



*Accident  
on 25 July 2000  
at "La Patte d'Oie"  
in Gonesse (95),  
to the Concorde,  
registered F-BTSC,  
operated by Air France*

**Preliminary report  
translation  
f-sc000725pa**

## **FOREWORD**

*This document is based on the initial data collected on the circumstances of the accident. The investigation is continuing. Information on some points may evolve. It will only be possible to issue a final report on the circumstances and causes of this accident when all of the investigative work has been completed. Neither the presentation of the present report nor any of the issues raised should be interpreted as indicative of the direction the investigation will take or the conclusions to which the investigation will come.*

*In accordance with Annex 13 of the Convention on International Civil Aviation, with EC directive 94/56 and with Law N°99-243 of 29 March 1999, the analysis of the accident and the conclusions and safety recommendations contained in this report are intended neither to apportion blame, nor to assess individual or collective responsibility. The sole objective is to draw lessons from this occurrence which may help to prevent future accidents or incidents.*

*In accordance with Law n° 78-753 of 17 July 1978, this document is released subject to literary and artistic copyright. Copying, distribution or the use of this document for commercial purposes is forbidden.*

## **SPECIAL FOREWORD TO ENGLISH EDITION**

*This report has been translated and published by the Bureau Enquêtes-Accidents to make its reading easier for English-speaking people. As accurate as the translation may be, the original text in French is the work of reference.*

# *Table of Contents*

<b>FOREWORD</b>	<b>2</b>
<b>GLOSSARY</b>	<b>6</b>
<b>SYNOPSIS</b>	<b>8</b>
<b>ORGANISATION OF THE INVESTIGATION</b>	<b>9</b>
<b>1 – HISTORY OF FLIGHT</b>	<b>10</b>
<b>2 – INJURIES TO PERSONS</b>	<b>11</b>
<b>3 – DAMAGE TO AIRCRAFT</b>	<b>11</b>
<b>4 – OTHER DAMAGE</b>	<b>11</b>
<b>5 – PERSONNEL INFORMATION</b>	<b>11</b>
<b>5.1 Flight Crew</b>	<b>11</b>
5.1.1 Captain	11
5.1.2 First Officer	12
5.1.3 Flight Engineer	13
<b>5.2 Cabin crew</b>	<b>13</b>
5.2.1 Cabin Services Director	13
5.2.2 Flight Attendants	13
<b>6 – AIRCRAFT INFORMATION</b>	<b>14</b>
<b>6.1 Airframe</b>	<b>14</b>
6.1.1 Information (see appendix 1)	14
6.1.2 Maintenance	14
<b>6.2 Landing Gear</b>	<b>15</b>
6.2.1 General	15
6.2.2 Gear Retraction	15
6.2.3 Braking	16
6.2.4 Deflectors	17
6.2.5 Wheels and Tyres	17
<b>6.3 Fuel</b>	<b>18</b>
<b>6.4 Engines</b>	<b>19</b>
6.4.1 General	19
6.4.2 Contingency Mode	20
6.4.3 Reheat Cutout	20

6.4.4 Fire Protection	20
6.4.5 Engine Maintenance	21
<b>6.5 Weight and balance</b>	<b>21</b>
6.5.1 Weight	21
6.5.2 Balance	22
<b>6.6 Takeoff Performance</b>	<b>23</b>
<b>7 – METEOROLOGICAL CONDITIONS</b>	<b>24</b>
<b>7.1 General Situation at 12 h 00</b>	<b>24</b>
7.1.1 At Altitude	24
7.1.2 On the Ground	24
<b>7.2 Situation at the Aerodrome</b>	<b>25</b>
<b>7.3 Documents Supplied to the Crew</b>	<b>25</b>
<b>8 – AIDS TO NAVIGATION</b>	<b>25</b>
<b>9 – TELECOMMUNICATIONS</b>	<b>25</b>
<b>9.1 Radar Track</b>	<b>25</b>
<b>9.2 Telecommunications</b>	<b>26</b>
9.2.1 ATIS	26
9.2.2 Flight Data Frequency	27
9.2.3 Ground Frequency	27
9.2.4 Loc South Frequency	27
<b>10 – AERODROME INFORMATION</b>	<b>28</b>
<b>10.1 General</b>	<b>28</b>
<b>10.2 Runway Inspections</b>	<b>28</b>
<b>11 – FLIGHT RECORDERS</b>	<b>29</b>
<b>11.1 Recorder Types and Readout</b>	<b>29</b>
<b>11.2 CVR Readout</b>	<b>31</b>
<b>11.3 FDR Readout</b>	<b>33</b>
11.3.1 The Flight	33
11.3.2 Engines	37
11.3.3 Track	37
<b>12 – WRECKAGE AND IMPACT INFORMATION</b>	<b>38</b>
<b>12.1 The Runway</b>	<b>38</b>
12.1.1 Water Deflector	38
12.1.2 Pieces of Tyre	38
12.1.3 Piece of Metal	39
12.1.4 Structural Element	40
12.1.5 Brake Servo Valve Case	40

12.1.6 Piece of Concrete and Signs of Explosion	40
12.1.7 Lighting	41
12.1.8 Tyre tracks	41
12.1.9 Soot Deposit	42
<b>12.2 Between Runway 26 Right and the Site of the Accident</b>	<b>43</b>
<b>12.3 The Accident Site</b>	<b>44</b>
12.3.1 Description of Site and Plan	44
12.3.2 Instrument Indications	49
12.3.3 Examination of Engines	54
12.3.4 Examination of Wheels and Tyres	56
<b>13 – MEDICAL AND PATHOLOGICAL INFORMATION</b>	<b>57</b>
<b>14 – FIRE</b>	<b>57</b>
<b>15 – SURVIVAL ASPECTS</b>	<b>58</b>
<b>16 – TESTS AND RESEARCH</b>	<b>58</b>
<b>16.1 Flight Preparation at Air France</b>	<b>58</b>
16.1.1 Flight Planning	58
16.1.2 Flight Departure	58
16.1.3 Ramp	59
16.1.4 Traffic	59
<b>16.2 Aircraft Loading</b>	<b>59</b>
<b>16.3 Observation and Pictures of the Event</b>	<b>60</b>
<b>16.4 Previous Events</b>	<b>61</b>
<b>RECOMMENDATION</b>	<b>62</b>
<b>LIST OF APPENDICES</b>	<b>64</b>

# Glossary

AAIB	Air Accidents Investigation Branch
AD	Airworthiness Directive
ADF	Automatic Direction Finder
ADI	Attitude Director Indicator
ADP	Aéroports de Paris (Paris Airports Authority)
AJ	Adjustable Jet
AOA	Angle Of Attack
ASDA	Accelerated Stop Distance Available
ATIS	Automatic Terminal Information Service
BEA	Bureau Enquêtes-Accidents
BRS	Baggage Reconciliation System
CAS	Calibrated Airspeed
CC	Cabin Crew
CG	Centre of Gravity
CMB	Climb
CPEMPN	Principal flight crew medical test centre
CRM	Cockpit Resource Management
CRZ	Cruise
Cu	Cumulus
CVR	Cockpit Voice Recorder
EGT	Exhaust Gas Temperature
EIC	Equipment in Compartment
FC	Flight Crew
FD	Flight Director
FDAU	Flight Data Acquisition Unit
FDR	Flight Data Recorder
FE	Flight Engineer
FF	Fuel Flow
FO	First Officer
FOD	Foreign Object Damage
FQIP	Fuel Quantity Indicator Panel
ft	Feet
Gaétan	Passenger baggage registration system used by Air France
GEAS	General Electric Aircraft Engine Services
GPWS	Ground Proximity Warning System
HP	High Pressure
hPa	Hectopascal
HSI	Horizontal Situation Indicator
IDG	Integrated Drive Generator
IFR	Instrument Flight Rules
INS	Inertial Navigation System
kt	Knots
kW	Kilowatts
LDA	Landing Distance Available

LP	Low Pressure
METAR	Meteorological Aviation Report
MWS	Master warning System
N1	Low pressure turbine rotation speed
N2	High pressure turbine rotation speed
NOTAM	Notice to Airmen
P/N	Part Number
P7	Jet exhaust pressure
PF	Pilot Flying
PFCU	Power Flight Control Unit
PI	Pilot Instructor
PNF	Pilot Not Flying
Psi	Pounds per Square Inch
QAR	Quick Access Recorder
QNH	Altimeter setting to obtain aerodrome elevation when on the ground
RFFS	Rescue and Fire Fighting Service
SAT	Static Air Temperature
SC	Stratocumulus
SIGMET	Significant Meteorological Message
TAF	Terminal Area Forecast
TCA	Turbine Cooling Air
TCAS	Traffic warning and Collision Avoidance System
TCU	Throttle Control Unit
TEMSI	Significant weather forecast chart
TODA	Take Off runway Distance Available
TOP	Transoceanic and Polar licence
TORA	Take Off Runway length Available
UTC	Universal Time Co-ordinated
Vmca	Minimum air control speed
VmCG	Minimum ground control speed
VOR	VHF Omnidirectional Radio Range
VR	Rotation speed
Vz	Vertical speed
Vzrc	Zero rate of climb speed
ZFW	Zero Fuel Weight

## SYNOPSIS

**Date and time**

Tuesday 25 July 2000 at 14 h 44<sup>1</sup>

**Aircraft**

Concorde  
registered F-BTSC

**Site of accident**

La Patte d'Oie in Gonesse (95)

**Owner**

Air France

**Type of flight**

Charter flight  
Flight AFR 4590

**Operator**

Air France

**Persons on board**

Flight Crew: 3  
Cabin Crew: 6  
Passengers: 100

**Summary:**

During takeoff from runway 26 right at Roissy Charles de Gaulle Airport, shortly before rotation, the front right tyre of the left landing gear was damaged and pieces of the tyre were thrown against the aircraft structure. A major fire broke out under the left wing. Problems appeared shortly afterwards on engine N° 2 and for a brief period on engine N° 1. The aircraft was neither able to climb nor accelerate. The crew found that the landing gear would not retract. The aircraft maintained a speed of 200 kt and a radio altitude of 200 feet for about one minute. Engine n° 1 then stopped. The aircraft crashed onto a hotel at La Patte d'Oie in Gonesse.

	People			Equipment
	Killed	Injured	Uninjured	
<b>Crew</b>	9	-	-	<b>Destroyed</b>
<b>Passengers</b>	100	-	-	
<b>Third parties</b>	4	6	-	

<sup>1</sup> Except where otherwise noted, the times shown in this report are expressed in Universal Time Co-ordinated (UTC). Two hours should be added to obtain the legal time applicable in metropolitan France on the day of the accident.

## ORGANISATION OF THE INVESTIGATION

On Tuesday 25 July 2000 at around 14 h 50 UTC, the BEA was informed of the accident to a Concorde in the commune of Gonesse (95) after takeoff from Paris Charles de Gaulle. In accordance with Annex 13 to the Convention on International Civil Aviation and the law of 29 March 1999 relating to technical investigation of accidents and incidents in civil aviation, a technical investigation was launched. A Principal Investigator was nominated as Investigator-in-Charge.

In accordance with the provisions of Annex 13, a British accredited representative and two investigators from the AAIB, accompanied by several experts from BAE SYSTEMS and Rolls Royce, joined the investigation as representatives of the State of Manufacture, along with German (BFU) and American (NTSB and FAA) observers. Air France, EADS and SNECMA made numerous experts available to the BEA.

The Minister of Equipment, Transport and Housing established a Commission of Inquiry, in accordance with the law of 29 March 1999. This Commission has assisted the BEA in its work. Two meetings were held in the course of which the Commission was informed of the progress of the investigation. The Commission approved the process.

\*  
\*       \*

The Investigator-in-Charge established seven working groups to find and collate the information necessary for the investigation. The groups worked in the following specific areas:

- site and wreckage
- aircraft, systems and engines
- preparation and conduct of the flight, personnel information
- flight recorders
- aircraft performance
- witness testimony
- examination of previous events.

These groups have worked continuously since 27 July. Two plenary sessions of the working groups took place on the 3rd and 22 August to summarise the progress of the investigation.

All operations carried out at the site or on parts of the aircraft have been conducted in coordination with those responsible for the judicial investigation, in accordance with judicial procedures. The accident site and all parts of the aircraft are under the control of the judicial authorities. The majority of technical examinations have yet to be performed.

\*  
\*       \*

On 16 August, on the basis of the findings of the investigation, the BEA and its British counterpart the AAIB issued an initial safety recommendation.

The initial results from the investigation are contained in this report, which has been presented to, and approved by, the Commission of Inquiry.

## 1 – HISTORY OF FLIGHT

On Tuesday 25 July 2000 the Concorde registered F-BTSC, operated by Air France, took off from Paris Charles de Gaulle to undertake charter flight AFR 4590 to New York with nine crew members (3 FC, 6 CC) and one hundred passengers on board. The Captain was Pilot Flying (PF), the First Officer (FO) was Pilot Not Flying (PNF).

The total weights of the aircraft and of the fuel on board stated by the Flight Engineer (FE) at the time the aircraft started were 186.9 t and 95 t respectively. The speeds selected by the crew were V1: 150 kt, VR: 198 kt, V2: 220 kt.

At 13 h 58 min 27 s, the crew contacted ATC on the Flight data frequency and requested the whole length of runway 26 right for a takeoff at 14 h 30.

At 14 h 07 min 22 s, the controller gave startup clearance and confirmed runway 26 right for takeoff.

At 14 h 34 min 38 s, the Ground controller cleared the aircraft to taxi towards the runway 26 right holding point via the Romeo taxiway.

At 14 h 40 min 02 s, the Tower controller cleared 4590 to line up. At 14 h 42 min 17 s, he gave it takeoff clearance, and announced a wind from 090° at 8kt. The crew read back the takeoff clearance. The FE stated that the aircraft had used eight hundred kilos of fuel during taxiing.

At 14 h 42 min 31 s, the PF commenced takeoff. At 14 h 42 min 54 s, the PNF called one hundred knots, then V1 nine seconds later.

A few seconds after that, the right front tyre on the left main landing gear was destroyed, very probably after having run over a piece of metal. The destruction of the tyre resulted in large pieces of rubber being thrown against and damaging parts of the aircraft.

