Meteorology to obtain full, current meteorological data for Girona, and also for Barcelona when this was requested by the crew. The transcript showed that the Girona controller informed Barcelona ACC of G-BYAG's missed approach to Runway 02. The transcript also showed that:

1. There were various interruptions in the Airport's electricity supply in the minutes subsequent to the event and possibly also during the aircraft's final approach to Runway 20.

2. When the Tower controller selected the Emergency Alarm it failed to sound in some of the airport sections where an alarm was fitted. The controller then contacted the SEI and other sections by telephone.

3. Misunderstandings occurred in respect of the aircraft's suspected final position, the runway direction in which it had landed and whether it was communicating on another radio frequency.

4. At 2206 hrs a fire-fighting vehicle located the wreckage of the aircraft outside the airport perimeter and to the right of Runway 20.

1.10. Information on the aerodrome

1.10.1. General

Girona Airport has an International Civil Aviation Organisation (ICAO) Classification Code of 4E. The airport is at an elevation of 469 feet amsl. It has a single runway, Runway 02/20, 2,400 × 45 metres (7874 × 148 feet) in size with an average downslope of 0.84% in the Runway 20 direction. The runway surface is asphalt and on each side there is an 11 metre wide concrete surfaced shoulder.

ICAO Annex 14 defines a «strip» associated with a runway that should have certain slope, vertical step, load bearing and freedom from obstacle characteristics. The Annex defines the recommended characteristics and the size of the strip for various categories of runway.

At Girona Airport the runway strip is 150 metres wide and 2,520 metres long, including in this area a clearway zone of 60 × 150 metres on each of the runway thresholds. The grassed area outside the runway shoulders is called the «margin» in some parts of this report.

The runway lighting consists of approach, edge and end of runway lights. The approach lighting is Precision Category I, five bars and 900 metres long, for Runway 20 and sequenced flashing lights over a distance of 350 metres for Runway 02. Each runway has PAPI lights set at 3°. To switch on the approach lighting there is an illuminated press-button keypad with independent buttons for each of the following lights: Approach 02, PAPI 02, Approach 20, PAPI 20. However, the lighting of Runway 02-20 has a single button for all the lights (edge, threshold and end).

The Girona Control Tower had a single controller covering the APP and tower (TWR) frequencies. Girona Airport has a capacity for 12 aircraft per hour. A supervisor post was not provided.

To obtain meteorological information, there is an anemometer at each threshold, giving wind information in real time, and the aerodrome METAR which supplies the Meteorology Office every half hour. There was no image of meteorological radar.

To activate the Emergency Alarm from the Tower, there is a duplicated pushbutton system which should activate three sirens, one in the SEI and two in airport offices.

1.10.2. *Electrical supply*

The electricity supply to the airport is provided by the electricity company which is the major distributor in the area, Fecsa-Endesa. The airport secondary power source is supplied by generators.

The Control Tower and radio-aid installations have an uninterrupted supply of electricity provided by batteries. The other airport installations do not have this.

There were several failures in the supply to the airport around the time of the accident, causing loss of the Airport Terminal and runway lighting. The equipment maintenance log recorded breaks in the electrical supply at 2148, 2152 and 2157 hrs; the back-up supplies were operational throughout. The accuracy of the records and the difference in times between the clock used for the log and the Control Tower clocks could not be established.

The power supply company was asked twice for information on the number and time of interruptions to the electrical supply. No reply was obtained.

Attempts were made to establish the timings of the power supply interruptions from memory within airport electronic equipment but no suitable memory was found. Witness statements indicated that there was an initial failure in the electricity supply seconds before the aircraft contacted the runway and after it had been cleared to land, and that there were subsequently between 3 and 5 further interruptions.

After the accident it was established that the back-up supply restored the lighting 11 seconds after the initial failure of the external supply.

ICAO Annex 14 recommends that the back-up electrical power supply for Category I precision approaches should be connected within a maximum period of 15 seconds for runway and approach lighting.

1.10.3. *Physical characteristics of the aerodrome*

The Runway 20 average downward gradient of 0.84% is made up of downslopes of 1.25% over the first third of its length, 1% over the central part and 0.46% over the final third.

The specifications contained in ICAO Annex 14 recommend that the maximum gradients, for a Code 4 runway, in the first and final quarter, should not exceed 0.8%.

According to the airport AIP, the runway strip is 150 metres wide, i.e. 75 metres on either side of the runway centreline. ICAO Annex 14 recommends that, whenever possible, the runway strip for precision approaches extend laterally to at least 150 metres on each side of the runway centreline for a Code 4 airport.

On the subject of the recommendations concerning transverse gradients in this strip, beyond the part which must be levelled, 75 metres to each side, it is stated these should not exceed an upslope of 5%.

There is a steep drop in the terrain to the right of the latter part of Runway 20, starting around 400 metres from the end of the runway. This embankment, roughly paralleling the runway, is between 55-75 m from the edge of its right shoulder and the outer terrain is around 8-9 metres (25-30 feet) below the level of the runway.

A single-track paved perimeter road at the base of the embankment runs around the south end and west side of the runway. An airport boundary fence runs outside this road.

Adjacent to the northern end of the embankment there was an approximately 6 metre (20 feet) high earth mound on the airfield boundary, in the form of a elongated dome with its long axis parallel to the runway. It appeared likely that it was formed of spoil that had been surplus to airport construction activities. A cut-out part way up the eastern face of the mound accommodated the perimeter road. Above the road, the face of the mound had a gradient estimated at around 50%. Both the embankment and the mound lay at the edge of the 75 metre strip centred on the runway.

The terrain under the approach path to Runway 20 is sloped and undulating and thus aircraft radio altimeter height indications do not accurately correspond with the aircraft's height above the runway threshold.

The specifications contained in ICAO Annex 14 recommend that there should be an operating area for the radio altimeter in the zone preceding the threshold of a runway for precision approaches. Spain has notified a difference in relation to ICAO in respect of this standard, stating that this is only met for Category II/III precision approaches.

1.11. Flight recorders

1.11.1. *Recorder recovery and details*

The crash protected flight recorders from G-BYAG were transported to the facilities of the Air Accident Investigation Branch, UK (AAIB) for replay.

Details of both recorders were as follows:

Cockpit Voice Recorder	Part Number	Allied Signal 980-6020-001
	Serial Number	1317
	Date Code	9646
Digital Flight Data Recorder	Part Number	Allied Signal 980-4700-034
	Serial Number	0996
	Date Code	9612

Both flight recorders had been installed in the rear of the aircraft and neither showed signs of having been damaged during the accident. A photograph of the units is shown in Figure 11.1.

A damaged Quick Access Recorder (QAR) cassette tape was sent to the AAIB for analysis during the course of the investigation. The tape had been found at the accident site near to the QAR itself. The QAR and a small stowage locker for a spare tape had been located in the main equipment centre of the aircraft, just aft of the nose gear bay. Photographs of the recorder and damaged cassette are shown in Figures 11.2 to 11.4.

1.11.2. *Recording system description*

1.11.2.1. Cockpit voice recorder (CVR)

The CVR was a solid state memory design providing recording capability for 30 minutes of four independent audio channels; one each for the pilot, co-pilot, public address and cockpit area. The crew and public address inputs were taken from the aircraft audio system whereas the source of the cockpit area channel was a microphone mounted centrally on the flight deck.

1.11.2.2. Digital flight data recorder (DFDR)

The DFDR recording medium was also solid state and provided the capability of retaining 25 hours of aircraft data. Parameters were measured by various transducers distributed throughout the aircraft, digitised and transmitted throughout the aircraft by data buses. The Digital Flight Data Acquisition Unit (DFDAU) assembled required data bus parameters and also interfaced directly to a number of additional analog parameters from synchros (such as control column and control wheel) and low level dc sources (such as accelerometers). The assembled data was then transmitted serially to the DFDR. Each data frame comprised 64 parameter word slots and was of one second duration. Most digitised aircraft parameters were allocated at least one recording slot per data frame, with parameters requiring a higher sampling rate (such as vertical acceleration) allocated additional, equally time-spaced slots.

Some parameters, which could not vary significantly over time, were recorded less frequently with a maximum period between samples of sixty four seconds. Details of the data frame layout and conversion to engineering units for a B757 type 2 recording system are given in Boeing document D6-55333.

1.11.2.3. Quick access recorder

The QAR utilised industry standard computer cassette tape cartridges as the recording medium with a capacity in excess of 25 hours of recording time. The capability of the QAR was in excess of that of the DFDR in that additional parameters and parameters at higher sampling rates were recorded. Whereas the DFDR operated continuously (when powered), recording over data that was in excess of over 25 hours old, once the QAR cassette tape was full of data it had to be replaced with a previously erased one. This tape changing procedure was incorporated into the operator’s daily aircraft check.

1.11.3. *Replay assessment and information recovery*

1.11.3.1. Cockpit voice recorder

The CVR recording was of excellent quality. Crew speech was continuously recorded on the respective audio channel regardless of whether a radio push-to-talk switch was depressed.

The CVR recording started at 2116 hrs during the descent into Girona Airport and ended at about the time of the second touchdown, which occurred at 2147 hrs. The total CVR recording time was just over 31 minutes which was in excess of the mandatory minimum.

1.11.3.2. Digital flight data recorder

The DFDR recording was also of excellent quality with the exception that the synchronisation word at the start of the last recorded data frame of the accident flight had been corrupted. In total the DFDR retained complete data from the last ten sectors that the aircraft had flown, including that of the accident flight. The data ended at about the time of the second touchdown.

The recovered data was decoded and converted to engineering units using the algorithms set out in the Boeing data frame layout document D6-55333. The following table lists the control input limits derived from the data frame layout document and analysis of the «full and free» checks recorded on the DFDR from previous flight sectors:

Control	Limit
Control column position	–13.3° aft to +9.2° forward
Control wheel position	–85° clockwise to +85° counter clockwise
Power lever angle	0° (full reverse thrust) 50° (idle) 130° (full power)
Elevator position	–21.5° nose down to +31.5° nose up
Aileron position	–20° trailing edge down to +20° trailing edge up (limit reached at ±50° control wheel)
Rudder position	–30.6° yaw left to +30.6° yaw right
Rudder pedal position	–14.5° yaw left to +14.5° yaw right
Stabilizer position	–11.5° nose up to +4° nose down (not pilot trim units)
Speedbrake handle	0% fully down 12% armed 100% fully up

Graphical representations of pertinent parameters recorded during the accident flight were produced (Figures 12, 13 and 14).

1.11.3.3. Quick access recorder cassette

The cassette had been split open during the accident but all component parts had been retained within the casing. Most of the magnetic tape was wound onto one of the two tape spools and the tape had split just beyond the first pair of end-of-tape marker holes. As there were four tracks on the tape and the recording was conducted in a serpentine manner, this indicated that the tape was either completely full of data or exactly half full.

The tape was spliced at the break and wound into an undamaged cassette. Upon replay it was found that the tape was full of data but was from the period of 7 August to 8 August 1999. Technical records from the operator indicated that this may have been the last data recorded on the QAR as there were no tapes available from a later period. The presence of a quantity of mud within the cassette aperture of the QAR would also seem to indicate that no cassette was present at the time of the accident.

1.11.4. *Time correlation of DFDR and CVR recordings*

As both DFDR and CVR used accurate, crystal controlled timebases to record into solid state memory there was no difficulty in correlating the two sources. The criteria used were the states of the push-to-talk discrete parameters on the DFDR which changed whenever a radio transmission was made, the change in state of the GPWS discrete parameter and the recorded noise and normal acceleration peak at the first touchdown. Once the two sources had been time-correlated it was apparent that, although the CVR had recorded the start of the sound of the second hard touchdown, there was no such indication within the DFDR recorded values of normal acceleration.

The Flight Data Acquisition Unit (FDAU) was equipped with an internal power supply, derived from the main aircraft supply, to provide electrical power to the accelerometer which was mounted near the aircraft's centre of gravity. It is conceivable that either the wiring carrying this local accelerometer supply or the power circuitry within the FDAU itself was disrupted during the first or second touchdown phases. The progressive, but rapid failure of the excitation voltage to the transducer could have resulted in decreasing, incorrect acceleration readings being recorded. Due to the extensive mechanical disruption in the area of interest it was not possible to determine whether this had occurred. An assessment of the recording of longitudinal acceleration, derived from a co-located transducer with the same power source, was inconclusive. However, it was noted that, at the second touchdown, a short period of DFDR data corruption occurred. It is considered that the likely cause was an upset in the power supply to the FDAU and / or DFDR as solid state recording systems such as was fitted to the aircraft are largely unaffected by mechanical disturbance. This is in contrast to the performance expected from a mechanical, tape based recorder under similar conditions where data corruption of this nature is not unusual.

1.11.5. *History of flight (recorded information)*

Graphical traces of the pertinent data parameters from the accident flight are shown in Figures 12 to 15 of Appendix A and plots of the track over the ground are shown in Figures 16 and 17.

This history of flight takes the form of a table of significant CVR and DFDR events against time (GMT recorded on DFDR), as follows. Note: All quoted altitudes greater than 10,000 feet are based on 1,013 mb, all quoted altitudes less than 10,000 feet are QNH corrected.

GMT	Event
19:52:00	Takeoff from Cardiff on Runway 30.
20:12:48	Top of climb FL370.
21:06:17	Top of descent. 97.5 DME inbound to Girona VOR.
21:17:04	Level off at FL130, 23 DME inbound to VOR.
21:18:12	Further descent initiated. ATC handover to Girona Approach.
21:18:35	Speedbrakes extended at 16.5 DME inbound to VOR.
21:19:46	Cleared for VOR/DME approach to Runway 02. Girona surface wind 330°/8 kt. QNH 1010.
21:20:53 to 21:21:20	Crew carry out approach checklist.
21:21:46	Cabin crew advise of possible lightning strike. 3 DME inbound to VOR.
21:22:26	Passed overhead VOR at 7,200 feet. Girona surface wind 330° / 9-12 kt.
21:23:20	Fuel checked as 4.2 tonnes.
21:23:58	Levelled off at 5,000 feet. 5.75 DME outbound.
21:24:23	Furthest outbound before turning in to beacon 6.25 DME.
21:25:45	Girona surface wind reported as 350° / 12 kt.
21:26:29	Passed overhead VOR at 5,000 feet.
21:26:58	Flap 1 selected.
21:27:33	Further descent initiated whilst in right turn through 169°M, 3.0 DME outbound.
21:27:43	Flap 5 selected.
21:28:26	First Officer states that the Company Minimum Reserve (CMR) fuel is 2.8 tonnes.

GMT	Event *(continuation)*
21:29:11	Girona conditions reported as: visibility 4 km, scattered 1500, few 3000, CB broken 4000. Thunderstorm over the airfield.
21:29:20	Levelled off at 3,400 feet. 6.5 DME outbound.
21:29:33	Crew discuss possibility of go-around and diversion.
21:30:33	Fuel checked as 3.6 tonnes.
21:31:33	Furthest distance on outbound leg 12.0 DME.
21:32:14	Flap 20 and gear down selected at 10.5 DME inbound.
21:32:34	Further descent initiated at 10.0 DME inbound.
21:32:42	Flap 30 selected.
21:33:01	Speedbrake lever moved from extended to armed at 8.75 DME inbound. Crew start landing checklist.
21:33:12	Girona weather–revised QNH 1011 and wind more southerly at 200°/12 kt. Approach to Runway 20 offered by ATC.
21:33:54	7 DME, 100 feet too high on approach.
21:34:17	6 DME, landing checklist completed.
21:34:43	5 DME, 250 feet too high on approach.
21:35:12	4 DME, 200 feet too high on approach.
21:35:31	Windshear caution.
21:35:35	3 DME.
21:35:37	840 feet (474 feet radio height), 138 kt, go-around initiated.
21:35:43	Minimum altitude during go-around 820 feet (429 feet radio height).
21:35:46	Flap 20 selected.
21:35:53	Gear up selected.
21:36:22	Flap 5 selected.
21:36:43	Passed overhead VOR climbing through 3,450 feet at 201 kt. Flap 1 selected.
21:37:03	First Officer reported «right forward fuel pump» warning, Commander acknowledged.
21:37:12	Barcelona weather reported as: wind 360°/10 kt. Scattered at 3000.
21:37:43	Levelled off at 5,000 feet, 3.5 DME outbound.
21:37:48	Commander elects for ILS approach.
21:38:14	Flap selected up.
21:38:22	Flap 1 selected.
21:38:28	Cleared for ILS approach to Runway 20. Wind 190°/15 kt. RVR 1500, scattered 1400.
21:38:50	Flap 5 selected.

GMT	Event *(continuation)*
21:39:15	Commander asked First Officer to brief cabin crew for one further approach followed by a diversion to Barcelona.
21:39:52	Start of base leg turn for Runway 20 at 10.75 DME.
21:40:25	Descent initiated at 12.25 DME outbound.
21:40:30	First Officer alerts Commander to «FMC message, insufficient fuel».
21:41:03	Crew conduct approach checklist.
21:41:23	Furthest north on base leg 14.5 DME at 4,300 feet descending.
21:41:48	Localizer established. Surface wind 170°/12 kt.
21:42:35	Levelled off at 3,700 feet, 11.5 DME inbound.
21:42:46	Flap 20 and gear down selected at 11.0 DME inbound.
21:42:58	Fuel checked by Commander as 2.8 tonnes.
21:43:15	Autobrake four selected.
21:43:18	Glideslope captured and further descent initiated at 9.25 DME inbound.
21:43:24	Revised QNH 1012 and confirmation that the runway was «quite wet».
21:44:18	FMC message noted by the crew.
21:44:20 to 21:44:43	Sound of outer marker beacon.
21:44:35	Aircraft cleared to land. Wind reported as 150°/9 kt.
21:44:56	Crew conduct landing checklist.
21:45:01	First Officer speed call of «bug minus ten» (speed 10 kt below target).
21:45:08	First Officer speed call of «on the bug».
21:45:10	Descended through 2,200 feet at 4.25 DME inbound, flap 30 selected.
21:45:27	Windshield wipers turned on.
21:45:53	First Officer call of «bug plus five, thousand down» (speed 5 kt above target; one thousand feet per minute descent rate).
21:45:59	First Officer call of «thousand above touchdown».
21:46:21	First Officer speed call of «bug plus ten».
21:46:22	Descended through 1,130 feet at 1.0 DME inbound, windshear caution recorded on the DFDR.
21:46:30	Descended through 1040 feet at 0.75 DME inbound, windshear caution recorded on the DFDR.
21:46:30	First Officer speed call of «bug plus fifteen».
21:46:32	Commander call of «lights in sight».
21:46:40	First Officer call of «bug plus ten, eight hundred down».

GMT	Event *(continuation)*
21:46:47	Commander call of «contact».
21:46:49	Start of the sound of middle marker beacon passage.
21:46:54	First Officer speed call of «bug minus five». Power levers advanced and aircraft started to pitch up.
21:46:55	Aircraft seen by tower, surface wind reported as 150°/6 kt.
21:46:58	Descended through 705 feet (approx 250 feet agl), autopilot and autothrottle disconnected. Pitch attitude approximately 4.5° nose up. Start of large excursions in controlinputs. Aircraft started to rise above glideslope.
21:47:00	Aircraft pitched down to between –1° and +1°. Still above glideslope.
21:47:02	First Officer call of «on the bug, six hundred down».
21:47:10	Descended through 590 feet (approx 120 feet agl). Muted exclamation heard on commander's CVR channel and momentary near full nose down elevator followed by left then right on control wheel was applied. Aircraft pitched down with load factor of 0.55g. First Officer vertical speed call of «five hundred down».
21:47:11	First Officer call of «full scale fly down».
21:47:12	Aircraft had temporarily pitched down to 4.5° nose down with increased descent rate.
21:47:13.0	Aircraft pitch raised slightly to 2.5° nose down. GPWS Mode 1 caution «SINK RATE» started between 80 feet and 54 feet radio altitude.
21:47:14.5	First Officer vertical speed call «thousand down» and second GPWS «Sink Rate».
21:47:15.9	Automatic height call «Ten».
21:47:16.2	Power levers brought back to idle.
21:47:16.8	Aircraft touched down at 2° nose down pitch, pitch rate 1°/sec nose down, wings level at 141 kt airspeed. Peak normal acceleration of 3.11g. Rate of descent approximately 14 ft/sec (840 ft/min). Air / ground logic not activated, no ground spoiler deployment.
21:47:17.6	Aircraft bounced, pitching up to 3.3° nose up, power levers advanced. Clockwise control wheel input made-right roll started. Full nose down elevator applied and held–rapid pitch down.
21:47:18.7	Second touchdown at 0.5° nose down pitch, pitch rate 7°/sec nose down, 4.2° right wing down roll. DFDAU / DFDR lose 11 bits of data. Start of large impact noise on CVR but no «g spike» on normal acceleration recording. Control column and elevator returned to neutral.
21:47:19.1	Pitching down through 6.8° nose down, right roll increasing through 5.3°, EPR both engines increasing through 1.27. Air / ground logic not activated, no ground spoiler or thrust reverser deployment.
21:47:19.3	Recording on CVR and DFDR cease.

1.11.6. *Wind speed, direction and windshear*

Wind speed and direction was recorded on the DFDR, as were two discrete parameters for windshear caution and windshear warning. During the latter stages of the ILS approach the wind recorded onboard the aircraft backed round from northerly through westerly to southerly as the aircraft descended and two instances of windshear caution were recorded. The first, at a height of approximately 800 feet agl, was coincident with an increase in recorded airspeed of 8 kt and reductions in angle of attack and normal acceleration for approximately 2 seconds. The second instance, eight seconds later at a height of approximately 540 feet agl, also coincided with temporary reductions in angle of attack and normal acceleration but this time with a momentary reduction in airspeed.

Although the final stages of the approach were relatively turbulent, as indicated by the excursions in normal acceleration and the magnitude of control inputs made by the crew, no further evidence was found of significant windshear activity during the remainder of the flight. In an attempt to verify that the windshear detection system on the accident aircraft was serviceable, the aircraft manufacturer was requested to program the DFDR data into their B757 simulator to confirm that further instances of windshear caution or warning would not have been triggered. The manufacturer reported the following:

«This analysis shows that insufficient conditions existed at the time of approach to generate significant windshear that would affect the performance of the airplane; the simulator results agree with the FDR [Flight Data Recorder] that only a windshear pre-alert condition occurred due to the headwind.»

1.11.7. *CVR aural warnings*

During the first approach, when Flap 30 was selected, the speedbrakes were still in the deployed position. In this configuration the «SPEEDBRAKES» light on the warning/caution indicator panel would have illuminated and a «SPEEDBRAKE EXT» message would have appeared on the Engine Indication Crew Alerting System (EICAS) displays. There was no associated aural warning or master caution indication. The presence of either of the above visual alerts was not recorded on the DFDR. The alerts would have been removed when the speedbrake lever was subsequently selected to the ARMED position.

Although both windshear cautions and warnings were recorded on the DFDR, the customer option fitted was such that only a windshear warning would have resulted in aural and visible warnings to the crew.

It was noted that, when the autopilot was disconnected prior to the final landing, there was no associated audio warning tone recorded on the CVR. The operator of the aircraft stated that the aircraft was fitted with a customer option which inhibited the audio warning if the autopilot was disconnected by double-clicking the autopilot disconnect button on either control column.

1.12. Crash site and wreckage examination

1.12.1. *Crash site*

1.12.1.1. General description

A series of markings and items of wreckage attributable to G-BYAG's landing were found on the surface of Runway 20 and its surrounds. Aircraft positions given below are datumed on the estimated position of the aircraft center of gravity (CG) from the start of the Runway 20 tarmac surface, measured along the aircraft's track. The positions are outlined in Figures 18 and 19 and distances are summarised in Figure 20 of Appendix A. The terrain heights given were estimated. The Runway 20 heading was measured at 197°M. This value is included on the Jeppesen Chart (see Figure 2 of Appendix A).

1.12.1.2. Initial part of runway

The initial set of marks commenced 566 meters from the start of the runway tarmac surface, near the centreline. Close examination of the runway surface between the start of Runway 20 and the initial marks found no other markings that could be positively attributed to G-BYAG.

The initial markings (Fig 21) consisted of shallow gouges in the runway surface and scraped deposits of paint and/or metal. The spacing and characteristics of the markings, in conjunction with witness markings on the wreckage, indicated that the initial marks had been made by contact of parts of the NLG doors and the NLG doghouse with the runway. This had been closely followed by a light, momentary contact of the underside of the No 2 engine nacelle. Measurement showed that when the initial contact of the forward fuselage parts occurred the aircraft CG had been positioned 557 metres along the runway and 3 metres right of the centreline. The markings from the forward fuselage parts became lighter as the scraping continued and faded out after around 24 metres.

After an interval of 53 metres, a second set of markings commenced, with the aircraft positioned 644 metres from the start of the runway and 2 metres right of the centreline (Figure 22). The runway and wreckage markings indicated that they had resulted initially from further contact of parts of the NLG doors and the NLG doghouse with the runway (Figure 23.1). This had been followed after 11 metres by brief runway contact of the fuselage nose undersurface and then by a second momentary contact of the No 2 engine nacelle (Figure 23.2). The markings again became lighter as the scraping continued and faded out after 39 metres. No further runway scrape marks were evident, except for minor markings as noted in Section 1.12.1.3.

A number of small wreckage items that had clearly detached from G-BYAG were reportedly found on the runway (Figure 23.3) but were collected before site examination started and specific information on their original position was not available. The identifiable items were from the NLG bay area.

Numerous small wreckage items remained on the grass margins of the runway after the runway clearance. It appeared that the location of some of these could have been altered by the effects of wind and by runway sweeping operations but the available position evidence indicated that they had not detached prior to the initial runway marks. A group of these items was found between 550-900 metres along Runway 20. Some were positively identified as having originated from the NLG bay and the engine fan cowl areas; other had characteristics that were fully consistent with their having originated from the NLG wheelwell/doghouse, the lower part of the forward fuselage, the MEC, the engine cowl and cable/pulley control systems. A further group of similar items was found between 1,400-1,700 metres along the runway.

1.12.1.3. Central part of runway

A short distance beyond the end of the scrape markings three pairs of tyre tracks were visible on the runway, initially faint but becoming more defined with distance along the runway.

The tracks had a lateral spacing corresponding to that for the three landing gears on the B757 and led unbroken into tyre tracks across the runway surround that were undoubtedly from G-BYAG. It was thus clear that from the end of the 2nd runway markings the aircraft was running on all three landing gears, despite the evidence indicating that the NLG had been displaced. The tyre tracks indicated that the aircraft initially had run generally fairly centrally on the runway, deviating left and right of the centreline by a few metres. The tracks showed that it began a sustained turn to the right 1,187 metres from the start of the runway and at 1,557 metres (along track) departed the runway shoulder onto the grass surround.

Over the latter part of the run, some signs of slight runway surface scraping associated with the nosewheel tyre tracks were apparent in places, suggesting momentary tyre dragging. There was also one small area of paint deposition and runway surface gouging; the location and characteristics suggested momentary contact of the NLG/fuselage nose region.

Also in the latter part of the run, the outboard tracks (Tyres 1/5 and 4/8) showed similar signs of momentary tyre dragging. Black rubber-like deposits apparent in these two tracks shortly before they departed the runway suggested that Tyre 1 and/or Tyre 5 and Tyre 4 and/or Tyre 8 had intermittently skidded in this region. Near the runway shoulder, the left outboard track deposits developed into two narrow continuous black trails corresponding to the tyre shoulder spacing, indicating that Tyre 1 or Tyre 5 was running deflated at this point (Figure 24.1).

1.12.1.4. Margins of the runway

Tracks from all three landing gears continued across the grass surface towards the airfield boundary (Figure 24.2). This area had a slight downslope to the west. Two detached tyre fragments, around 45 × 15 cm (18 × 6 inch) in size, were found close to the left MLG tracks shortly after they departed the runway.

The central track initially consisted of a single tyre track together with a light scrape mark around 1 metre to its right. After passing over a dip in the ground the central track altered, with two tyre tracks then becoming apparent and the scrape mark diminishing. A pair of wheel tracks on either side of the central track had clearly been made by the MLG tyres. The ground was somewhat soft and the MLG tyre tracks were impressed into the surface, initially by a few centimetres. Shortly after entering the grassed area the depth of the right MLG tracks began a marked oscillatory variation, giving a sinusoidal vertical profile (Figure 24.3). The characteristics clearly indicated that this feature had been caused by a marked pitch oscillation, or «nodding», of the right MLG truck. The manufacturer of the aircraft later noted that they considered that fore/aft movement, or «gear walk» of the landing gear associated with a fracture of the gear support structure could have contributed to the nodding. The nodding was sustained for the remainder of the run across the grassed area.

1.12.1.5. Off the runway

At the edge of the grassed area, 343 metres after departing the runway and about 1.5 metres (5 ft) below the runway level, the aircraft encountered the earth mound (Section 1.10.3) on the airfield boundary (Figure 24.4). In the direction from which G-BYAG had approached the mound a concave slope led up from the grassed area to the road; above the road the eastern face of the mound sloped up at around 45°. There was an area of trees growing on the western side of the mound and there were several isolated trees nearby on the south side.

G-BYAG's contact with the mound was oblique and ground marks showed that it was initially made by the right MLG wheels, closely followed by the undersurface of the No 2 engine nacelle. As the right MLG and nacelle climbed the bank, the left MLG wheels descended into a depression and an area of particularly soft ground associated with a buried drainage conduit. It was clear that the combined effect would have caused the aircraft to assume an appreciable left roll angle. Geometric considerations indicated little or no ground clearance of the left wing tip at this point, but no evidence was found that contact had occurred.

A local deviation in the left MLG tracks indicated that the drag restraint for the left MLG leg had failed as the wheels encountered a sharp lip in the terrain at the eastern edge of the road (Figure 25.1). A subsequent absence of ground marks from this gear, together with evidence of a lack of contact of the left wing with a nearby tree, suggested that the encounter of the left MLG with the slope and the lip had the effect of reducing the aircraft's left bank.

Furrows in the face of the mound from the right MLG tyres suggested that the right MLG had experienced high vertical and drag loads as its truck climbed the mound. The markings did not indicate that the landing gear had collapsed as a result, but it appeared possible that damage to the landing gear or its support structure could have occurred at this point.

Ground contact marks ceased as the aircraft crested the mound (Figure 25.2) and it appeared that the passage over the mound propelled the aircraft out of ground contact. Damage to the upper branches of the trees growing on the western side of the mound was indicative of contact by the right wing with the aircraft approximately level in roll.

1.12.1.6. Boundary fence

The ground sloped downwards from the top of the mound in the direction of aircraft travel. Wreckage distribution and markings showed that around 100 metres after the aircraft topped the mound, the No 2 engine nacelle contacted the airfield boundary fence. This was a 2.5 metre high steel chain-link fence carried on steel posts. The aircraft's contact with the fence was at a shallow angle and an approximately 100 metre length of the fence was damaged or destroyed. Substantial parts of the No 2 nacelle detached at the point of collision with the fence. The evidence also showed that the NLG and the doghouse had contacted the fence, become entangled in the chain-link and separated from the aircraft as a unit, coming to rest just outside the airfield boundary.

1.12.1.7. Off airport

Markings and wreckage distribution showed that the aircraft then made ground contact in a field outside of the airfield boundary, 144 metres after the mound and an estimated 12 metre (40 feet) below the level of the mound's summit. Available evidence indicated that the aircraft was approximately level in pitch and roll at touchdown. The field was level and relatively flat, with dense sodden soil with a short crop. It was clear that the touchdown was heavy and probably made with a substantial right yaw angle.

Shortly after touchdown both MLGs collapsed. G-BYAG slid across the field on its engine nacelles for a distance before both powerplants detached. The main wreckage of the aircraft came to rest after a slide of 244 metres across the field. A number of craters and extensive furrows were evident in the field, clearly the result of the aircraft's landing and ground slide. The scale of the cratering suggested high touchdown retardation forces. The considerable length, depth and width of some of the ploughed furrows was indicative of very substantial and sustained drag forces on the aircraft during this part of its ground run.

G-BYAG came to rest around 65 metres outside the airfield boundary, almost level with the end of Runway 20, 1,734 metres along the ground track from the initial runway marks and an estimated 8-9 metres (25-30 feet) below the local level of the runway.

