F I N A L   R E P O R T

concerning the accident occurred
on 31 March, 1992,
to the BOEING 707 registered 5N-MAS
(Nigeria) - Trans-Air Limited Company.

MINISTRY OF EQUIPMENT, TRANSPORTS AND TOURISM
GENERAL INSPECTORATE FOR CIVIL AVIATION AND METEOROLOGY

FRANCE

MINISTRY OF EQUIPMENT, TRANSPORTS AND TOURISM

Paris, 28 June, 1993

R E P O R T

concerning the accident which occurred on 31 March, 1992
to the Boeing 707 registered 5N-MAS (Nigeria),
operated by the Trans-Air Limited Company

F O R E W O R D

This report reflects the technical point of view of the French Accident Investigation Bureau BEA team assembled to investigate the circumstances and causes of the accident.

In compliance with Annex 13 to the Convention on International Civil Aviation, the analysis was not carried out and the conclusions and safety recommendations were not drawn up with an objective to apportion blame or individual or collective liability. Basically, this technical investigation aims at preventing further accidents. Consequently, since doubt must benefit safety, some recommendations that have been suggested refer to points whose accurate demonstration has not always been possible, or in some case, are not directly connected with the causes of this accident.

This report has been drawn up after thorough investigation and, therefore, is based on knowledge which may notably differ from that prevailing when the accident took place.

Finally, although the people and the organizations, whose opinions have been considered as relevant, have been requested to submit their information in due time, this inquiry has been carried out without using contradictory proceedings.

Consequently, using this report for other purposes than the prevention of further accidents might be misleading.

SPECIAL FOREWORD TO ENGLISH EDITION

This report has been translated and published by the French Accident Investigation Bureau to make its reading easier for English speaking people. As precise as this translation may be, please refer to the original text in French.

C O N T E N T S

S Y N O P S I S

Date of accident :

Tuesday, 31 March, 1992
at 08.40 hrs UTC (°)

Aircraft :

Boeing 707-321CH
Registration :5N-MAS

Place of accident :

Flight over France
(flight level 330)

Owner and operator :

Trans-Air Ltd
5, Bompai Road
Kano
PO Box 2773
Nigeria

Type of flight :

Charter flight
Cargo transport

Occupants :

Captain
First officer
Flight engineer
Cargo supervisor
Maintenance man

Summary :

The cargo aircraft was performing a flight Luxemburg-Kano (Nigeria). As the aircraft, climbing towards flight level 330, was flying over the Drôme area, both right engines separated from the wing. The crew succeeded in controlling the aircraft and landed at the Istres air base, landing gear and flaps down, with the right wing on fire. The aircraft rolled off the runway to the left. The 5 crewmembers left the aircraft. The firemen extinguished the fire.

Consequences :

Persons			Aircraft	Cargo	Third Party Damage
killed	injured	unhurt			
/	/	5	Destroyed	Intact	None

(°) The times given in this report are in Universal Time Coordinated

(UTC). Add one hour to obtain the time for France.

1. **Factual information**

1.1 History of the flight

The aircraft, under an IFR (°) flight plan, was flying from Luxemburg to Kano (Nigeria), carrying freight. It took off from Luxemburg aerodrome at 07.14 hrs with the peak load of 150 tonnes (38 tonnes of freight, 116 000 pounds of fuel).

The crew was composed of three men, the captain, the first officer, and the flight engineer. Two passengers were on board; a maintenance man, and a cargo supervisor.

The aircraft, on a heading of 199°, when passing "VILAR" and the VOR of Martigues, over the Drôme province, was authorized by le Centre Régional de Navigation Aérienne sud-est : CRNA/SE (South-East Aircraft Navigation Regional Center), to leave flight level 290 and climb to flight level 330. This flight section was performed in IMC, in turbulent air. With the throttles at climb power and automatic pilot engaged, the aircraft was flying at an indicated air speed (IAS) of 280 kt passing the flight level 320. It flew over the far south-east of the Drôme area, 20 NM to the west of Sisteron.

At this moment, the crew was experiencing severe turbulence and heard a "double bang". The aircraft suddenly rolled to the right. The captain disengaged the automatic pilot and struggled to keep control by "countering" with the control stick and the rudder pedals.

The continuous fire warning system sounded. According to the visual warning, this corresponded to a fire on engine n°4. A short time later, a visual warning lit up to report a fire on engine n°3. The crew noted that the throttles of these engines had moved forwards on their own.