At 14 h 43 min 13 s, as the PF commenced the rotation, the controller informed the crew the presence of flames behind the aircraft. The PNF acknowledged this transmission and the FE announced the failure of engine n° 2. The recorded parameters show a momentary loss of power on engine n° 1 that was not mentioned by the crew. Eight seconds later the fire alarm sounded and the FE announced that he was shutting down engine n° 2. The fire alarm then stopped. The PNF drew the PF's attention to the airspeed.

At 14 h 43 min 30 s, the PF called for landing gear retraction. The controller confirmed the presence of large flames behind the aircraft.

At 14 h 43 min 42 s the fire alarm recommenced.

At 14 h 43 min 56 s, the PNF commented that the landing gear had not retracted and made several callouts in relation to the airspeed.

At 14 h 43 min 59 s, the GPWS alarm sounded several times. The FO informed ATC that they were trying for Le Bourget aerodrome. The recorded parameters then indicate a loss of power on engine n° 1. A few seconds later, the aircraft crashed onto a hotel at La Patte d'Oie in Gonesse at the intersection of the N17 and D902 roads.

## 2 – INJURIES TO PERSONS

Injuries	Crew Members	Passengers	Others
Fatal	9	100	4
Serious	0	0	0
Slight/None	0	0	6

## 3 – DAMAGE TO AIRCRAFT

The aircraft was destroyed on impact.

## 4 – OTHER DAMAGE

The hotel that the aircraft crashed onto was destroyed.

## 5 – PERSONNEL INFORMATION

### 5.1 Flight Crew

#### 5.1.1 Captain

Male, 54 years old

- Commercial pilot's licence n° 193067 issued 12 July 1967
- First class Commercial pilot's licence n° 208369 issued on 8 August 1969
- Airline transport pilot's TOP licence n° 195176 issued on 19 February 1976
- Last medical at the CPEMPN (Paris) on 5 May 2000
  
- IFR rating obtained 2 June 1969, valid until 31 August 2000
- B 727 rating on 4 December 1970
- A 300 rating on 24 April 1974
- B 737 rating on 13 December 1977
- Captain on 3 February 1983
- Pilot Instructor from 31 December 1985, valid until 30 June 2001
- A 320 rating on 18 November 1988
- A 340 rating on 27 February 1993
- Concorde rating on 16 August 1999, valid until 31 August 2001
- Pilot's competency check on 9 June 2000, valid until 31 August 2001
- CRM training course on 6 January 1994

- Line check planned for October 2000
- Base check on 4 February 2000
- Total flying hours: 13 477 of which 5 495 as Captain
- Flying hours on Concorde: 317 of which 284 as Captain
- Flying hours in the last six months: 177.91
- Flying hours in the last three months: 95.34
- Flying hours in the last thirty days: 23.86

### 5.1.2 First Officer

Male, 50 years old

- Commercial pilot's licence n° 411171 issued on 16 December 1971
- First class commercial pilot's licence n° 263672 issued on 9 October 1972
- Airline transport pilot's TOP licence n° 232079 issued on 2 February 1979
- Last medical at the CPEMPN (Paris) on 17 January 2000
- IFR rating valid until 31 December 2000
- Nord 262 rating on 31 March 1972
- Morane Saulnier 760 rating on 26 March 1972
- Caravelle rating on 1<sup>st</sup> June 1974
- A 300 rating on 16 November 1979
- Concorde rating on 10 January 1989, valid until 31 December 2000
- Pilot's competency check on 23 (S1) and 24 (S2) November 1999, valid until 31 December 2000
- CRM training course on 9 May 1994
- Line check 1<sup>st</sup> August 1999, valid until 31 August 2000
- C1 base check on 26 November 1999 valid until 31 December 2001
- Concorde Simulator Flight Instructor from 15 March 1999, valid until 31 March 2000
- Total flying hours: 10 035 of which 2 698 as FO on Concorde
- Flying hours as instructor: not calculated before 1997 at Air France
- Flying hours in the previous six months: 127.25
- Flying hours in the previous three months: 50.13
- Flying hours in the previous thirty days: 7.64

Note: The Captain's and First Officer's licences are covered by the FCL1 regulations (July 1999), the type rating renewing the licence as long as the medical certificate is valid. For those over 40 years of age, the medical certificate is valid for six months. Unlike the previous regulations, its validity runs from a specific date to a specific date rather than to the end of the month.

### **5.1.3 Flight Engineer**

Male, 58 years old

- Flight Engineer's Licence n° 142568 issued on 22 March 1968, valid until 30 June 2001
- Last medical at the CPEMPN (Paris) on 20 June 2000
  
- Caravelle rating on 8 March 1968
- Falcon 20, rating on 27 March 1968
- B 727 rating on 4 January 1973
- B 737 rating on 28 February 1978
- B 747 rating on 29 May 1980
- B 747-400 rating on 3 November 1990
- Concorde rating on 28 February 1997, valid until 30 June 2001
  
- Total flying hours: 12 532 of which 937 as FE on Concorde
- Flying hours in the previous six months: 131.64
- Flying hours in the previous three months: 62.19
- Flying hours in the previous thirty days: 23.62

Note: the FE's licence is subject to the former regulations, as defined by the modified Order of 31 January 1981. The licence is valid for one year; the medical check-up is valid from the day of the check-up to the end of the same month the following year. The test and the medical check-up must be carried out in the same month.

## **5.2 Cabin crew**

### **5.2.1 Cabin Services Director**

Female, 36 years old

Qualifications:

- Initial training: Safety Certificate on 2 October 1986.
- Concorde professional aptitude certificate on 4 May 1992

### **5.2.2 Flight Attendants**

Female, 36 years old

Qualifications:

- Initial training: Safety Certificate on 4 March 1991
- Concorde professional aptitude certificate in January 1999

Female, 49 years old

Qualifications:

- Initial training: Safety Certificate on 20 February 1978
- Concorde professional aptitude certificate in July 1990

Female, 27 years old

Qualifications:

- Initial training: Safety Certificate on 2 February 1996
- Concorde professional aptitude certificate in August 1999

Male, 32 years old

Qualifications:

- Initial training: Safety Certificate on 24 February 1993
- Concorde professional aptitude certificate in January 1999

Male, 38 years old

Qualifications:

- Initial training: Safety Certificate on 14 May 1990
- Concorde professional aptitude certificate in June 1997

## **6 – AIRCRAFT INFORMATION**

### **6.1 Airframe**

#### **6.1.1 Information** (see appendix 1)

- Manufacturers<sup>(2)</sup>: EADS / BAE SYSTEMS
- Type: Concorde type 1 - version 101
- Serial number: 3
- Registration: F-BTSC
- Entry into airline service on 24 October 1979
- Airworthiness Certificate issued on 23 December 1975, valid until 29 September 2002
- Flying hours up to 25 July 2000: 11989 hours and 4873 cycles
- Since type DO1 general overhaul on 1<sup>st</sup> October 1999: 576 hours and 181 cycles.

#### **6.1.2 Maintenance**

The aircraft had undergone a scheduled check AO1 in accordance with the approved maintenance programme. The check commenced on 17 July 2000 and was completed on the 21<sup>st</sup>. During the check, the left main landing gear bogie had been replaced in order to correct an acceptable deferred defect related to the under-inflation detection system.

Since the A check, the aircraft had undertaken four flights, on July 21, 22, 23 and 24. On the 24<sup>th</sup>, several maintenance operations had been carried out:

---

<sup>2</sup> When the aircraft was constructed, these companies were called SNIAS and BAC respectively.

<b>Problems</b>	<b>Maintenance Actions</b>
Slight thrust surges in cruise at mach 2, with illumination of start pump warning light.	Checks on both TCU's, replacement of the N1 limit amplifier, check on the EGT line, ground test OK.
Brake overload warning light for wheel n° 4.	Cable changed.
Slow leak in blue hydraulic system in flight.	Connecting joint on the artificial feel cylinder on the blue hydraulic system replaced.
Tyre on wheel n° 5 worn.	Wheel n° 5 replaced.

The aircraft was originally planned as a reserve for 25 July. F-BVFA was planned to carry out scheduled flight 002 in the morning and F-BVFC to undertake Flight 4590. For maintenance reasons, there was an allocation change between F-BVFA and F-BVFC. F-BVFA was finally declared unavailable during the night and the reserve aircraft, F-BTSC, was programmed in its place to carry out Flight 4590.

The aircraft was airworthy and there were no acceptable deferred defects for Flight 4590. Prior to the flight, the GARRETT pneumatic motor which activates the engine n° 2 secondary exhaust nozzle buckets, had been replaced. Tests had been carried out and they revealed no anomalies.

## **6.2 Landing Gear**

### **6.2.1 General**

The Concorde has a nose gear, an auxiliary gear situated at the rear of the fuselage and two main landing gears, each with a bogie with four wheels. The bogies are equipped with a system which detects under-inflation of a tyre and transmits a visual signal to the cockpit. This detection system is inhibited when the speed of the front wheels is less than 10 kt or when the indicated airspeed is above 135 kt.

### **6.2.2 Gear Retraction**

Gear retraction is controlled electrically by the landing gear control lever situated on the pilot's panel (three-position lever: up, neutral, down) and is activated by hydraulic pressure from the Green circuit (see figure 1). The lever cannot be moved from the "neutral" position to the "up" position unless the left main landing gear shock strut is no longer compressed.

Conditions for gear retraction:

- The gear doors must be unlocked and open.
- The main and nose gears must no longer be compressed.
- The front wheels must be centred
- The main landing gear bogies must be perpendicular to the gear leg.

When all of the landing gear is locked in the "up" position, the gear doors close. During retraction of the main gear, the shock struts are retracted into the gear leg to allow them to fit in the gear well. The wheels are automatically braked when the gear selector is in the "up" position.

For the landing gear, the Yellow hydraulic circuit is used only if there is a failure in the Green circuit. The perpendicularity of the gear is ensured by two autonomous nitrogen-powered pneumatic actuators

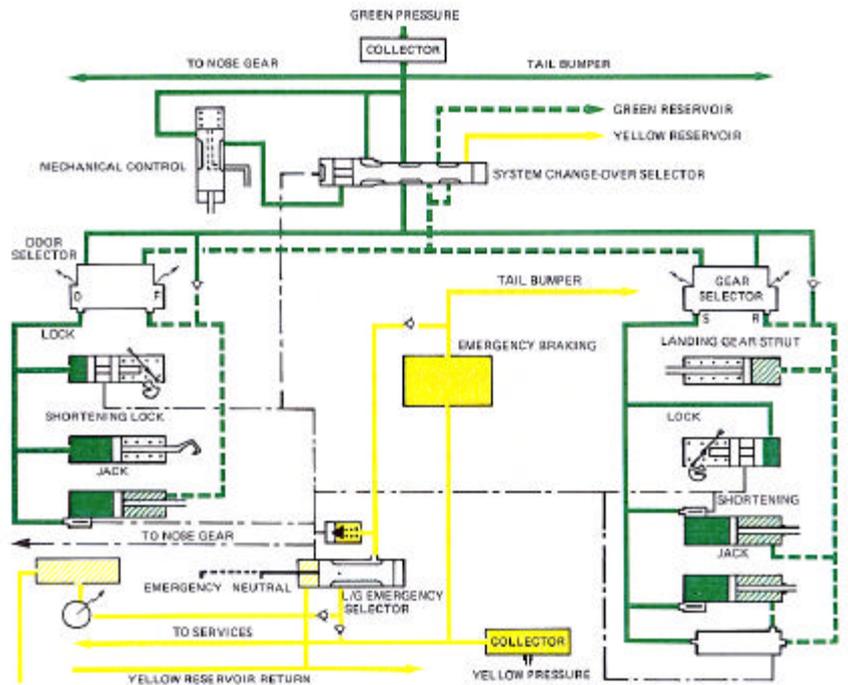


Figure 1 – Synoptic diagram of the main gear hydraulic system

### 6.2.3 Braking

The brakes are manufactured by Dunlop. Braking is electrically controlled and is activated by hydraulic pressure from the Green circuit in normal conditions.

In case of failure in the Green circuit, an automatic switch allows the Yellow circuit to be used. In case of emergency braking, only the Yellow circuit is used in direct hydraulic liaison with the rudder bars.

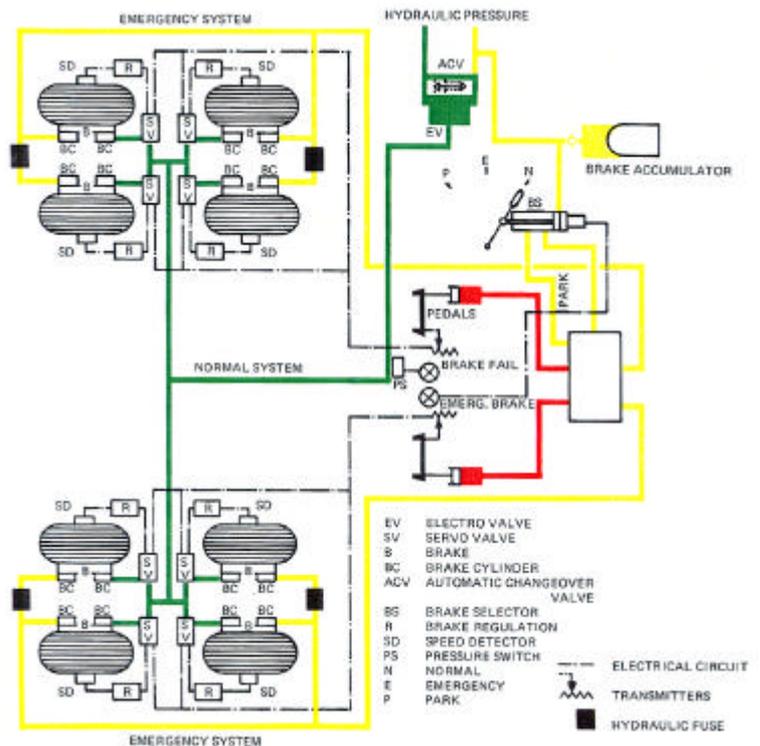


Figure 2 - Synoptic diagram of main landing gear braking

## 6.2.4 Deflectors

The deflectors are made of composite materials and fibreglass (to make them frangible) except for the bogie fasteners. Each deflector weighs around 4 kg and is located at the front of each main landing gear. Their function is to deflect water and spray to ensure it does not enter the engine air intakes. These deflectors were the subject of an optional Service Bulletin (SST 32-103 of 12/01/95 modified on 28/02/95) which proposed the insertion of two cables in the leading edge in order to retain pieces of the deflectors in case of failure. Air France did not apply the aforementioned Service Bulletin.