1.12.2. *Wreckage*

The wreckage examination was mostly carried out in the field, with limited facilities, partly in concert with a prolonged salvage operation. A complete assessment of the complex, multiple impact damage sequence was not possible in all areas but adequate evidence was available to cover the relevant aspects.

1.12.2.1. Fuselage

The main part of the aircraft came to rest on the undersurface of the fuselage and the No 1 powerplant pylon, with the centre fuselage and wings heading 263°M. The fuselage sustained two circumferential fractures. Pipelines and electrical cable looms traversing the fracture areas had apparently helped to prevent complete separation of the fuselage sections.

The forward fracture was at around Sta 615 (just forward of the No 2 doors). The fracture, through the skin and stringers, appeared to extend around the complete circumference (Figure 26.2). The crown skin had suffered compressive buckling at the fracture and the lower cheeks had deformed outwards on both sides. The evidence suggested that the fracture had resulted from heavy ground contact of the forward fuselage undersurface, combined with right yaw bending loads on the forward fuselage.

The aft fracture was at around Sta 1275 (just forward of the No 3 doors). It extended around most of the circumference (Figure 26.4) but part of the right sidewall remained intact. There was severe compressive buckling on the left side. The evidence indicated that the failure had been caused by overload in bending in the horizontal plane, with the rear section yawing right of the centre section.

The three fuselage sections remained together but with the forward section yawed 12° right and the rear section yawed 13° right relative to the centre fuselage section. All three sections were approximately level in pitch, and rolled left, up to 16°; cabin floor angles are given in Section 1.12.2.7.

Much of the fuselage suffered extensive undersurface deformation and disruption. From the damage characteristic it appeared unlikely that the forward fuselage had suffered major deformation or fracture as the result of the loads that caused the NLG displacement (Section 1.12.2.2), but the possibility that a buckling failure had resulted could not be totally dismissed.

Areas of deformation of the fuselage nose undersurface area and associated abrasion damage to the outside skin were apparent, somewhat biased towards the right hand side. The forward equipment bay access hatch (Figure 26.3) and portions of the NLG bay doors had also suffered abrasion damage. The abrasion generally affected only the paint layer and the skin surface. The marking was even and aligned with the longitudinal axis of the aircraft, with features indicating local distortion occurring as the abrasion occurred. The characteristics indicated that the damage had generally been caused by comparatively brief scraping contact of the aircraft's nose with the runway surface. The corner of the fuselage where it joined the right side of the wheelwell had been more heavily machined, indicating a more prolonged contact.

Much of the fuselage structure below cabin floor level in the region of the MEC detached, particularly on the right side (Figures 26.1 and 26.2). Many of the MEC electrical and electronic units were severely disrupted. Wreckage distribution indicated that some had detached during the latter parts of the ground run. The fuselage and MEC damage appeared consistent with the combined effects of disruption caused by doghouse displacement and eventual detachment (Section 1.12.2.2) and, in the latter parts of the ground trail, by heavy, sliding ground contact with the aircraft yawed right. Severe local damage to the cabin floor beams above the doghouse position occurred, particularly between the floor beams at Sta 365 and Sta 395 (Figure 27.1), consistent with the effects of impact by the aft upper portion of the doghouse. Overall, floor beam damage was particularly marked in the area extending around 1 metre left to 0.5 metre right of the fuselage centreline between approximately Sta 360-418.

In the region of the forward baggage bay, upward displacement of the fuselage undersurface structure caused the baggage to be crushed up against the underside of the cabin floor.

Damage to the empennage was limited to small chips on the left side of the fin and minor denting to the leading edge of the left horizontal stabiliser. The rudders and elevators showed no signs of damage.

1.12.2.2. Nose landing gear and support structure

The NLG bay structure fractured near the junction between the wheelwell and the doghouse. The wheelwell structure remained attached to the fuselage and approximately in position but displaced upwards, and somewhat to the right, in conjunction with upward crushing of the fuselage undersurface (Figure 27.1). The wheelwell came to rest in contact with the underside of the cabin floor beams.

Local damage characteristics suggested that the frame at Sta 395, attaching the aft end of the doghouse to the fuselage, had buckled on either side of the doghouse due to upward overload.

The wheelwell/doghouse sidewalls had fractured in tension overload; the forward part of the doghouse roof had suffered compressive buckling and separation from the sidewalls. These and other features indicated that the support structure failure had probably initiated with failure of Frame 395. The doghouse had then rotated anticlockwise (in the vertical plane, viewed from the left) and separated from the wheelwell. The sequence was consistent with the effects of upward and aftward overload on the NLG wheels.

A portion of the doghouse sidewall on each side carrying the NLG drag strut trunnions was torn out; these remained attached to the pintles (Figure 29.2). There were signs that the NLG leg had pivoted back somewhat relative to the doghouse and contacted the doghouse aft bulkhead. Markings were also found consistent with contact of the NLG torque links with the underside of the fuselage beneath the MEC. Abrasion was evident on several parts of the doghouse. This was heavy on one edge of the left pintle sidewall portion, to the extent that the fractured edge had been rounded. Lighter abrasion damage was present on the right pintle sidewall portion and on the lower central part of the doghouse forward edge.

The doghouse fractured away from the fuselage undersurface structure and detached from the aircraft in the latter part of the wreckage trail (Figure 29.1). It appeared likely that the damage to the right side of the lower fuselage in the region of the MEC, with the structure torn and heavily deformed to the right, had largely been caused by the passage of the NLG and doghouse through this area.

The NLG remained intact and attached by its leg trunnions to the remains of the doghouse. The paint and metal surface on parts of the steering actuators had been eroded, apparently by a particulate blasting type process. The left tyre had an extensive cut and was found deflated. The right tyre was found inflated to 170 psig.

1.12.2.3. Control cables running in fuselage

The control cables running through the cabin floorbeams had been damaged, with idler pulleys disrupted and cables jammed and/or severed, as follows:

System	Cable Damage
Rudder	RA and RB intact in forward fuselage
Aileron	A1B severed at Sta 390
Aileron	A2B severed at Sta 350
Elevator (System 2)	E2B severely distorted and partially severed at Sta 300
Flaps	WFA severed at Sta 350
Flaps	WFB severed at Sta 350
Wheelbrakes	LGB4A severed at Sta 350
No 1 Powerplant	TLA intact from forward pulley to pylon pulley
No 1 Powerplant	TLB severed at Sta 377
No 2 Powerplant	TRA intact from forward pulley to pylon pulley
No 2 Powerplant	TRB severed at Sta 304

Given the disruption and the possible effects of the fuselage breaks the above damage Stations are approximate. However, the cable damage was particularly marked in the region of severe floor beam damage above the NLG support structure (Figure 27.2). The evidence strongly indicated that the cables had been damaged by impact of the doghouse, and possibly the wheelwell, either directly or by disruption of the floor beams through which the cables passed (Figure 28). It appeared quite possible that interference by the damaged floor beams could have jammed the control cables that remained intact.

1.12.2.4. Main landing gear

The left MLG was found with both the sidestay lock fuse and the leg forward trunnion fuse failed, consistent with the effects of rearward overload on the truck. The failure was not totally in accordance with the design intent but no damage to the wing torque box resulted. The gear had displaced to the right and came to rest underneath the fuselage, with the truck embedded into the aft cargo bay. No signs of tyre skidding or aquaplaning were found.

In the case of the right MLG the rear support beam fractured in bending, consistent with the effects of upward overload applied at the aft trunnion. A fractured part of the beam was found lying on the upper surface of the right wing. The aft trunnion and the inboard part of the beam had pushed upwards, through the wing trailing edge panels, and this had apparently caused the forward trunnion bearing to fracture. The sidestay lock fuse had failed. The leg trunnion fuses remained intact but no damage to the wing torque box resulted. It appeared that the failures had been caused by an upward and rightward overload on the truck.

The aircraft manufacturer calculated, based on FDR data, that the right MLG shock strut would have fully compressed at the second touchdown, immediately before the end of the FDR recording. After failure of its supports, the right MLG displaced somewhat aft and came to rest at an angle just behind the wing root training edge, damaging the inboard flap (Figure 29.3).

Thus neither MLG collapse was completely in accordance with the design intent. As this was of interest to the aircraft manufacturer but not considered central to the investigation, it was agreed that the manufacturer's landing gear representative would carry out the detailed investigation and report on the failure modes. This report was submitted to the investigation team.

The evidence indicated that passage over the mound caused failure of the drag support for the left MLG leg and may also have initiated failure of the right MLG and/or its support structure. Both MLGs then contacted the ground hard when the aircraft touched down in the field and both legs completely collapsed at this point. All failures were fully consistent with the effects of excessive vertical and/or drag loads.

1.12.2.5. Powerplants

Both engine nacelles were found in pieces in the latter part of the trail, consistent with their detachment as the result of impact with the fence and/or the ground after the MLG collapse. Both engines had clearly been torn off their pylons during the aircraft's slide across the field, coming to rest some metres before the aircraft. The pylons remained attached to the wings. Both engines suffered severe external damage. Extensive examination was not possible.

Four of the six actuators for the thrust reverser translating cowl on the No 1 engine and five of the No 2 engine actuators were identified. All were found fully retracted and features of the actuators made it unlikely that they had been moved to this position by impact forces. The available evidence therefore indicated that both thrust reversers had been in the forward thrust position. Fan blade deformation and leading edge damage showed that the fan on each engine had been rotating at the time of powerplant ground contact. The features suggested that the No 1 engine fan had probably been at relatively high speed and the No 2 engine fan at intermediate speed.

The FMU from each engine was examined in detail at the FMU manufacturer's facility under the control of a member of the investigation team with the aim of quantifying the power settings at the time of aircraft touchdown in the field. The units were robust and the examination indicated that they had received insufficient shock loading to cause positive witness marking. It was clear that the settings were likely to have been altered by the disruption associated with the engine detachment and no reliable conclusions as to the settings at the time of the field touchdown could be reached.

1.12.2.6. Wings

The wings remained substantially intact, but with severe local damage. There were some signs that the left wing tip had made ground contact, but without appreciable damage having resulted. Most of the leading edge slats and flaps had suffered impact damage, consistent with strikes on the trees and possibly collision with items detached from the aircraft. Some of the devices had been partially torn off; those that remained in place appeared to be fully deployed. The trailing edge flaps generally did not suffer extensive damage; all were found deployed at around 30°.

All spoiler panels were found fully retracted. It was reportedly usual for some of the spoilers to retract under the influence of gravity after the loss of hydraulic pressure, but not for all of them to do so. The panels were generally undamaged, suggesting that they had been retracted at the time the aircraft struck the trees and during its slide across the field.

The wing torque boxes were generally undamaged, but an area of the underside of the left torque box inboard of the No 1 powerplant had been heavily distorted, with associated extensive fracture of the skin. It appeared likely that the damage, which penetrated directly into the inboard underside of the left main fuel tank, had been caused by impact with the No 1 engine after its detachment.

1.12.2.7. Passenger cabin

The cabin remained generally intact, but with severe local disruption in the region of the two fuselage breaks (Figure 30). This affected the cabin floor, passenger seats, overhead baggage lockers, ceiling panels and one television monitor.

The cabin floor at the forward break was not greatly disrupted, but the floor beams between Seat Rows 5-7 were fractured on the left side, apparently due to local deformation of the cabin lower sidewall, and the associated floor panels were appreciably distorted. This created a slope in the floor and areas of unevenness and increased flexibility but did not represent a significant incursion into the cabin space. It did appear to have contributed to the release of a number of seat row attachments. In the area of the rear cabin break the floor suffered local compression buckling and the floor beam at Sta 1200 displaced upwards. This created a steep lateral ridge, approximately 20 inch high on the left and 2 inch high on the right, severely displacing passenger seat rows in the area and causing some to detach (Figure 31.3). The shrouded APU fuel supply line running through cut-outs in the floor beams was damaged but apparently not ruptured.

The relative displacement of the three fuselage sections, in combination with the distortion, produced overall floor angles relative to the horizontal as follows:

Cabin Section	Pitch Angle	Roll Angle
Forward-forward part	2° nose up	16° left
Forward-aft part	2° nose down	8° left
Centre	2° nose down	8° left
Rear	2° nose up	13° left

Many of the seat rows throughout the three cabin sections were distorted, with the leg structures parallelogramed to the left, clearly due to inertial deceleration loads. The right hand seat rows were particularly affected (Figure 31.2), consistent with most of the left hand seats having been supported by the fuselage sidewall. Leftward distortion of left seats (Rows 7L and 8L) had also occurred where the sidewall had deformed outwards. The side loading did not apparently cause severe structural damage to the seats; the badly damaged and detached seat rows were all in the regions of floor damage.

The floor damage in the forward cabin associated with the fuselage forward break and fuselage deformation caused a number of attachments, or portions of the rails, for seat Rows 4L to 10L to release from the floor, although none of the rows completely detached. On the right hand side, four seat rows were severely damaged and two of these completely detached. At the fuselage rear break four seat rows detached from the floor (Rows 28L, 28R, 29L and 29R). They remained generally in place. Row 29L had been rammed against the forward wall of a toilet unit located immediately behind it and Rows 27L, 28L and 29L had been pushed into contact with each other due to the local concertina effect on the left side of the cabin.

A number of the cabin overhead baggage lockers were displaced, due to a combination of mounting rod fracture and locker bracket insert detachment. The aft attachments for the Seat Row 8L/9L locker failed and the aft end of the locker dropped to 15 cm (6 inch) above the seat backs and the Seat Row 10L/11L locker completely detached and was found lying in the aisle. Either forward or aft attachments for Seat Row 8R/9R, 10R, 25/26L, 28/29R and 30R lockers also failed; none of the lockers displaced appreciably but the door of the Row 8/9R locker detached and was found in the aisle. All the locker attachment damage was consistent with the effects of the fuselage breaks and associated distortion.

An appreciable number of PSUs displaced. In most cases the associated oxygen masks deployed and were hanging down. Nineteen of the PSUs were found unlatched and hinged open to the extent allowed by the lanyard. In one case (Seat Row 9R) one of the composite hinges had fractured and the PSU remained attached by the other hinge and the lanyard, with its lower corner having dropped around 56 cm (22 inch). In three cases (Seat Rows 27R, 30R and 41R) both hinges had fractured and the PSU remained hanging on the lanyard, with the lower edge having dropped around 84 cm (33 inch).

Additionally, approximately 15% of the seatback trays were found down.

Cabin furnishings generally remained in place but some items in the area of the fuselage breaks were displaced. Near the forward break the conditioned air duct running above the aisle disconnected at Seat Row 5 and the end dropped to 38 cm (15 inch) above the seat backs. The video monitor mounted on the duct partially detached and dropped onto the top of the Seat 6R seatback (Figure 31.1). A number of ceiling panels in the area displaced and/or detached. At the fuselage aft break the door of the rearmost toilet had detached and was found in the rear cabin. One centreline ceiling panel had dropped 13 cm (5 inch) on its lanyard.

Additionally, the battery pack for the aisle exit sign just forward of Door 3 detached and was found hanging on its lead by Seat Row 30R. The pack, which weighed 2 kg, dropped to around 69 cm (27 inch) below the level of the PSU covers. The similar pack for the Door 3R exit sign also detached and was found hanging on its lead in front of the door 53 cm (21 inch) below ceiling level.

Checks of the cabin portable safety and emergency equipment indicated that all the scheduled items had been in place and serviceable. All cabin crew seats were found stowed.

1.12.2.8. Doors and escape slides

Examination of the cabin doors and escape slides found the following:

No	Door	Slide
L1	Found fully open, door assist bottle discharged	Dropped 0.6 m to ground, not inflated
R1	Found cracked open. Slight further movement towards open caused assist bottle to fire and door to fully open	Found armed, not deployed
L2	Door found fully open	Inflated
R2	Door found fully open	Inflated
L3	Found closed. Load required to fully open handle generally 50 lb, occasionally 100 lb	Found armed, not deployed
R3	Door found fully open	Inflated
L4	Door found fully open	Dropped 0.6 m to ground, not inflated
R4	Found cracked open with door assist bottle discharged	Found armed, not deployed

Thus 5 of the 8 doors were found open. Manual operation of each cabin door was checked during the investigation. Handle operating loads were generally in the range

40-129 Newton (9-29 lb), with the exception of Door L3 (see above). Opening loads for the doors on the right side were relatively high as a result of the fuselage left roll attitude. Single person operation of these doors without power assist was found to be marginal, or in some cases impossible, because of difficulty in gaining sufficient purchase on the floor carpet. No other problems with handle loads or door opening or closing were found, with the exception of Door L3. Examination indicated that the excessive handle load on this door was consistent with the effects of slight fuselage distortion in the doorframe area associated with the compression damage at the left side of the fuselage aft break.

The 5 slides associated with the opened doors deployed. Three of them inflated but, with the aircraft's fuselage on the ground, remained at a shallow angle. The other two did not inflate because they did not drop far enough to operate the automatic inflation lanyard.

1.12.2.9. Flight deck

The flight deck remained undamaged, with the exception of fracturing and deformation of the floor on the right side and some floor deformation at the rear. The right side of the floor beneath the right pilot's seat had displaced around 13 cm (5 inch) downwards and the two rear attachment fittings for the seat had failed and detached from the floor, consistent with the effects of the floor damage. The seat was found displaced forward, but remained upright.

Signs were found that the commander's head had struck the post forming the left side frame of the left windscreen (Figure 32.1) The trim appeared to be a thin, rigid plastic layer applied directly to the structure with little or no padding.

A 1 litre (ltr) bottle of drinking water was found in the tunnel for the captain's right rudder pedal (Figure 32.2) and a crew member's flight bag was found loose on the flight deck floor. No suitable secure stowage on the flight deck for either of these items was identified.

As-found flight deck control settings and instrument indications of possible relevance were as follows:

Control/Instrument	Left	Right
Pilot's seat shoulder strap selector	Lock	Lock
Airspeed Indicator Pointer (kt)	<60	143
Airspeed Indicator Digital Display (kt)	0	143
Altimeter Subscale (mb)	1,012	1,012.5

Control/Instrument *(continuation)*	Left	Right
Standby Altimeter Subscale (mb)	1,012	
Flap Selector (°)	30	
Speedbrake Lever	Armed	
Landing Light Selector	Both On	
Runway Turnoff Light Selector	Both On	
Nose Gear Light Selector	On	
Wiper Selector	High	
Emergency Light Selector	Armed/guarded	
Overhead Circuit Breaker (CB) Panel	12 CBs tripped	
Right aft Circuit Breaker (CB) Panel	3 CBs tripped	

1.12.2.10. Electronic Units

Some electronic units from the MEC survived the accident apparently relatively unscathed. The following units were returned to their manufacturer for attempted retrieval of data from their electronic memories in order to obtain information on the aircraft's behaviour after the DFDR had ceased recording:

EICASC (Engine Indicating & Crew Alerting System Computer)	2 off
FMC (Flight Management Computer)	2 off
GCU (Generator Control Unit)	2 off
APU GCU (Auxiliary Power Unit Generator Control Unit)	1 off
BPCU (Busbar Power Control Unit)	1 off
EFISSG (Electronic Flight Indication System Symbol Generator)	3 off

It was reported that undamaged non-volatile memory was generally not present and no data was obtained.

1.13. Medical information

Forty-four persons, including the aircraft commander, received hospital treatment. Information on the injuries sustained by the passengers and crew was not made available to the investigation by the hospital.

A passenger who was taken to hospital apparently with minor injuries and released next day, died five days later. Medical evidence indicated that the death had resulted from internal injury to which he may have been more susceptible due to a pre-existing medical condition.

The pilot in command suffered a short period of loss of consciousness during the accident at some time after the aircraft departed the runway. He suffered a blow to the head which corresponded with visible signs of an impact against the frame member between the left windscreen and the left side window.

Some two months following the accident the aircraft commander underwent an opthalmological examination. The examination showed that there were no abnormalities present which could account for any sudden loss of visual reference and the report thereby concluded that the loss of visual reference described by the commander was not as a result of any disease in the visual pathways.

1.14. Fire

There was no fire.

1.15. Survival aspects

1.15.1. *The accident*

The cabin crew members were interviewed during the week following the accident and during the following week questionnaires were sent to all the passengers. Responses were received from approximately 160 of the passengers. The cabin crew and passenger accounts were generally as follows.

All of the cabin occupants had been secured by seat belts at the time of touchdown. The first touchdown of the aircraft was described as a heavy landing, followed by a second much heavier impact during which some overhead lockers and PSUs opened. The main interior lights failed at the second touchdown but the emergency lighting appears to have illuminated immediately in all cabin sections. The progress along the ground run was accompanied by an increasing lateral shaking of the airframe, which some passengers considered caused minor injuries such as bruising or strains. Passengers and cabin crew reported having been thrown upwards against their seat belts in the course of the ground run, in some case contacting overhead equipment as a result, but apparently without serious injury resulting.

This was followed by a severe ground impact and high longitudinal deceleration and, as the fuselage yawed right, increasing lateral deceleration, particularly in the forward cabin.

By the time the aircraft had come to rest, considerable floor and seat disruption had occurred in the regions of the fuselage breaks and in the flight deck. The aircraft was approximately level fore and aft but with varying amounts of roll in the different cabin sections. Some cabin overhead fittings had been displaced.

All of the cabin occupants remained conscious and without incapacitating injury. Some passengers had to be released in the area of the cabin breaks where seats had been forced together or where overhead fittings had collapsed onto them.

1.15.2. *Evacuation*

Externally it was dark and raining heavily. Evacuation commenced by the light of the emergency lighting system, with assistance being required by some passengers from the crew and each other in the areas of disruption around the fuselage breaks. The cabin crew had difficulty in opening some of the doors and were assisted by passengers. Hand baggage had to be cleared from some floor areas and to permit door opening. Emergency exit doors L3 and service door R4 could not be opened and R1 door was only partly opened (Figure 26.1). Evacuation slides inflated at L2, R2 and R3. The passengers using the slides bunched up against those in front due to the slides being almost level. The slides rapidly filled with water from the heavy rain, adding to the difficult progress away from the aircraft. At the L1 and L4 doors the power assist functioned and the slides deployed but the drop to the ground was insufficient to cause them to inflate. The passengers stepped onto the ground or slide packs some 12-18 inches below the door sill.

Despite the difficulties encountered, evidence from both passengers and crew indicated that the aircraft had been evacuated rapidly, without external assistance. The exits reportedly used by the passengers relative to their seating positions are shown in Figure 30.

The aircraft had come to rest in a very muddy field, which caused many people to sink up to their ankles, loosing footwear and in some cases becoming stuck and unable to move until assisted. Illumination of the scene was mainly from the lightning flashes and escape from the field was restricted by the airfield fence and a treeline. Apart from several emergency torches no cabin portable emergency equipment was carried off the aircraft. The crew reported that there was not sufficient time for them to collect such equipment during the evacuation.

1.15.3. *Search and rescue*

The rescue services had difficulty locating the aircraft and, having done so, found access to the aircraft impeded by the unbroken portion of the boundary fence and the field conditions. It was reported that at least one passenger had made their own way to the terminal building in the period before rescue was effected.

The Airport's Rescue and Fire Fighting Service's (SEI) difficulties in locating the wreckage of the aircraft were due to the torrential rain and the interruptions in the electricity supply. At 2148 hrs the controller confirmed the alarm and informed the SEI, by dedicated telephone line, that the aircraft had crashed to the south of the airfield, adding that she could not see it but that it must be to the south, at the end of the runway. The vehicles went to the area but the aircraft could not be located at that time.

Records indicated that the sequence of actions was as follows:

At 2154 hrs the search personnel confirmed that they were at the Runway 02 threshold.

At 2154 hrs they confirmed to the Tower that they could not see the aircraft and went along the runway to the Runway 20 threshold.

At 2156 hrs, after communicating with the Tower and confirming the aircraft's landing direction, the vehicles returned to the end of Runway 20. They continued, without locating the aircraft, and decided to move off the runway towards the west, crossing the margin until they reached the perimeter road. Some vehicles got stuck in the margin and reversed without reaching the road.

At 2203 hrs the vehicles managed to reach the perimeter road to the west of the runway. They continued, without being able to locate the wreckage of the aircraft.

Before the aircraft had been located, one of the passengers arrived at the Terminal on foot and provided information on the location of the aircraft.

At 2206 hrs the search personnel informed the Tower that that the aircraft's fuselage had been located and passed its position.

At 2210 hrs the rescue vehicles reached the perimeter fence at the point closest to the aircraft. It took them several minutes, possibly between 5 and 10 minutes, to get through this fence which still separated them from the passengers and the aircraft.

At 2215 hrs outside emergency services arrived at the airport.

At 2220 hrs the SEI personnel reached the wreckage of the aircraft and sprayed it with foam.

The controller put out a call on the Tower frequency asking for the assistance of nurses, doctors and anybody on board the aircraft on the apron, asking them to go to the ATS office in the Terminal.

Witness statements taken indicated uncertainty and communication problems in respect of first aid to the injured and the evacuation of the passengers.

At 2235 hrs the first ambulances carrying the injured left for the hospital. The assembly and transfer of the passengers who had not been injured was carried out with the assistance of buses. The transfer of passengers to the First Aid room in the Airport Terminal was completed at 2300 hrs.

1.16. Tests and research

1.16.1. *Landing gear examination*

The three landing gear legs were examined in an attempt to determine the magnitude of G-BYAG's impacts with the runway, in view of the corruption of some the final DFDR data at the time of the second touchdown and the cessation of the data shortly thereafter. The legs were taken to a maintenance organisation with the aim of establishing, for each MLG, whether the head of the oleo piston had contacted the end of the cylinder and the depth of any resultant indentation.

Both MLG oleos exhibited deformation indicative of high compressive and bending loads. In the case of the right MLG, deformation of the piston and cylinder prevented their separation. Internal boroscope inspection failed to yield positive indications and specialist opinion indicated that the appreciable thickness of the cylinder wall would preclude meaningful results from X-radiography. The deformation of the left MLG oleo was similar and it was decided not to section the cylinders.

1.16.2. *Flight simulation*

An evaluation of the final stages of the approach and landing was carried out in a B757 flight simulator of Britannia Airways at Luton Airport, UK. The objectives were to assess the visual aspects of the landing using a selection of parameters established from the DFDR data. In particular, the aim was to evaluate the visual perspective of the runway following a loss of runway lighting, below 150 feet agl, and thereby to attempt to gain a better understanding of the actions of the crew. The details of the evaluation are included in Appendix C.

1.16.3. *Calculated groundspeed*

The tracks on the runway surround made by G-BYAG's right MLG clearly showed that the truck of this landing gear began a sustained pitch oscillation of significant amplitude shortly after the aircraft ran off the runway. The aircraft left the paved surface of Runway 20 after a ground run of 1,000 meters from the second touchdown point.

Evidence from the aircraft manufacturer indicated that previous instances had occurred of pitch oscillation of the B757 MLG truck on the ground. This had generally been during operation on particularly uneven runway surfaces. As the condition was believed to be responsible for excessive wear of the truck pivot, the manufacturer had investigated it in some detail and had conducted related trials. From these the manufacturer had concluded that the natural frequency of the oscillation was virtually independent of the resilience of the ground or the load on the landing gear and would be in the range 16-17 Hz. However, those investigations only considered an intact landing gear that is rolling over a hard paved surface of asphalt or concrete. The manufacturer subsequently considered that significant differences in either the tire pressure or the type of ground surface would result in significant difference in the natural pitch frequency of the main landing gear truck.

Measurement of G-BYAG's right MLG tracks over a 27 cycle length found that the wavelength was generally in the range 15-19 ft (4.6-5.8 m), with an average of 17.3 ft (5.3 m). It appeared that much of the variation was due to difficulties in accurately defining the position of the peaks of the cycles and that averaging would eliminate much of this error. However, the full range of values is considered in the following calculation of the range of groundspeeds corresponding to the above frequency and wavelength values:

	Predicted Cycle Frequency (Hz)	Measured Wavelength (ft)	Calculated Groundspeed (kt)
Minimum	16	15	142
Mean	16.5	17.3	169
Maximum	17	19	191

The aircraft manufacturer subsequently considered that for this accident, significant differences in frequency (and therefore in calculated groundspeed) would have resulted if the landing gear tires were flat (which the manufacturer considered was quite likely after the second touchdown) or were rolling over a very soft surface such as that encountered when the aircraft left the paved runway surface. Further, the manufacturer considered it possible that the oscillatory marks had resulted from «gear walk».

From the above, Boeing did not believe that an actual groundspeed could be calculated with any certainty using the ground indentations left by the right main landing gear. Their conclusion was that the evidence suggested that the aircraft had left the paved surface «with a relatively high speed and that, in the absence of DFDR recorded data, calculation of groundspeed to any degree of accuracy involves too many unknown variables».

1.16.4. *Landing gear touchdown loads*

The aircraft manufacturer estimated that the 14 ft/s (840 ft/min) aircraft sink rate at initial touchdown, estimated from the DFDR data, represented a severely heavy landing. However, while the associated energy exceeded the ultimate load requirement of FAR 25.303 and 25.473, the manufacturer thought that «it appears not to have resulted in significant damage of the NLG or the MLGs».

Estimated sink rates at the second touchdown were around 22 ft/s (1,320 ft/min) at the NLG and 16 ft/s (960 ft/min) at the right MLG. The manufacturer considered that this would have induced NLG loads significantly higher than the ultimate capability of the NLG support structure and easily capable of causing major displacement of the NLG and doghouse. Such a failure would have been assisted by NLG loads induced by the banked aircraft attitude at touchdown. Additionally, it was predicted that the estimated sink rate would have caused the right MLG shock strut to bottom and the loads on both the gear and its support structure to probably exceed the design ultimate values, possibly causing fracture of the support beam.

1.17. Organisational and management information

1.17.1. *Operator procedures*

Britannia Airways first started operations in 1962, in the holiday charter market. At the time of the accident the airline was operating a fleet of Boeing 757 and 767 aircraft.

The operator's FOM (Flight Operations Manual) was in JAR-OPS 1 (Joint Aviation Requirements-Operations) format and the company operated in accordance with Joint Aviation Requirements and the company Air Operators Certificate (AOC). The operator flight time limitations scheme complied with the requirements laid out in Civil Aviation Publication (CAP) 371. Crew scheduling was achieved with a computerised rostering system.

The operator's operational procedures as shown in its Operations Manual (OM) were examined and the following are some aspects which are considered of possible relevance to the accident.

1.17.1.1. Instrument approach procedures

Amongst the requirements established by the operator to start and continue an instrument approach from the «Initial Approach Point» (IAP) are the following:

— «The crew will complete a standard instruction, «briefing», for the descent, approach and landing».
— «Before commencing an approach to land, the Commander will satisfy himself that, according to the information available to him, the weather at the airfield and the condition of the runway intended to be used will not prevent a safe approach, landing or missed approach, having regard to the performance information contained in the Britannia Operations Manual.»

The operational restrictions as a result of failures or degradation of ground equipment are specified in a tabular form: «If a failure occurs after passing the outer marker (or equivalent position) there will be no time to consult the tables and the approach should be continued at the Commander's discretion but where there is any doubt the approach should be discontinued.»

In the event of a failure of the approach lights reference should be made to the approach chart (in the case of Girona, a minimum of 1,200 meters). Circumstances which preclude an approach during a Non-Precision and CAT I approach at night are: failure of the whole runway lighting system; failure of the runway edge lights.

1.17.1.2. Approach briefing

It is defined that the object of the briefing is to ensure that both pilots are fully informed and in agreement with the proposed plan of action. This is generally presented by the PF. It is not necessary to repeat the standard operating procedures (SOP). Any special requirement or unusual factor must, however, be included. This produces an environment in which the PNF can perform his primary task of monitoring the flight with the maximum efficiency. If the receiver of the briefing is not certain of the intentions in this respect he must ensure that all points are clarified before taking any actions.

The minimum aspects which must be addressed in the descent, approach and landing briefing are included. Also in the briefing for the diversion to an alternate when this possibility is considered.

1.17.1.3. Crew co-ordination procedures

It is established that the commander will make the landing when the surface of the runway has standing water and also that the commander will take the controls whenever the approach becomes destabilised below 500 feet, whether to make a go-around or to complete a safe landing.

In a descent it is established that the speedbrakes control is always operated by the pilot seated on the left and that while the speedbrakes are in use the pilot will keep his hand on the control lever.