The cockpit noise level was extremely significant dominated by the engine fire warning that the flight engineer could not switch off despite the fact he repeatedly pressed the cap on the panel. Another warning system sounded at the same time to indicate the cabin depressurization and continued for most of the flight and until the landing (intermittent warning horn).

The cockpit voice recorder (CVR), as well as the crewmewbers'additional information enabled identification of the essential actions respectively executed in this emergency situation by the captain, the first officer, the flight engineer and both passengers. It should be noted that these actions ended in the successful landing at a diversion field.

(°) : Instrument Flight Rules

The captain was worried about the origin of the "fire" warning. The first officer annouced that engine n°4 (right outboard) "had separated from the wing" and immediately sent out the distress call "MAYDAY MAYDAY". A short time later, he specified that, in fact, both right engines "had gone".

The flight engineer suggested lightening the aircraft by fuel dumping. The captain immediately agreed.

While the first officer was in charge of radio communications and determining the nature of the aircraft's damage, the captain, who was struggling at the flight controls, asked for the meteorological conditions in Marseilles and ordered the gear extension. Then, a descent towards Marseilles was initiated.

The flight engineer, helped by the maintenance man, extended the gear according to the emergency drill and continued with fuel dumping.

The first officer checked that the emergency drill recommended in case of engine separation was in progress and, still being in charge of the ATC communications, attempted to obtain the meteorological conditions in Marseilles. At the captain's request, the first officer specified to air traffic control that they were capable of only limited manoeuvring.

The first officer noticed "an airfield ahead", and asked for its identification. This airfield proved to be the Istres military field. Then, he asked about the length of the runway (4000 meters) and quickly got from Marseilles air traffic control the landing clearance.

He asked for a left hand circuit so as to land on runway 15 (downwind runway 33). The Istres controller immediately agreed.

By listening to the cockpit voice recorder, it was apparent how difficult it was for the captain to complete the last turn before alignment. The first officer encouraged him by repeating six times "left turn".

During this last turn, the controller informed the crew that the aircraft was on fire.

The landing took place slightly to the left of the centreline, the aircraft touching down on the runway at 190 kt. The first officer and the flight engineer helped the captain during this phase. The first officer held the left engines throttles. The captain specified that there were "no hydraulic brakes!", and thus resorted to the "emergency brake system". The left main gear tyres burst. The flight engineer selected maximum reverse power on engine n°2.

The aircraft, after a 2,300-meter-ground roll, went out off the left side of the runway and stopped 250 meters further on, heading approximately 90° from the runway axis. The firemen estinguished the fire with their high-capacity fire vehicles (fire brigade: SSIS).

The crewmembers evacuated the aircraft through the cockpit side window panels with the help of escape ropes. Both passengers went out through the left front door.

The crewmembers only realized that the right wing was on fire when the aircraft landed and stopped. In particular, it appeared that the first officer had not heard the remark of the controller.

The landing took place at 08.35 hrs, that is to say approximately 24 minutes after the loss of the two right engines.

1.2 Injuries of persons

None

1.3 Damage to aircraft

The aircraft was severely damaged by the right wing fire (the wing was practically destroyed, the right rear part of the fuselage was damaged by the fire, see the photos in the Annex).

1.4 Other damage

The cargo (spares parts for the oil industry, and medecines) was undamaged.

The engines, lost during the flight, fell over a rocky desert area, without causing particular damage.

1.5 Personnel information

1.5.1 Captain

. Male, aged fifty-seven, Swedish.

Aircraft ratings :

. Airline transport pilot licence n°D3506218555 issued on 22 December, 1966 by the Swedish Aviation Authority.
. Equivalent licence issued on 19 March, 1992 by the Ministry of Nigerian Civil Aviation, valid to September 1992.

Qualifications :

. B707 qualification issued in March 1982, as

a Captain.
. Other qualifications : DC6 , L188, S210, B737.

Experience :

. Approximately 26 000 flight hours.
. On B707 : 7 100 hours.
. During the last 30 days : 33.10 hrs + 4 hours on a B707 simulator .

Engaged by the Trans-Air Service Ltd on 16 March, 1992.

1.5.2 First officer

Male, aged forty-four years, British.

Aircraft ratings :

. Airline transport pilot licence issued by the United Kingdom Civil Aviation Authority, C.A.A.
. Equivalent licence n° CP 2134839/A issued on 19 March, 1992, by the Ministry of Nigerian Civil Aviation, valid to 18 September, 1992.