## 6.2.5 Wheels and Tyres

The wheels were manufactured by Dunlop, and the tyres used by Air France were manufactured by Goodyear in the United States. No retread tyres have been used since 1997.

On the day of the accident, the main landing gear wheels and tyres on F-BTSC were installed as follows:

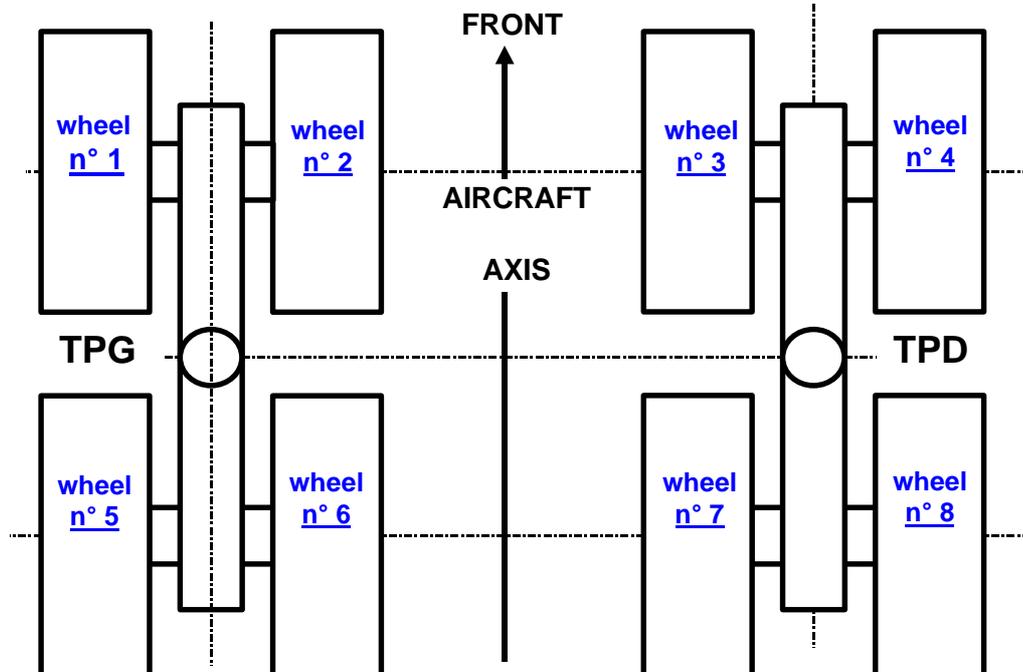


Figure 3 (from above)

WHEEL P/N	WHEEL S/N	Position on aircraft	Workshop issue date	Date installed on aircraft	TYRE S/N	Number of cycles
<b>AHA1216</b>	<b>531</b>	<b>1</b>	<b>09/06/00</b>	<b>10/07/00</b>	<b>91510047</b>	<b>9</b>
<b>AHA1216</b>	<b>579</b>	<b>2</b>	<b>25/05/00</b>	<b>29/05/00</b>	<b>91831651</b>	<b>37</b>
AHA1216	594	3	10/05/00	18/05/00	91801029	45
AHA1216	500	4	17/02/00	22/06/00	91831659	23
<b>AHA1216</b>	<b>446</b>	<b>5</b>	<b>06/07/00</b>	<b>24/07/00</b>	<b>91560078</b>	<b>0</b>
<b>AHA1216</b>	<b>581</b>	<b>6</b>	<b>12/07/00</b>	<b>18/07/00</b>	<b>91570604</b>	<b>4</b>
AHA1216	518	7	22/06/00	24/06/00	91870259	19
AHA1216	591	8	04/07/00	09/07/00	91930448	9

*N.B. notation in bold type refers to left main landing gear.*

### 6.3 Fuel

The signal from each fuel gauge is sent simultaneously to the corresponding indicator and to a totaliser. By design, error in measurement of the total fuel quantity must not exceed 5 % in extreme flight conditions, and the error in measurement on each of the tanks must not exceed 2 %. The quantity of fuel present in a tank can be considered to be correctly indicated when the reading is greater than zero. The quantity present cannot be presumed if the above does not apply.

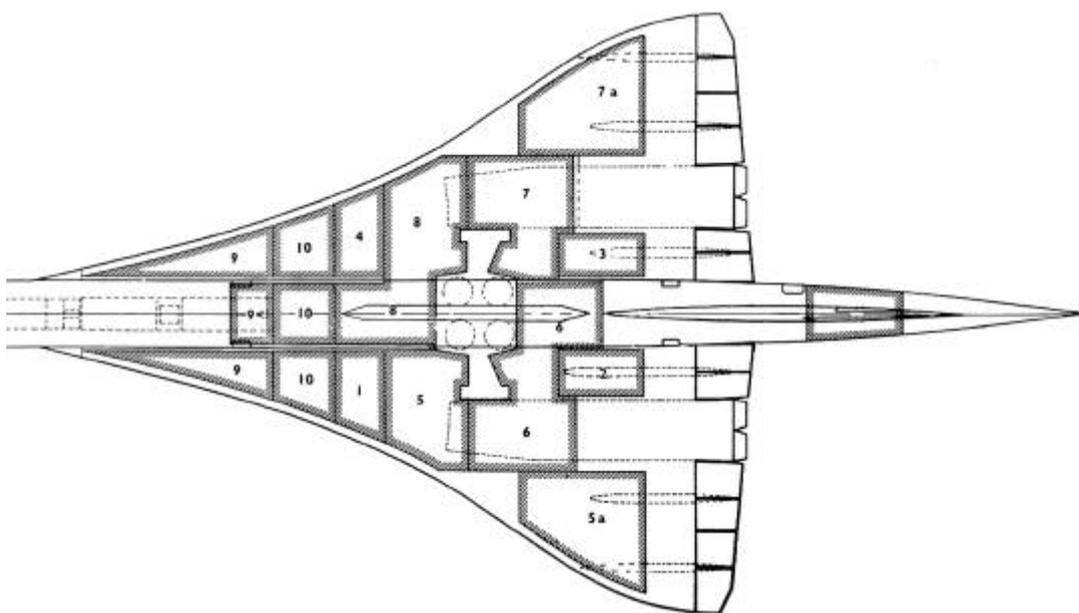
Note: a general electrical power cut fixes the last indication supplied by the needles and masks the indications on the rollers with a flag. The failure of an electrical connection from a fuel gauge leads to an indication of zero on the corresponding indicator.

Before the accident flight, the tanks had been filled with jet fuel (Jet A1). An overfill of 300 litres, equivalent to a quantity of 237 kg had been added. In total, the quantity loaded was around 94 800 kg.

Note: the overfill procedure allowed loading of a maximum of 1 630 litres extra, compared to the quantities mentioned below.

The capacity of the thirteen tanks is presented in the table below. These represent maximum capacities without exceeding the level of the upper sensors.

Function	Number	Capacity (litres)	Quantity (kg) density=0.792
Engine supply	1	5 300	4 198
	2	5 770	4 570
	3	5 770	4 570
	4	5 300	4 198
Main tanks	5	9 090	7 200
	6	14 630	11 587
	7	9 350	7 405
	8	16 210	12 838
Auxiliary tanks	5A	2 810	2 225
	7A	2 810	2 225
Transfer tanks (balance)	9	14 010	11 096
	10	15 080	11 943
	11	13 150	10 415
Total		119 280	94 470



## 6.4 Engines

### 6.4.1 General

Power is supplied by four twin spool turbojets installed in pairs, each being equipped with a reheat, a variable area air intake and variable primary and secondary exhaust nozzle used to optimise performance. The secondary exhaust nozzle also incorporates the thrust reverser.

The n° 1 and n° 2 engines are respectively the outer and inner left engines, engines n° 3 and n° 4 the inner and outer right engines.

Manufacturers: Rolls Royce and SNECMA.

- Type: Olympus 593 MK 610-1428.
- Reheat provides 18 % extra thrust at takeoff.

	n° 1	n° 2	n° 3	n° 4
Serial number	CBE031	CBX115	CBE092	CBE051
Installation date	03/02/2000	01/08/1999	14/06/2000	23/08/1999
Total hours	11 200	9 158	8 394	11 670
Hours since installation	342	576	84	576
Cycles since installation	106	181	28	181

### 6.4.2 Contingency Mode

The contingency mode can be activated manually or automatically in the case of engine failure on takeoff. Thrust above the maximum takeoff thrust can then be provided by remaining engines. Automatic mode is activated when:

- The throttle levers move above the 10 % level,
- Reheat is activated on any engine,
- The take off monitor is armed,
- N2 on an engine goes below 58.6 %.

The power of the other three engines then increases automatically up to a level which may reach 105 % of N2.

### 6.4.3 Reheat Cutout

As soon as an engine's N1 falls below 75 %, reheat on that engine is disconnected. Reheat is re-activated when N1 exceeds 81 %.

### 6.4.4 Fire Protection

Fire detection on an engine is ensured by two loops which react to increases in temperature. They are made up of four components assembled in line so as to detect:

- A fire around the engine and/or
- A torch flame fire around the combustion chamber.

If only one loop detects a fire, the loop is indicated as faulty and has to be shut off by the crew. If both loops detect a fire, the Gong sounds and the appropriate red ENGINE warning light comes on in the Main Warning System (MWS) panel, followed by a flashing red warning light on the engine shutdown/fire handle of the corresponding engine and an aural warning (bell).

Pulling the engine shutdown/fire handle shuts:

- The air conditioning valve
- The hydraulic shutoff valve
- The LP and HP fuel supply valves
- The reheat fuel supply valve
- The fire doors.

The dual head extinguishers are activated by two push buttons located behind each engine shutdown/fire handle.

Note: the red warning light in the Main Warning System is also associated with alarms for low oil pressure, engine TCA overheat, and detection of liquid in the dry bays.

### 6.4.5 Engine Maintenance

Each engine consists of twelve modules whose maintenance is undertaken by Air France, by SNECMA Services or by GEAS. The final assembly is performed by GEAS. Tasks performed can be of three types: visual inspection, partial repair or major repair based on the Olympus Maintenance Manual.

Readings taken by the FE during supersonic flight of parameters such as EGT and FF assist in assessment of engine condition. The readings from these engines on previous flights have not revealed any malfunctions.

## 6.5 Weight and balance

### 6.5.1 Weight

The weights listed in the first table hereafter are those which were entered by the Dispatcher to establish the forecast weight, then the final weight. The second table shows the real weights as established by the investigation.

<b>Computer-generated weight (kg)</b>	<b>Phase 1 forecast</b>	<b>Taxi weight</b>	<b>Takeoff weight</b>
Corrected basic weight	81 560	81 560	81 560
Baggage	1 651	2 131	2 131
Fuel + taxiing	93 400 + 2 000	92 936 + 2 000	92 936
Passengers	8 253	8 253	8 253
EIC	0	0	0
<b>Total weight</b>	<b>186 864</b>	<b>186 880</b>	<b>184 880</b>

Real or noted weight (kg)	Phase 1 forecast	Taxi weight	Takeoff weight
Corrected basic weight	81 560	81 560	81 560
Baggage	1 651	2 525 (1)	2 525
Fuel + taxiing	39 730 ( before refuelling)	94 853	93 853 (4)
Passengers	8 253 (2)	8 253 (2)	8 253 (2)
	7 759 (3)	7 759 (3)	7 759 (3)
EIC	60 (5)	60	60
<b>Total weight</b>		<b>187 251 (2)</b>	<b>186 251 (2)</b>
		<b>186 757 (3)</b>	<b>185 757 (3)</b>

(1) Nineteen items of baggage loaded on board were not taken into account, only 103 items appearing on the load sheet. There were 122 items of baggage loaded on board, with an average estimated weight of 20.7 kg each, making a total of 2 525 kg.

Note: these items of baggage had not been taken into account by the Gaétan system nor by the Baggage Reconciliation System (See paragraph 16.2).

(2) By applying the fixed average for passengers: one passenger = 84 kg, one child = 35 kg.

(3) By applying the fixed average for men and women: one man = 88 kg, one woman = 70 kg, one child = 35 kg.

Note: for holiday charter flights, it is also possible to use a fixed average of 76 kg per passenger.

(4) Allowing that the aircraft consumed a ton of fuel during taxiing.

(5) The EIC corresponds to 60 kg of newspapers.

### 6.5.2 Balance

The CG noted on the final load sheet gives a figure of 52.3 % at Zero Fuel Weight and 54.2 % for taxiing with fuel; this is the normal CG for a takeoff at maximum takeoff weight.

## 6.6 Takeoff Performance

The following parameters are used hereafter for performance calculations:

- QNH of 1 008 hPa
- temperature 19 °C
- a dry runway
- a CG of 54 %.

The Operating Manual provides the maximum structural weights:

- for taxiing 186 880 kg
- at takeoff 185 070 kg

Since the wind readings at different test points show a light and variable wind, the calculations are made with calm wind conditions.

Note: the takeoff limitations evaluation gives a maximum performance weight of 186.7 tons. With this weight and the associated speeds (V1, V2, VR), the second segment limitation and the tyre limitation have to be taken into account. The higher the aircraft speed on takeoff, the further the second segment limitation is pushed back. However, this speed is further limited by the constraints imposed by the tyres.

At the maximum structural weight at takeoff, the calculations provide the following values:

- V1: between 139 and 162 kt (the crew selected 150 kt)
- VR: 199 kt
- V2: 220 kt (1.125 V<sub>ZRC</sub>)
- Three-engine trim: 12.9°

The Flight Manual provides the following zero rate of climb (V<sub>ZRC</sub>) figures.

V <sub>ZRC</sub> (kt) 185 t	3 engines	2 engines
Gear retracted	193	262
Gear extended	205	>300

Note: the notion of V<sub>ZRC</sub> is important for Concorde. It is the cruising threshold speed, which allows the aircraft to remain in level flight at zero rate of climb. On a thrust/speed diagram, V<sub>ZRC</sub> is located at the intersection of the thrust available curve and the thrust required curve. These points represent an unstable condition. Furthermore, these speed values are highly influenced by the actual weight of the aircraft.

Ground and air minimum control speeds:

- VMCA = VMCG = 132 kt on three engines,
- VMCA = VMCG = 157 kt on two engines.

Takeoff runway length required and takeoff distance required (Flight Manual):

- TORA = 3 370 metres
- TODA = 3 700 metres

Note: These distances are regulated distances taking into account the failure of one engine.