«Special care will be taken to avoid any tendency to nose over when becoming visual after an instrument approach and thus increasing the rate of descent. To avoid this reference to the instruments will continue to be made by PNF and also, wherever conditions allow, by PF. PNF will monitor the instruments to touchdown.»

Programmed automatic voice warnings which are heard on all approaches are: «two thousand five hundred», «one thousand», «fifty», «forty», «thirty», «twenty» and «ten».

It is stated that high rates of descent close to the ground inhibit, in the GPWS, the automatic voice warnings «fifty», «forty», «thirty». «twenty» or «ten». It is added that if an automatic voice warning is not heard when anticipated, the PNF should give this at the appropriate time. In an approach and landing, if the automatic height warning «fifty» is not heard in an approach with manual landing, the PNF will warn «thirty feet» when indicated by his radio altimeter.

1.17.1.4. Stabilised approaches

Various procedures and instructions have been found which concur on the concept of the stabilisation of approaches. No explicit, concrete and detailed reference has been found, however, which addresses the Stabilised Approach concept as a whole. The operator informed that they had a well developed concept of «Being in the Slot» which embodies the Stabilised Approach concept.

There are various references to a requirement for an approach to be stabilised. For example, 1,000 feet is set as reference for being established in instrument approaches and 500 feet in all approaches. The word established is defined as being in landing configuration, the aircraft flying at the correct speed for this phase, trimmed and on the correct approach trajectory.

1.17.1.5. Criteria for operation in storms

It is stated that operator's policy is to avoid storm activity whenever possible. It is permitted to fly through storms when no alternative action is possible, provided the recommended techniques are employed. The most up-to-date meteorological information will be used to plan the route.

An extract has been made of the recommended procedures most closely related to the event:

— On approaching the area of the storm, ignore the output of radio aids subject to static interference, for example Automatic Direction Finder (ADF).
— On landing, keep a holding position away from the storm if this is over the airport or approaching it. Go to the alternate if necessary.
— Avoid severe storms including at the cost of diverting to another aerodrome or making a stop-over landing. If it is impossible to avoid it, always follow the procedures included here.
— Various recommendations are established as a guide to pilots in respect of the use of weather radar. There are, however, no procedures and instructions for use of the radar in respect of management of the range, antenna angle and calculations of vertical separation with the echo in the various phases of the flight.

1.17.1.6. Missed approach criteria

Various reasons are established to break off an instrument approach. Amongst these are the following: the visual reference required is not achieved or cannot be maintained, doubts exist as to the accuracy of any indication and a safe landing is not guaranteed as the aircraft is not correctly positioned on the ILS glide path.

It is established that in the case of two successive approaches being broken off due to meteorological conditions, a third landing approach cannot be made except in case of emergency or of receiving an air control report specifying an improvement in the landing conditions.

1.17.1.7. Criteria for continuing the approach below the Decision Altitude/Height

The maintenance of a visual reference is required to continue an instrument approach below the minimum values. The definition of «Visual Reference» in the company operations manual is: «that section of the visual approach aids or of the approach area which must be in view at DH or MDH for sufficient time for the pilot to make an assessment of the aircraft position and rate of change of position, in relation to the desired flight path to be able to safely continue the approach and land.»

With regard to the use of the PAPI, it is stated that below 200 feet its guidance should be interpreted with caution on the final approach. Such systems should not be used to provide vertical guidance. They may, however, have a little limited application to confirm the position of the aircraft in relation to the touchdown area and can, in some circumstances, provide a gross undershoot warning.

1.17.1.8. Flight planning

The minimum operating requirements which must be satisfied by the destination airport and alternates, in respect of meteorological conditions, are established. Two operational aspects are highlighted:

— In the planning of the flight and selection of an alternate only a 40% PROB prognosis or higher need to be considered.
— «Prior to selection as a destination alternate, the met reports and/or forecasts must indicate the weather will be at or above the planning minima specified (in company table) for ±1 hour of the estimated time of arrival (ETA)». (The planning minima in the table for airfield with a category 1 approach aid are for the non-precision approach RVR and cloud ceiling minima to be available).

1.17.1.9. Fuel policy

The operator's fuel policy objectives are as follows:

a) A sufficient quantity of fuel is carried for the intended flight with a safe margin for contingencies.

b) The range capability of the aircraft is fully exploited.

c) The uneconomic carriage of fuel is minimised.

«The operational flight plan gives the correct amount of fuel necessary to complete the flight safely in normal operating conditions. Flight plan required fuel, rounded up to the nearest even 100 kg, will be loaded unless the Commander can identify good operational reasons for carrying more.»

The flight plan fuel includes fuel required for taxi, en-route, en-route contingency of at least 5%, final reserve fuel (30 minutes) and alternate fuel.

«The company accepts that with this policy technical stopovers may be required. This is preferred to the frequent carriage of fuel in excess of the flight plan requirement.»

Final reserve fuel is the fuel required to fly for 30 minutes at holding speed above aerodrome elevation. Alternate fuel is that required from go-around at destination (taking into account the missed approach procedure) through climb, cruise, descent, arrival procedure to touchdown. Extra fuel is defined as the fuel which is carried over and above the minimum required, at the discretion of the commander. It will be carried when there are sound operational or economic reasons for doing so.

The fuel policy allows for the possibility of landing at the destination with fuel available less than final reserve plus alternate fuel in certain circumstances at the discretion of the commander.

The criterion for the selection of an alternate is always the nearest for fuel planning purposes, unless operational circumstances preclude this.

1.17.2. *Information on the Airport Operator*

The operator of Girona Airport is the public body Aeropuertos Españoles y Navegación Aérea, AENA, both in respect of the airport aspect and air traffic control.

AENA has a policy of opening its airport installations, independent of the meteorological conditions. It does not consider, for example, that the presence of storms over an airport should cause it to shut. The assessment of the operational risk lies exclusively with the Commander of the aircraft.

The Rescue and Fire-Fighting Services are not equipped with special systems for guidance and the location of aircraft in reduced visibility conditions.

A direct connection has been established for the exchange of information and air navigation support between the air traffic control services and the Oficinas Meteorológicas de Aeropuertos (OMA, Airport Meteorological Division).

The VOLMET meteorological information transmissions do not systematically take in the active SIGMET messages.

1.18. Additional information

1.18.1. *Summary of witness statements*

Witness statements were taken from various persons who were around in the airport at the time of the event; a member of the airport's Security personnel, a Commander and a passenger from an aircraft stationary on the stand and one located at a point outside the airport.

The information collected has been amalgamated in an attempt to clarify some aspects directly related to the development of the event and the subsequent rescue and recovery. There are however a number of discrepancies between the reports of the different witnesses.

1.18.1.1. Trajectory and impact of the aircraft on the runway

A witness remembers having seen sparks and not having seen the aircraft's landing lights, at a point earlier than half way down the runway.

Another saw the aircraft landing, the runway lights, the aircraft's navigation lights, the anti-collision lights and the cabin lights, all illuminated.

Finally, another person saw the aircraft on the runway when the runway was illuminated, in contrast to the horizon, as a result of the sparks being produced by the aircraft, without being able to specify whether the runway lights were alight.

1.18.1.2. Meteorological conditions at the time of the event

There was heavy rain, wind and poor visibility, according to one of the witnesses.

Another observed the storm approaching the airport and, when it was over the airport, there was torrential rain and flooding in the parking area.

Another remembered that the event had occurred during a period of heavy rain, 15 minutes after the previous missed attempt and he estimated the horizontal visibility at approximately 700 metres, with rain.

1.18.1.3. Airport lighting conditions

One of the witnesses observed that there were four power failures during the night, close together in time, but he could not say whether the last of these occurred moments before the event.

Another stated that there were frequent cuts in the power supply, estimating the number at four within the space of one hour and on each occasion power was restored after some 30 seconds.

Another remembered that approximately 15 minutes after the missed approach to Runway 02 there were several power cuts but that the lights, including the runway lights, came back on and that subsequently, some 10 seconds after the lights of the crashed aircraft went out, the airport suffered a total blackout, with the power being restored after 30 seconds.

1.18.1.4. Passenger recovery and rescue

When the Safety Officer went to his vehicle to go to the accident site he was informed by an air company employee that a passenger had appeared wandering up the runway and that he had been taken to the stand.

The Officer saw the passenger and obtained information on the location of the aircraft. He then went, with a colleague, to the area indicated where they met the fire-fighters who had already located the wreckage. He returned to the Terminal for emergency equipment and found ambulances at the airport gate. He accompanied them to the site of the wreckage. As they could not get close to it as passage was blocked by fire-fighting vehicles, they got out of the vehicles and approached on foot.

The Commander of the other aircraft which was parked came over, together with his crew, to assist the rescue team, at the request of the Tower. He stated that the location of the aircraft did not become clear until approximately 30 minutes after the event and that there were scenes of uncertainty. He then learnt that the recovery of passenger to the terminal took at least 40 minutes and that one passenger from the crashed aircraft had reached the Terminal earlier, by his own means, and could say where the aircraft was.

1.18.2. *Previous cases of B757 nose landing gear failure*

Available information indicated that there had been 2 previous cases where NLG overload had caused disruption of the B757 NLG support structure. The failure mode and some of the effects in these cases appeared similar to those in G-BYAG's accident. The available information on these cases was as follows:

1.18.2.1. B757 in San José

B757, registration N523EA, suffered an accident in San José (Costa Rica) on 28 September 1988. Available information indicated that loud noises, possibly caused by NLG tyre failure, caused take-off to be aborted at an airspeed of about 134 kt as the aircraft rotated for take-off. The aircraft de-rotated rapidly and the NLG support structure failed and the doghouse displaced within the fuselage. The MEC was substantially disrupted and most or all of the electrical power on the aircraft was lost as a result, including the autobrake and antiskid. The fuselage suffered severe wrinkling just forward of the L2/R2 doors.

1.18.2.2. B757 PH-TKC in Amsterdam

B757-236, Registration PH-TKC, suffered an accident at Amsterdam Airport on 24 December 1997 as the aircraft was landed in strong and gusty crosswind conditions.

Touchdown was made approximately 400 metres from the start of the 3,300 metre long runway. Following an initial touchdown and bounce on the right MLG, the NLG touched down while the aircraft was pitching nose down at a rate of at least 9°/second in response to a pilot control input. The NLG shock strut bottomed and the maximum design energy limit was exceeded by about 20%. The NLG support structure displaced, structurally separated from the fuselage and rotated backwards, causing serious damage to electrical and electronic systems and to control cables. The FDR and CVR stopped recording, the flight deck instrument lighting extinguished and cabin lighting reverted to the emergency system. The PA and interphone systems also probably ceased functioning. The aircraft slid down the runway on the MLGs and forward fuselage structure.

The pilot had difficulty keeping the aircraft on the runway, using differential thrust, differential braking and rudder. As it approached the end of the runway he allowed it drift off the right side into soft ground, after an almost 3 km run. After a further 100 metre ground run, with the MLG wheels sinking heavily into the ground, the aircraft came to rest. There was a small fire in one of the wheelbrakes, apparently due to excessive braking heat build-up.

Some of the MLG tyres and wheels had signs of tyre skidding and deflation. Nine control cables, for brakes, flaps, elevator, MLG extension and both engines, were found severed above the NLG doghouse. They included the «B» cable for No 1 engine and both the «A» and «B» cables for No 2 engine.

1.18.3. *Stabilised approach*

The ICAO doctrine created in the program of Approach and Landing Accident Reduction (ALAR) defines the stabilised approach in the following manner:

A stabilised approach is characterised by an approach profile defined by a constant angle, which establishes a correct and constant rate of descent, ending at the point where the landing manoeuvre starts.

An approach is considered stabilised when the following conditions are simultaneously met:

1. The aircraft is on the correct flight path.

2. Only small changes in heading and angle of pitch are required to maintain the flight path.

3. The aircraft's indicated speed is in the range between V_{REF} and V_{REF} + 20 knots.

4. The aircraft is in the landing configuration.

5. The rate of descent is not greater than 1,000 feet per minute.

6. The power setting is appropriate for the configuration of the aircraft and is not below the approach minimum, defined in the aircraft's operating manual.

7. All the briefings and check lists have been completed.

8. According to the different types of approach: an ILS approach should be flown within the margin of ±1 point (dot) of the localiser and the glide path; a category II or III ILS approach should be flown within the «expanded localiser» band; in a circuit approach the wing must be levelled on final when the aircraft is 300 feet above the aerodrome.

9. Special approaches or approaches in abnormal conditions which demand deviations from the above criteria require a special briefing.

In the Airplane Flight Manual of the B757, dated March 1998, «unacceptable deviations from the flight path» are defined as those which occur below 1,000 feet AGL, and therefore on approach, which exceed any of the following parameters:

— 15 knots above target speed, V_{TARGET}.
— 500 feet per minute over the vertical velocity.

- 5° over the angle of pitch.
- 1 dot of displacement on the glide path.
- Unusual position of the thrust levers over a significant period of time.

These conditions must be considered triggers to start a missed approach.

1.18.4. *De-rotation during landing*

As a result of various incidents/accidents during landing, the NTSB issued safety recommendations (A-94-118 and 119) in which it requested the Aeronautical Certification Authority to include clear and specific information in the B757/767 Operating Manuals for the landing manoeuvre. These instructions should state that, after the main landing gear has made contact, the nose leg should be lowered gently, relaxing the pressure on the control column and never moving the control from the top to the bottom. The pilot training programmes should also be amended to include training in this manoeuvre and a discussion on de-rotation accidents.

Shortly after this, the Manufacturer included these instructions in the Flight Crew Training Manual and the Certification Authority issued a Bulletin (Flight Standard Information Bulletin) containing this information and instructions for a smooth de-rotation.

1.18.5. *Correction to the commercial chart used during the approach*

During the course of the investigation it was discovered that there was an error in the Jeppesen approach chart used by the crew during its Runway 20 ILS approach on the day of the accident. The error appeared in a note which stated:

> «GS not to be used for coupled approaches below 720’ (251’)»

The correct text for the note as published in the Aeronautical Information Publication (AIP) Spain was:

> «GP U/S below 720’ (260’)».

The publishers were informed of this fact and a new, corrected chart was issued.

1.19. Useful or effective investigation techniques

None.

2. ANALYSIS

2.1. General

The weather forecast at the time of departure from Cardiff indicated that there could be thunderstorm activity in the destination area and in fact at the time the aircraft arrived overhead Girona Airport there were active storms to the south and south-west.

The first approach was discontinued and a go-around carried out following which the commander reviewed his earlier decision to divert after one attempt and decided to carry out a second approach. This was probably because the change in wind conditions now made the ILS 20 approach preferable and the aircraft was already in a position from which it could continue straight outbound on the procedure. Furthermore, following a second missed approach the aircraft would then be heading in the direction of Barcelona.

During the investigation, the possibility that the airport approach and PAPI lights were inadvertently not switched over from Runway 02 to Runway 20 was considered. The air traffic controller stated that she was absolutely sure that such lights were connected, and also that the pilots never told her that the lights were off. The commander stated that he did not recall having seen the approach and PAPI lights during the second approach. In any case, it is considered that the commander acquired sufficient external visual references before decision height, with the aircraft correctly positioned. Immediately after disconnection of the autopilot and autothrottle the aircraft diverged above the approach path which the commander attempted to correct. At a late stage of the approach the commander experienced a loss of visual reference for which he could not account. It appeared that a failure of the ground electrical supply, possibly because of storm damage, caused loss of the runway and environmental lighting a few seconds before touchdown. The commander was unable to comprehend what had occurred leading to an uncontrolled landing.

An automatic callout of «SINK RATE» suppressed most of the normal automatic callouts of height immediately before touchdown, a flare was not made and the aircraft landed very heavily in a flat attitude and bounced. Control inputs, possibly inadvertent, pitched the aircraft nose down with a high rate of de-rotation and a second touchdown on the nose landing gear occurred less than 2 seconds after the initial touchdown.

The nose landing gear support structure was displaced by the second touchdown. It could reasonably be expected that from this point directional control of the ground slide could be maintained and that the aircraft would slow to a halt on the runway, undamaged apart from localised disruption in the nose landing gear area. However, it appeared that the effects on various aircraft systems caused the aircraft to accelerate and consequently sustain major damage that led ultimately to the death of one passenger and could have been catastrophic to many of the other occupants.

It could be argued that a successful landing could have been carried out if the visual reference had not been lost. However, the expected response from the crew when the visual reference was lost and when the approach became destabilised would be to carry out an immediate go-around. The investigation tried to analyse why the approach was not discontinued and identified and evaluated a considerable number of factors that may have influenced the commander's decision to land, caused the heavy initial touchdown, the rapid derotation of the nose landing gear and the subsequent aircraft behaviour. These are considered below.

2.2. Flight operation

2.2.1. *Crew qualifications and performance*

The flight crew held valid licences, ratings and medical certificates. They had complied with the required minimum rest period before reporting for duty.

The flight crew operated the flight using their operator's standard operating procedures and there was a good level of communication between themselves and also with the cabin crew.

There was no evidence that the crew had received specific training in deciding upon and initiating missed approach action once a decision to land has been made and the aircraft is below the MDH/DA. The reversal of the decision to land may be particularly difficult at a late stage.

During the evacuation of the aircraft the cabin crew demonstrated their thorough preparation and efficiency despite the adverse conditions including the limited available light, the roll attitude of the aircraft, the weather and the failure of the intercom and loudspeaker systems. It should be noted that they did not have time, or were otherwise unable, to pick up the portable emergency equipment, with the exception of some torches, when they abandoned the aircraft.

2.2.2. *Operating procedures*

2.2.2.1. Flight planning

The operational flight plan was prepared at 1816 hrs on the 14th, using current forecasts, with departure scheduled for 1945 hrs. Three alternates were included in the plan: Barcelona, Reus and Toulouse. A probability of thunderstorms, for periods of time, was forecast for the destination and for the first two alternates at the ETA of the flight. The fuel requirement for the flight was calculated by the commander using the nearest alternate, Barcelona, and an additional 780 kg of fuel was added to allow for possible storms at the destination, this amount being enough for 15 minutes of holding. The only available airport forecast to be free of storms for the period was Toulouse.

Analysis of these data in accordance with the JAR-OPS 1 planning requirements and the company operations manual demonstrates fulfilment of the planning and destination minima. The regulations consider planning minima to be solely those relating to visibility and cloud base conditions. For planning purposes, therefore, storms are not included as an adverse meteorological condition for clearance on departure or re-clearance in flight.

In accordance with the above conditions and taking into consideration the prohibition on carrying out approaches and landings in storms, stated in the operator's Operations Manual, more attention could have been paid to the forecast of storms in the flight planning and clearance. This is additionally true given that storms may be associated with a reduction in visibility, a low cloud base and the runway being adversely affected by rain.

The policy of the operator was to avoid approaches or landings in the presence of storms. However, there was no requirement for storms to be taken into account when considering the meteorological minima for approach at destination and alternate aerodromes at the pre-flightplanning stage.

Therefore, a safety recommendation is issued on this matter.

2.2.2.2. First approach

The commander decided to carry out the non-precision VOR/DME approach to Runway 02 in view of the surface wind, direction 360° and 10 kt in strength, and the wet runway. He also decided, because of the more complex nature of the non-precision approach, to take over as PF and the FO then assumed the role of PNF.

The speedbrakes were used in the descent to increase drag and to make it possible to lose more height in a shorter time without increasing the speed. The standard procedure of the operator requires the commander to keep his hand on the speedbrake lever while the speedbrakes are extended. The speedbrakes were inadvertently left extended inappropriately for 10 minutes, from the time the aircraft levelled at 5,000 feet, throughout the intermediate and final approach phase of the approach, until the selection of landing flap. For periods of time the engines were above idle thrust with the speedbrake extended.

The procedure recommended by the manufacturer and contained in the operator's Operations Manual that the pilot flying keeps a hand permanently on the speedbrake lever when the speedbrakes are extended in flight does not appear feasible in practice as the commander (who was the pilot flying in this case) uses the same hand to manage other controls, and he therefore ends up losing awareness of the status of the speedbrakes. It has been considered appropriate to issue a safety recommendation to modify this procedure and/or to provide an alert to the crew in the event the speedbrakes are inadvertently left extended.

Keeping the speedbrakes extended was detrimental to the flight for two reasons. One was that the speed stability was poor, even in view of the turbulence, demonstrated by the numerous «SPEED» monitoring calls given by the PNF. Another was that it resulted in an increase in fuel consumption of between 300 and 400 kg which, although in a normal flight situation would not have had an undue effect, in this case reduced the fuel available so that subsequently the minimum diversion fuel was reached during the course of the second approach.

The commander lost his approach chart during the outbound section when it came loose from its fixing device on the control column. He continued the approach without the chart with the assistance of the FO. This circumstance was inconvenient and increased the commander's workload. Information that the thunderstorm was over the field was given by the controller to the crew and acknowledged by them around this time, but may not have been given full consideration. The controller's report of the storm position appears to have conflicted with the on board weather radar information and the crew's own observations later on in the missed approach.

During the final descent and approach there was a change in wind direction (probably as a result of the storm activity) leading to tailwind conditions, which resulted in the correct descent profile not being maintained. Revised weather information was then passed to the crew by the controller indicating that Runway 20 would be available. The aircraft was now too high and when the PNF reported contact with the runway lights the PF, realising a successful landing could not be made, ordered «go-around».

2.2.2.3. Second approach

After aborting the approach to Runway 02 the crew received an update on the weather conditions at Barcelona, which were favourable. The commander reviewed the situation and decided to carry out an ILS approach to Runway 20, revising the plan made before the first approach. This was most probably because the wind was now favourable for landing on Runway 20, which was equipped with an ILS, making a successful approach and landing more probable. Also in the event of a diversion to Barcelona the conditions there were good.

The aircraft was stabilised on the approach in good time and the check lists were completed. The commander requested «AUTOBRAKE LEVEL FOUR» (the next to maximum braking capacity level), higher than usual, probably because of the wet runway and the downslope.

The PF said «lights in sight» at 500 feet agl and then said «contact» some 15 seconds afterwards (around 10 seconds before reaching minima). The commander disconnected the autopilot and autothrottle at the approach minima. The PNF continued to monitor the instruments, in accordance with the SOP, including the ILS glidepath and vertical speed indications, and did not appear to have looked outside again.

The phrases «lights in sight» and then «contact», both said by the commander and PF, could be a clue that the approach and PAPI lights were on, because at the time of the first phrase the aircraft was approximately at 45 sec from touchdown (1.5 nm from the threshold) and it could be referred to the approach lights that extend 900 m before such threshold. The next phrase was said approximately 30 seconds before touchdown and it seems to refer to «visual contact with the runway», that is, both phrases probably referred to different lights.

2.2.2.4. Final approach manual flight

From the time of the disconnection of the autopilot the DFDR graphics showed oscillations in the vertical profile of the flight. As has already been stated (see Section 1.11.6), it has been determined that turbulence and windshear did not significantly affect the performance of the aircraft. However at the time the autothrottle was disconnected a power correction had just been made to a setting of 1.51 EPR, a higher than usual approach setting (around 1.2 EPR). This would have caused the aircraft to deviate above the glidepath unless quickly corrected and is probably the reason why the aircraft became high. Rapid control column inputs caused short term variations in the aircraft pitch attitude. The start of this activity on the flight controls coincided with the disconnection of the autopilot. The recorded data also indicated that these oscillations in attitude (pitch) were induced by the commander's pitch inputs, likely to have been made in his attempt to maintain the glidepath because he probably only had limited visual reference information.

The commander described experiencing a sudden blackness, which could have been as a result of the airport lights extinguishing at the moment at which he was looking inside the cockpit at the glideslope pointer. It is possible that the pointer would have shown him that he was too high and it is likely that he made an immediate forward control column input to correct the situation. This probably corresponds with the near full nose down elevator input observed on the DFDR and accounts for the nose down landing attitude. Subsequently, looking out to regain his visual reference, he was unable to comprehend what had occurred or to respond. In this situation the commander should have initiated a missed approach in accordance with the operator's procedures but was, however, unable to do so because of his mental block at the unforeseen events; thus the aircraft continued to land. Perhaps if the commander had specific training to make a go-around below the decision height, he could have reacted more quickly, and therefore it is considered appropriate to issue a related safety recommendation.

The visual reference that would have been available with a nose down attitude, no runway lighting and aircraft landing lights would be a truncated area of the touchdown zone. It is known that a shortened runway perspective creates the illusion of being high and, although the commander cannot recollect any visual cues, may have led to his being unaware of the proximity of the ground.

The activation of the GPWS audio caution twice between a height of 80 and 10 feet indicates that the aircraft reached a rate of descent of more than 1,000 feet/minute. According to the SOP this caution requires a correction to the descent rate or possibly a go-around. This descent rate also indicates a destabilised approach which would require the missed approach to be initiated immediately.

However the «SINK RATE» cautions were not heard by the commander. They did, however, override the automatic height warnings of 50, 40, 30 and 20 feet. The absence of these callouts may have affected the lack of perception of the proximity of the ground of the commander, evidenced by the lack of any attempted flare. The callouts, and the rate at which they occur, normally assist the PF to decide when to start the flare for landing. The company's operations manual contains a procedure whereby the PNF is required to make a call of «THIRTY FEET» if there is no automatic «FIFTY FEET» call, but even at an average rate of descent of 600 feet per minute this would allow him only two seconds (and in this case around one second) in which to recognise the omission and to make a correct call. This procedure is therefore impractical.

In accordance with the above, a GPWS Mode 1 which below a certain height activated the «PULL UP» warning instead of the «SINK RATE» caution, with rates of descent above approximately 1,100 feet/minute, would be more likely to result in a «go-around».

However, the modification of the envelope of the GPWS to give priority to the «PULL UP» warning under those conditions could result in inappropriate warnings being generated in other situations and therefore a related safety recommendation has not been issued.

The manufacturer of the aircraft informed that the GPWS height callouts are advisory in nature, and there are no requirements to mandate their use, and that the «SINK RATE» caution provided a higher level of awareness regarding rate of descent. They also stated that some operators do not use the automatic callouts but require the «pilot monitoring» the approach to verbally make the callouts per the operator's policy.

2.2.2.5. Landing

The attitude of the aircraft on first contact with the runway, 2° nose down, caused the aircraft to rebound and to bounce heavily, with a rapid increase in nose up pitch recorded in the data. This must have caused powerful accelerations on the flight deck, making it difficult for the PF to regain control and an instinctive tendency of the latter to offset the increase in the angle of pitch. The control column moved forward giving rise to rapid de-rotation of the nose towards the runway, and engine thrust increased.

Whether these were deliberate actions or happened as a result of the PF being thrown forwards upon the first heavy contact with the ground it was not possible to determine.

2.2.3. *Meteorological conditions*

For the dispatch of the flight from Cardiff, the crew had access to the meteorological information at 1800 hrs, both to the aerodrome METARs together with the TAFs for the destination area. The information confirmed the presence and/or forecast of storms and rain at the destination and alternate airports at the time of operation, with the exception of Toulouse.

This forecast, common to Girona, Barcelona and Reus, carried the qualification TEMPO which indicated changes which could occur at any time from 2000 UTC on 14th until 0400 hrs UTC on 15th and would last for less than an hour within the forecast period. The validity of these forecasts was confirmed by subsequent weather at the three airports mentioned. The storms were moderate to severe in intensity with considerable electrical activity and torrential rain. The actual duration of the storms as they passed over Barcelona and Girona was slightly longer than one hour.

During the descent, the crew obtained meteorological information supplied by the Girona Tower. This confirmed the presence of the forecast phenomena, storms and rain to the south-west of the field. At 2129 hrs when the aircraft was at 6.5 nm, outbound from the DME on the first approach the controller advised the crew that the storm was over the airfield. A shift in surface wind direction also occurred around this time possibly indicating the presence of a storm cell.

During the approaches and until landing, the controller maintained constant and up-dated transmission of the Girona and Barcelona conditions, at the request of the crew. The up-dating of the meteorological information was based on the data read from the instruments which could be read in the Tower and on reports requested by telephone from the Girona OMA. The meteorological information transmitted by radio did not include the rating of the storm as severe, which appeared in the METAR and in the information provided by the OMA. It is considered appropriate to recommend to increase the training of the air traffic controllers to determine what meteorological information must be provided to the flight crews.

During the go-around from the approach to Runway 02, at 2137 hrs, the crew asked for meteorological information to the north of the airfield. The controller did not have this information, which was not being provided to her.

She did not have any actual data on the development of the storm. The information on intensity and evolution of the storm would have been most beneficial to the crew, and therefore a related safety recommendation to the meteorology services is issued.

The crew had weather radar and, therefore, should also have had images of the area. Although they were using the equipment they did not observe evidence of a storm over the airfield, however, there is high terrain surrounding the airport and it can be difficult to distinguish between ground and weather returns.

Analysis of all the meteorological information obtained subsequently indicated that the storm developed as it moved from the south-west to the north-east, with the situation in Barcelona improving and the situation in Girona worsening between 2100 and 2230 hrs. At the time of the two approaches made by the aircraft there was torrential rain at Girona Airport whilst the conditions at Barcelona Airport were good and free of storms.

Although the commander reported turbulence at the time of disconnecting the autopilot, which could affect the control of the aircraft, a study of the wind data recorded on the DFDR showed that there was no significant windshear which could have affected the aircraft performance. The two windshear alert cautions recorded but not presented to the crew related to headwind.

The heavy rain which fell during the final approach together with the night visibility conditions could have made the capture and maintenance of visual references difficult and possibly produced visual illusions. The effects of rain refraction on the windscreen and effects of lightning were considered. Although the RVR given at the start of the approach was 1,500 metres when the commander achieved visual contact it was probably greater than this because the aircraft was at a range of around 2,500 metres.

The volume of rain which fell, together with the statements taken, indicate that the runway was not only wet but had standing water. However, in response to the question from the crew, the controller answered with the words «quite wet», which was acknowledged from the aircraft. Although this form of giving information is not standardised, it is considered that it provided enough information to the flight crew, which, on the other hand, had already overflown the airfield during the missed approach.

2.2.4. *Air traffic control and communications*

Despite the fact that this was the only traffic for which the controller was responsible, for some moments during the missed approach to Runway 02 and during the second approach, it is possible there was a moderate workload in the Tower as a result of the multiple radio and telephone communications which the controller had to maintain with the Barcelona ACC, the Girona OMA, Tower teams and the Air Traffic Services Notification Office (ARO). At the time of the selection of the alarm and during the subsequent search for the aircraft, the work load was greater and prolonged, which would help to explain the misunderstandings which occurred during the search.

After the missed approach to Runway 02, the controller held a telephone conversation with Barcelona ACC, which lasted one and a half minutes, to connect with another conversation with the Girona OMA. These conversations coincided with the interval of time in which there was a change of runway to Runway 20 and when the controller should have changed the approach and PAPI lights, lighting those for Runway 20.

There were no standardised procedures or checklists available in the Tower for this task, in a situation in which there could have been some workload. These procedures could have served in any case as a protection against an unnoticed omission, allowing it to have been detected and corrected. The commander stated that he did not recall having seen the Runway 20 approach lights or PAPI but had seen the lighting of the runway itself. However, as discussed in Section 2.2.2.3 above, the phrases «lights in sight» and then «contact» that he said during the approach could refer to two different lights. The controller stated that she was absolutely sure that the approach and PAPI lights were on.

Although it is considered that in this case it is probable that the switching of the lights was not omitted, it is considered appropriate, as an additional safety protection and as an aid to controllers in the same situations, to issue a safety recommendation that standardised procedures, including checklists, are provided to control tower personnel.

The duty periods in the Girona Tower took the form of two 12 hour shifts, starting at 0800 and at 2000 hrs, which means that the controller had been on duty for 1.40 hours. The minimum preceding rest period had been 12 hours. No indications were found that fatigue had affected the actions of the Girona Tower controller.

The controller reacted quickly, selecting the alarm within the same minute in which the impacts of the aircraft on the runway occurred and despite the uncertainty caused by losing sight of the aircraft, both as the result of the loss of the runway lighting and of the aircraft's lighting. In addition, the failure in the alarm was rapidly rectified by a telephone communication.

2.2.5. *Aids to navigation*

In the AIP ILS Approach Chart to Runway 20, there was a note which indicated that the descent path could not be used below a height of 260 feet, approximately the decision height, 251 feet. This note did not appear on the Jeppesen chart used by the operator. The reason for the inclusion of this note on the Chart was that irregularities were encountered in the calibration of the aid below that height and that these had not yet been rectified.