A calculated simulation can be performed based on these parameters and a serviceable aircraft with four engines operating. Since it is not possible to know the exact weight at brake release (because of utilisation of the average passenger weights, for example), the maximum structural weight at takeoff (185.070 kg) is used for the calculations.

The results of this simulation are as follows (rounded figures):

- V1 is reached 1 150 m, or 33 s, after brake release
- VR is reached 2 070 m, or 43 s, after brake release
- V2 is reached 2 700 m, or 48 s, after brake release
- The wheels leave the ground 2 600 m after brake release
- The distance run to reach 35 feet is 2 950 metres

For all of these values, the influence of an increase in weight of one ton was examined and found to be negligible.

## **7 – METEOROLOGICAL CONDITIONS**

### **7.1 General Situation at 12 h 00**

#### **7.1.1 At Altitude**

At level 500 hPa (around 5 500 m), a depression associated with a pocket of cold air (temperature < -16 °C) was centred over the Gulf of Gascony. It was moving from the southwest towards the northeast and arrived over the Paris region during the night. It was associated with the rear of the disturbance covering the southwest of the country.

An analysis of the meteorological situation at 12 h 00, performed using the Météo-France, Aladin model, with a mesh of 0.1° at heights of 100, 200 and 500 m above the ground, showed a small anti-cyclonic cell centred on the Seine et Marne which was moving north-east at forecast times of 15 h 00 and 18 h 00. Because of its progression, this cell maintained an easterly flow over the whole Paris region during the afternoon.

#### **7.1.2 On the Ground**

A succession of low-pressure areas stretched from La Coruna to Leningrad. At midday one of these low-pressure areas was centred over the Poitou and Au-

vergence regions and was moving northeast. In front of its warm front, in the cool wet air left by the previous day's disturbance, the cloud cover was essentially made up of cumulus and stratocumulus with little vertical development.

This slightly subsiding intermediate zone had a weak pressure gradient. Consequently, it produced variable winds of less than 10 kt, locally calm.

## **7.2 Situation at the Aerodrome**

After the dispersal of morning mist at around 10 h 00, the increase in temperatures provided visibilities and ceilings which removed any operating restrictions on the aerodrome.

At 14 h 43, visibility was 15 km, the sky was cloudy with 2/8 Cu at 540 m, 2/8 Cu at 720 m and 5/8 SC at 1 020 m. The temperature was 19 °C and the humidity 74 %. The average wind at the threshold of runway 26 was 090°/3 kt and 320°/3 kt at the threshold of runway 08.

At 14 h 44, the average wind at the threshold of runway 26 was 020°/3 kt and 300°/3kt at the threshold of runway 08.

Note: wind measurements are taken every half a second and averaged over two minutes.

Between 14 and 15 h, the surface wind varied in strength at the two thresholds between calm and 9 kt and between 330° and 170° in direction. The runway was dry.

## **7.3 Documents Supplied to the Crew**

The meteorological dossier supplied to the crew consisted of wind and temperature charts with forecasts at flight levels 300, 390 and 530 at 12h and 18 h, two TEMSI charts for the north Atlantic between flight levels 250 and 360 for the same times and TAF, METAR and SIGMET reports valid for the destination and alternate aerodromes.

## **8 – AIDS TO NAVIGATION**

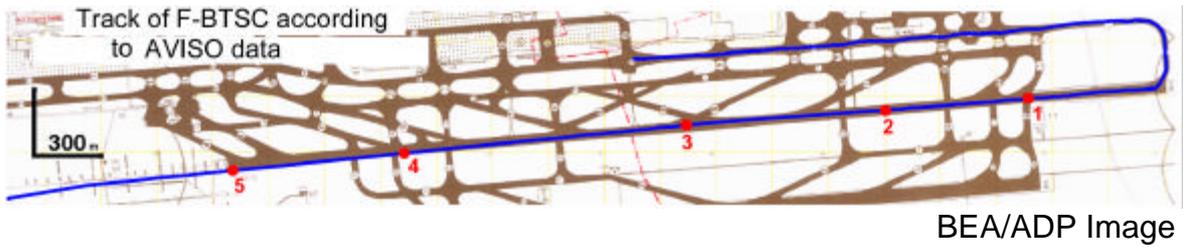
Not applicable.

## **9 – TELECOMMUNICATIONS**

### **9.1 Radar Track**

In order to obtain a precise position of the aircraft on the runway, the track was based on data from the AVISO system, the digitising system for the analogue

ground radar.



N.B: the numbers on the track refer to chapter 11.

## 9.2 Telecommunications

Flight AFR 4590 was contacted successively on the following frequencies:

- ATIS on 126.175 MHz
- Flight data on 126.65 MHz
- Traffic on 123.6 MHz
- Ground on 121.8 and 121.975 MHz
- Loc South on 120.9 MHz

Relevant communications are mentioned below.

### 9.2.1 ATIS

The "XRay" recording at 12 h 10 included:

- Takeoff runways 27 and 26 right
- Runway 27 LDA 2 630 metres
- TORA 2 900 metres
- ASDA 2 900 metres
- TODA 2 900 metres
- Wind 350°/ 7 kt
- Temperature 16 °C
- QNH 1008

The "Yankee" recording at 13 h 50 included:

- Takeoff runways 27 and 26 right
- Runway 27 LDA 2 630 metres
- TORA 2 900 metres
- ASDA 2 900 metres
- TODA 2 900 metres
- Wind 010°/ 4 kt
- Temperature 19 °C
- QNH 1008

### 9.2.2 Flight Data Frequency

At 13 h 58, the crew requested "*Concorde for New York on Echo 26 we need the whole length of 26 right*"

At 14 h 07, the controller confirmed "...*plan for 26 right ...*", the crew read back "... *on 26 right ...*".

### 9.2.3 Ground Frequency

At 14 h 34, the controller said "*Air France 45 90, good morning, taxi to holding point 26 right via Romeo*" then added "... *do you want Whisky 10 or do you want taxiway Romeo*". The crew confirmed "*we need the whole runway*". The controller replied "*OK so you're taxiing for Romeo, Air France 45 90*". The crew read the information back.

### 9.2.4 Loc South Frequency

At 14 h 40 min 02 s, the controller transmitted "*45 90 line up 26 right*", then crew replied "*we line up and hold on 26 right, 45 90*".

At 14 h 42 min 17 s, the controller said "*45 90 runway 26 right wind 090 8 kt cleared for takeoff*", the crew replied "*45 90 takeoff 26 right*".

At 14 h 43 min 13 s the controller stated "... *45 90 you have flames ... you have flames behind you*". The crew acknowledged this transmission.

At 14 h 43 min 28 s, a transmission, whose source could not be identified, was made on the frequency "*it's really burning and I'm not sure it's coming from the engines*".

A 14 h 43 min 31 s, the controller confirmed "*45 90 you have strong flames behind you*" and he continued "... *as you wish you have priority for a return to the field*". The crew acknowledged this transmission.

A 14 h 44 min 05 s, the controller transmitted "*Fire Service Leader err ... the Concorde I don't know his intentions get into position near the southern parallel runway*" then "*Fire Service Leader correction the Concorde is returning on runway 09 in the opposite direction*". The crew then transmitted "*we're trying for Le Bourget...*"

A 14 h 45 min 10 s, the controller told the Fire Service Leader "*The Concorde has crashed near Le Bourget Fire Service Leader*".

A 14 h 46 min 09 s, the controller announced "*For all aircraft listening I will call you back shortly we're going to get ourselves together and we're going to recommence takeoffs*".

A 14 h 55 min 47 s, an aircraft informed the controller "...there is smoke on runway 26 right, there's something burning apparently, for information ..."

A 14 h 57, a runway vehicle (Flyco 9) told the controller "there's tyre" then "pieces of tyre which are burning".

## 10 – AERODROME INFORMATION

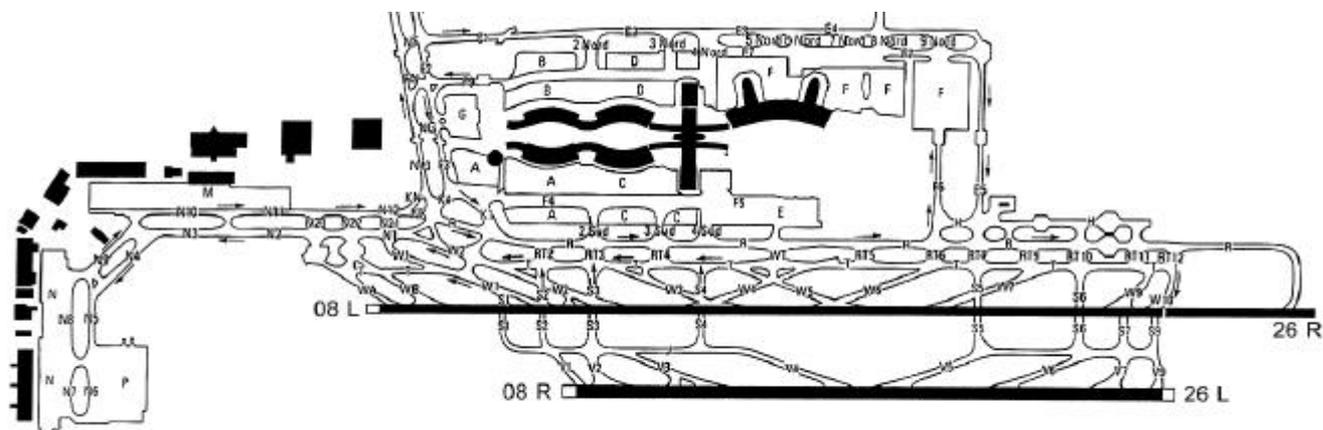
### 10.1 General

Paris Charles de Gaulle Aerodrome currently has one northern runway 09/27 and two southern parallel runways 08/26. Work was being carried out on the north runway, from 15 June to 17 August 2000, and its available length was reduced during this period of time from 3 600 to 2 700 metres, its width being unchanged at 45 metres.

Runway 08L/26R (26 right) is 4 215 m long and 45 m wide. Runway 08R/26L is 2 900 m long and 60 m wide.

Runway 26R has 600 m of tarmac followed by 7.5 metre square concrete slabs, its threshold being at an altitude of 312 feet.

The aerodrome has two fire fighting centres, a north RFFS and a south RFFS. Each centre is able to mobilise the men and equipment required for a Category 9 airport such as Paris Charles de Gaulle.



### 10.2 Runway Inspections

ADP Note 10/AD/98 specifies three daily inspections in addition to the lighting inspection: before 7 h 00, around 14 h 00 and around 21 h 00 local time.

On 25 July at around 04 h 30 (local time), an inspection of the runway was performed in two passes by a flyco runway inspection vehicle. Nothing was reported.

At around 14 h 30, a partial inspection of the runway was performed by a flyco vehicle in the vicinity of taxiway W2 following suspicion of a bird strike.

Between 14 h 35 and 15 h 10, an exercise with several fire service vehicles took place on runways 26 right and 26 left. To allow for this exercise, the runway inspection planned for 15 h 00 was delayed.

## **11 – FLIGHT RECORDERS**

### **11.1 Recorder Types and Readout**

Two flight recorders were installed on board F-BTSC, in addition to a Quick Access Recorder (QAR) which was also interrogated to assist in the investigation.

The flight recorders were found at the accident site by a technical investigator four hours after the accident. They were recovered as soon as conditions at the site permitted. They were placed under seal and taken to the BEA by two police officers.

#### **Cockpit Voice Recorder (CVR)**

- Make: Fairchild
- Type number: 93-A100-83
- Serial number: illegible

The CVR was opened, read out and a copy of the recording made during the night of the 25/26 July.

The outer casing of the CVR showed signs of exposure to fire and impact damage. The serial number was illegible because of marks left by fire. Nevertheless, the CVR's thermal protection had functioned and the tape was found intact inside its protective box.

In the following days, a transcript of the entire length of the recording was made. The validation of the identity of the voices of the crewmembers was made with Air France Concorde pilots. Access to the recording was then limited to relevant members of some of the working groups, as well as members of the Commission of Inquiry.

#### **Flight Data Recorder (FDR)**

- Make: Sundstrand
- Type number: 981-6009-011
- Serial number: 3295

Since the equipment normally used for the readout of this type of recorder at the BEA was temporarily unavailable, the recorder was taken to the Bretigny Flight Test Centre by a police officer, in accordance with the agreement between the two

organisations. The recorder was opened during the night of the 25/26 July, in the presence of two BEA investigators.

The outer casing of the FDR was damaged by impact and showed signs of exposure to fire. After the protective box was opened, the following was noted:

- The tape wind mechanism appeared to be in good condition
- The tape was in position, not stuck to the read and record heads
- There were black marks on the tape and various mechanisms
- The read and record head cables were stuck at the level of the protective box joint, some black marks being visible there inside the casing.

The tape, after extraction, was cleaned with distilled ethyl alcohol. It was strengthened at one point where the beginnings of a tear had been observed.

Readout of the whole of the tape, with simultaneous synchronisation of the signal being read out, was performed with Sundstrand IAE (Incident Analysis Equipment) (PN 960-0145-002).

Because of the condition of the tape, readout of the recording was of medium quality, and this caused a certain loss of signal synchronisation. This first readout made a preliminary analysis possible, but it was decided to seek better quality data at the same time, either by reading out the QAR or by a new readout of the FDR tape with digitisation of the signal so as to improve synchronisation by using algorithms appropriate to a poor quality signal.

## **QAR**

- Make: Dassault
- Model: EQAR F6217
- Type number: 1374-100-000
- Serial number: 290

The QAR is an unprotected recorder. It contains a copy of the FDR data on a magneto-optical disc and is used by Air France for flight analysis. The write procedure for the disc uses three backup memories whose role is to stock data sent by the Flight Data Acquisition Unit (FDAU) until such time as the vibration conditions detected by an internal accelerometer in the QAR are favourable for writing on the disc. The memories are volatile and must remain powered for the information they contain to be conserved.

The data readout was performed on 1<sup>st</sup> and 2nd August at Elancourt by personnel from Thomson CSF, the manufacturer of the QAR, in the presence of a judicial expert and a BEA investigator.

The QAR's box was crushed and the magneto-optical disc was deformed. The memory card, visible through the half torn-off casing, seemed to be in good condition. It was therefore decided to concentrate the work on this card. Two of the three memories had been torn off at impact. The third was still in place and was powered.