The crew made some use of the glideslope indications below minima and, according to the data recorded on the flight recorders, there were no on-board indication failures of this radio aid. The glidepath emissions could, however, have been in error and led the crew to a descent slope different from the nominal angle of 3°. There was however no evidence that this had occurred or that the glideslope was in fact inaccurate. The error in this respect in the Jeppesen Chart was discovered during the course of the investigation and was notified to the publishing company which subsequently issued a corrected chart.

The slight deviations of the service range of the radio aids found in calibration flights subsequent to the event did not affect the course of the flight.

2.2.6. *Airport*

Girona Airport has a relatively small and seasonal activity, with a maximum capacity of 12 movements/hour and the emergency services and installations cover the needs of medium size aircraft, with the B757/767 and A310 being the largest aircraft which normally operate out of the airport.

As has been stated, there were various interruptions to the electrical supply to the airport, which coincided with the time of the final approach, landing, search and rescue. Attempts were made by various means to establish the exact time at which these occurred, through the supplier, Fesca-Endesa, and through any of the Airport's electronic equipment containing non-volatile memory, without success. The reason for the interruptions is also unknown, although it appears likely that there was a direct relationship with the storm activity and the heavy rain.

From the analysis of the information available and the statement of the commander, it was established the hypothesis that the first or second black out occurred when the aircraft was on final approach, below minima, and that it was during this black-out period that the touchdown on the runway occurred. This means that the failure probably started at approximately 2147:10 hrs.

As was demonstrated subsequent to the event, the Airport's secondary source of supply restored the supply after 11 seconds which indicates that the maximum time established in ICAO Annex 14 for Category I precision approaches, which was 15 seconds, was met.

In accordance with this data, the lighting would have come on again at approximately 2147:21 hrs, some 4 seconds after the first contact of the aircraft on the runway. At the time at which the runway lighting came back on, therefore, the aircraft was some 700 m from the threshold and now without its own lights as a result of the displacement of the nose leg support structure. It subsequently covered a further 850 metres on the runway before running off onto the right hand margin. These blackouts, both of the runway lights and of the aircraft's lights, would explain the variable and scanty visual contacts which the controller had of the aircraft as it was travelling along the runway.

The failure of the airport's emergency alarm when it was selected by the controller could have been caused by this coinciding with a subsequent power loss which left the system non-operational, including its button in the Control Tower, as its power supply was not connected to the uninterrupted supply. However, the controller rectified this failure by immediately confirming activation of the alarm to SEI by dedicated telephone line.

The mean downslope of Runway 20 is 0.84%. The gradient of the first third is less than the mean, 0.46%, the figure for the second section is 1% and for the final section 1.25%. This last section exceeds the maximum recommended gradients in ICAO Annex 14 which states that for the first and last quarters of Code 4 runways, the gradient should not exceed 0.8%.

The undulating terrain in the area in front of the Runway 20 threshold, which gives rise to radio-altimeter readings which are not consistent with the height over the threshold, is a difference, which has been notified to ICAO, of deviation from the recommended standard and which does not comply for Cat. I approaches. There are no indications, however, that it could have adversely affected the automatic height callouts based on radio-altimeter readings.

After crossing the right-hand runway strip, of 75 m of width, the aircraft came up against a steep upward gradient, of more than 15%. This encounter, as will be analysed later, influenced the damage suffered by the aircraft and could, in any other case, have affected the survival of the occupants of an aircraft which left the runway in this area.

ICAO Annex 14 recommends that the strips of runways for precision approaches should extend to 150 metres to either side of the centreline and that the gradients beyond the part which must be levelled, 75 metres in width on either side, should not exceed 5% in upward gradient. The mound parallel to the runway centreline, approximately 6 m (20 ft) in height, which extends to the right of Runway 20 beyond the levelled margin zone, 75 metres wide, exhibited gradients higher than those recommended. In the same way as with the runway, it would be appropiate to assess the possibility of bringing the runway strip of Girona in compliance with the text of ICAO Annex 14, and a safety recommendation is issued to cover this aspect.

2.3. Human factors

2.3.1. *Flight scheduling and fatigue*

The flight crew were scheduled in accordance with UK Regulation CAA CAP 371 «The Avoidance of Fatigue in Aircrews» and the maximum duty periods and minimum rest periods were complied with. The crew, when questioned as to whether tiredness or fatigue was a factor in the accident, did not consider that it was.

However, because the crew members were carrying out a third consecutive night flight, it was considered whether fatigue may have affected the flight. An analysis of the schedules flown by both pilots during the period leading up to the accident was carried out by The Centre for Human Sciences at Defence Evaluation and Research Agency (DERA). The analysis concluded that cumulative fatigue did not appear to be an issue. Short-term fatigue was considered to be a possibility although the recovery period appeared to be adequate. It was pointed out in the report that the flying duty period on the night preceding the accident exceeded the NASA and European scientists recommended 10 hour limit for duties starting or finishing between 0200 and 0600 hrs local time. It was also noted that in other areas of industry studies had shown that the accident rate for shift workers increases on consecutive working nights.

Various scientific studies[2] show that with age there is a change towards being active in the daytime rather than at night. Improved resistance is acquired to the loss of non-accumulative sleep. More difficulties appear in adapting to time changes as the result of a shortening of the circadian rhythms. The flight commander, 57 years of age, was within the risk spectrum and on his third consecutive night of duty and it is therefore probable that he had suffered an accumulative loss of sleep.

2.3.2. *Crew co-ordination*

2.3.2.1. Distribution of tasks

On contacting Girona Airport and in view of the wind conditions and complex meteorological situation with storms, the commander requested a VOR/DME approach to Runway 02. He also decided to act as PF, thus reversing the roles initially assigned during the flight.

The commander took this decision in response to the greater complexity of the approach, as Runway 02 was not equipped with ILS, and the weather was not good. When the commander took over the role of PF his workload increased as he added the task of flying the aircraft to his flight management tasks. The first officer, now acting as PNF, gave a number of monitoring calls of speed and other parameters during the approaches, as corresponded to his duties. He communicated information about fuel, discussed the planned course of action and reviewed the respective allocation of crew duties. He did not question the decisions of the commander and there was no indication that he did not agree with the proposed course of action.

[2] «Principles and guidelines for duty and rest scheduling in commercial aviation» (NASA Ames Research Report 1996); «Age, circadian rhythms and sep loss in flight crew» (Philippa H. Gander and other, Aviation Space and Environmental Medicine, 1993).

2.3.2.2. Gradient of experience on the flight deck

The gradient between the qualification profiles of the pilots (experience, age and rank or position principally) who made up the flight crew was considered. This crew exhibited a gradient of authority on the flight deck with a pronounced downward slope from the commander (57 years of age, ATPL, 3 type ratings and 16,700 flying hours) to the first officer (33 years of age, CPL, 1 type rating and 1,494 flying hours).There was no indication that this gradient affected the conduct of the flight.

2.3.2.3. Crew efficiency

This was a demanding operational environment engendered by the poor weather conditions, lighting failures, fuel limitations and the characteristics of the airfield. The commander and first officer were subject to a high work load but co-operated well as a team. However, the balance of distribution of the tasks seems to have been unequal with the commander having the greater workload. One possible recourse to improve the distribution of tasks between the crew could have been to reverse their roles (PF the first officer and PNF the commander). With this change, the commander would have been released from the task of flying, could have monitored the PF, taken other decisions and planned the remainder of the flight. This procedure is adopted by various Operators and is generally known as «monitored approach».

With this task assigment, the crew member with higher experience, the commander, is in a better situation to make decisions or even initiatives to modify the course of the events.

Taking into account the controllability problems that appeared below the decision height it cannot be concluded that an approach made under the «monitored approach» criteria could have prevented the accident.

2.3.3. *Decision making process and factors affecting it*

On the basis of the meteorological information provided for dispatch, loading diversion fuel for Barcelona represented a risk as storms were forecast both for the destination airport and for the chosen alternate airport where, in accordance with the Operations Manual, landings should not be made in thunderstorms.

There were a number of pressures that were experienced by the crew during the course of the flight. Up to the point of the landing manoeuvre these had been adequately managed, but the unexpected and unpredictable failure of the runway lights, which was outside the experience of the commander, led to an incapacity to respond to the problem. Whether this incapacity was as a result of a deterioration in the commander's performance due to workload or would have occurred in the majority of situations was not possible to determine. There is not any data on a reasonable response time to an unexpected and disorientating event. Available data considers responses to pre-considered emergency situations. As was mentioned in Section 2.2.2.4, a specific training to carry out go-around below the decision height may have helped the commander to make such a decision. Also, had the FO recognised and responded to the «SINK RATE» caution and called go-around, heavy ground contact may have been avoided. However the caution occurred less than four seconds before ground contact.

A possible explanation for the inability of the commander to comprehend what had happened was that he was not looking at the runway at the exact moment at which the lights failed. If at that moment his attention was directed inside the aircraft, to the flight instruments, it could provide a reason for his subsequent confusion. To carry out a go-around would require a positive decision, but without a clear idea of the position and attitude of the aircraft he would not have had enough information to act.

2.4. Final approach, touchdown and accident ground run

2.4.1 *Final approach*

Below the decision height (251 feet) and after disconnection of the autopilot, the descent destabilised. As a result of control column inputs, the pitch angle and the rate of descent exhibited significant variations, between +4.5° and –4.5° in pitch angle and between 500 to 1,000 feet/minute in descent rate.

The aircraft made contact with the surface of the runway with a high descent rate and in a nose down attitude because the touchdown flare had not taken place.

2.4.2. *Touchdown*

The DFDR data showed that G-BYAG first contacted the runway at 2147:16.8 hrs with a pitch attitude of –2°, a pitch rate of 1°/second nose down, an indicated airspeed of 141 kt and a descent rate of 840 fpm (14 ft/sec). The absence of ground spoiler deployment at this point was consistent with the aircraft's air/ground logic not having changed over to «GROUND» because the aircraft bounced after touchdown. Following the initial touchdown the pitch angle increased to +3.3°, the forward thrust levers advanced and full aircraft nose down elevator and right roll control wheel was applied.

The peak normal (vertical) acceleration of 3.11g recorded at the first touchdown was higher than the 1.8g limit in the Aircraft Maintenance Manual at which a heavy landing inspection was mandated. As the accelerometer measuring normal acceleration is located near the aircraft's CG, the acceleration experienced at the flight deck was likely to have been appreciably higher because of the ground reaction from the adjacent NLG which, as seen above, was sufficient to reverse the initial nose down pitch rate. It was clear that the commander was holding the control wheel and the forward thrust levers at the time. It is therefore possible that the forward movement of the controls at initial touchdown was involuntary, caused by inertial loads on the commander, although it is also possible that these were deliberate actions. This also applies to the right control wheel input.

The second touchdown, following the bounce and 1.9 seconds after the first touchdown, was made with a pitch attitude of –0.5°, a pitch rate of 7°/second nose down and a right roll angle of 4.2°. Some DFDR data was corrupted and the recorders ceased recording around 0.6 seconds after the second touchdown. Recovery of corrupted data showed that at the end of the recording the pitch attitude had increased to –6.8°, the right roll angle had increased to 5.3° and the EPR for both engines was increasing through 1.27. By the end of the recording the air/ground logic had not changed over to «GROUND» and there were no indications of ground spoiler or thrust reverser deployment.

As it was considered important to the investigation to establish the point at which G-BYAG had initially touched down and, in the absence of DFDR or CVR recordings after the second touchdown, its subsequent behaviour, the ground marks, aircraft damage and wreckage distribution were examined in detail.

The characteristics of the initial marks on the runway made it clear that by this point the NLG had suffered gross displacement, allowing the underside of the forward fuselage to contact the runway surface. Corresponding distortion and abrasion markings on the fuselage were fully consistent with this evidence. The NLG was found still mounted in the doghouse in the latter part of the wreckage trail. This, together with the spacing of the linear gouges forming part of the initial marks and the abrasion damage present on parts of the NLG doghouse indicated that the doghouse had separated from the wheelwell and displaced with the NLG. The abrasion evidence also indicated that the drag strut trunnions had torn out. Witness marking suggested that the NLG had rotated slightly until stopped by contact with the doghouse aft bulkhead. The wheelwell was pushed up into contact with the cabin floor, but no evidence was found to indicate at what stage of the ground run this had occurred.

The contact of the NLG structure and fuselage nose with the runway was very shortly followed by contact of the underside of the No 2 nacelle. With the MLG wheels and the nose fuselage in contact with the runway the aircraft pitch attitude would have been around 7° nose down (see Figure 33 in Appendix A) and only a few degrees of roll would have been required for a nacelle to also make contact. These conclusions on runway contact by the above parts of the aircraft structure were borne out by the available information on the distribution of the detached wreckage.

The DFDR data showed that no appreciable nose down pitch angle had occurred during G-BYAG's first touchdown and this could therefore not have been the point at which the nose fuselage had contacted the runway. The data indicated that during its 1.9 second bounce the aircraft travelled approximately 140 m along the runway before making its second touchdown. The indications from the wreckage distribution that parts had probably not started to detach from the aircraft before the initial runway marks suggested that failure of the NLG support structure had not occurred before this point. This was consistent with the conclusion of the aircraft manufacturer, based on the DFDR data, that the loads on the NLG at the first touchdown would have been within the capability of the structure. However, on the second touchdown the loads would have considerably exceeded the capability.

Thus it was concluded that the attachments for the NLG doghouse failed at the second touchdown, immediately before the start of the initial marks. This resulted in gross rotational displacement of the NLG and doghouse as a unit, allowing parts of the doghouse, the fuselage nose and No 2 nacelle to contact the runway.

The first touchdown would therefore have occurred around 140 m before the start of the initial marks. The location and track of these marks showed that the aircraft was tracking parallel to the centreline, 3 metres to its right, at the time the marks were made. The DFDR data showed that there had been no appreciable heading change between the first and second touchdowns. It was therefore concluded that G-BYAG had made its first touchdown approximately 417 m from the start of Runway 20, probably a few metres right of the centreline.

2.4.3. *Initial ground run*

Both the crew and passenger reports and the cessation of the DFDR and CVR recordings suggested that most or all of the normal electrical power supplies on the aircraft were lost very shortly after the second touchdown. Cabin emergency lighting illuminated almost immediately. Severe damage to the MEC and its electrical and electronic system components was found, but there was no positive evidence as to when this had occurred. It did appear that at least some of the damage had been caused by the NLG and doghouse pulling out of the fuselage in the latter part of the run. This would have masked MEC damage that occurred earlier.

The progressive lightening of the initial runway marks with distance, followed by a second set of marks that also became less distinct with distance, indicated that the aircraft had oscillated in pitch somewhat following the second touchdown. The tracks that commenced shortly after the end of the second marks and continued to the mound were clearly tyre tracks made by G-BYAG and showed that the aircraft had rolled on all three landing gears. It was also clear that the NLG and doghouse had already displaced far enough to allow brief fuselage nose contact (Section 1.12.1.2). It was therefore concluded that the structurally detached NLG/doghouse unit had rotated and jammed in the forward fuselage such that the NLG tyres remained in contact with the runway, rolling apparently normally and supporting the nose of the aircraft. It appeared likely that the NLG/doghouse assumed a position approximately as shown in Figure 33; this was consistent with the observed damage to cabin floor beams (Figure 27.1).

It was possible that forward fuselage damage could have affected the FEC and caused loss of aircraft battery supplies. The predicted NLG/doghouse displacement would cause major disruption and incursion in the MEC and severe disruption of the electrical and electronic system components housed within. The control panels for both engine generators, the principal sources of electrical power for the aircraft, were positioned immediately behind the doghouse and this made them particularly vulnerable.

It was therefore concluded that damage to the MEC electrical components caused by gross displacement of the NLG and doghouse had caused the loss of most or all of the aircraft normal electrical power supplies at the second touchdown. FEC centre damage may have contributed.

2.4.4. *Second part of runway run*

Accident site inspection showed that the aircraft had travelled considerably further than would be expected after the failure of the NLG support structure and suggested that this had been responsible for most of the aircraft damage. As the cessation of the DFDR at the second touchdown meant that no direct evidence as to the operation of aircraft retardation or control systems during the ground run was available, these factors were assessed from the ground marking and wreckage evidence.

Severe damage and/or interference to control cable runs for the wheelbraking, engine/thrust reverser and rudder systems was found, associated with the displacement of the NLG support structure. Given the evidence of the doghouse displacement at the second touchdown (Section 2.4.3), it was likely that many of these effects had occurred at this point. It was also possible that doghouse movement during the ground run caused further effects on the systems. Thus it was likely that G-BYAG experienced failure, jamming or uncommanded operation of some or all of these systems during the runway ground run.

The characteristics of the tracks on the runway, particularly in the latter part of the run before the aircraft departed the runway, suggested that some MLG wheelbraking may have taken place, but the evidence was not positive. Electrical power loss would have disabled the autobrake system. The nature of the damage to both engines indicated that they continued to run and should therefore have continued to produce hydraulic power. Pressure should also have been maintained to some extent by system accumulators and therefore hydraulic power should have remained available. However, electrical power loss would also have disabled the antiskid system. In this case, it would be expected that brake pedal application would have locked the MLG wheels, and there were no signs that this had occurred, except possibly momentarily. The amount of wheelbrake effect achieved on the runway could therefore not be established.

The effectiveness of any wheelbraking would normally be greatly increased by ground spoiler deployment but this was probably not the case in this situation where the aircraft had a pronounced nose down pitch attitude. However, spoiler deployment would also provide some additional drag retardation. The evidence indicated that spoilers were probably in the fully retracted position at the end of the run. There were no signs as to when this had occurred but it was likely that the aircraft bounce after the first touchdown followed by loss of electrical power supplies would have prevented their deployment.

Thrust reversers were found retracted and the evidence suggested that they were probably not deployed at any stage. Overall aerodynamic drag during the runway ground run would have been appreciably greater than normal because of the aircraft's nose down pitch attitude.

Thus the likely retardation forces on the aircraft during the ground run on the runway could not be positively determined but it was likely that spoiler deployment, reverse thrust and substantial wheelbraking were absent. In the worst case to be expected, both engines would have been producing idle forward thrust and the main retardation force would have been greater than normal aerodynamic drag. In such a case it was judged that the groundspeed would have reduced appreciably from the 140 kt at the first touchdown by the time G-BYAG departed the runway 1,140 metres later.

Similar considerations applied to directional control of the aircraft. It was possible that the veer off the runway resulted from a steering effect produced by the displaced NLG, from uncommanded asymmetric wheelbraking and/or engine thrust and/or rudder movement but the actual cause could not be established.

2.4.5. *Off-runway ground run*

The ground markings showed that G-BYAG was retarded in several stages after leaving the runway. The grassed runway surround was relatively soft and the tyre tracks fairly deep in places, indicating an appreciable, sustained rolling resistance for the aircraft over this 343 metre long portion of the run. The regularity of the MLG track spacing prior to the mound indicated that neither MLGs not their supporting structure had suffered major failure up to this point.

The aircraft's passage over the mound, with its steep profile and heavy ground tracks, applied further appreciable retardation. This was followed by relatively minor impact with trees and a series of oblique, extended impacts with the fence. In the final touchdown area, the extensive cratering and the failure of attachments for the MLGs, powerplants and other components indicated major further retardation. The extensive deep ploughing of the soil by the aircraft over its 244 metre slide in the final part of the run clearly corresponded to sustained high retardation forces that finally brought the aircraft to rest.

It was thus clear that a very substantial amount of energy had been expended in bringing the aircraft to rest and that the groundspeed after leaving the runway had been unexpectedly high. High speed was also indicated by the aircraft having left the ground again, either ballistically or airborne, for a substantial distance after passage over the mound. These judgements were supported by the speed estimate based on measurement of the pitch oscillation of the right MLG truck, which indicated an aircraft groundspeed of between 142-191 kt shortly after departing the runway.

Thus the evidence strongly indicated that G-BYAG did not decelerate during its 1,000 metre run on the runway and probably accelerated considerably after its second touchdown. As this was not considered consistent with the effects of runway slope or idle forward engine thrust acting on the aircraft it could only have been caused by increased forward thrust on one or both engines.

While no evidence was available to directly establish the power settings after the DFDR data loss, uncommanded forward thrust increase was consistent with the powerplant control cable damage found. For each powerplant, the «B» cable had been severed, apparently by the displaced doghouse, while the «A» cable remained intact between the forward pulley and the engine pylon pulley. Severance of the «B» cable would release the tension on this side of the control run and cause the tensioned «A» cable to rotate the pylon pulley in the increased forward thrust direction. Any lateral displacement of the «A» cable by the doghouse, either directly or by portions of the fractured floor beams displaced by the doghouse, would further increase the uncommanded forward thrust.

The point of engine control cable damage could not be positively established but it could well have been at the second touchdown, given the doghouse displacement that must have occurred at this time (Section 2.4.3). Displacement of one or both «A» cables could also have occurred at this point. It was therefore concluded that displacement of the NLG doghouse at the second touchdown caused damage and displacement of the powerplant control cables that resulted in significant uncommanded forward thrust increase on one or both engines. This resulted in G-BYAG probably having a higher groundspeed at its departure from the runway than when it touched down, probably by an appreciable amount, and may have caused or contributed to the veer off the runway.

2.5. Survivability

2.5.1. *General*

The aircraft suffered severe damage in the course of its extended high-speed ground run across very considerable obstacles. Nevertheless, any appreciable variation in the track would have involved a more unfavourable path due to either the steep embankment or the mound and tree area and would probably have resulted in considerably more severe damage. It was most fortunate that the contact with the mound was sufficiently oblique and made in such a way that the aircraft managed to pass over it without breaking up and, in doing so, to be levelled for a relatively flat landing in the field. It was also very fortunate that there was no fire, particularly given the major electrical system disruption and the penetration of the left wing tank by the hot No 1 engine. It appeared possible that the torrential rain and sodden mud may have tended to suppress potential ignition sources.

2.5.2. *Cabin*

As it was, G-BYAG came to rest with the cabin severely disrupted, particularly in the two fuselage break areas. The disruption included:

— Severe damage to nine seat rows, including detachment of four rows and jamming together of three other rows.
— Deformation of the floor, forming a large step in the centre cabin.
— Detachment of one overhead baggage locker and displacement of others.
— Gross incursion of an air duct and television monitor into the cabin space.
— Displacement and/or detachment of ceiling panels, PSUs, battery packs, seat trays and cabin baggage.

Most of the disruption was directly attributable to the structural damage at the fuselage breaks and it was judged that the cabin had generally performed well in the circumstances. It was particularly notable that no overhead baggage lockers had displaced under the effects of inertial loads. However, the displacement and/or detachment of an appreciable number of PSUs appeared unwarranted. The units had an appreciable weight and relatively sharp edges, were located close above the passengers and clearly had the potential to cause significant injury if they dropped. It appeared that the displacement could readily have been prevented by use of a more positive catch and the detachment by more robust hinges. Similarly, it appeared that improvement in the retention of the exit light battery packs was warranted. It is therefore recommended that the aircraft manufacturer take measures aimed at ensuring adequate crashworthiness of the B757 passenger service units and exit sign batteries.

2.5.3. *Injuries*

The detailed causes of the injuries suffered by a number of the occupants could not be established, although neither the forces imposed during the ground run nor the cabin disruption resulted in extensive serious physical injury. However, one passenger died later as a result of injuries sustained in the accident, but he may have been more vulnerable because of a pre-existing medical condition. The evidence indicated that the captain's injury was caused by his head striking the left windscreen frame, probably during the latter part of the ground run. This frame did no have any padding. The pilots were apparently wearing locked shoulder harnesses and the injury appeared unreasonable in a situation where the flight deck had survived virtually intact and flight crew survival was not otherwise threatened. Apart from the direct effects of the injury, the captain's resulting temporary disablement at a potentially critical point could have adversely affected aircraft shutdown and evacuation operations.

The seat shoulder strap selector position was lock or manual for both pilots, while the normal position should have been, according to the manufacturer of the aircraft, «automatic» to allow the functioning of the inertia reels. The operator used the position of «lock» for flight in turbulent conditions. The possible influence of the shoulder strap selection on the injuries suffered by the pilot in command could not be determined. However, it is considered that the safety conditions against impact of the cockpit could be improved by the addition of padding to the frame. It is therefore recommended that the FAA require the B757 aircraft manufacturer to take measures aimed at improving the protection of flight crew members subjected to inertial loading while restrained by their harness against impact with flight deck components, with the shoulder harness selected to either «lock» or «manual».

2.5.4. *Evacuation*

The causes of the reported difficulty in opening some of the right hand cabin doors could not be fully established. The investigation showed that none had been significantly affected by distortion but full checks with active door assist systems were not possible. It appeared likely that in some cases, with the cabin rolled appreciably left, the door weight had prevented the door from being opened sufficiently to activate the assist system. A factor in this, particularly with the floor no longer horizontal, may have been difficulty in gaining sufficient purchase on the carpet when attempting to push the door open. In other cases, where the assist system had operated, it appeared that it had not had sufficient power to drive the door fully open against its weight.

The only problem with door opening on the left side, Door L3, was attributable to doorframe distortion. It appeared unlikely that this could reasonably have been avoided, given the door's nearness to the fuselage break.

No escape slide deployment problems occurred. The failure of several of them to inflate was the result of the short drop to the ground. Had they inflated they would have been virtually horizontal and would have probably impeded evacuation. In the deployed but uninflated state they represented a potential hazard to evacuees stepping on them, but this appeared unavoidable in such a situation.

Following the shock and injury resulting from their ride during the ground run, the aircraft occupants were thus presented with a number of significant obstructions to evacuation. These included an appreciable floor roll attitude; displacement, detachment and/or incursion of items in the cabin; the unavailability of three of the eight exits; and exterior darkness, torrential rain and thick mud. Despite this, crew and passenger reports suggested that evacuation of the cabin was completed rapidly.

2.5.5. *Search for the aircraft and rescue of the occupants*

Selection of the airport emergency alarm was rapid, despite the controller having lost sight of the aircraft, and occurred approximately 45 seconds after the second touchdown, after she had attempted to make radio contact, without success. As the button did not appear to be working, the controller contacted the SEI by dedicated telephone line to confirm activation of the alarm.

The airport's emergency plan was then activated, in a situation of torrential rain together with a number of lighting blackouts in all the airport installations except the Control Tower, with its uninterrupted power supply.

In response to the query from the fire team as to the aircraft's location the controller hesitated, as she had had no clear sight of it or even positive evidence that an accident had occurred. However, she appeared to suspect that something untoward had happened and directed the team to the area of the south end of the runway. Confirmation that the SEI vehicles were at the Runway 02 threshold came some 6 minutes after the activation of the alarm. While this exceeded the planned maximum response time, it may not have been unreasonable in the adverse circumstances.

Finding the aircraft main wreckage in the darkness and heavy rain would clearly have been difficult, given that it was not illuminated and located outside the airport boundary and some 8-9 metres below the local runway level. Having travelled the whole runway without sighting the aircraft, the SEI vehicles extended the search to the west of the runway. However, the vehicles became stuck in soft ground caused by the rain and were unable to reach the perimeter road by this route. It is considered that more effort would be needed to reduce the time to locate crashed aircraft in adverse meteorological conditions, as well as the time to reach the runway threshold, and therefore it is recommended to AENA to increase both the training and the available means provided to the emergency teams.

By going a different way, the SEI vehicles managed to reach the western perimeter road 15 minutes after the activation and located the main wreckage 3 minutes later. At this point the accident was confirmed and additional rescue services from outside the airport were requested. The additional few minutes taken to reach the aircraft occupants occurred because the boundary fence had remained intact adjacent to the area of the road closest to the main wreckage.

Witness evidence indicated that there had been appreciable confusion in the recovery of the occupants and the prioritisation of injury treatment. It was likely that this had resulted from the combined effects of the magnitude of the event at an airport with a small and seasonal traffic flow, the adverse environment and communication difficulties occasioned by the language barrier between the SEI personnel and the aircraft occupants.

2.6. Nose landing gear failure mode

The injuries suffered in the accident and most of the aircraft damage resulted from the high-speed ground run over very significant obstacles. Had the engines remained at forward idle thrust after the landing, it was likely that the aircraft would have come to rest on the runway or, at worst, run off at relatively low speed. The disabling of spoilers, thrust reversers and the wheelbrake antiskid system due to MEC damage would have been undesirable, but probably not critical, and damage was likely to have remained limited to the NLG support structure and MEC areas and the MLG tyres. Thus the uncommanded forward thrust increase caused by interference of the displaced doghouse with the powerplant control cables was responsible for converting the consequences of the accident from relatively benign to potentially catastrophic.

It appeared that a similar effect of uncommanded forward thrust increase had probably occurred in a previous case of B757 NLG overload. The report on the accident to PH-TKC (Section 1.18.2.2) showed that the aircraft had travelled almost 3 km along the runway after landing and then for 100 metres in soft ground before coming to rest. The long ground run occurred in spite of an apparently abnormally high energy absorption by the wheelbrakes, as indicated by the brake fire that occurred. There were thus strong indications that forward thrust on at least one engine had been above idle. This was fully consistent with the reported damage to the control cables for No 1 engine, which was similar to that in G-BYAG's case. Extensive MEC damage and electrical power supply loss also resulted in PH-TKC's case.

The failure mode of the NLG support structure was very similar in both cases and it appeared likely that it would be closely reproduced in any situation where the B757 NLG experienced a rearward and upward overload. It is therefore recommended that the FAA require the B757 aircraft manufacturer to take measures aimed at preventing potentially hazardous effects on aircraft systems as the result of overload failure of the nose landing gear leg or its support structure. In particular, the measures should aim to prevent uncommanded forward thrust increase.

3. CONCLUSIONS

3.1. Findings

3.1.1. *Aircraft*

1. The aircraft had a valid Certificate of Airworthiness and records indicated that it had been maintained in accordance with an approved maintenance schedule.

2. There were no indications of any aircraft malfunction prior to touchdown.

3. The aircraft made an initial touchdown on the runway in the normal touchdown zone.

4. There was a high descent rate at initial touchdown and the aircraft bounced.

5. The ground spoilers were armed but did not probably deploy at initial touchdown as the aircraft air-ground logic was not activated before the aircraft bounced.

6. The sustained and quick forward movement of the control column after the initial touchdown caused the aircraft to develop an excessive nose down pitch rate.

7. During a second touchdown a high nose down pitch rate contact of the nose landing gear with the runway overloaded the nose landing gear support structure and caused it to displace within the fuselage.

8. Damage resulting from displacement of the nose landing gear support structure caused loss of virtually all aircraft electrical power, disabling spoiler and autobrake systems, and severely affected aircraft and engine control systems.

9. The thrust reversers probably did not deploy; it could not be determined whether they had been selected but engine control cable damage would have prevented their deployment.

10. Interference with engine control cables by the displaced nose landing gear support structure caused significant uncommanded forward thrust increase on one or both engines after touchdown.

11. Uncommanded forward thrust increase, in conjunction with the disabling of autobrake, spoiler, reverser and possibly manual braking systems, caused an extended high-speed ground run that resulted in potentially catastrophic damage.

12. Previous B757 accidents had occurred in which overload displacement of the nose landing gear support structure had caused loss of virtually all aircraft electrical

power and, in at least one case, probable uncommanded forward thrust increase. No relevant modification of the nose landing gear, its support structure or aircraft systems had been made as a result of those accidents.

13. The aircraft cabin and furnishings generally performed well during the ground impacts but the dislodgement of some cabin equipment appeared unwarranted.

14. The commander was rendered unconscious during the ground run when his head struck the unpadded frame of the flight deck windshield.

3.1.2. *Flight crew*

1. The crew was not able to obtain in-flight meteorological information on thunderstorm activity.

2. The crew members were aware of the general weather conditions of thunderstorm and heavy rain in the vicinity of the destination airport before commencing their approach.

3. The decision on departure fuel quantity underestimated the forecast weather conditions at the destination and nearest alternate airports.

4. The crew members used the aircraft weather radar.

5. The crew members had complied with flight duty and rest period requirements.

6. The crew could not complete the first approach and executed a go-around.

7. There was no significant windshear affecting the aircraft during the final approach.

8. During final approach the flight path became vertically destabilised below the decision height.

9. An excessive descent rate very shortly before touchdown caused the caution «SINK RATE» to sound and the suppression of some of the usual automatic height callouts.

10. There was no record, nor was there required to be, that the crew members had received specific training in flight simulator in initiating a go-around from below decision height.

11. The absence of a flare before touchdown probably resulted from the effects of shock upon the commander at the runway lights extinguishing very shortly before touchdown, visual illusion after they had gone out and/or the loss of the usual automatic height callouts.

12. The fuel quantity remaining when the aircraft touched down was probably below that required by the operator's policy for a go-around and diversion, although it complied with the exceptions contained in such policy.

3.1.3. *Air Traffic Services and Airport Installations*

1. Detailed information on the development and intensity of the storm was not provided to the aircraft's crew. The air traffic controller at the Girona tower did not have information on the development of the storm.

2. Commercial charts used for the final approach did not include information contained in the official Spanish aeronautical publication that ILS glideslope indications for the runway used should not be used below 260 ft agl.

3. The main electrical power supply to the airport and surrounding area failed immediately before the aircraft touched down.

4. The ground power supply failure probably resulted from heavy rain and storm activity near the airport. During tests carried out after the accident it was noted that automatic systems restored emergency supplies to the airport within the 15 second ICAO specification.

3.1.4. *Search and Rescue*

1. All passengers had been strapped in and remained conscious, and did not sustain injuries sufficiently serious to prevent their rapid evacuation.

2. The Airport Fire and Rescue Service vehicles arrived at the runway approximately 6 minutes after the airport emergency alarm was activated.

3. The Airport Fire and Rescue Services located the main wreckage of the aircraft in severe weather conditions around 18 minutes after the accident, and reached it around 14 minutes later, by which time all of the occupants had been evacuated.

4. No aircraft lighting or emergency location signal was used to assist the emergency services in locating the main wreckage.

3.1.5. *Flight Recorders*

1. Portions of the DFDR data following the second touchdown were lost or corrupted, probably due to aircraft power supply distortion.

2. Data and sound recordings ceased very shortly after the second touchdown, probably due to aircraft power supply loss.

3.2. Causes

It is considered that the most probable cause of the accident was the destabilisation of the approach below decision height with loss of external visual references and automatic height callouts immediately before landing, resulting in touchdown with excessive descent rate in a nose down attitude. The resulting displacement of the nose landing gear support structure caused disruption to aircraft systems that led to uncommanded forward thrust increase and other effects that severely aggravated the consequences of the initial event.

Contributory factors were:

1. Impairment of the runway visual environment as a result of darkness and torrential rain and the extinguishing of runway lights immediately before landing.

2. Suppression of some automatic height callouts by the GPWS «SINK RATE» audio caution.

3. The effect of shock or mental incapacitation on the PF at the failure of the runway lights which may have inhibited him from making a decision to go-around.

4. The absence of specific flight crew training in flight simulators to initiate a go-around when below landing decision height.

5. Insufficient evaluation of the weather conditions, particularly the movement and severity of the storm affecting the destination airport.

4. SAFETY RECOMMENDATIONS

REC 26/04. It is recommended that the FAA require the B757 aircraft manufacturer to take measures aimed at preventing potentially hazardous effects on aircraft systems as the result of overload failure of the nose landing gear leg or its support structure. In particular the measures should aim to prevent uncommanded forward thrust increase.

REC 27/04. It is recommended that the aircraft manufacturer consider the possibility of modifying the procedure or the design of the alert system of the aircraft to minimise the possibility of B757 flight crews inadvertently leaving the speedbrake deployed with engine thrust above idle.

REC 28/04. It is recommended that the FAA require the B757 aircraft manufacturer to take measures aimed at improving the protection of flight crew members subjected to inertial loading while restrained by their harness, against impact with flight deck components, with the shoulder harness selected to either «lock» or «manual».

REC 29/04. It is recommended that the aircraft manufacturer take measures aimed at ensuring adequate crashworthiness of the B757 passenger service units and exit sign batteries.

REC 30/04. It is recommended to European Aviation Safety Agency (EASA) that they evaluate the possibility of making mandatory the requirements to train flight crews in go-around manoeuvres even from below the decision height, with the aim of reducing the response time when faced with unforeseen events.

REC 31/04. It is recommended that the Aircraft Operator should review its flight planning and clearance procedures in order to take into consideration probable meteorological conditions at the destination and alternate airports, including thunderstorms.

REC 32/04. It is recommended that the Girona Airport operator study the possibility of modifying the physical characteristics of the runway strip to make them compliant with the levelling and slope recommended in ICAO Annex 14.

REC 33/04. It is recommended that AENA should evaluate the possibility of increasing the training and available means to improve the search of crashed aircraft and to reduce the time to locate and actuate on the wreckage in adverse meteorological and reduced visibility conditions.

REC 34/04. It is recommended that AENA should establish standardised Control Tower procedures that include checklists to prevent and detect errors of execution and omission in the control tasks, and also to increase the training of air traffic controllers to determine what meteorological information must be provided to the flight crews.

REC 35/04. It is recommended that the National Meteorology Institute (INM), in collaboration with the air traffic services, establish a standardised system to inform the flight crews on the evolution and intensity of storms, particularly regarding storms that could be a hazard to the operation in the areas of initial climb and approach to aerodromes.

APPENDICES

APPENDIX A
Photographs, figures and graphs

Illustration not Available

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MAIN WRECKAGE

Figure 3.1 – Aerial View

Figure 3.2 – Main Wreckage looking North-West

Figure 3.3 – Main Wreckage looking West

B757-200 GENERAL ARRANGEMENT

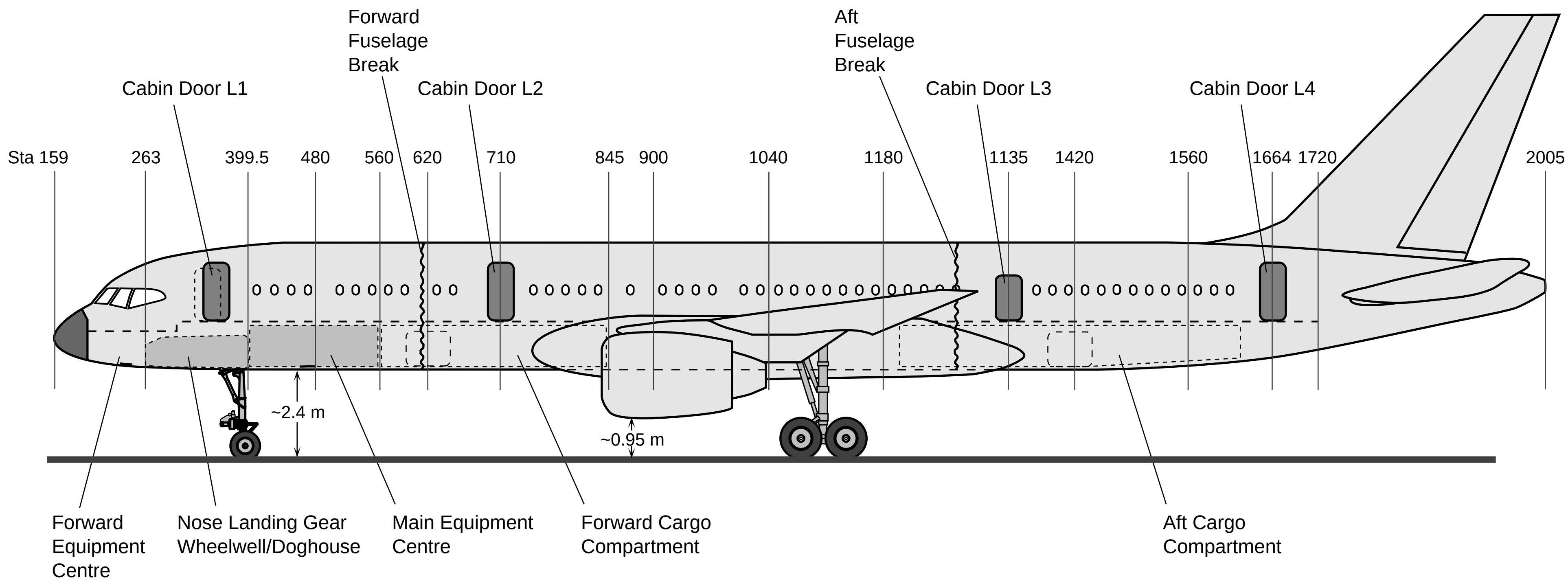
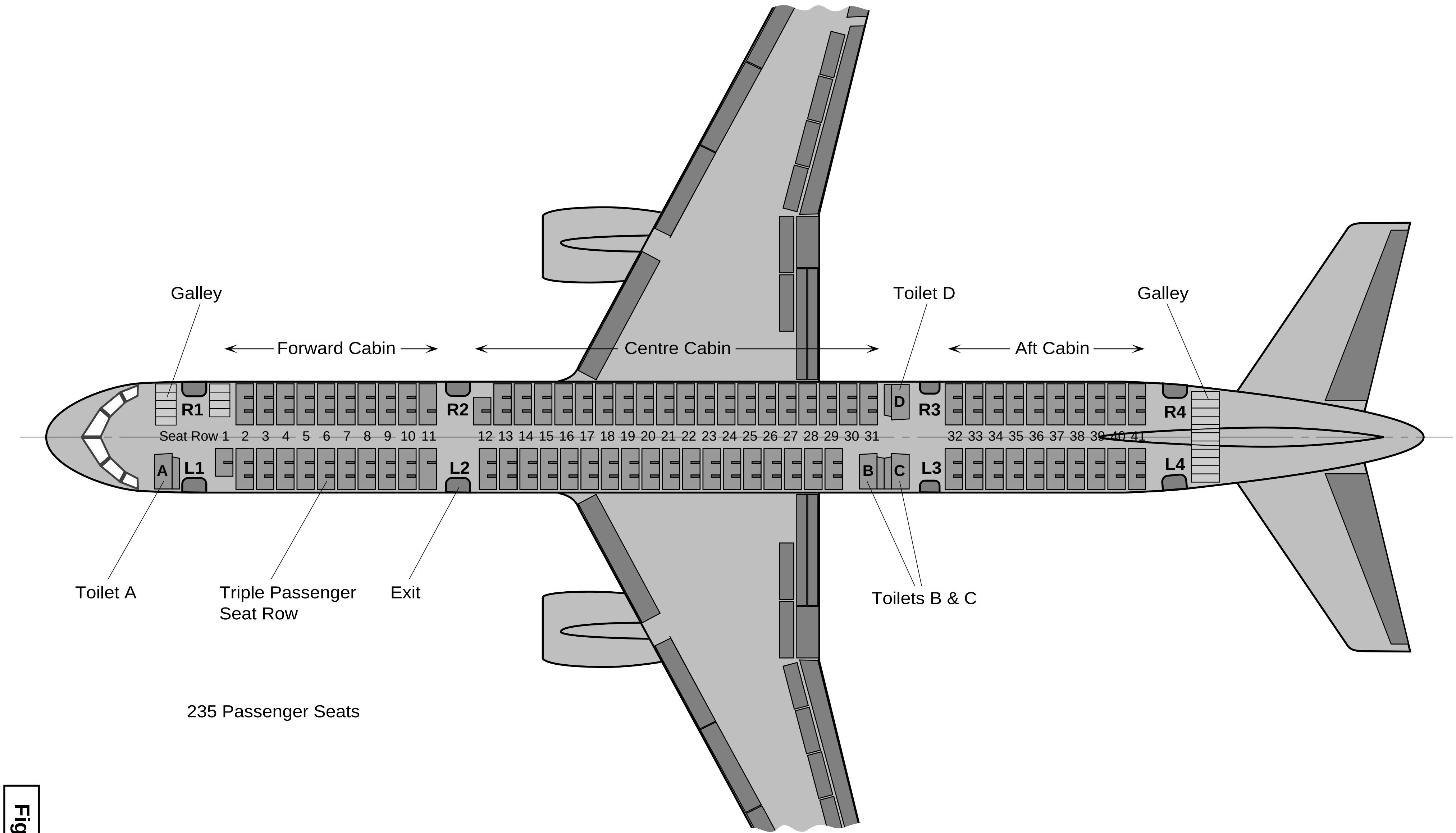


Figure 4

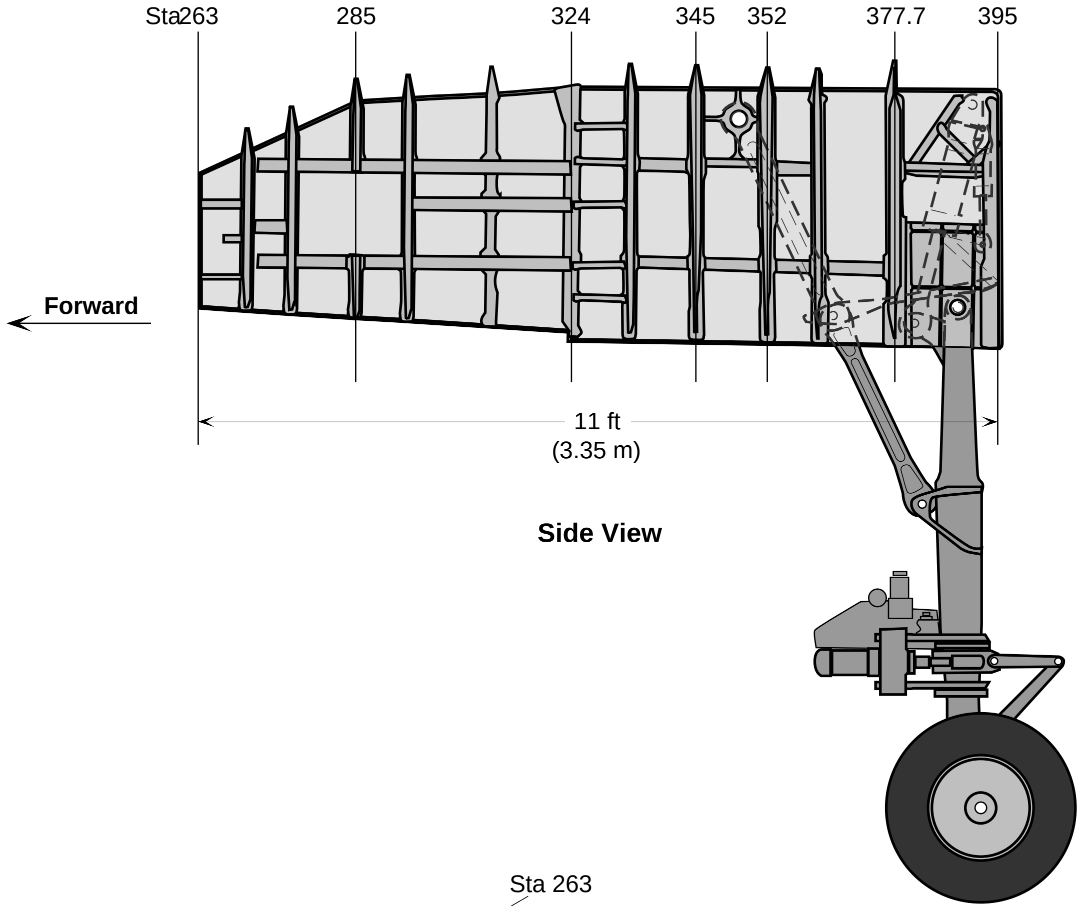
CABIN LAYOUT



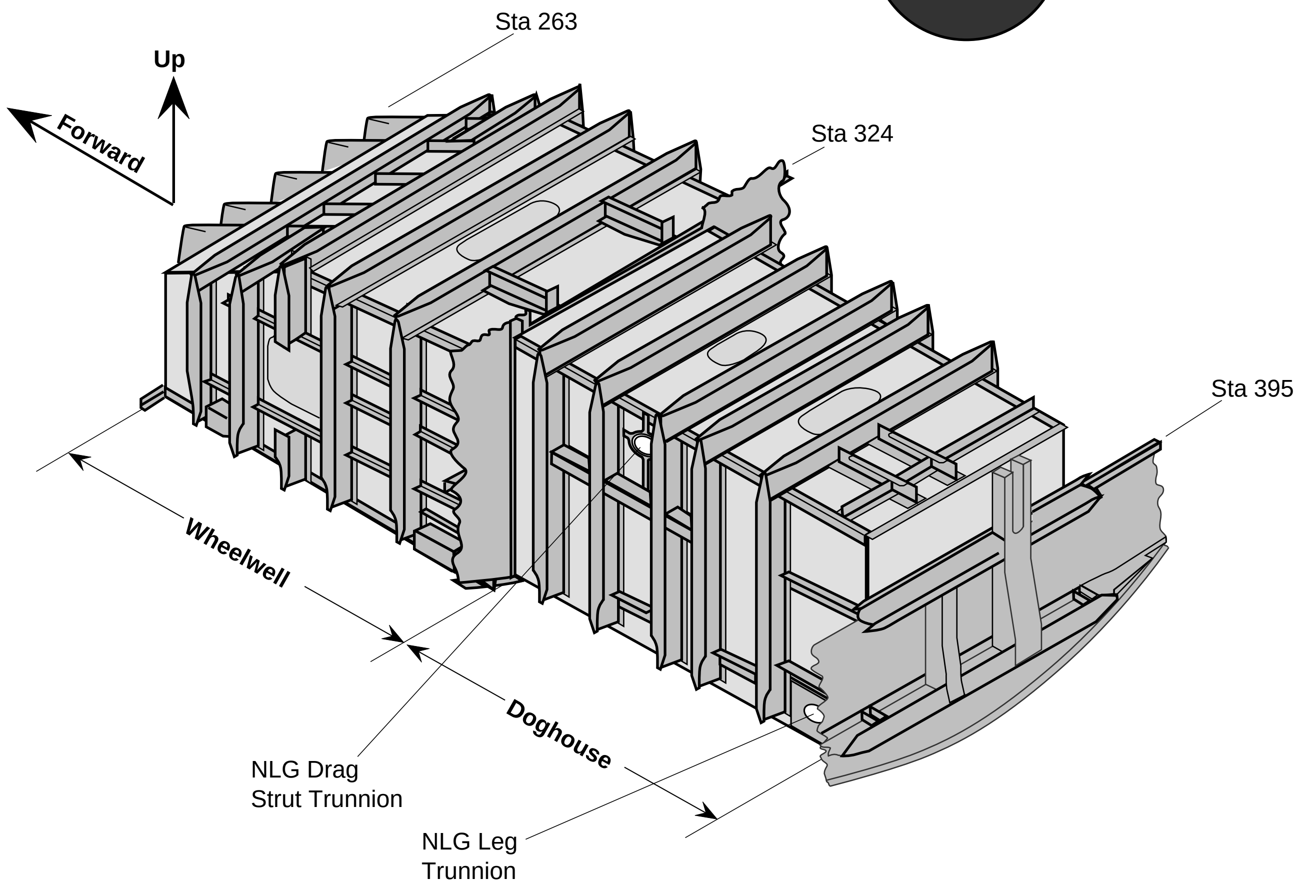
235 Passenger Seats

Figure 5

NOSE LANDING GEAR SUPPORT STRUCTURE



Side View



Isometric View

Figure 6

B757 DETAILS (Similar Aircraft to G-BYAG)

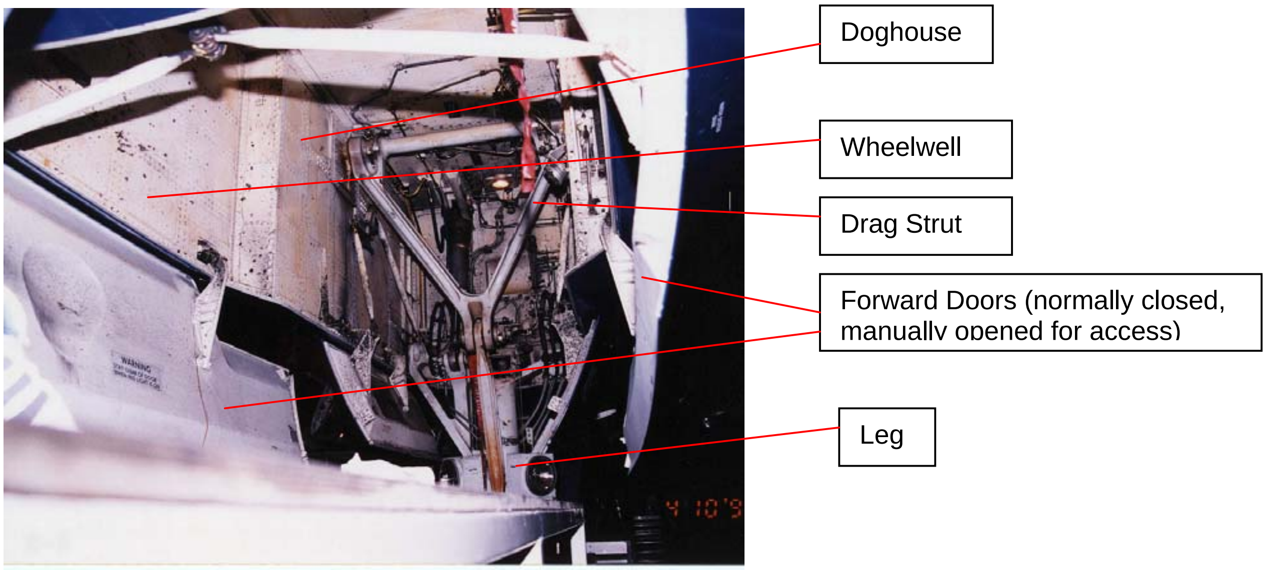


Figure 7.1 – Nose Landing Gear

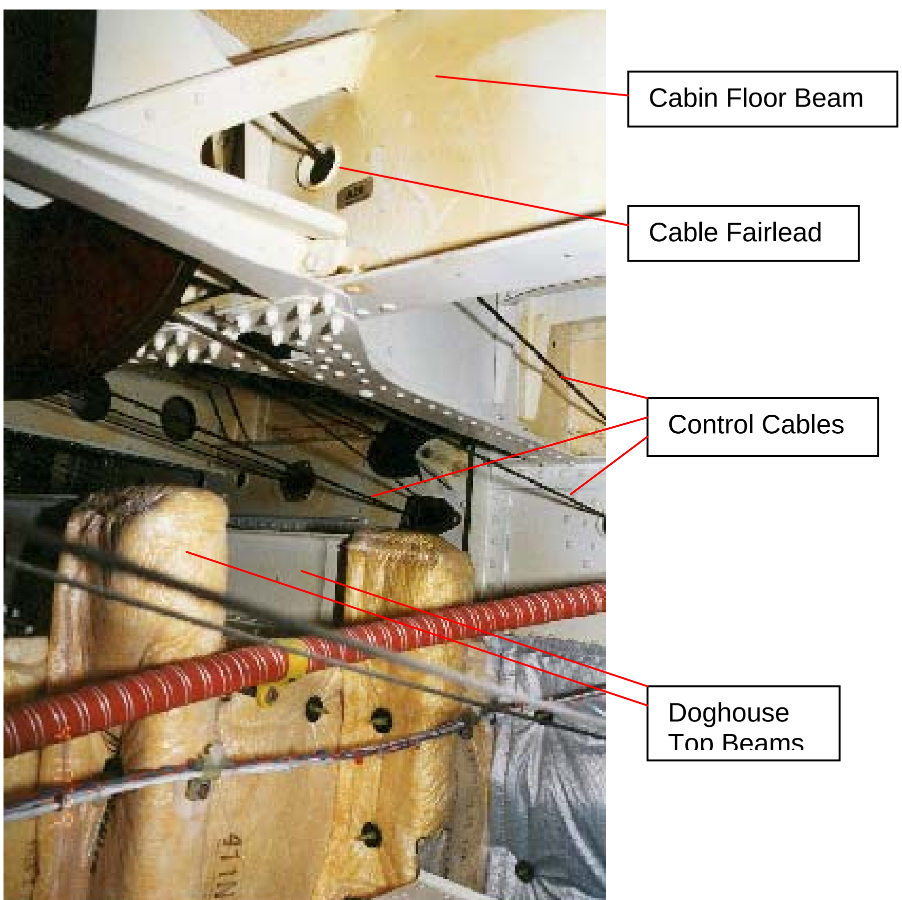


Figure 7.2 – Control Cables Underfloor

POWERPLANT CONTROL CABLES

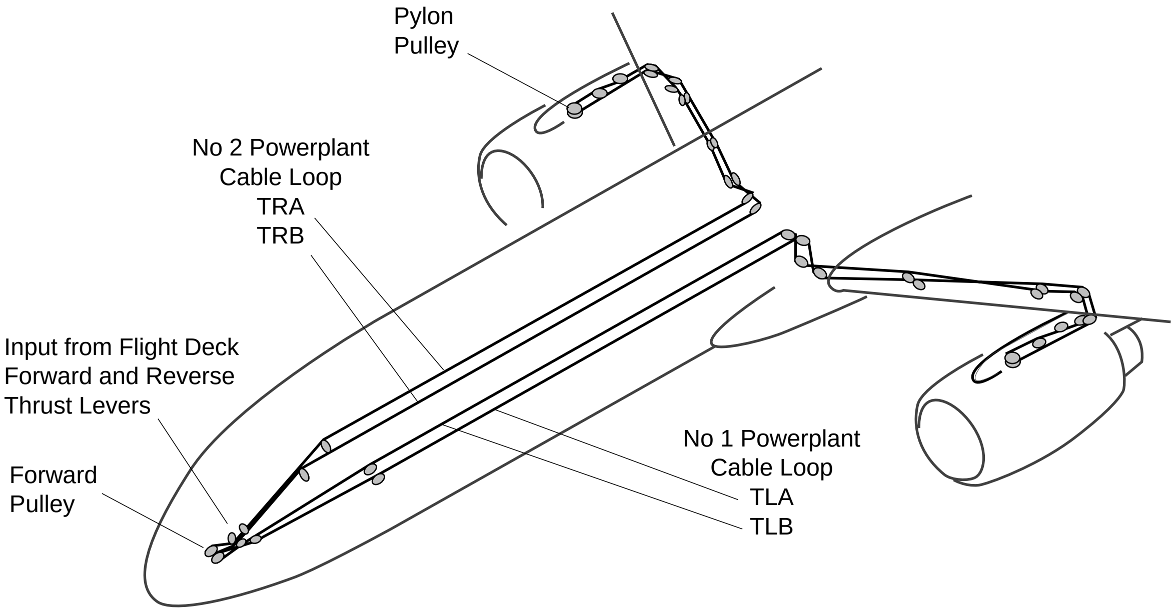


Figure 8.1 - Powerplant Control Run Schematic

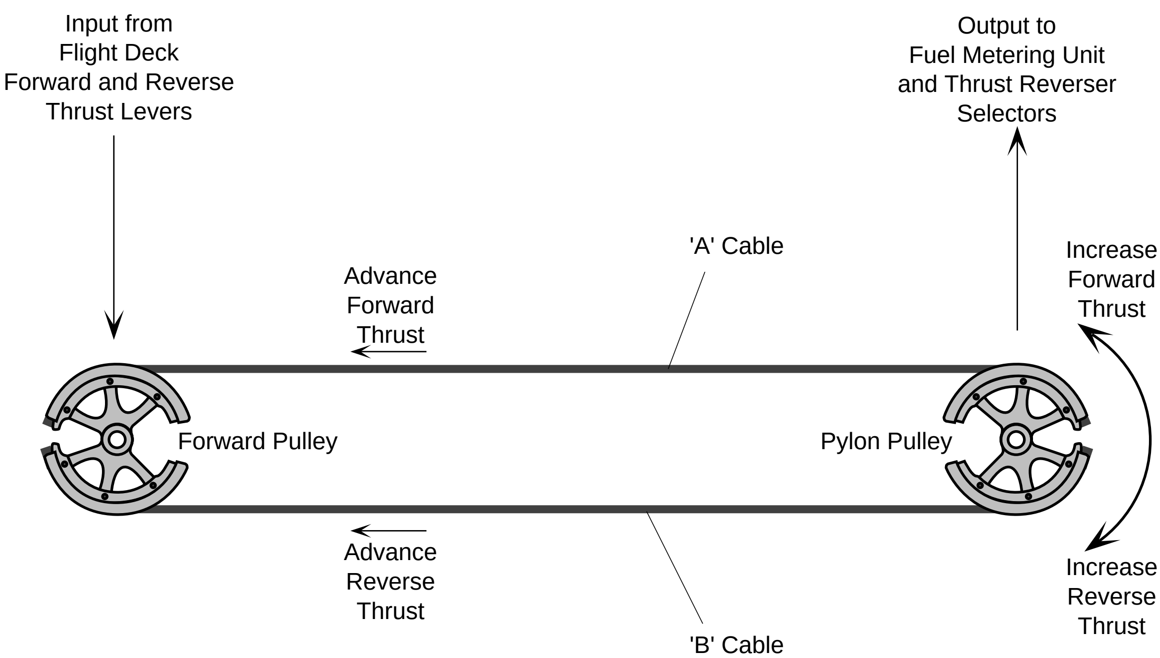
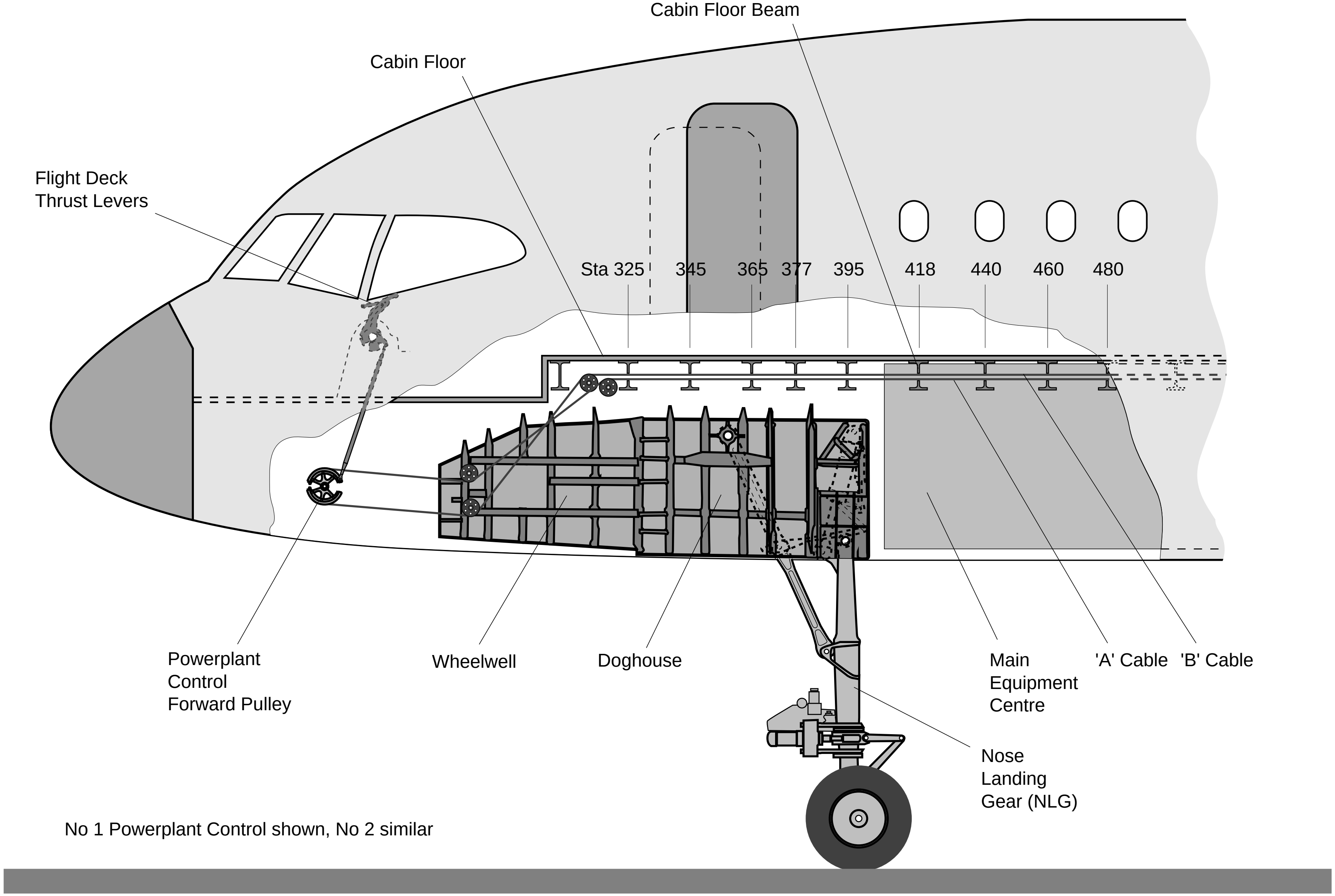