Tests were performed on check sample cards so as to define a method of data extraction, since this operation had never been carried out before. The method used was to connect a parallel power supply to the memory so as to be able to transfer it from its card to a receiver card. An uninterrupted series of zeros had first been written onto the two other memories of the receiver card.

The content of the third memory could thus be read out and a copy of the disc was given to the BEA. After analysis, it appeared that the parameters of the accident flight were present on the only one of the three memories which had remained powered. The quality of the recording, because of the technology used, was excellent and there was no de-synchronisation. It was not therefore necessary to try to read out the magneto-optical disc nor to proceed with further acquisition work on the FDR tape signal.

## 11.2 CVR Readout

A synchronisation of the CVR recording was performed with the radio-communications recording (UTC time) and with the FDR recording.

Ground test were performed on Concorde using a recorder of the same type. A spectral analysis comparison of the recordings helped identify the sound of certain selectors and alarms.

In collaboration with a researcher from the *Institute of Sound and Vibration Research* in Southampton (GB) an attempt was made to detect, on the sound recording, possible noises of impacts on the aircraft structure by demodulation of the onboard power supply frequency (400 Hz). This technique proved fruitless.

A transcription of the last five minutes of the recording is attached in appendix 2. Of the thirty minutes on the CVR, the following points are of note:

N.B.: the numbers (❶, etc.) refer to positions on the track in 9.1 and in appendix 5.

14 h 13 min 13 s, FE "*so total fuel gauge I have ninety-six four with ninety-six three for ninety-five on board*".

14 h 13 min 46 s, FO "*fire protection*", FE "*tested*".

14 h 14 min 04 s, FO "*ZFWZFCG*", FE "*so I have ninety-one nine and fifty-two two*".

14 h 14 min 17 s, Captain "*the reference speeds so V1 one hundred fifty, VR one hundred ninety-eight, V2 two hundred twenty, two hundred forty, two hundred eighty, it's displayed on the left*".

14 h 14 min 28 s, FO "*Trim*", Captain "*it's thirteen degrees*".

14 h 14 min 53 s, Captain "*Then the lever is at fourteen and you'll have an N2 of ninety-seven and a bit*", FE "*ninety-seven*".

14 h 22 min 22 s, Captain "*right we're going to do one hundred eighty-five one hundred that's to say we're going to be at the ... structural limits*", "*structural error fifty-four per cent balance (\*) see*".

14 h 39 min 04 s, Captain "*So the takeoff is ... at maximum takeoff weight one hundred eighty tons one hundred which means four reheats with a minimum failure N2 of ninety-eight*", "*Between zero and one hundred knots I stop for any aural warning the tyre flash*", "*tyre flash and failure callout from you right*", "*Between one hundred knots and V1 I ignore the gong I stop for an engine fire a tyre flash and the failure callout*", "*after V1 we continue on the SID we just talked about we land back on runway twenty-six right*".

14 h 40 min 19 s, Captain "*How much fuel have we used ?*" FE "*We've got eight hundred kilos there*".

14 h 41 min 09 s, FE "*Brake temperatures checked one hundred fifty ...*".

14 h 42 min 31 s, Captain "*top*".

❶ 14 h 42 min 54 s, FO "*one hundred knots*".

14 h 42 min 57 s, FE "*four greens*".

❷ 14 h 43 min 03 s, FO "*V1*".

Of 14 h 43 min 07 s to 14 h 43 min 13 s, various noises which have not been identified at this stage of the investigation

❸ 14 h 43 min 13 s, message from the controller informing them of flames at the rear, read back by the FO.

14 h 43 min 20 s, FE "*Failure eng... failure engine two*".

❹ 14 h 43 min 22 s, fire alarm

14 h 43 min 24 s, FE "*cut engine two*".

14 h 43 min 25 s, Captain "*engine fire procedure*" and one second later, end of fire alarm

14 h 43 min 27 s, FO "*Watch the airspeed the airspeed the airspeed*".

❺ 14 h 43 min 30 s, Captain "*Gear on retract*". Over the following eight seconds, the crew mentioned the landing gear several times.

14 h 43 min 42 s, Fire alarm.

14 h 43 min 46 s, Captain "*(are you) cutting engine two there*".

14 h 43 min 48 s, FE "*I've cut it*".

14 h 43 min 49 s, FO "*the airspeed*".

⑥ 14 h 43 min 56 s, FO "*the gear isn't retracting*".

Between 14 h 43 min 59 s and 14 h 44 min 03 s, three GPWS alarms are heard and at the same time the FO says "*the airspeed*".

⑦ 14 h 44 min 14 s, FO "*Le Bourget Le Bourget*" then a few seconds later ⑧ "*negative we're trying for Le Bourget*".

14 h 44 min 31 s, end of the recording.

## 11.3 FDR Readout

### 11.3.1 The Flight

The recordings were decoded with the aid of documents provided by Air France and EADS. Four hundred parameters were recorded. Some of these parameters posed validation problems, in particular for their neutral or reference values. The SAT recording was invalid.

The previous flights, supplied by the Air France flight analysis service, were analysed for the purpose of validation and comparison.

Graphs derived from the recorded parameters for the whole of the flight are shown in appendix 4. Details of some significant parameters are listed below.

The following tables show the recorded values of certain parameters. For a given generated time, the associated parameters are values sampled at a specified moment in the course of the corresponding second. This indication does not appear in the tables. In addition, only the parameters of one engine are recorded each second. Thus, the parameters of each engine appear only every four seconds.

N.B.: The numbers (①, etc.) refer to the track shown in 9.1 and in appendix 5.

① 100 kt callout, generated time 97585

CAS: 100 kt

Control Column: 0.4°

Trim: 0.4°

Heading: 270°

Rudder bar: - 0.6° (right)

Lateral acceleration: between - 0.04 and 0.01

Longitudinal acceleration: 0.27

Engine	Time	N1	N2	EGT	FF t/h	P7
n° 4	97585	93.16	102.83	723.6°	20.27	40.19
n° 1	97586	94.10	102.63	750°	21.57	41.08
n° 2	97587	93.96	103.04	750°	21.49	41.21
n° 3	97588	89.94	102.83	763.7°	22.11	42.39

② one second after the V1 callout, generated time 97595

CAS: 151 kt  
Control Column: 0.4°  
Trim: 0.4°  
Heading: 269°  
Rudder bar: - 1.8 (right)  
Lateral acceleration: between - 0.05 and - 0.04  
Longitudinal acceleration: 0.28

Engine	Time	N1	N2	EGT	FF t/h	P7
n° 2	97595	94.54	103.13	756.8°	22.34	42.49
n° 3	97596	89.88	102.77	769.5°	22.92	43.47
n° 4	97597	93.84	102.83	730.5°	21.23	41.96
n° 1	97598	94.51	102.54	755.9°	22.54	42.89

③ flames reported by the controller, generated time 97604

CAS: 188 kt  
Control column: - 3.8°  
Trim: 1.3 (up)  
Heading: 267°  
Rudder bar: - 6.4 (right)  
Lateral acceleration: between - 0.11 and - 0.17  
Longitudinal acceleration: 0.16

Engine	Time	N1	N2	EGT	FF t/h	P7
n° 3	97604	90.12	102.74	756.8°	23.33	44.11
n° 4	97605	94.16	102.89	769.5°	21.67	42.88
n° 1	97606	86.95	98.58	730.5°	18.28	38.04
n° 2	97607	48.69	73.30	755.9°	0.95	17.30

④ radio altitude positive, generated time 97614

CAS: 201 kt  
Control column: 0.6°  
Trim: 12.8° (up)  
AOA: 13.35°  
Heading: 270°  
Rudder bar: - 16.4 (right)  
Radio altitude: 6 ft

Engine	Time	N1	N2	EGT	FF t/h	P7
n° 1	97614	50.77	74.77	480.5°	1.32	17.54
n° 2 *	97615	57.07	77.52	446.3°	3.48	19.54
n° 3	97616	90.67	102.69	770.5°	22.97	43.72
n° 4	97617	94.72	102.92	732.4°	21.47	42.33

\*: engine fire warning

⑤ request to retract landing gear, generated time 97621

CAS: 199 kt

Control column: 0.5°

Trim: 11.1°(up)

AOA: 12.27°

Heading: 266°

Rudder bar: - 11.9 (right)

Radio altitude: 100 ft

Engine	Time	N1	N2	EGT	FF t/h	P7
n° 4	97621	94.66	104.12	758.8°	23.87	44.08
n° 1	97622	91.08	100.9	648.4°	14.22	41.04
n° 2	97623	15.97	33.9	320.3°	0	13.78
n° 3	97624	90.97	103.89	801.8°	25.67	45.16

⑥ non retraction of gear noted, generated time 97647

CAS: 211 kt

Control column: 1.7°

Trim: 9.3°(up)

AOA: 11.89° then 13.28°

Heading: 271°

Rudder bar: - 12.5 (right)

Radio altitude: 182 ft

Engine	Time	N1	N2	EGT	FF t/h	P7
n° 2	97647	6.27	13.92	235.4°	0	13.37
n° 3	97648	91.64	104.00	796.9°	25.60	45.21
n° 4	97649	95.13	104.21	762.7°	23.82	43.65
n° 1	97650	94.92	103.54	758.8°	22.43	42.57

From generated time 97649 to generated time 97653, GPWS "Whoop Whoop Pull Up" alarm.

⑦ FO "Le Bourget Le Bourget", generated time 97665

CAS: 208 kt  
Control column: 1.9°  
Trim: 10.6°(up)  
AOA: 12.08°  
Roll: - 2.57° then - 4.69° (to the left)  
Heading: 270°  
Rudder bar: - 18.1 (right), Mechanical mode  
Radio altitude: 199 ft

Engine	Time	N1	N2	EGT	FF t/h	P7
n° 4	97665	95.01	104.18	758.8°	23.67	43.82
n° 1	97666	43.56	81.36	855.5°	3.64	15.01
n° 2 *	97667	5.60	12.92	182.6°	0	13.88
n° 3	97668	90.91	103.68	793.9°	25.52	44.97

\*: engine fire warning

⑧ message "negative we're trying for Le Bourget", generated time 97673

CAS: 181 kt  
Control column: 7.6°  
Trim: 16.5°(up)  
AOA: 19.52°  
Roll: - 38.82° then - 40.93° (left)  
Heading: 238°  
Rudder bar: - 22.5° (right), Mechanical mode  
Radio altitude: 300 ft (1)

Engine	Time	N1	N2	EGT	FF t/h	P7
n° 4	97673	95.13	104.21	757.8°	23.22	42.53
n° 1	97674	25.17	51.39	640.6°	0	14.35
n° 2 *	97675	5.19	12.30	168.9°	0	14.05
n° 3	97676	91.41	103.98	798.8°	24.55	42.33

\*: engine fire warning

⑨ four seconds before the end of the recording, generated time 97677

CAS: 136 kt  
Control column: 3.4°  
Trim: 13.2°(up)  
AOA: 25.15°  
Roll: - 95.58° then - 108.17°(left)  
Heading: 193°  
Rudder bar: - 28.3 (right), Mechanical mode  
Radio altitude: 459 ft (1)

Engine	Time	N1	N2	EGT	FF t/h	P7
n° 4	97677	96.39	104.62	764.6°	22.90	40.04
n° 1	97678	20.04	42.60	585.9°	0	13.71
n° 2 *	97679	5.13	11.98	164.1°	0	14.02
n° 3	97680	55.11	80.60	776.4°	14.63	17.75

\*: engine fire warning

(1) the radio-altimeter readings are no longer representative due to the extreme roll attitude of the aircraft.

### 11.3.2 Engines

This paragraph presents a preliminary explanation of the engine parameters. Note that these parameters are recorded every four seconds.

Note: Data on engine speed (N1 for the LP turbine and N2 for the HP turbine) presents a lag relative to the theoretical value. This lag is identical for all four engines. We may consider that it represents of an error in the recorded values.

The initial acceleration values of the engines and their behaviour during the initial phase of the takeoff (up to 97602) are normal on all four engines. From time 97603 onwards, significant changes appear in the parameters of engines 1 and 2. Speed, temperature and flow parameters indicate deceleration. Within the limitations of sampling error, this behaviour appears simultaneously on both engines. Initially engine 2 is more affected than engine 1. Engine 1's parameters return to normal values from generated time 97626.

In the CVR recording, the FE announces engine 2 cut off. A noise similar to an engine shutdown/fire handle being pulled is then heard. The change in the parameters of engine 2 confirms the shut down of the engine. This engine's parameters then appear to be normal for an engine windmilling in these flight conditions.

From time 97620 onwards, the parameters of engine 3 then of engine 4 behave in a manner consistent with a switch from "Take Off" to "Contingency" modes. From time 97626 onwards, after the initial problem, the parameters of engine 1 also show engine speeds consistent with a change to "Contingency" mode. The fuel flow, primary exhaust nozzle area and P7 pressure are consistent with reheat operating on these engines.

From time 97654 onwards, the parameters of engine 1 indicate a deceleration and an increase in EGT. From time 97680 onwards, the parameters of engine 3 and then engine 4 indicate a sharp deceleration.

### 11.3.3 Track

The aircraft's track (see appendix 5) was calculated by integrating the airspeed and magnetic heading parameters, by positioning the first and last points of their

known or estimated position. A reasonable approximation of the ground track was thus obtained. Bearing in mind the method used, the tolerance is of the order of about a dozen metres at the ends of the track. It is at its greatest in the middle of the track (around a hundred metres).

## **12 – WRECKAGE AND IMPACT INFORMATION**

### **12.1 The Runway**

Various debris and marks were found on the runway after the accident (see drawing in appendix 3). They are identified in the following by the grid number of the concrete slab where they were found, the distances being measured in relation to the eastern end of the tarmac part of the runway (see section 10). Thus, for example, an element identified at Slab 180 level was found 1 950 m from the point of origin ( $600 + 180 \times 7.5$ ). Debris was also found under the aircraft's flight path.

Note: the point at which the brakes were released is located between 65 and 85 m from the beginning of the runway.

#### **12.1.1 Water Deflector**

Parts of the water deflector of the left main landing gear were found between Slabs 139 and 166, that is 1 642 to 1 845 m from the beginning of runway 26 right, more precisely at 139, 149, 151, 157 and 166. The parts found did not include metallic parts.



*Part found at Slab 166 level: right part of the deflector*

#### **12.1.2 Pieces of Tyre**

Pieces of tyre from the Concorde were found at slab levels 146, 152, 166, 180, 186 and 187. The parts found at Slab 152 level (a piece measuring 100 x 33 cm and weighing more than 4 kg) and that found at Slab 180 level fitted together. Vis-

ual inspection revealed a transverse cut about 32 centimetres long.



*Piece of tyre at Slab 180 level*

*Piece of tyre at Slab 152 level*

### **12.1.3 Piece of Metal**



*Piece found at Slab 152 level*

A strip of metal about 43 centimetres long, bent at one of its ends, was found on the runway shoulder at Slab 152 level. Its width varies from 29 to 34 mm and it has drilled holes, some containing rivets, similar to the Cherry aeronautical type. The holes are not at regular intervals.

On visual inspection, the piece appeared to be made of light alloy, coated on one side with epoxy primer (greenish) and on the other side with what appeared to be red aircraft mastic for hot sections (RTV 106). It did not appear to have been exposed to high temperature.

This piece was not identified as part of the Concorde.

#### 12.1.4 Structural Element

A ribbed structural part measuring about 30 x 30 cm was found at Slab 160 level. It was white on the external side and dark on the ribbed side. It came from the aircraft's No. 5 fuel tank. It showed no signs of impact damage.



*Part found at Slab 160 level*

#### 12.1.5 Brake Servo Valve Case



An alloy part, identified as the brake servo valve case, from the left main landing gear, was found at Slab 175 level. This part was sooted and had clearly been overheated. It had impact deformation.

*Part found at Slab 175 level*

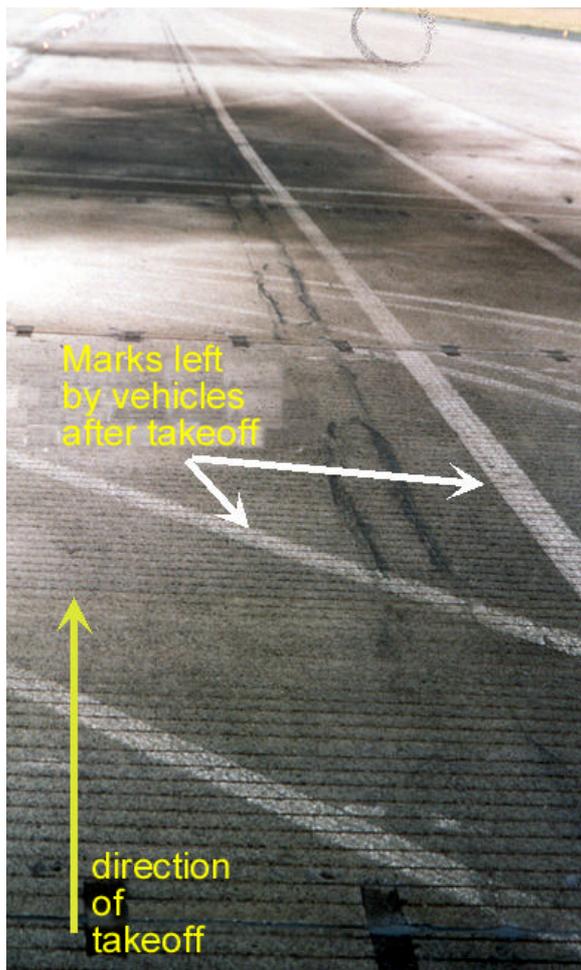
#### 12.1.6 Piece of Concrete and Signs of Explosion

Signs of an explosion and a piece of concrete torn from the runway were found at the Slab 181 level. The piece of concrete was about one centimetre thick, 10 centimetres wide and 25 to 30 centimetres long. Found intact, it was later broken in two.

### 12.1.7 Lighting

The runway edge light at the Slab 293 level (about 2 800 m from the origin) was broken and small pieces of the light were found nearby. Ground marks showed that this light was broken by the Concorde's left main landing gear.

### 12.1.8 Tyre tracks



Irregular marks made by the left landing gear were noted up to the broken light (around 2 800 metres).

After this point, the marks became intermittent then disappeared at about 2 830 m from the runway threshold.

From Slab 161 level to Slab 232 level, that is between 1 807 and 2 340 m, the mark of a flat tyre with an incomplete tread was observed.

This mark was parallel to the runway axis (at about 3.8 m) then diverged at about 2 200 metres.

When this mark disappeared at about 2 340 m, its displacement from the centreline was about 8 m. This corresponded to the right front tyre of the aircraft's left landing gear.



*Mark left by the left truck and broken light*

### 12.1.9 Soot Deposit

Traces of soot, produced by incomplete combustion of kerosene, were apparent on the runway 1 860 m onward from the origin (Slab 168). These were large and dense up to 2 300 m and then became less dense and rich in carbon up to taxiway S4, at 2 770 metres. The traces, which were on average 7 m wide, were initially centred on the damaged wheel ground mark and progressed to a position corresponding to the far left of the aircraft.



Slab 202

A further sooted area was apparent after taxiway S4 up to the broken edge light.



Slab 290



*Between Slabs 310 and 340*

The grass was burnt adjacent to the runway edge, between 2 902 and 3 165 metres. This area, also featuring soot deposits, indicated that there was an extensive flame after the aircraft became airborne.

## **12.2 Between Runway 26 Right and the Site of the Accident**

In the 1 000 m after the end of the runway, along the extended centreline, the following elements were identified:

- a piece of fire-damaged fuel tank,
- the tail cone anti-collision light,
- a severely fire-damaged inspection panel from the wing lower surface,
- seven inspection panels identified as coming from the upper surface of the left wing dry bay, with no signs of fire,

From 1 000 to 2 500 m after the end of the runway:

- an inspection panel identified as also coming from the upper surface of the left wing dry bay, showing no signs of fire,
- a fire-damaged piece of duct,
- fire-damaged structural parts that appear to have come from the aircraft tail cone.

Burn marks on the ground were visible where certain items of debris were found, particularly where the tar had melted adjacent to items found on the roofs of buildings in the freight zone. A wheat field was damaged by fire 2 500 m from end of the runway.

Beyond this point, the following was noted:

- two hydraulic shutoff valves, one damaged by fire,
- two lower inspection panels from the engine nacelle, one melted, the other intact,
- debris from the wings, in particular fuel tank parts,
- a fire-damaged hydraulic line.

Leading up to the crash site, many small pieces of metal, honeycomb components, pieces of riveted structure and parts of the rear fuselage, were found. Most of these parts show traces of fire and their distribution was continuous along the aircraft's track.

## 12.3 The Accident Site

### 12.3.1 Description of Site and Plan

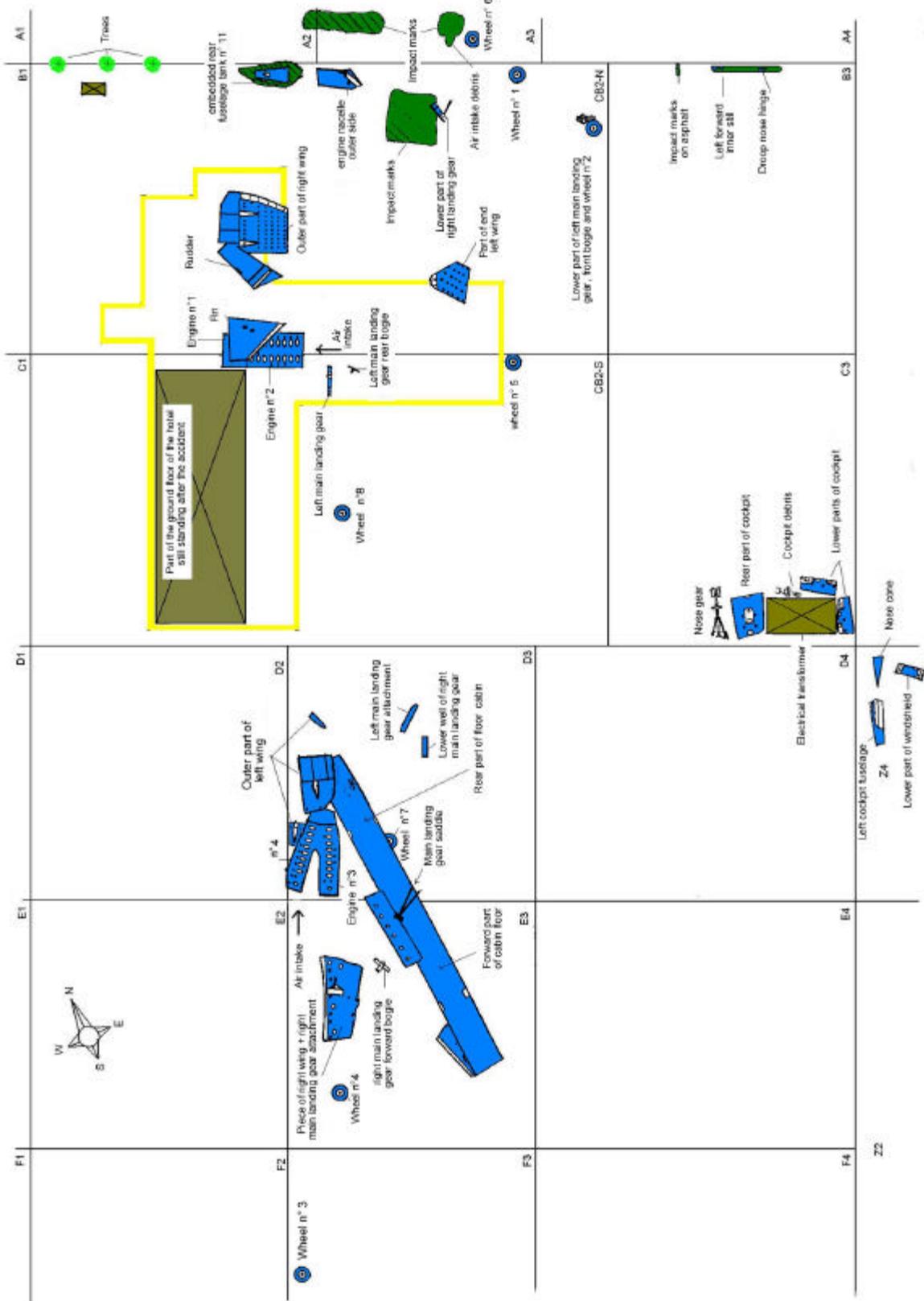
The crash occurred south-west of Paris Charles de Gaulle airport at about 9 500 m from the threshold of runway 26R in a level area. The altitude of the area is 400 feet. The wreckage was at the intersection of the N17 and the D902 roads.



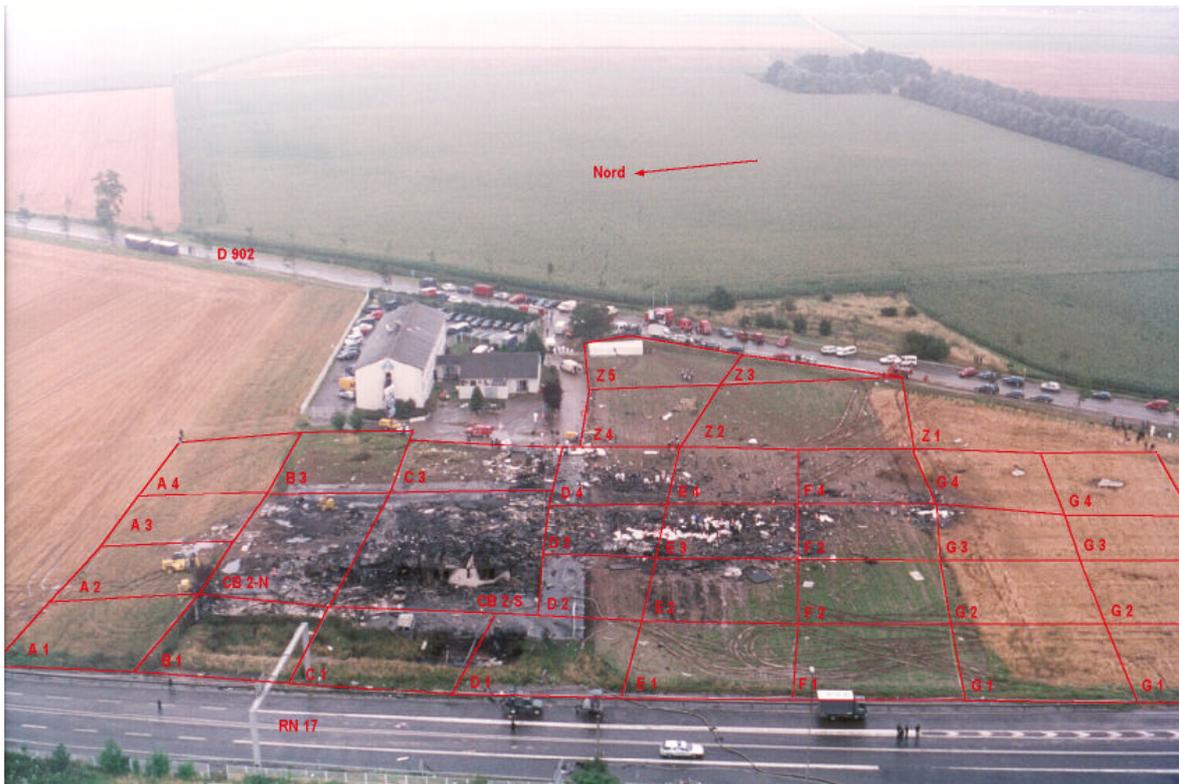
*BEA/IGN/FLEXIMAGE image*

*Aerial photo of the accident area*

The crash site was divided into a grid. The various areas were referenced to this grid.



Map showing aircraft wreckage distribution at the crash site



*Aerial view showing grid*

Examination of the site showed that the aircraft had struck the ground on heading 120° left, with little horizontal speed. After the impact, it broke and spread generally to the south, with the aircraft upright.