Figure 8.2 - Powerplant Control Run Operation

Figure 8

POWERPLANT CONTROL CABLE LAYOUT



No 1 Powerplant Control shown, No 2 similar

Figure 9

MAIN EQUIPMENT CENTRE

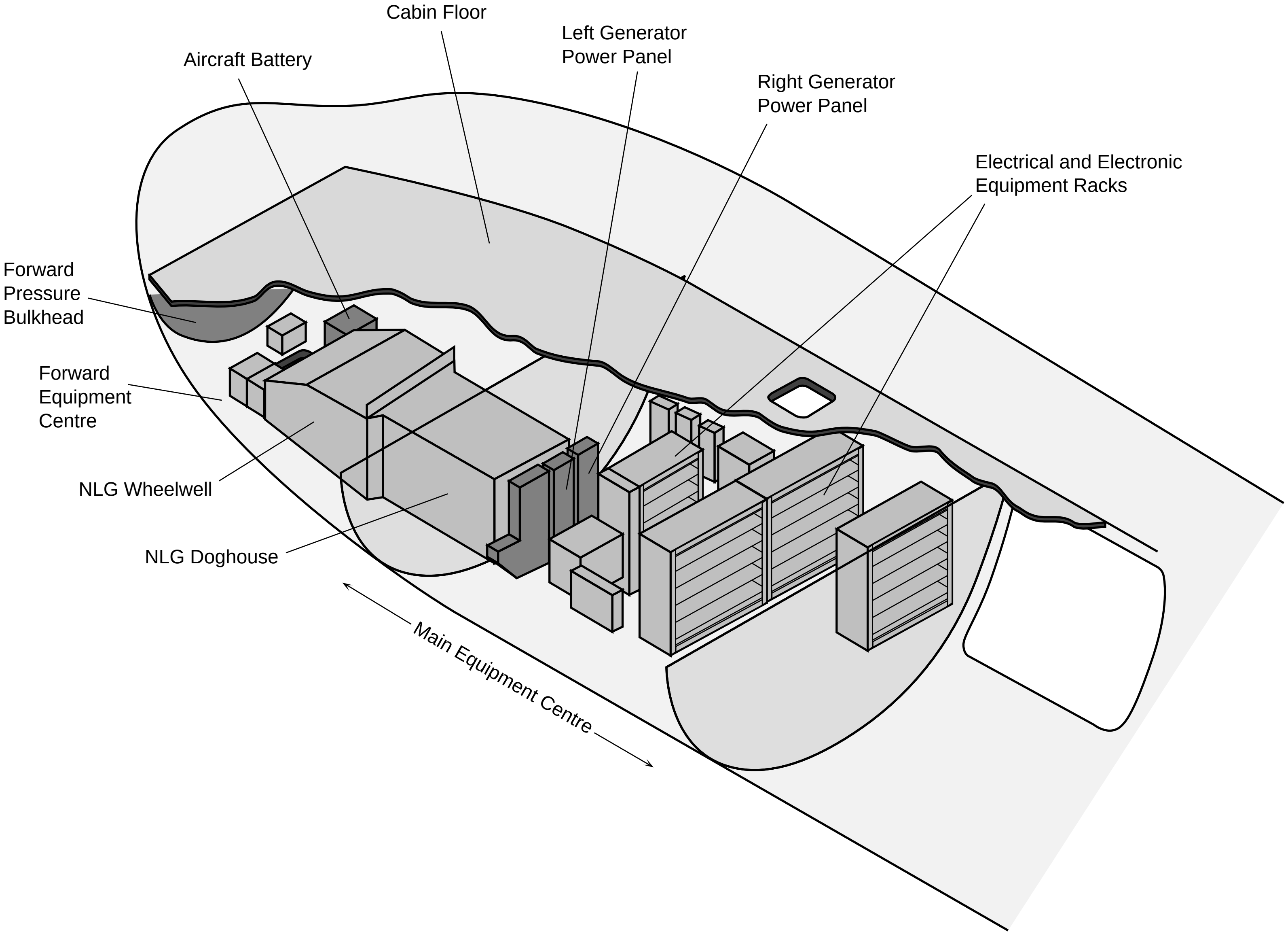


Figure 10

FLIGHT RECORDERS

Figure 11.1 – Flight Data Recorder and Cockpit Voice Recorder

Figure 11.2 – Quick Access Recorder (QAR)

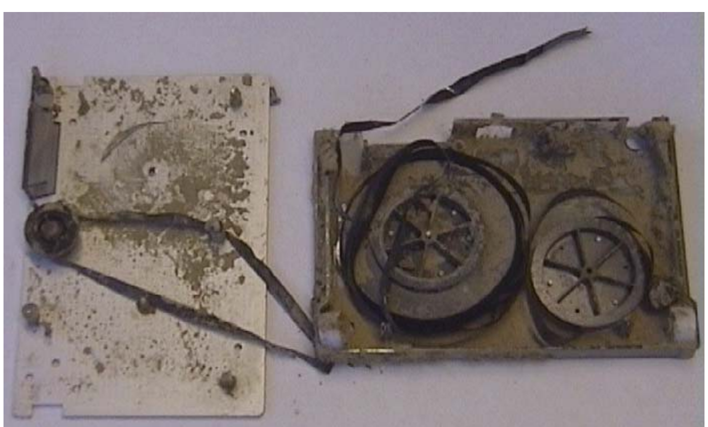


Figure 11.3 – QAR Cassette

Figure 11.4 – QAR

Figure 11

FDR DATA - GLIDESLOPE INTERCEPT TO FIRST TOUCHDOWN

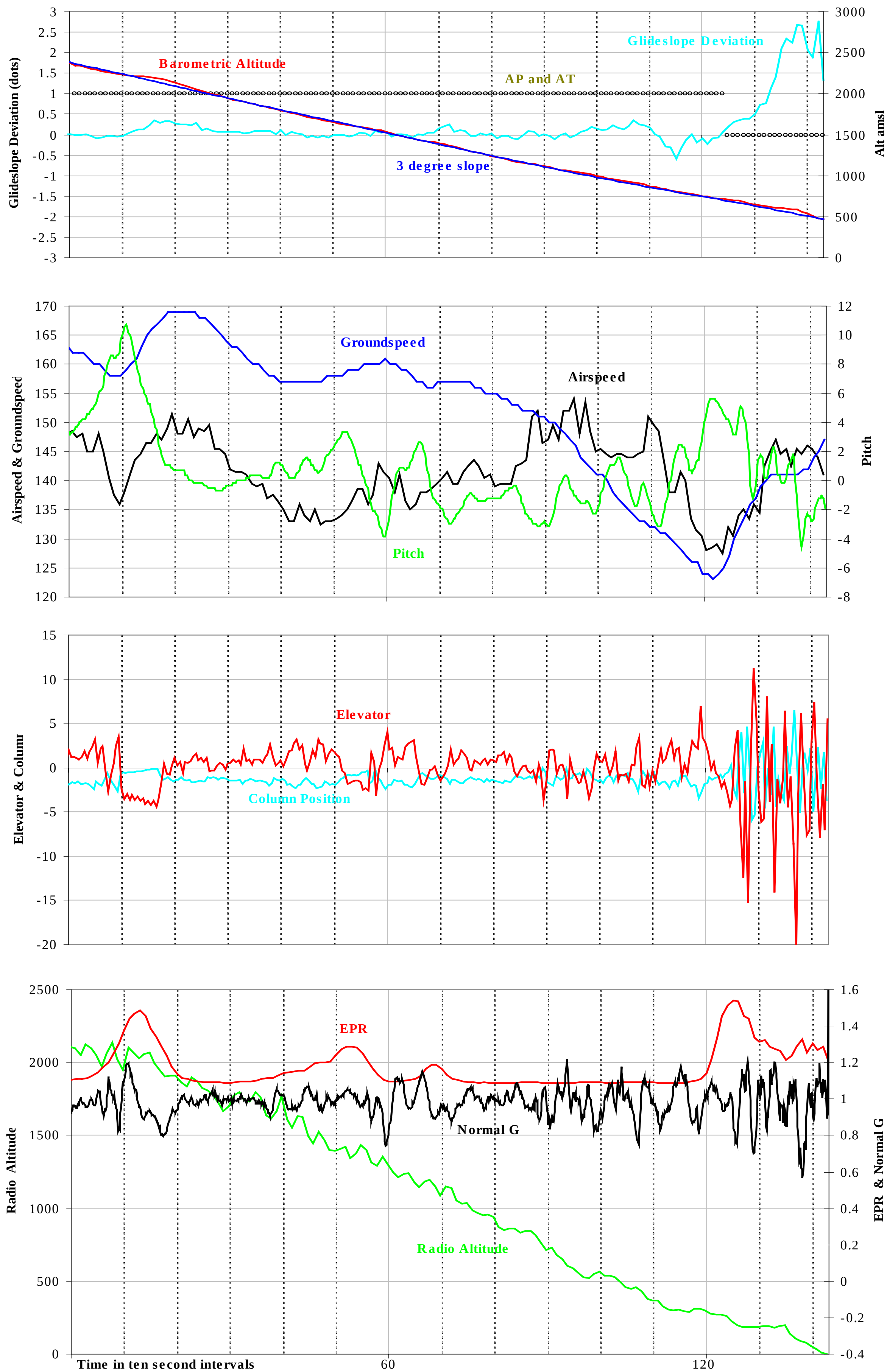


Figure 12

FDR DATA - MANUALLY FLOWN SEGMENT TO FIRST TOUCHDOWN

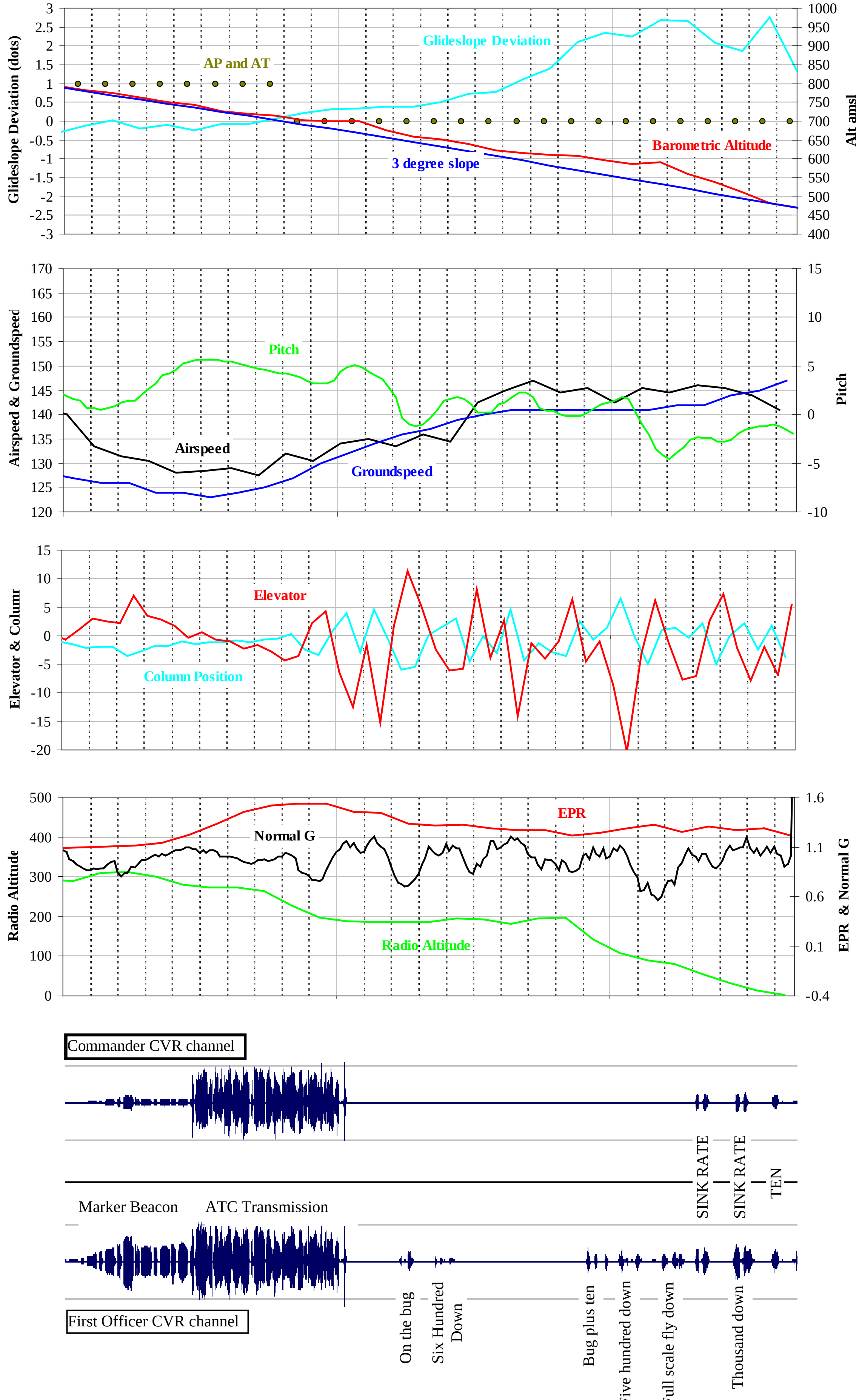


Figure 13

FDR DATA - EXPANDED VIEW OF FIRST AND SECOND TOUCHDOWN

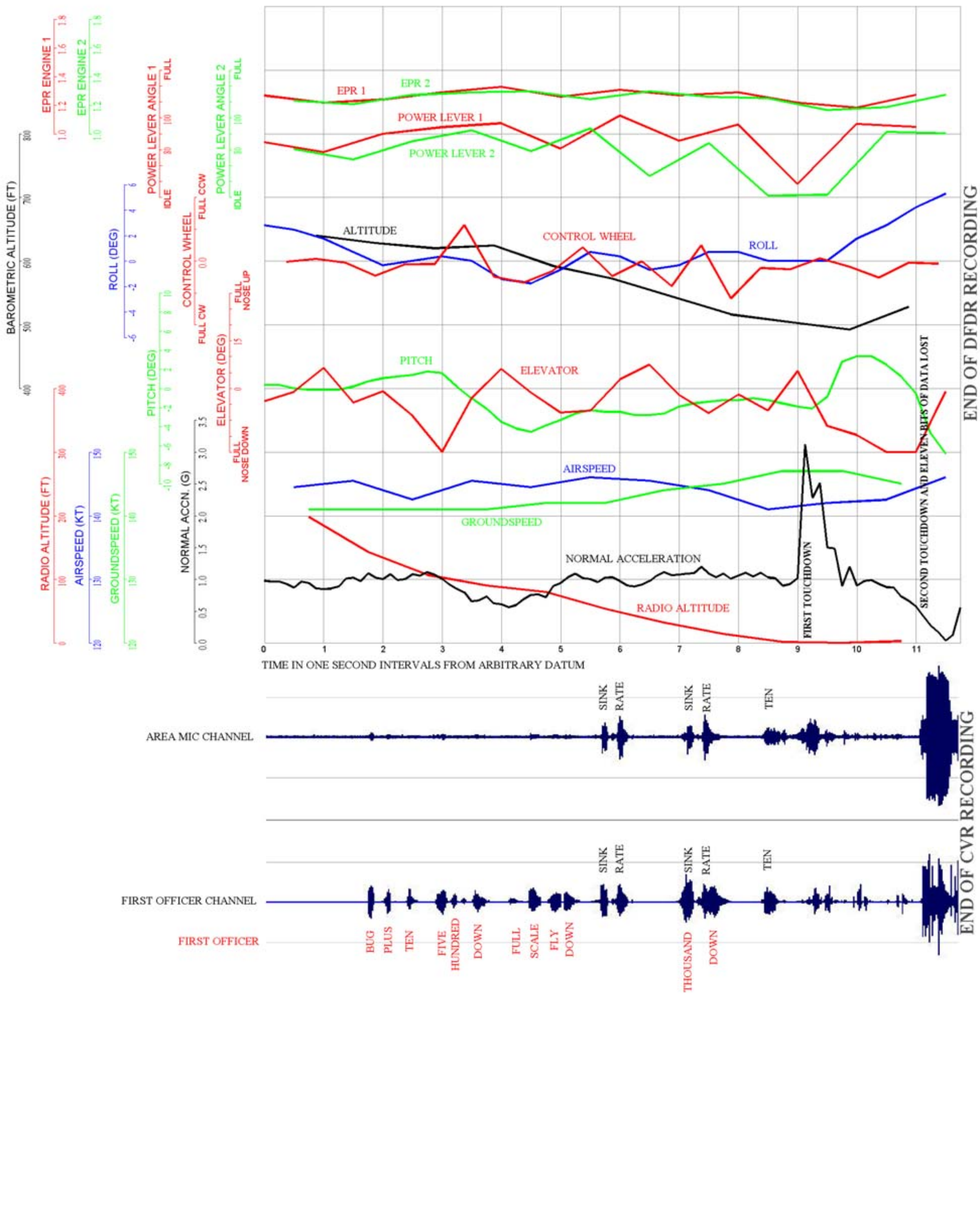


Figure 14

FDR DATA - WIND PROFILE DURING FINAL APPROACH

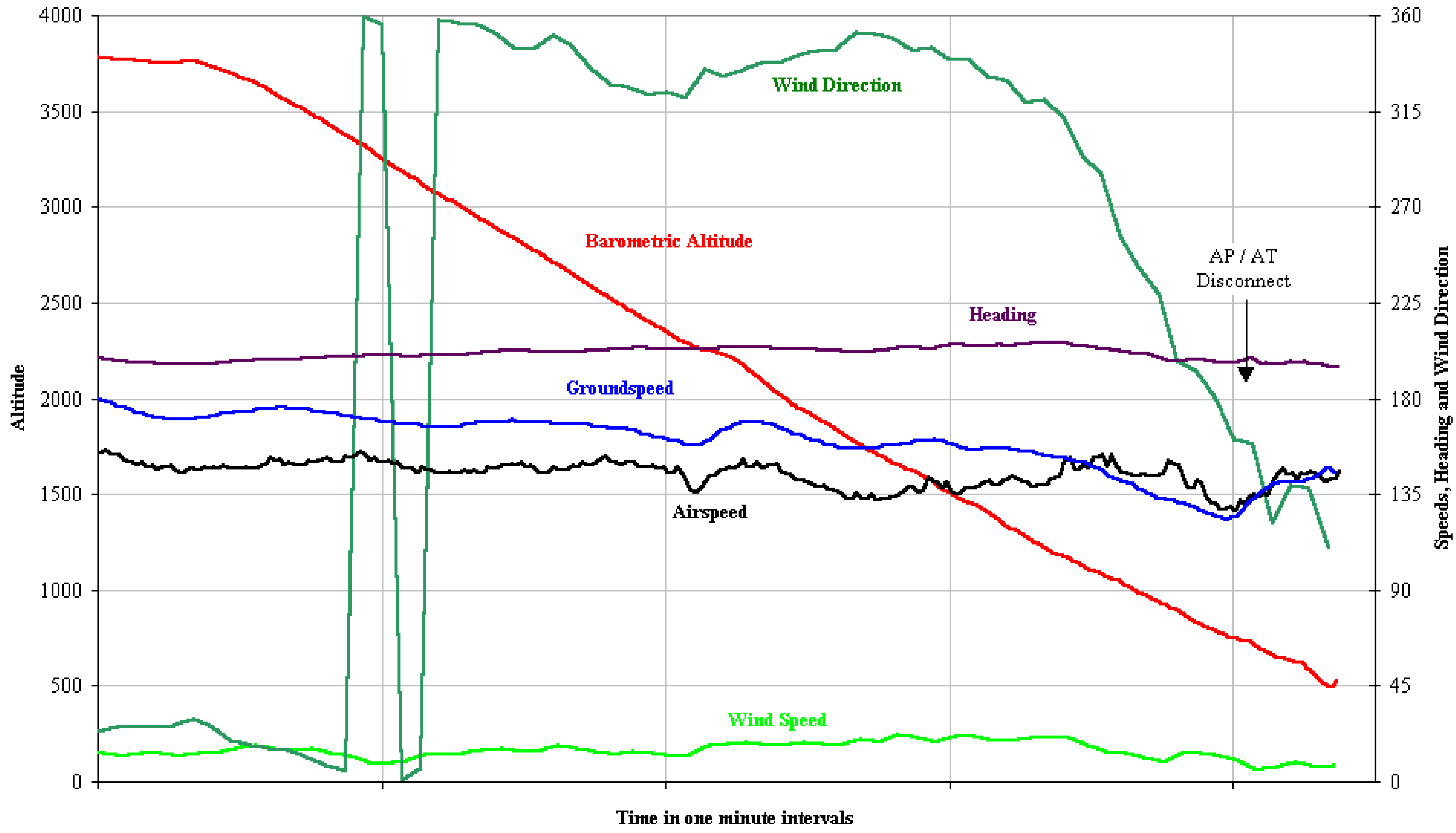


Figure 15

FIRST APPROACH

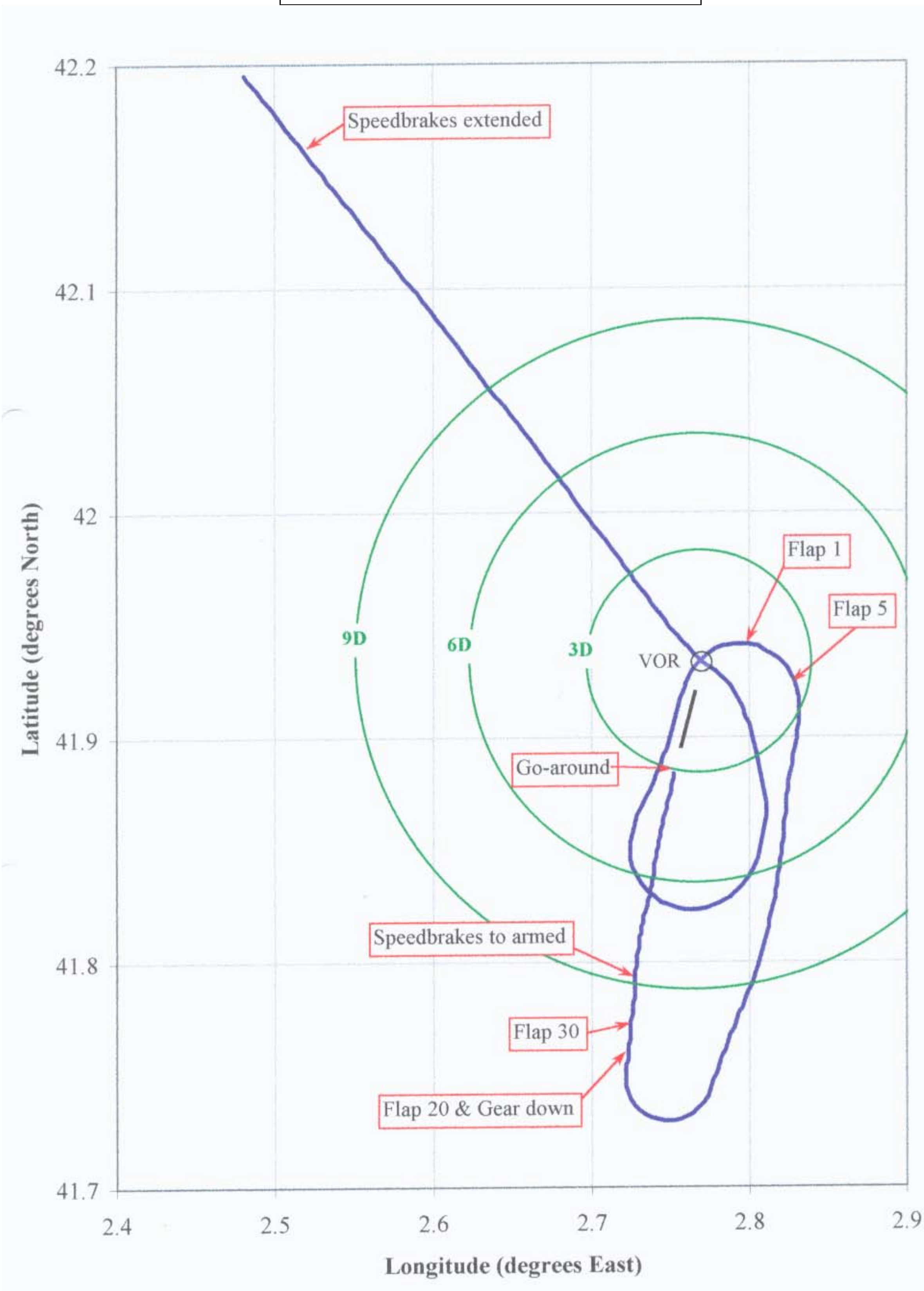


Figure 16

SECOND APPROACH

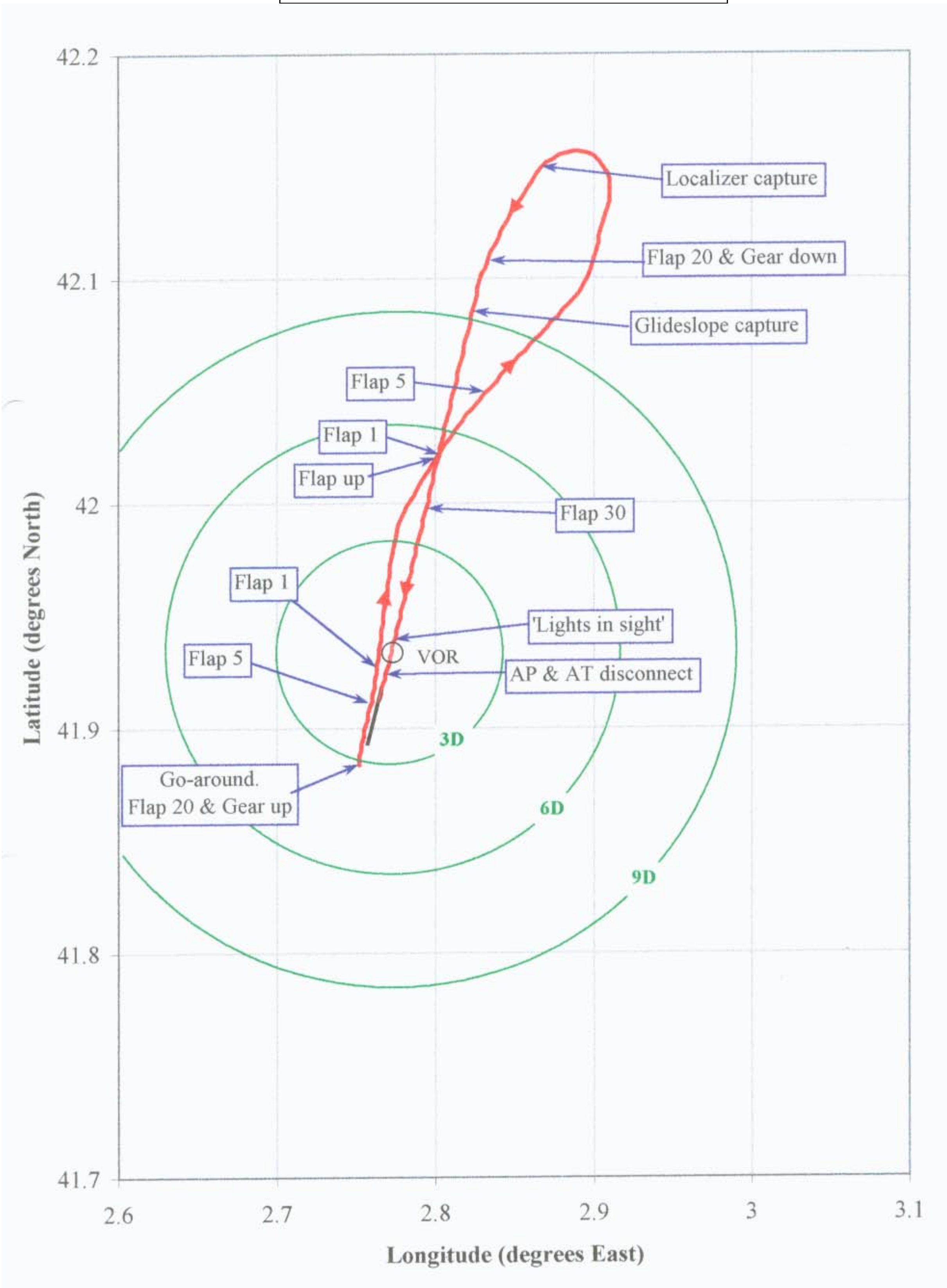


Figure 17

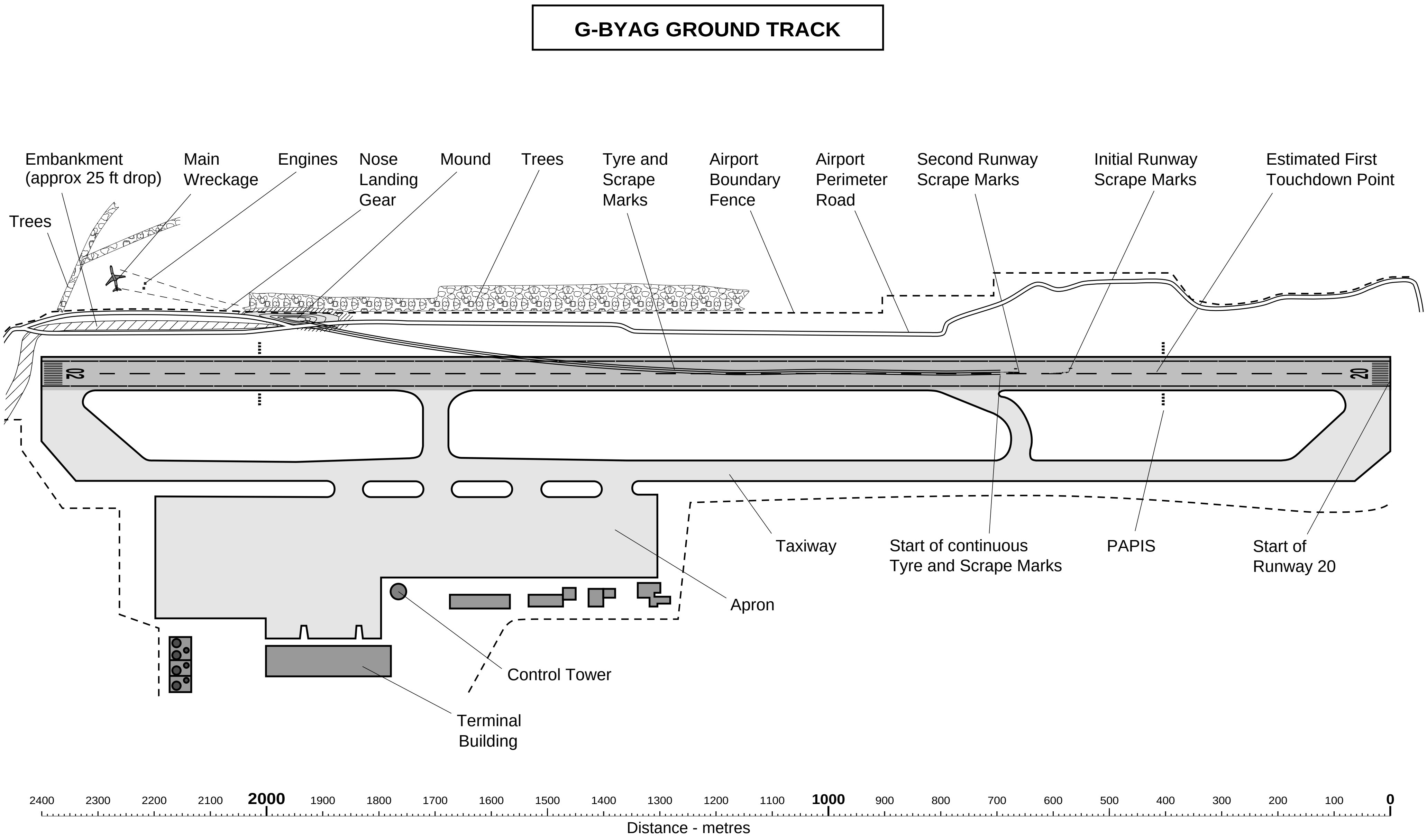

G-BYAG GROUND TRACK
Embankment (approx 25 ft drop)
Main Wreckage
Engines
Nose Landing Gear
Mound
Trees
Tyre and Scrape Marks
Airport Boundary Fence
Airport Perimeter Road
Second Runway Scrape Marks
Initial Runway Scrape Marks
Estimated First Touchdown Point
Trees
02
20
Taxiway
Start of continuous Tyre and Scrape Marks
PAPIS
Start of Runway 20
Apron
Control Tower
Terminal Building
2400 2300 2200 2100 2000 1900 1800 1700 1600 1500 1400 1300 1200 1100 1000 900 800 700 600 500 400 300 200 100 0
Distance - metres

Figure 18

G-BYAG GROUND TRACK - FINAL PART

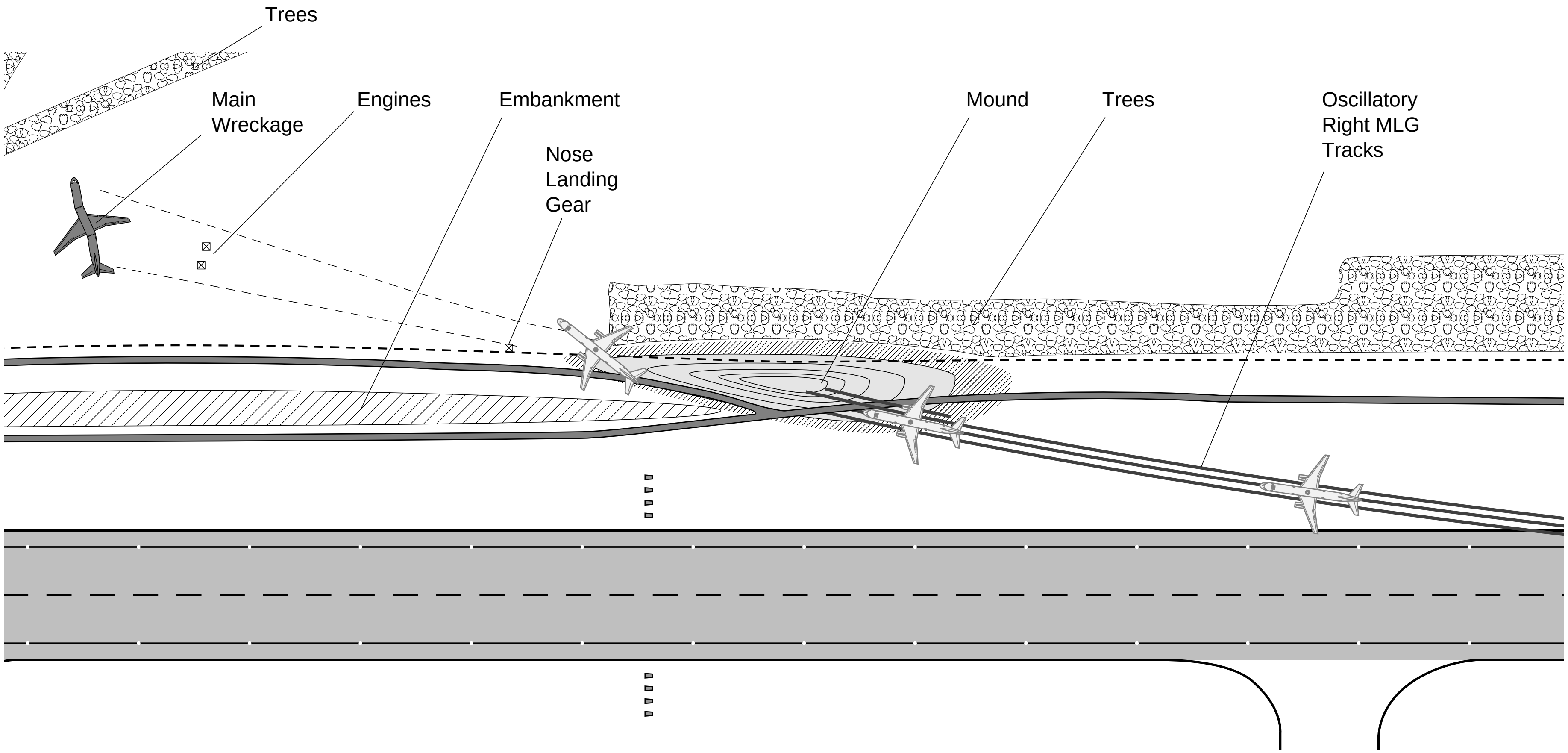


Figure 19

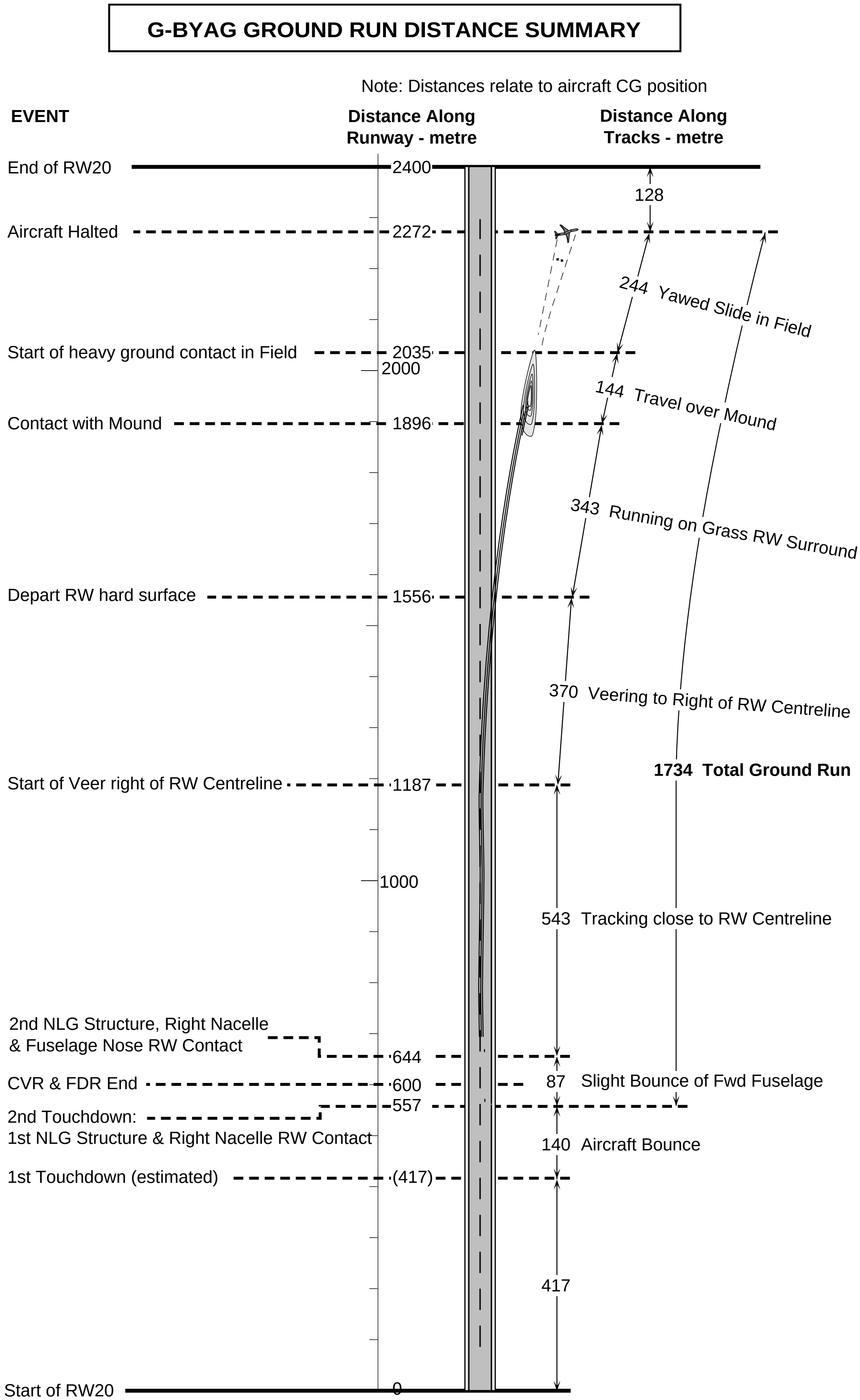

G-BYAG GROUND RUN DISTANCE SUMMARY
Note: Distances relate to aircraft CG position
EVENT
Distance Along Runway - metre
Distance Along Tracks - metre
End of RW20
2400
128
Aircraft Halted
2272
244 Yawed Slide in Field
Start of heavy ground contact in Field
2035
2000
144 Travel over Mound
Contact with Mound
1896
343 Running on Grass RW Surround
Depart RW hard surface
1556
370 Veering to Right of RW Centreline
1734 Total Ground Run
Start of Veer right of RW Centreline
1187
1000
543 Tracking close to RW Centreline
2nd NLG Structure, Right Nacelle & Fuselage Nose RW Contact
644
CVR & FDR End
600
87 Slight Bounce of Fwd Fuselage
2nd Touchdown: 1st NLG Structure & Right Nacelle RW Contact
557
140 Aircraft Bounce
1st Touchdown (estimated)
(417)
417
Start of RW20
0