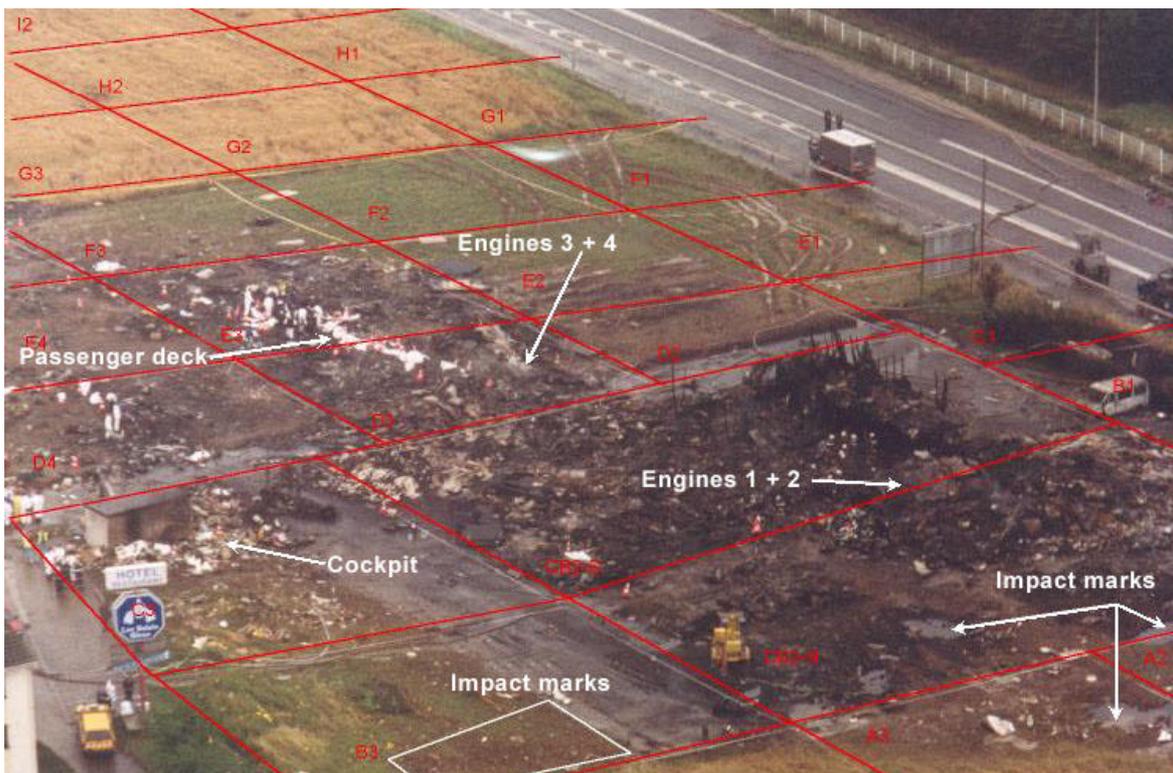
The wreckage was extensively burnt. Only the front parts of the aircraft, found mainly in areas C3, D4 and Z4 escaped the ground fire, together with a few pieces of the fuselage scattered over the site. Most of the wreckage, with the exception of the cockpit, remained within a rectangle measuring a hundred metres long by fifty metres wide (areas CB2, D3 and E3).

Signs of ground impact were found to the north of the site at the intersection of areas A and B. There was a row of trees about three metres high, oriented east to west, then a crater at the bottom of which was rear tank No. 11. Pieces of engine air intake were found half-buried at A3 and signs of ground impact were apparent at A3 and CB2-North. Wheel N° 6 was embedded in the ground.



*Ground impact marks*

At B3, an impact mark was visible in the asphalt. Forward parts of the aircraft were in a line embedded in the earth, including the front left door sill and a hinge from the aircraft's droop nose. Near these items of debris, the grass was sparse.



*Aerial view showing location of the main parts*

The hotel located at CB2-North was almost entirely flattened. The lower parts of the left and right main landing gears were close to the initial impact marks.

The outer part of the left wing, with the outer elevons still attached, was found melted on the ground. Nearby was the inner part of the wing with the left dry bay with engines 1 and 2 still attached. The rudder was found between these two

parts. The fin was resting on the dry bay. The left inner elevon was found beneath the two engines, still linked to part of the wing (this assembly is normally located between the left powerplants and the fuselage). The engines were resting on a water tank 1.5 m in height. Many wing parts were found nearby, including the lower surfaces of tanks 6 and 10.

The left main landing gear leg, still connected to its side strut, was found at CB2-South. Examination of the strut's locking mechanism showed that the landing gear was down and locked at the time of impact.

In the western area of the CB2-South rectangle, part of the ground floor of the hotel was still standing. A large number of items of debris from the building were found in the eastern area.

At C3, a large number of parts belonging to the cockpit had impacted an electric power transformer. The pilots' seats, the throttle levers and the autopilot control unit were found at this point. The seven landing gear ground lock pins were found with their stowage bag.

Next to this there was a section of the fuselage in which it was possible to recognise the aisle between cockpit and cabin. From this wreckage the QAR and the main components of the flight crew instrument panels were extracted (description follows).

Nearby, the nose landing gear was found, extended.

The main components of the Concorde's structure were found at D3 and E3, along the axis of the wreckage scatter. The passenger cabin was identifiable from pieces of fuselage, together with a large number of items of debris from the hotel. The passenger seats and most of the victims were found in these areas. The hydraulic tanks normally located in the rear hold and the CVR were found at E3 and the radio altimeters installed in the forward hold were found at D3. The structures of the main landing gear wheel well were grouped together at the intersection of areas D3 and E3, near the landing gear legs.

The right dry bay with engines 3 and 4 still partially attached was found at D3, to the right of the passenger cabin. Nearby, a large number of pieces of the right wing were found, including the three PFCU's that control the right elevons. The left main landing gear attachment structure was found to the left of the passenger cabin.

The right main landing gear attachment structure and a melted piece of the right wing were found at E3, to the right of the passenger cabin.

Pieces of fuselage were found in the peripheral areas H and I and in Z2.

### 12.3.2 Instrument Indications

The emergency landing gear extension selector on the rear of the flight deck centre console was not selected. The following indications were noted on the instruments found on the central panel:

Engine speed indicators:

	Engine 1	Engine 2	Engine 3	Engine 4
N1	Absent	Absent	52 %	58 %
N2	28 %	4 %	80 %	85 %

Fuel Flow indicators: For engine 4, a (yellow) pre-set display showed 19.6 kg/h x 1000.

	Engine 1	Engine 2	Engine 3	Engine 4
FF	0	Burnt	Burnt	Close to 0

EGT indicators:

	Engine 1	Engine 2	Engine 3	Engine 4
EGT	580 °C	220 °C	600 °C	600 °C

Brake pressure indicator: 400 Psi left and 1,500 Psi right.

AJ indicators: unreadable, the needles were missing for engines 3 and 4.

- one Primary Nozzle Area Indicator, S/N AA115
- one unidentified and unreadable temperature indicator.

On the FO instrument panel, the following items were noted:

- the Nose/Visor lever was in the "Down" position
- the landing gear selector was towards the "Down" position, past the gate
- on the rudder position indicator (damaged on impact), the rudder indicators were at 20° left for the upper control surface and 12° right for the lower control surface on "G" (Green). The indicators for the elevons were on "M" (Mechanical) and provided no information
- the airspeed shown on the airspeed indicator was 99 Kt, "STBY" flag, and V2 bug was on 230 kt
- HSI heading 105°, ADI 30° roll to the left and 32° nose down. Vz – 1 800 ft/min, altimeter - 240 feet "STBY" flag, radio altimeter unreadable, VOR1 028°, VOR2
- FD switch on number 2
- attitude selector on ATT INS3, comparator on COMP2, deviation on DEV2, navigation on NAV INS2
- clock on 14 hours 45 UTC



*Instrument panel*

On the Captain's instrument panel, the following items were noted:

- HSI heading 105°, ADI 15° roll to the left and 75° nose down, standby horizon 90° roll to the left and 18° nose-up, Vz – 1 200 ft/min, altimeter - 250 feet STBY, radio altimeter on 0, angle of attack indicator unreadable, RMI ADF heading 100°
- trim indicator on 54.3 %
- TCAS broken

On the coaming the following items were noted:

- auto-throttle 1 and 2: Off
- autopilot 1 and 2: Off
- flight director 1 and 2: Off
- auto-throttle, selected speed 285 kt
- altitude selected 9 500 feet
- left display, heading 329°, course 285°
- right display, heading 338°, course 287°

On the overhead panel, the following items were noted:

- servo-control hydraulic selectors on "Normal"
- Engine Flight Rating switches: No. 1 CRZ, No. 2, 3 and 4 CMB
- Auto Ignition 1, 2 and 3 switches "On", n° 4 melted
- auto-throttle 1, 2, 3 and 4 switches "On"
- Engine Rating Mode switches 1, 2, 3 and 4 on "Take-Off"
- HP Valve selector switches damaged and on positions: 1 "Open", 2 broken, 3 "Shut", 4 "Open"
- engine shutdown/fire handle No. 2 pulled and pointing upwards
- extinguisher bottle fired indicators unreadable
- flying control electrical system selectors:

	1	2
Auto stab	Unreadable	Pitch axis: "Off" Roll axis: unreadable Yaw axis: "Off"
Artificial feel	Blue circuit Pitch axis: "Off" Roll axis: unreadable Yaw axis: "Up"	Green circuit Pitch axis: "Off" Roll axis: "Off" Yaw axis: "Off"
Electric trim	"Off"	"Off"

- inverter controls difficult to read, with the following possible positions:
  - blue inverter on "Power Off" and control broken
  - green inverter on "Off"
- flight control mode selectors damaged, in the following possible positions:
  - outer and middle elevon on "Mech" (Mechanical)
  - inner elevon on "Green"
  - rudder on "Blue"
  - anti-stall 1 and 2 unreadable

The warning panel was destroyed, separated from the rest of the upper panel and most of the covers and bulbs were missing.

- fire loop selectors: 1 "both", 2 "loop A", 3 "loop B", 4 "neutral", switch twisted and blocked

On the flight engineer's left panel, the following items were noted:

	Engine 1	Engine 2	Engine 3	Engine 4
P7 indicators	18 Psi	12 Psi	18 Psi	18 Psi

The rest of the right part of this panel was unreadable. The air intakes panel was not read at the site.

On the flight engineer's upper left panel, the following items were noted:

- Engine Control Schedule function: selector on "Flyover", switch blocked on "HI"
- brakes hydraulic pressure: 6 000 Psi with flag
- brakes fan switch on "On"
- clock stopped at 14 hours 45 UTC
- brake temperature: 170 °C, pushbutton No. 3 crushed and deformed

	Engine 1	Engine 2	Engine 3	Engine 4
secondary nozzle indicators	0°	15°	5°	broken

The pressurisation system indications featured on this panel were not read out at the site.

On the flight engineer's central upper panel (fuel and air conditioning), the following items were noted:

Tank 9

- indicated quantity of fuel "11 t",
- left pump on "Auto", right pump on "On"
- main left Inlet Valve on "Shut" (free movement of the switch which has no locking device), Override on "O/ride"
- main right Inlet Valve on "Auto", Override on "Off"

Tank 10

- indicated quantity of fuel "12 t",
- left pump on "Off", switch damaged, right pump on "Auto"

Tank 5A

- indicated quantity of fuel "2.4 t",
- two pumps on "On"

Tank 7A

- indicated quantity of fuel "2.2 t"
- two pumps on "On"

Also

- Standby Inlet Valves 5, 6 and 1 on "Open", 2 on "Shut"
- Standby Inlet Valves 3, 4, 10 and 7 on "Shut", 8 on "Open"
- Jettison tank switches 1 and 3 in intermediate position, 4 on "Open", 2 on "Shut"
- Master Jettison and Trim Pipe Drain switches unreadable

On the flight engineer's central panel (fuel), the following items were noted:

Tank 5

- indicated quantity of fuel "2 t"
- pump switches unreadable

Tank 6

- indicated quantity of fuel "4.6 t"
- left pump switch unreadable, right pump switch on "On"

Tank 1

- indicated quantity of fuel "4.2 t"
- main pump on "On", STBY1 on "On", STBY2 on "Off"

Tank 2

- indicated quantity of fuel "0.1 t"
- three pumps on "On"

#### Tank 7

- indicated quantity of fuel "6.6 t"
- pump switches unreadable

#### Tank 8

- indicated quantity of fuel "12.8 t"
- two pumps on "On", right pump switch damaged

#### Tank 3

- indicated quantity of fuel "4.3 t",
- pump switches unreadable

#### Tank 4

- indicated quantity of fuel "4.3 t"
- pump switches unreadable

#### Tank 11

- indicated quantity of fuel "10 t"
- left hydraulic pump on "Auto", right on "Off"
- position of electric pumps unreadable
- main left Inlet Valve on "Shut", Override unreadable
- main right Inlet Valve and Override unreadable

FQIP (Fuel Quantity Indicator Panel) had the following pre-setting indications:

- ZFW (Zero Fuel Weight): 91.9 t
- CG 52.29 %,
- "Main" lane
- Total Contents indicator: 78.8 t with flag

On the flight engineer's right upper panel (electrical and hydraulic generation), the following items were noted:

#### Green Circuit

- Level below zero with flag
- Shut Off Valve indicators of pumps 1 and 2 with flags
- hydraulic pumps 1 and 2 indicators on "On"
- hydraulic pumps 1 and 2 switches on "On"
- hydraulic pressure 2 000 Psi with flag

#### Yellow Circuit

- "6 US Gal" level with flag
- Shut Off Valve indicators of pumps 2 and 4 with flags
- hydraulic pumps 2 and 4 indicators on "On"
- pump selector switches 2 on "Auto", pump 4 on "On"
- pressure unreadable

### Blue Circuit

- "2.7 US Gal" level with flag
- Shut Off Valve indicators of pumps 3 and 4 with flags scratched
- hydraulic pumps 3 and 4 indicators on "On"
- pump selector switch 3 on "Off", pump 4 on "On"
- hydraulic pressure 6 000 Psi with flag

### Also

- "Yellow Pump" switch on "Normal"
- IDG 1, 2 and 3 indicators unreadable, 4 on "60 KW"
- all alternator switches on "On"

On the flight engineer's right side panel (electrical generation), which was heavily damaged and burnt, only the following items providing information were noted:

- transformer rectifier unit (TRU) ammeters: 1 burnt "0", 2 broken "0", 3 "30A", 4 broken "70A"
- TRU selectors: TR1 unreadable, TR2 on "Normal", TR3 on "Isol", TR4 selector missing
- Eng 1 & 4 and Eng 2 & 3 nozzle safety switches on "Normal" but damaged on impact
- fuel tank pressure: "0" (touching red index)

On the flight engineer's lower right panel, which was heavily damaged and burnt, the following items were noted:

- passenger oxygen pressure: 40 Psi with flag
- crew oxygen pressure indicator damaged, indicating "0"
- oxygen selector missing
- four fire extinguisher cartridge indicators: "Full"
- extinguisher check selector unreadable

## 12.3.3 Examination of Engines

### Secondary exhaust nozzles



*General view of engine n° 4 upper secondary exhaust nozzle*

The upper secondary exhaust nozzles were still in place on engines 1, 2, 4 and separated from the nozzle structure on engine 3. The lower secondary exhaust nozzles were separated from the structure and three of them were found intact. The upper actuators from engines 2 and 4 were attached to the structure and to the nozzles. The lower actuators were found at the site with the exception of that of engine 3.