Figure 20

INITIAL RUNWAY MARKS

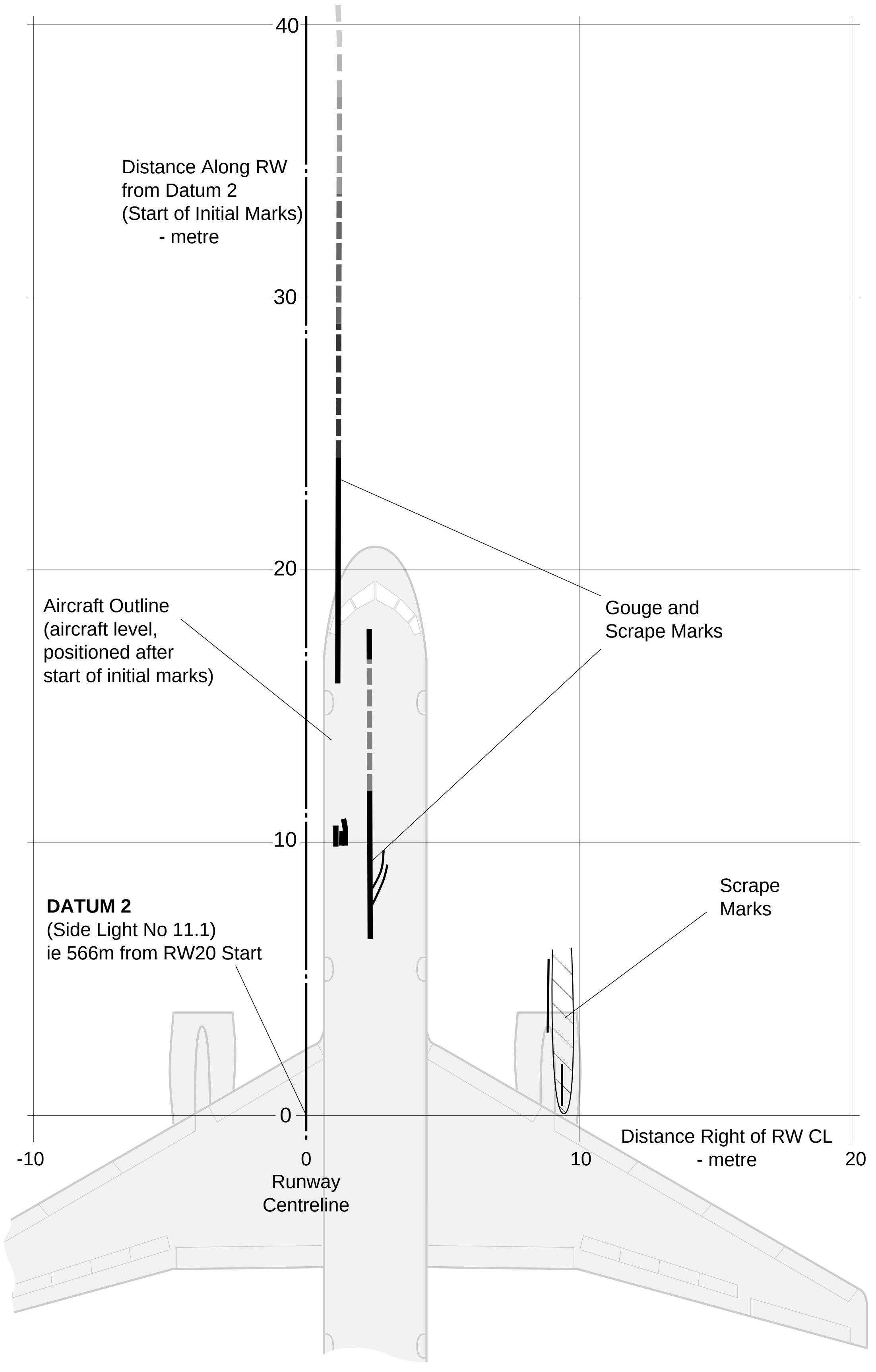


Figure 21

SECOND RUNWAY MARKS

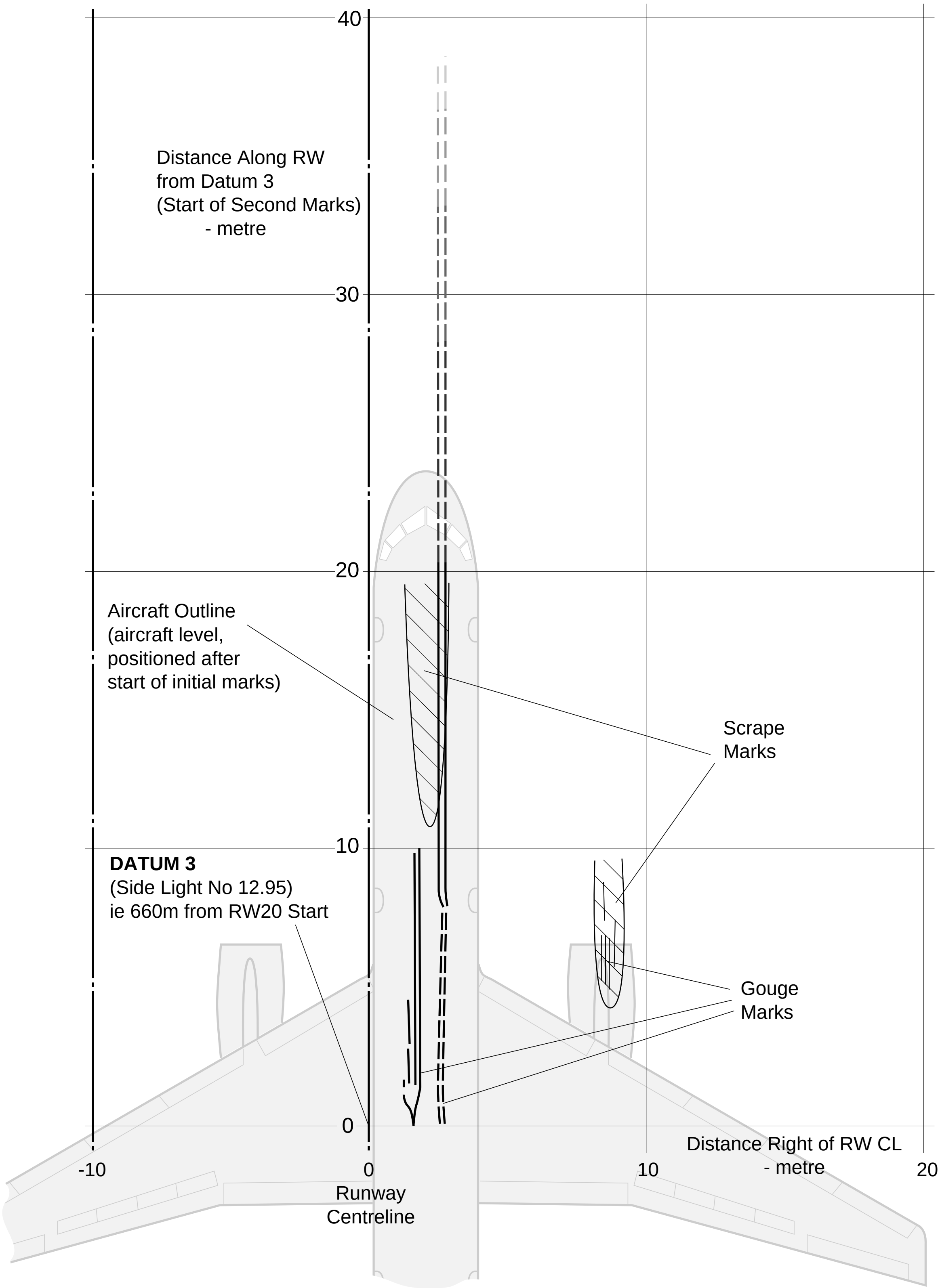


Figure 22

RUNWAY MARKS AND WRECKAGE

Figure 23.1 – Fuselage Marks

Figure 23.2 – Nacelle Marks

Figure 23.3 – Wreckage Items recovered from Runway

Figure 23

RUNWAY SURROUND

Figure 24.1 – Runway Edge Tracks

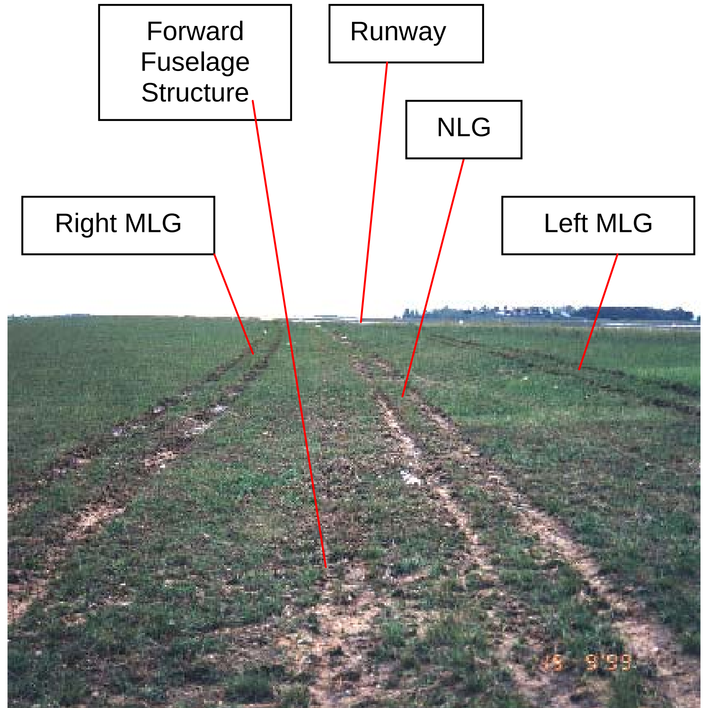


Figure 24.2 – Grassed Area

Figure 24.3 – Right MLG Tracks

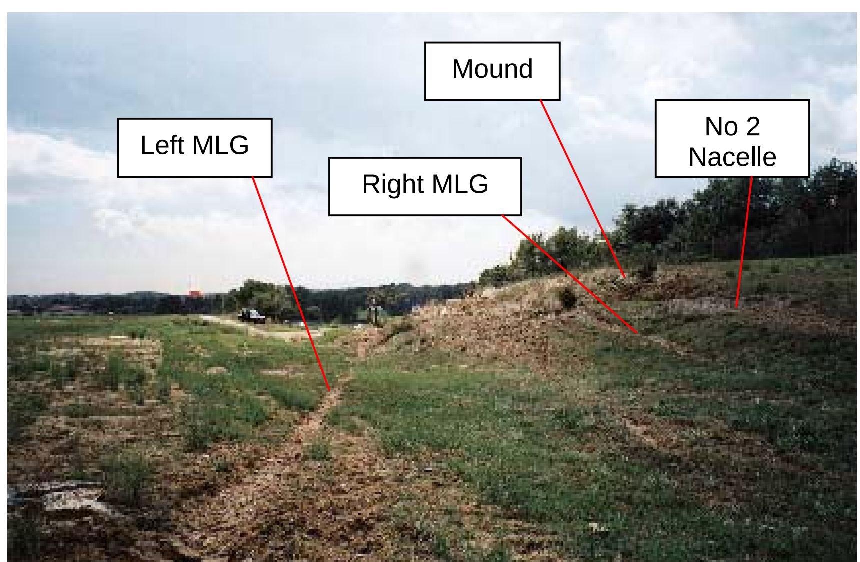


Figure 24.4 – Approach to Mound

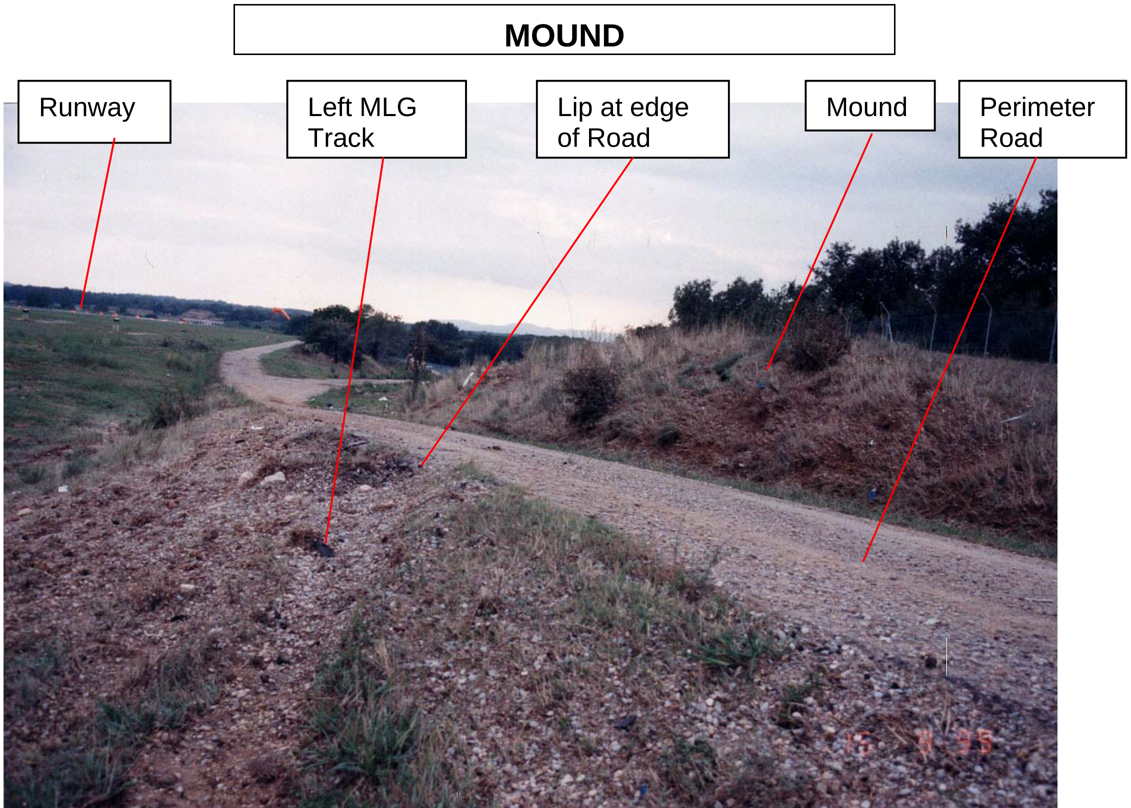


Figure 25.1 – MLG Tracks over Road

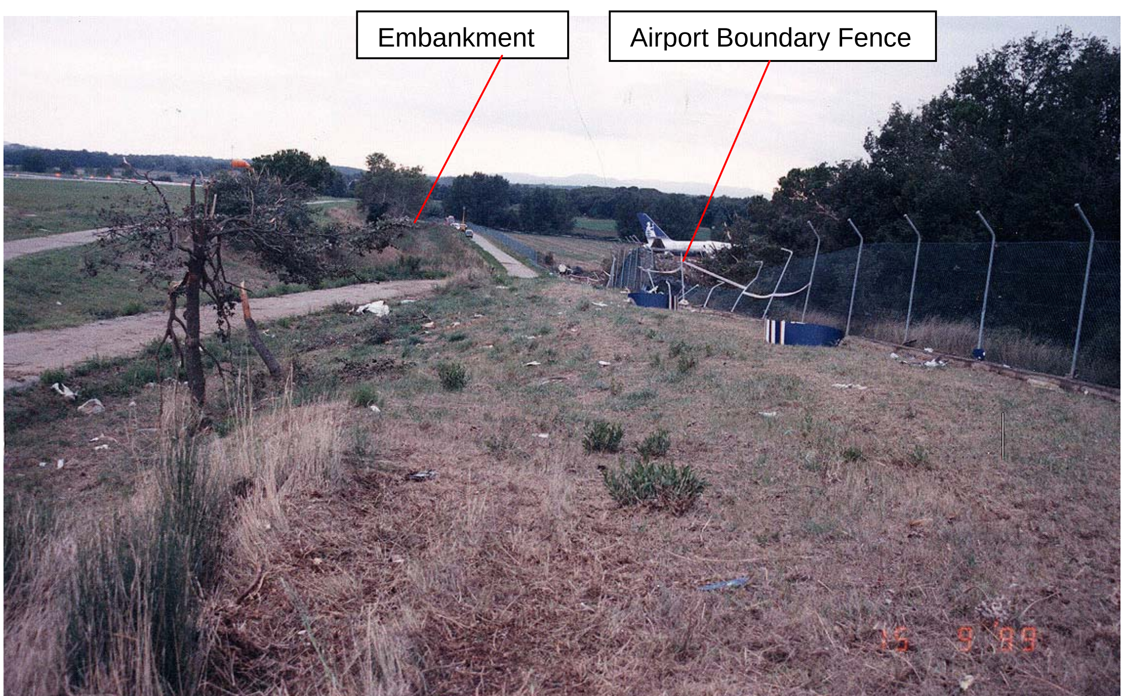


Figure 25.2 – View Along Track from Mound

Figure 25

WRECKAGE DETAIL

Figure 26.1 – Forward Fuselage

Figure 26.2 – Forward Fuselage

Figure 26.3 – Forward Equipment Centre Hatch

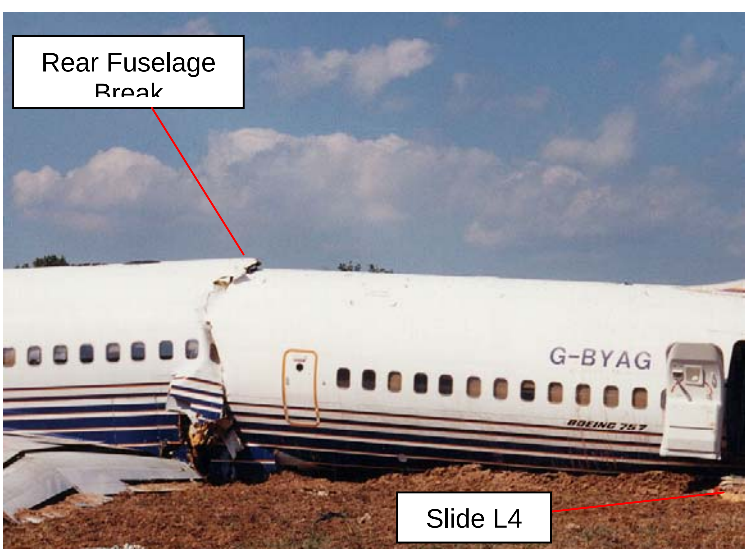


Figure 26.4 – Rear Fuselage

Figure 26

FORWARD FUSELAGE UNDERSIDE

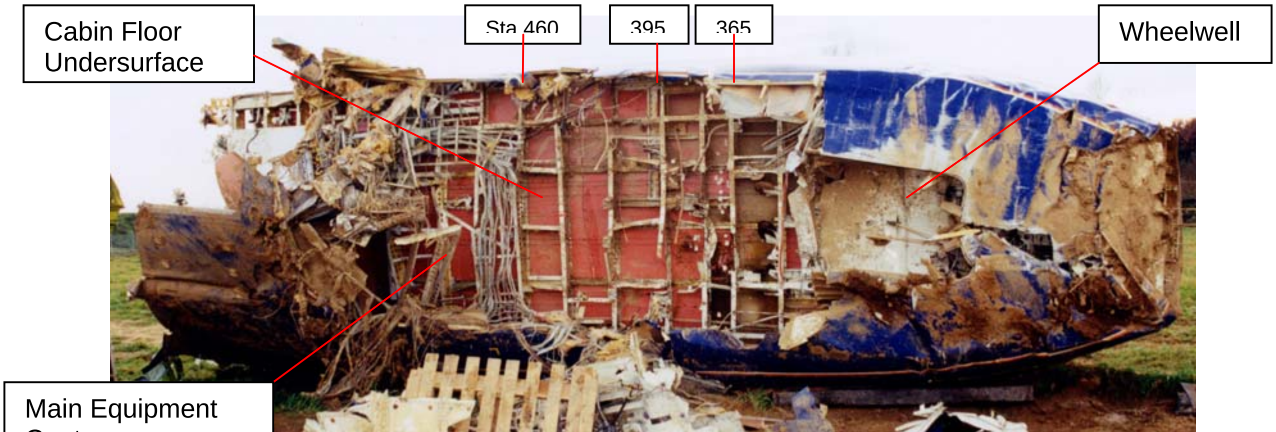


Figure 27.1 – Forward Fuselage Underside

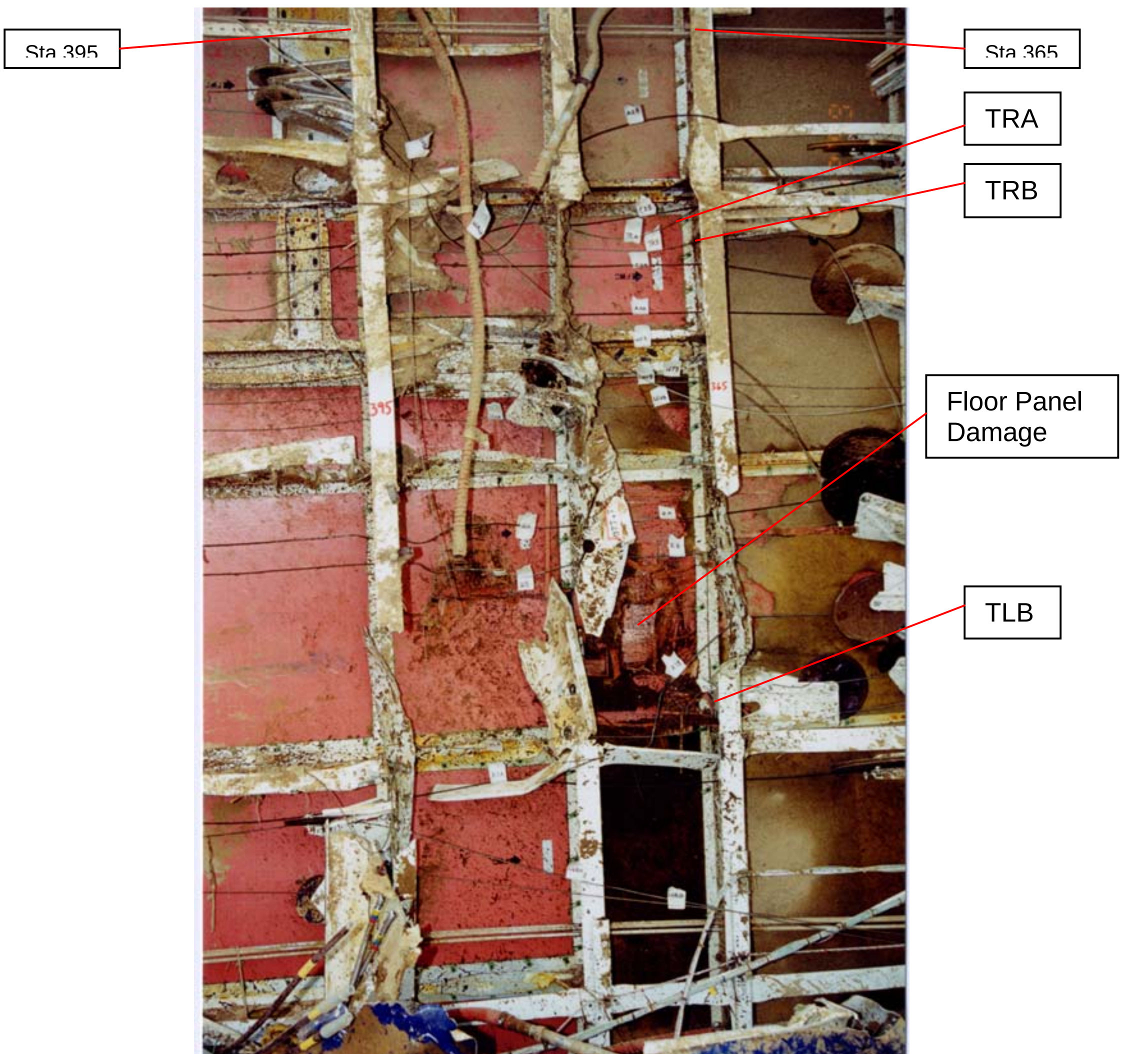


Figure 27.2 – Floor and Cable Damage

POWERPLANT CONTROL CABLES

Figure 28.1 – No 2 Powerplant Cables Underfloor

Figure 28.2 – Cable TLB Severance

Figure 28.3 – Cable TRB Severance

LANDING GEAR

Figure 29.1 – NLG and Doghouse

Detached Sidewall Portions remaining with Drag Strut Trunnions

NLG Leg Left Trunnion

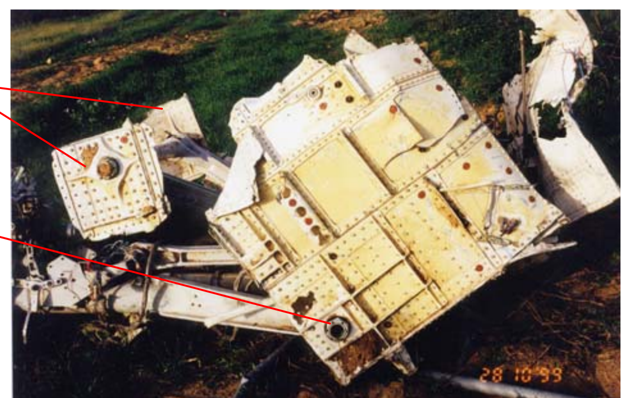
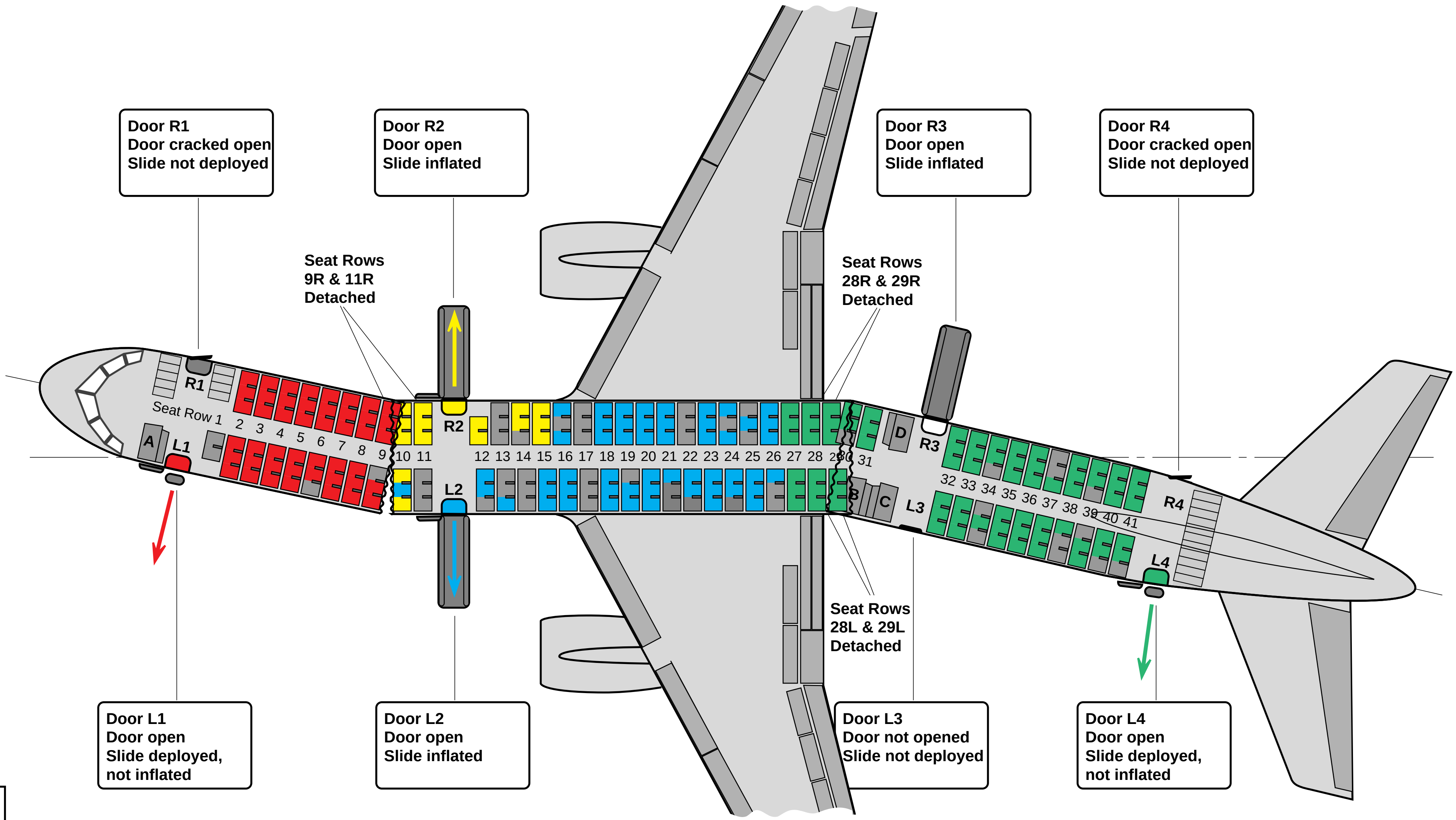


Figure 29.2 - Doghouse

Figure 29.3 – Right MLG

CABIN DISRUPTION



Exits used shown colour coded, where known

Figure 30

CABIN

Figure 31.1 – View Aft from Door L1

Figure 31.2 – Forward Cabin

Figure 31.3 - Rear Cabin

Figure 31

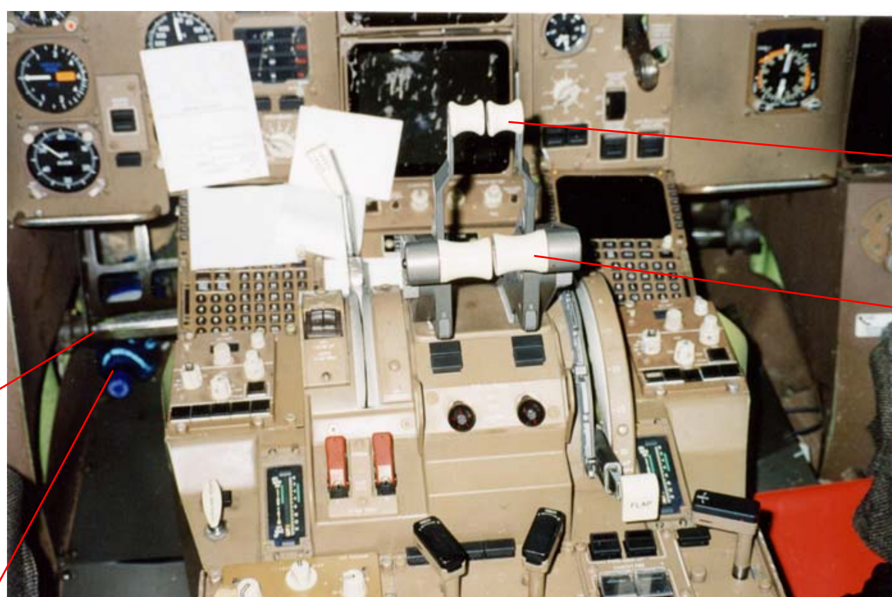
FLIGHT DECK

Left post of Left Windscreen

Captain's Seat

Figure 32.1 – Flight Deck

Co-Pilot's Seat



Reverse Thrust

Forward Thrust

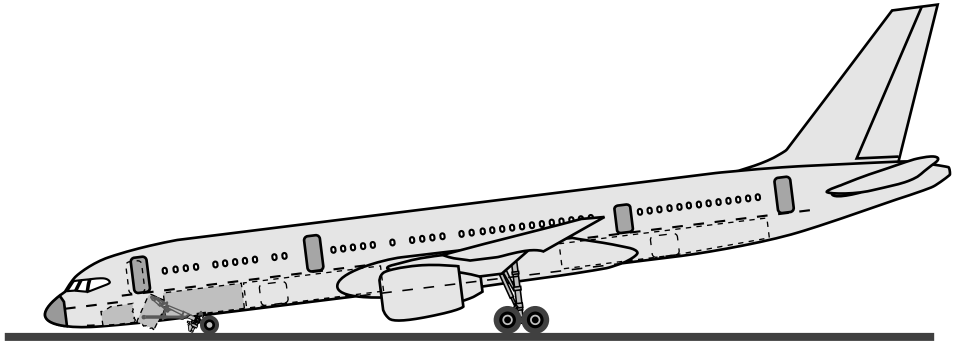
Captain's Right Rudder Pedal

Drinking Water Bottle

Figure 32.2 – Centre Console

Figure 32

NOSE LANDING GEAR SUPPORT STRUCTURE DISPLACEMENT



Pitch Attitude -7° (Nose Down)

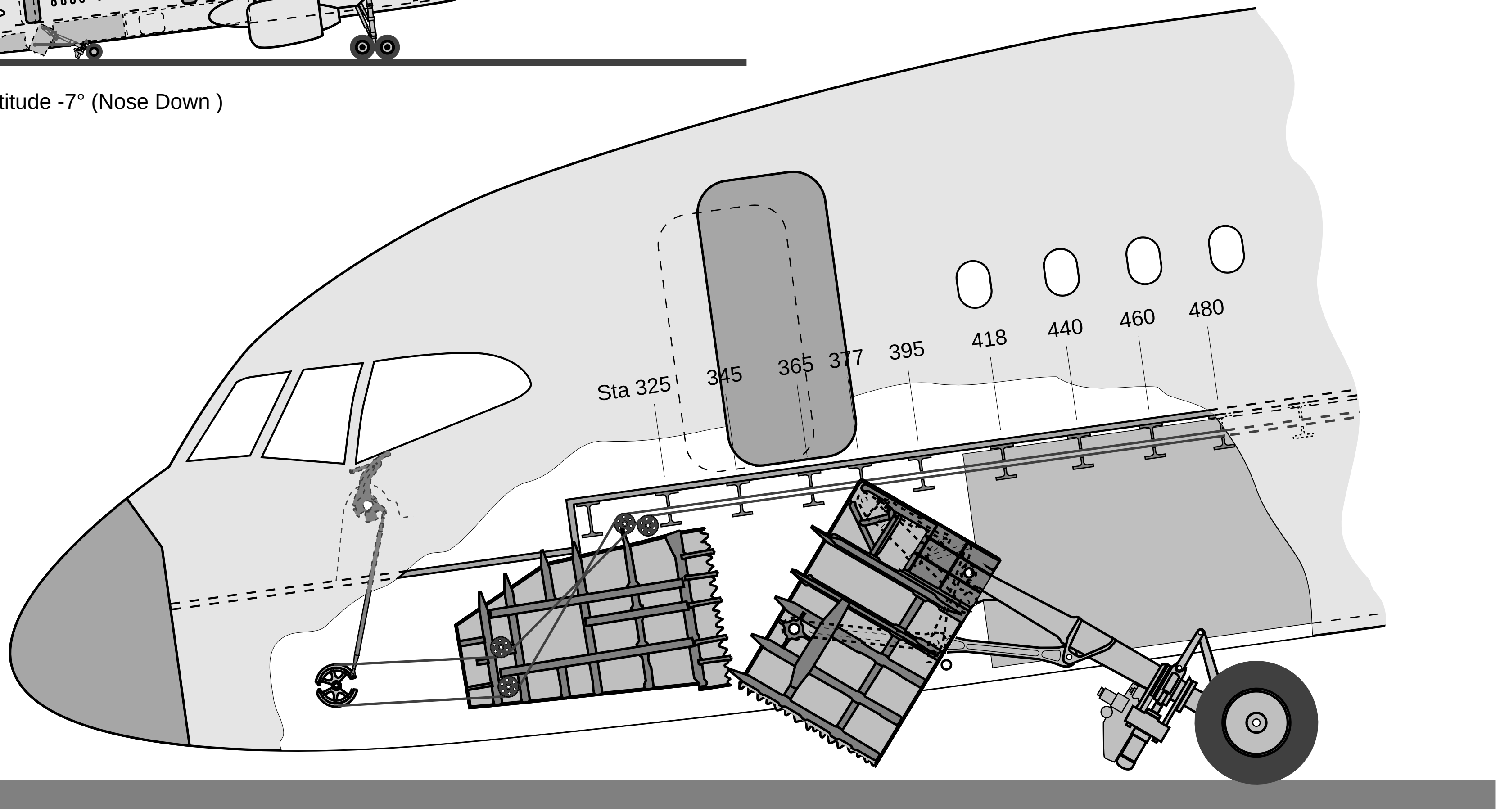


Figure 33

APPENDIX B
Meteorological Radar Images

Image from the meteorological radar
2133 hrs. 14 september 1999

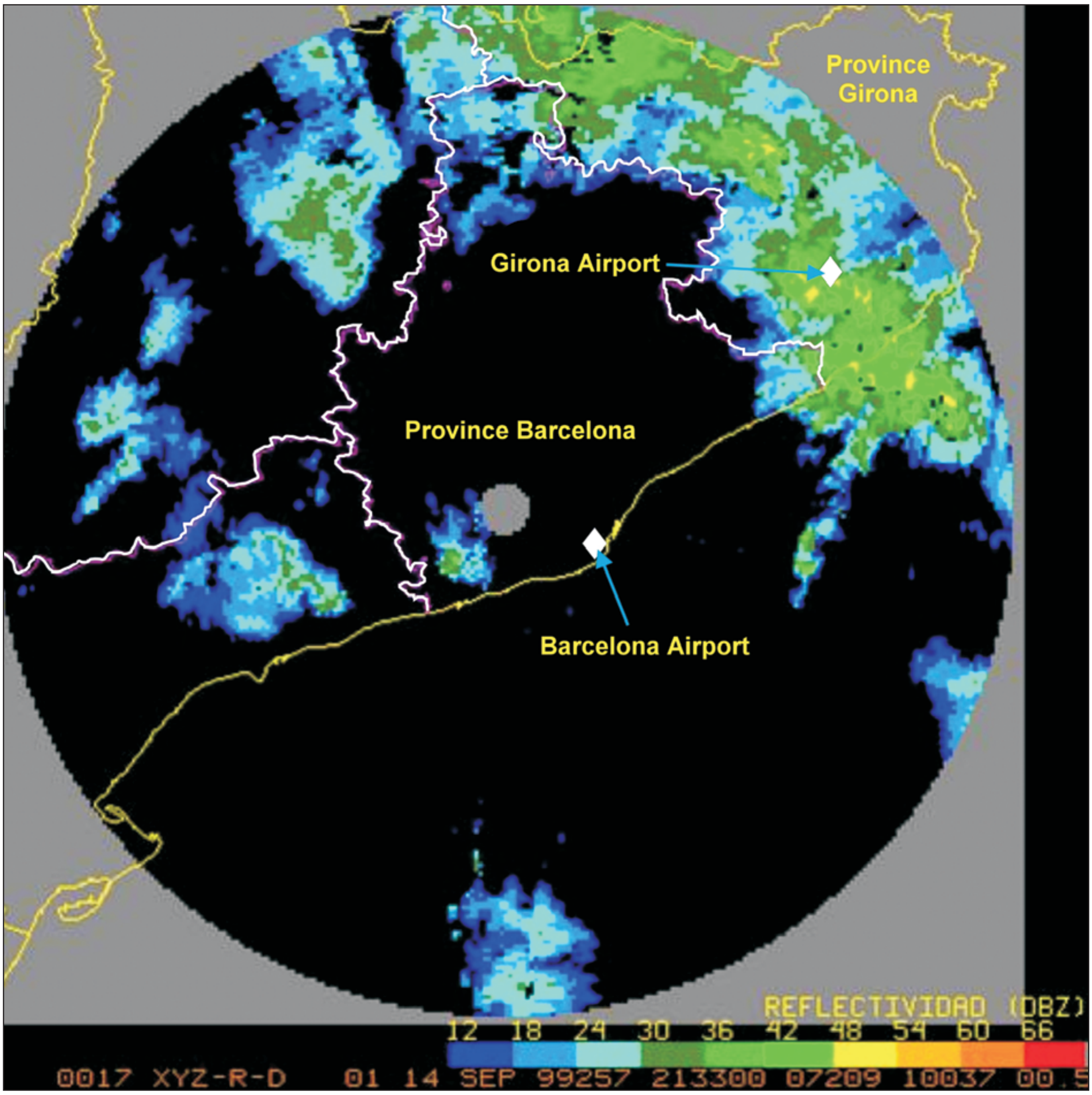


Image from the meteorological radar
2144 hrs 14 september 1999

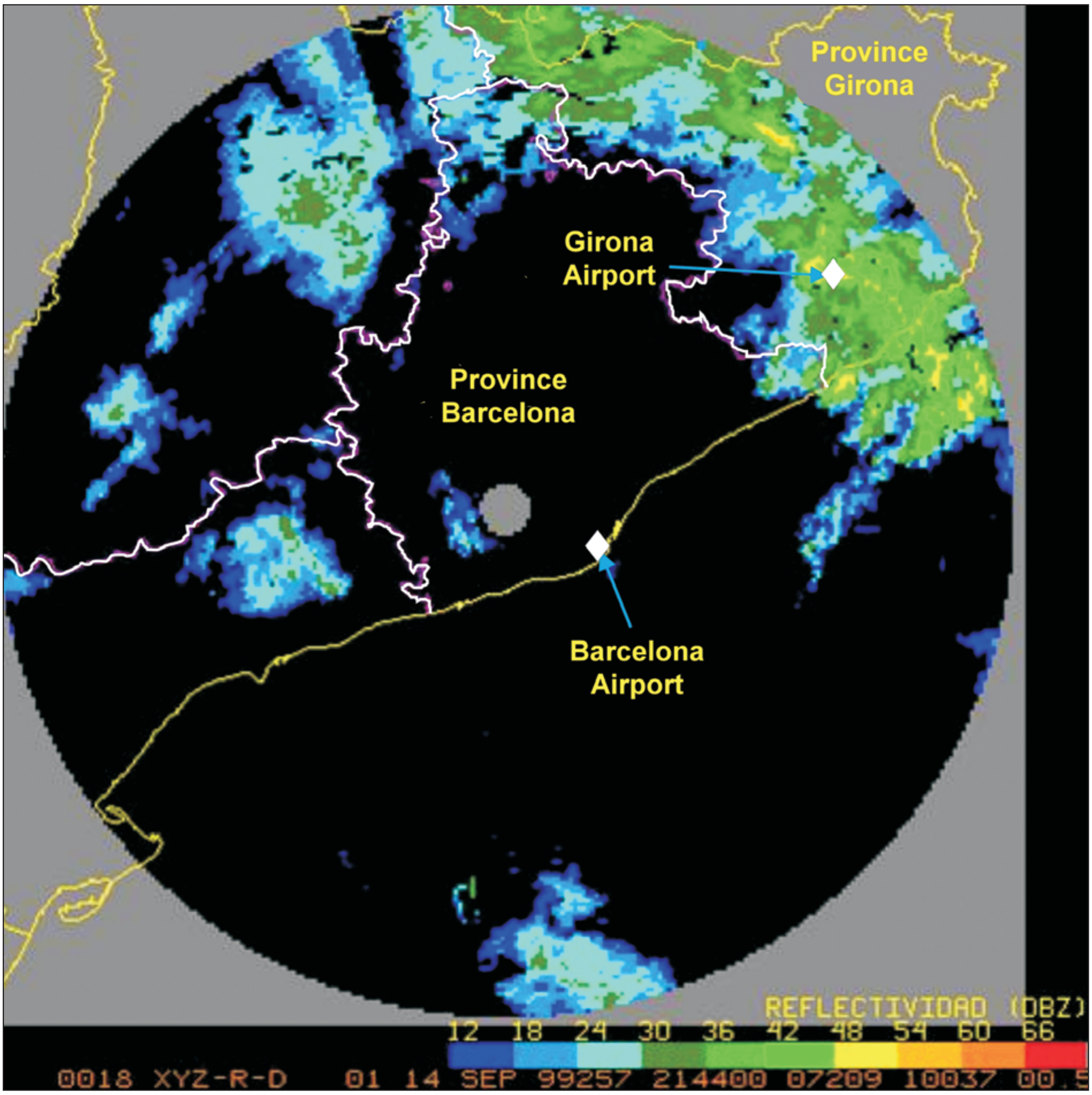
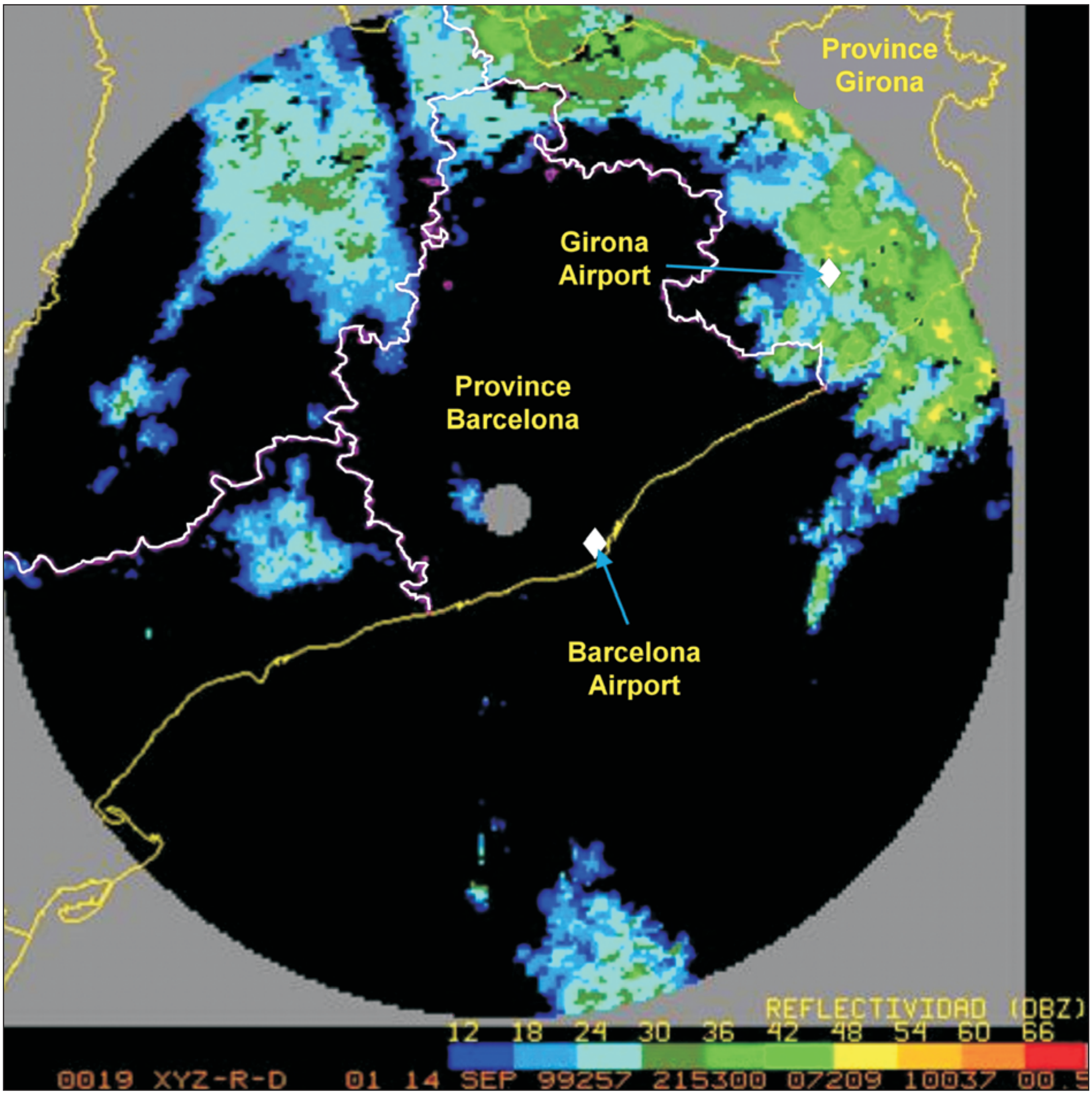
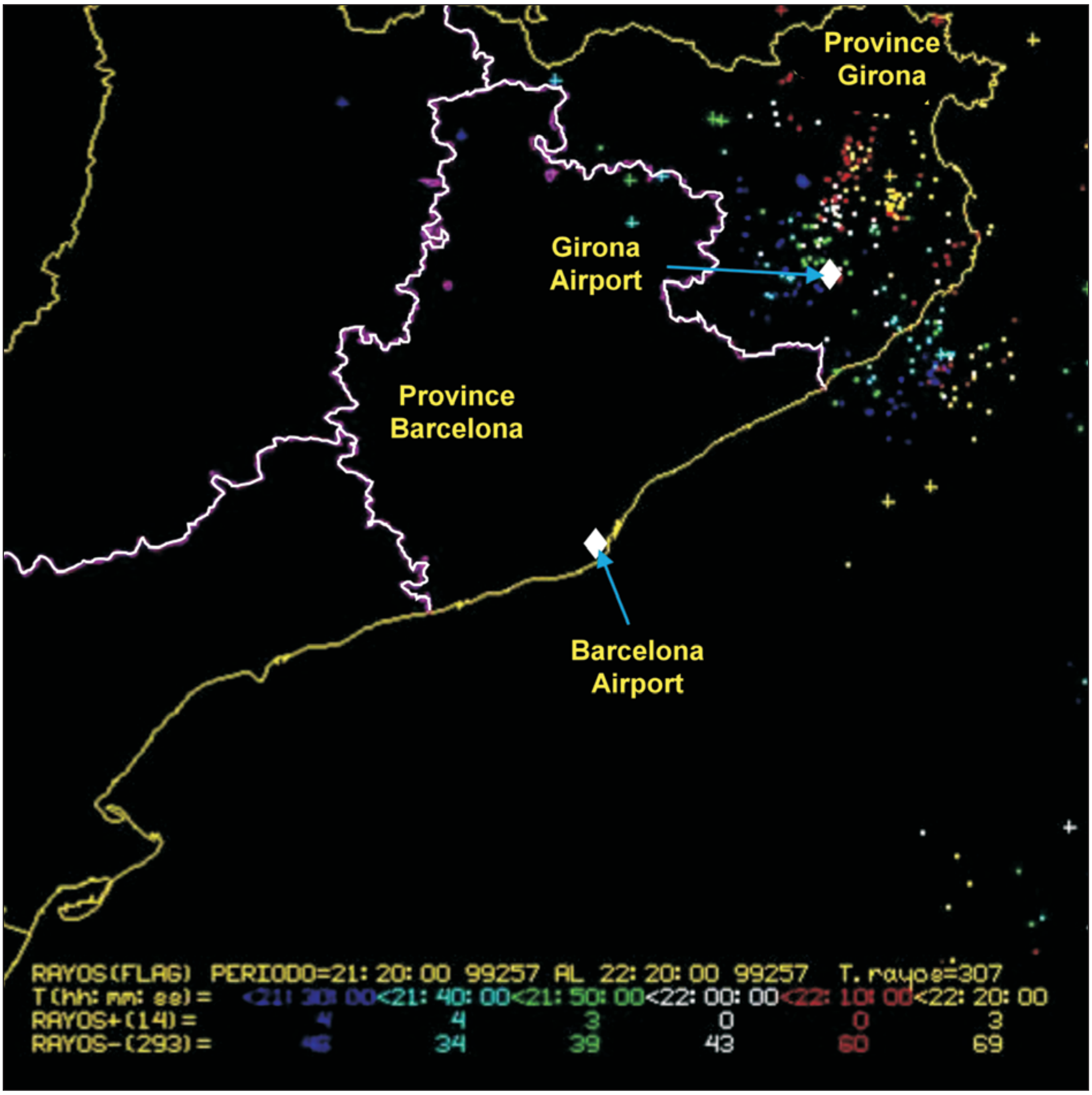


Image from the meteorological radar
2153 hrs 14 14 september 1999



Lightning map
14 september 1999



APPENDIX C
Flight Simulator Evaluation

C.1. General

An evaluation of the final stages of the approach and landing was carried out in a B757 flight simulator of Britannia Airways at Luton Airport, UK. The objectives were to assess the visual aspects of the landing using a selection of parameters established from the DFDR data. In particular, the aim was to evaluate the visual perspective of the runway following a loss of runway lighting, below 150 feet agl, and thereby to attempt to gain a better understanding of the actions of the crew.

C.2. Part 1 of the flight simulator evaluation

The simulator was frozen in a number of pre-selected height and attitude positions derived from the DFDR data so that an observation of the visual aspect presented to the crew could be assessed. The points selected were those considered to be of most interest. Visual aspects were examined with landing lights on, with runway lights on, and with runway lights off in some cases. Weather conditions were reproduced by using a visibility of 3,000 metres and with rain selected. The results are represented in Table 1 below.

Table 1

Height AGL (feet)	Time to touchdown (seg)	Control Column Position (% of travel)	Pitch (° + = Nose up)	Aspect	
				Runway lights on	Runway lights off
130	7	Central	+1	Normal	N/A
125	6.25	FWD 75%	+2	Normal	High with limited view ot touchdown area
105	4.5	FWD 15%	–4.5	Nose down, but landing possible	High with good view of touchdown area
50	2.25	Central	–2.5	Nose down, flare required to land	High with good view of touchdown area

Notes: The simulation of rain was felt to be unrepresentative.
Painted runway markings became the major reference in the absence of runway lights.

C.3. Part 2 of the flight simulator evaluation

The second part of the assessment used real time simulation to evaluate the likely actions and responses of the crew. Known facts and data were used to fly a similar profile to that of the accident. Observations as a result of this were:

1. After autopilot disconnect the aircraft became high on the approach. As a result the commander would probably have checked his flight instruments.
2. The glideslope indication on the Primary Flight Display is easily seen and would be likely to have influenced the actions of the commander.
3. The commander's input of full nose down elevator was probably in response to his seeing the glideslope pointer at full scale fly down.
4. The commander was looking in when he put in the nose down elevator.
5. The commander looked out again. If there were no runway lights the touchdown area would be clearly seen in the landing lights and he would appear high. If the runway lights were on the aircraft was still in a position from which it could have been landed successfully.
6. It may not have been obvious to the commander that there were no runway lights because part of the picture would have appeared normal.
7. The commander was probably unaware of having put in a large nose down elevator input.
8. It was more difficult to assess the landing flare with no runway lights because the visual segment was too short.

C.4. Conclusions of the flight simulator evaluation

It was possible to draw some further conclusions from the evaluation:

— There was an incomplete transition to visual flight after the decision to land. This was in accordance with company Standard Operating Procedures.
— The 4 second period from 100 feet to touchdown formed part of the landing phase after the decision to land had been made. Reversing this decision would have required positive decisive action.
— A pilot's attention would normally be focused on the landing when below 50 feet.
— The first officer did not look out much, if at all during the landing phase.
— If the runway lights remained on the commander should have had sufficient visual cues to land successfully or decide to go-around.
— The circumstances of the accident are consistent with the runway lights extinguishing between touchdown –6.5 sec and touchdown 5 sec while the commander's attention was on his flight instruments.