### **Primary exhaust nozzles**



The primary exhaust nozzle from engine 3 was separated from the structure of the secondary nozzle. The latter was torn away from the rest of the engine. The nozzles from engines 1, 2 and 4 were in place but flattened by the impact with the ground.

### **General findings**

The primary and secondary nozzles showed no signs of overheat on any of the engines. Black marks were visible on the inner panels of the engine 1 nozzles. Traces of soot were also found on the upper right part of the structure of the engine 2 nozzles. No trace of damage caused by an uncontained engine burst was noted.

The position of engines 1 and 2 nozzles was about 21°, a position compatible with the takeoff phase or the shutdown of an engine. The position of the engines 3 and 4 nozzles was 0°.

Examination of engine n° 2 appears to indicate a negligible N1 before impact. The rotor of the LP compressor of engine n° 1 apparently made less than a quarter of a revolution after the impact before being stopped by the casing being crushed.



*Engine n° 1 LP compressor*

Engines 1 and 2 showed signs of damage (FOD) by a soft object on the LP compressor rotor blades. Engine 1 also showed signs of FOD by a hard object. The damage found on engines 3 and 4 showed that they hit the ground with an N1 much higher than that of engine n° 1.

None of the engines showed signs of any fire occurring before the crash.

#### **12.3.4 Examination of Wheels and Tyres**

##### **Wheel n° 1**

The entire wheel was burnt. The tyre, although burnt, showed no abnormal absence of material before impact at the accident site. There was black powder, the residue of combustion, on the base of the wheel. No trace of fire prior to the crash was observed.

The two half rims appeared to be intact.

The brake pack was separated from the wheel, being found about two metres away in an area affected by fire. It was covered with a deposit of soot.

##### **Wheel n° 2**

The tyre was damaged by fire. The two beads were not linked by the tread. The outer bead of the tyre was complete and almost intact. The inner bead was broken and the metal wires of the bead cores were exposed and broken at the same point, characteristic of overload bursting on impact. The wire's protective rubber was burnt.

The sides showed local ruptures oriented at about 45°, this being characteristic of lateral overload.

There was an abnormal lack of material at the site. The black material which is left after the rubber combustion that would have corresponded to the volume missing at the base of the tyre could not be found.

The two half rims seemed to be complete.

The wheel coloration was still blue, which seems to indicate that it had not suffered from fire prior to the crash.

The brake pack was in place on the wheel axle.

### **Wheel n° 5**

The tyre showed no abnormal lack of material. It had a static rupture characteristic of overload. The entire wheel appeared normal except for the part exposed to the ground fire where the tread had been superficially burnt. This wheel did not suffer from fire during flight.

The two half rims seemed to be complete.

The brake pack was in place in the wheel.

### **Wheel n° 6**

The tyre showed no abnormal lack of material. It had a static rupture characteristic of overload. The entire wheel had a normal appearance, without traces of burning.

The two half rims seemed to be complete.

The brake pack was in place in the wheel.

## **13 – MEDICAL AND PATHOLOGICAL INFORMATION**

There was no evidence of medical or pathological factors likely to be relevant to the accident.

## **14 – FIRE**

An intense fire started under the left wing, in an area not provided with extinguishing equipment, while the aircraft was accelerating between V1 and VR.

On impact, the aircraft was immediately engulfed in fire. The intensity of the fire caused exposed plastic parts of the neighbouring hotel to be melted together. This is characteristic of a high temperature fireball.

Alerted by a fireman, the brigade from the south fire station at Paris Charles de Gaulle aerodrome immediately set out. At the same time, at 14 h 43, the crash

alarm was activated via the local network by the controllers on duty at the southern lookout post. Eight minutes later, firemen from Le Bourget aerodrome were first to arrive at the scene of the catastrophe. Faced with the scale of the fire, they were only able to limit the fire and provide aid to the injured.

The Paris Charles de Gaulle Rescue and Fire Fighting Service then intervened with their major equipment: twelve vehicles including six with foam fire-fighting systems and two for liaison. More than 180 000 litres of water and 3 800 litres of emulsifier were used.

Reinforcements from the neighbouring fire stations enabled the fire to be brought under control after three hours.

## **15 – SURVIVAL ASPECTS**

The crew were all found at their takeoff positions and the passengers in the seats assigned at boarding.

The seats were fragmented. All the seat belts found were fastened.

The circumstances of the accident and the condition of the aircraft meant that the accident was not survivable.

## **16 – TESTS AND RESEARCH**

### **16.1 Flight Preparation at Air France**

At Air France, four units take part in preparing for flights: Flight Planning, Flight Departure, Ramp and Traffic.

#### **16.1.1 Flight Planning**

Preparation for the flight starts around H-5 hours, H being the time planned for departure. The agent responsible for the plan draws up a flight dossier, parts of which are required by regulations to be archived for one month. He uses a computer program which includes the characteristics of each aircraft and, among other things, informs of NOTAMs, danger areas, aircraft limitations in relation to the prevailing conditions and generates the flight plan. As far as Concorde is concerned, certain elements, particularly the forecast takeoff weight and the fuel required for the flight, are calculated manually. Once the preparation is finished, the computer-processed part of the flight dossier is sent on automatically to the flight departure section while the manual part is passed on by the agent.

#### **16.1.2 Flight Departure**

The crew come to "Flight Departure" to collect and study their flight dossier. The latest meteorological information available is generally added to this dossier one or

two hours before departure. Once he has studied the dossier, the Captain signs the fuel loading sheet. This sheet is archived for one month.

### **16.1.3 Ramp**

The personnel preparing the aircraft on the ramp is as follows:

- An aircraft service technician responsible for supervision and inspection of equipment for aircraft assistance on the ground. He does this from H-150 minutes to H+15 minutes.
- Two all-purpose personnel who prepare the ramp equipment, assist mechanics and provide assistance for departure.
- A supervisor responsible for checking and loading baggage. This agent signs the load sheet handed over to the dispatcher after the baggage loading has been completed.
- Four aircraft service handling operatives.

### **16.1.4 Traffic**

From H-2 hours to about H-1, the dispatcher undertakes what is called the "D1" role for flight preparation and planning. In this context, he performs the following tasks:

- drawing up a forecast for the weight of freight and passengers
- drawing up a loading plan for the aircraft
- drawing up a forecast for the final weight of baggage according to the number of passengers planned, using the Gaétan system to determine the baggage already registered
- calculation of the balance forecast from the basic weight of the aircraft, the basic index, possible tolerances, etc.

From H-1 hour, he co-ordinates any actions on the aircraft on the ground and undertakes the final "D3" role of updating the data for the Gaétan system. At H-10 minutes, the weight and balance data have to be finalised. The corresponding sheet is handed over to the crew and signed by the Captain.

Note: the quantity of fuel taken on-board is requested directly by the flight crew. In no event can the dispatcher modify this without the approval of the flight crew.

## **16.2 Aircraft Loading**

On the day of the accident, a certain number of items of baggage present on the aircraft (twenty-nine in all) were declared to be unidentified.

When baggage is checked in, the Gaétan system sends information to the BRS,

(the baggage reconciliation system allowing for cross-checking as required by regulations for security purposes) enabling the baggage to be identified (label number or tag, passenger's name, etc.). This information is stored in the BRS database and Gaétan simultaneously updates the baggage load condition on the dispatcher's screen in real time.

During loading, the supervisor uses his portable terminal to read the number on the label attached to the baggage. This information is transmitted to the BRS, which authorises loading. If the number is not present in the database, the response will be "tag unknown".

For flight AFR 4590, the seats were assigned by name and a collective ticket issued in Paris. On departure of feeder flights (e.g., Dusseldorf – Paris), items of baggage were registered in the Gaétan system for those flights only, although they were labelled on to New York. Separate entry of data (weight and tag) therefore also had to be made for flight AFR 4590, though it appears that this was not done systematically, which explains why certain items of baggage were not recognised by the BRS.

These items were finally loaded once the dispatcher had checked that all the passengers were on board, that all baggage was clearly labelled and that they had all gone through X-ray inspection.

A comparison of the Gaétan and BRS printouts for flight AFR 4590 and the feeder flights shows that the items of baggage with "tags unknown" had not, in fact, been taken into account by the Gaétan system. As a result, they were not taken into account in the computerised load sheet used by the dispatcher to calculate the weight of baggage loaded on board.

However, ten items of baggage planned for the flight and accounted for in the Gaétan system were not loaded, which brings to nineteen the number of additional items of baggage taken on board as compared with the load report.

### 16.3 Observation and Pictures of the Event



The following was provided by examination of pictures available of the accident flight and from reports by various people who were at the airport or saw the aircraft flying. These in no way represent the conclusions of the investigation.

*Copying forbidden - Source Buzz Pictures/Corbis Sygma*

The initial fire began under the wing, between the left engine nacelles and the fuselage, a few seconds before the start of takeoff rotation, the aircraft being in the vicinity of W7 or S5. A small flame apparently appeared suddenly, similar to a blowtorch, and then got wider (enveloping the left engines) and longer (about the length of a fuselage). This flame was accompanied by thick black smoke. The noise of the aircraft was perhaps different from normal.

After having passed over the freight zone, the aircraft stopped climbing, with an apparently constant pitch attitude and with the landing gear extended. It flew over the N17 road at about two hundred feet, turned to the left at a steep bank angle, pitched nose up and crashed left wing first. There was a conflagration followed by one or more explosions.



*Copying forbidden*  
Source Buzz Pictures/Corbis Sygma

## 16.4 Previous Events

Since the Concorde's entry into service, six cases of damage to tanks have been recorded. No case of a fuel fire had ever been encountered. The examination of these events is under way.

**14 June 1979:** F-BVFC on takeoff from Washington Dulles Airport. Deflation of tyre n° 6 followed by loss of tread, leading to burst of tyre n° 5 and the destruction of the wheel. This event caused a variety of damage to the aircraft, including damage to the left main landing gear, to the hydraulic and electrical circuits and slight perforations in tanks 2, 5 and 6, mainly caused by pieces of wheel rim. After some unsuccessful attempts to retract the landing gear, and the loss of hydraulic circuits, the crew landed the aircraft back at Washington twenty-four minutes later. Four Airworthiness Directives (AD) were issued:

- AD of 14/01/81 calling for the installation of a system for detection of main landing gear tyre under-inflation,
- AD of 14/01/81 calling for improvements in protection in the normal braking hydraulic system,
- AD of 5/05/82 defining an inspection procedure for the main landing gear tyres and wheels before each takeoff,
- AD of 5/05/82 calling for the installation of new reinforced wheels and tyres.

**9 August 1981:** G-BOAG on takeoff from New York, burst of n° 1 and n° 2 tyres leading to minor penetration of tank n° 5.

**15 November 1985:** G-BOAB on takeoff from London Heathrow, burst of n° 5 tyre causing damage to the landing gear door. Minor penetration in tank n° 5, probably by a piece of the door mechanism.

**29 January 1988:** G-BOAF on takeoff from London Heathrow, loss of ten nuts from n° 3 wheel. A bolt puncture

**15 July 1993:** G-BOAF on landing at London Heathrow, burst of n° 4 tyre leading to damage to the gear door mechanism. Tank n° 8 was damaged, probably by a piece of this mechanism.

**25 October 1993:** G-BOAB during taxiing at London Heathrow, burst of n° 2 tyre leading to damage to the water deflector. Tank n° 1 suffered minor penetration, probably from a piece of the deflector. An optional Service Bulletin was issued (see paragraph 6.2.4).

\*

\*

\*

## **RECOMMENDATION**

On the basis of the initial facts established by the investigation, the BEA and the AAIB issued a safety recommendation concerning the aircraft on 16 August 2000. This recommendation was immediately accepted by the airworthiness authorities in France (DGAC) and the United Kingdom (CAA) and the Concorde's Certificates of Airworthiness were suspended.

*The technical investigation into the accident to Concorde F-BTSC operated by Air France which occurred at Gonesse on 25 July 2000, conducted by the BEA with the participation of representatives of the AAIB, has so far established the following facts:*

*During the take-off run the front right tyre of the left main landing gear was destroyed between V1 and VR, very probably because it ran over a piece of metal.*

*The destruction of the tyre caused damage, either directly or indirectly, to the aircraft structure and systems, leading to the crash less than one minute and thirty seconds after the destruction of the tyre.*

*The damage sequence and the links between the various events are not yet fully established. Nevertheless, the following events occurred:*

- *one or more punctures of at least one fuel tank with a major fuel leak.*
- *ignition of the leaking fuel and an intense fire which lasted for the duration of the flight. The fire appeared within a few seconds of the destruction of the tyre.*
- *a loss of thrust on one, and then two engines.*

*The crew had no means to make them aware of the nature of the fire nor to take action to contain it.*

*Moreover, the in-service experience shows that tyre damage during taxi, takeoff or landing is not an unlikely event on Concorde and that it may actually lead to damage to the structure and to systems. However, this had never caused a fuel fire.*

*The accident that occurred on July 25, 2000, has thus shown that the destruction of a tyre -a simple event which cannot be asserted not to re-occur- had catastrophic consequences in a very short time-scale without the crew being able to recover from this situation.*

*Consequently, without prejudice to additional elements that may arise during the course of the investigation, the BEA and the AAIB recommend to the Direction General de l'Aviation Civile of France and the Civil Aviation Authority of the United Kingdom that:*

- **The Certificates of Airworthiness of Concorde be suspended until appropriate measures have been taken to ensure a satisfactory level of safety as far as the tyre destruction based risk is concerned.**

# *List of appendices*

## **APPENDIX 1**

Three-view plan of Concorde

## **APPENDIX 2**

Transcript of the last five minutes of the CVR recording

## **APPENDIX 3**

Plan showing distribution of parts on the runway

## **APPENDIX 4**

Graphs drawn from recorded parameters

## **APPENDIX 5**

Reconstruction of flight path based on recorded parameters