Qualification :

. B707 qualification issued in March 1982, as a First officer.

Experience :

. 14 000 flight hours.
. On B707 : 4 500 hours.
. Since 1 January, 1992 : 60 hours.

Engaged by the Trans-Air Service Ltd on 16 March, 1992.

1.5.3 Flight engineer

Male, aged fifty-five, British.

Aircraft ratings :

. Flight engineer licence n° 1090 issued on 7 October, 1988, by the United Kingdom Civil Aviation Authority, valid to 18 September, 1992.
. Equivalent licence issued by the Ministry of Nigerian Civil Aviation, valid to 31 March, 1993.

Qualification :

. B707 qualification.

Experience :

. 18 000 flight hours, all on B707.
. During the last 30 days : 56 hours.

Engaged by the Trans-Air Service Ltd on 16 March, 1992.

1.5.4 Maintenance man

Male, aged thirty-six, Nigerian.

Not a flight engineer, on board as a supplementary crewmember. Good experience of B707.

Engaged by the Trans-Air Service Ltd on 2 March, 1992.

1.5.5 Cargo supervisor

Male, aged twenty-seven, Icelandic.

Engaged by the Trans-Air Service Ltd on 16 March, 1992.

1.6 Aircraft information

1.6.1 Airframe

Manufacturer : Boeing Aircraft Corporation.
Type : B707-321CH.
Serial number : 18718.
Delivered new on April 1964.
Registration : 5N-MAS.
Nigerian Registration Certificate n°772.
Airworthiness Certificate n°772, issued on 3 February, 1992, valid to 2 February 1993.
Flight hours : 60 895.
Number of operating cycles : 17 907.

1.6.2 Engines

Manufacturer : Pratt and Whitney.
Type : JT3D-3B.
Engines hours : see the following table.

	N°1	N°2	N°3	N°4
Serial Number	644426	645572	645468	643387
Flight hours	39281	59728	35702	43629

1.6.3 B707 concise technical description

1.6.3.1 Flight controls

Roll and pitch

The elevators are fitted with servo-tabs as well as balance panels. The tabs are manually operated by the flight controls : the aerodynamic loading generated by the tab produces elevator deflection.

Rudder

The rudder is operated by an hydraulic servo- control. In case of hydraulic power system loss, the tab enables rudder deflection with a reduced movement.

1.6.3.2 Hydraulic system

The hydraulic power system includes three different systems :

Utility system

Utility system pressure is generated by two-engine-driven pumps, one on engine n°2 and one on engine n°3. This system is used for :

. landing gear operation
. nose wheel steering
. brakes normal circuit
. flaps
. outboard spoilers

With an inboard engine inoperative, it is possible to isolate the corresponding hydraulic pump with an hydraulic supply shutoff valve using a switch on the flight engineer's sidewall panel (it should be noted that the hydraulic pump is also shut off by operating the "engine fire shutoff handle").

Two auxiliary circuits, pressurised by electrically operated pumps : the auxiliary system

These auxiliary circuits, interdependent (the circuit n°1 can supply pressure for the circuit n°2), are used for :

. rudder
. inboard spoilers

1.6.3.3 Braking

Normal hydraulic braking is operated by the utility hydraulic system, which includes in particular a specific brake accumulator. It can also be operated by the auxiliary hydraulic system.

Pneumatic brake system is operated, in case of total hydraulic system loss, by a pneumatic system (with an air bottle) controlled from the left pilot's panel. In case of emergency, there is no differential braking or antiskid protection available.

1.6.3.4 Rapid fuel dump system

Two retracting fuel dump chutes (one per wing) are operated from the flight engineer's sidewall panel.

1.6.3.5 Pressurization

The aircraft is pressurized with the air generated by turbocompressors driven by the engines n°2,3 and 4 gearboxes, or by bleed air from the engines. The air then goes through the air conditioning units.

An intermittent horn sounds if the cabin altitude is up to 10 000 feet +/- 250. A press-button on the flight engineer's upper panel enables cancellation of this warning.

1.6.3.6 Electrical power

Very briefly, the electrical power is composed of:

Primary electrical power

Triphase AC power supplied by four 115/200 V 400 Hz engine-driven generators.

Secondary electrical power

. 28 V DC power supplied by four transformer rectifier units and an emergency battery
. 28 V/400 AC power supplied by a series of autotransformers.

Power is distributed by bus bars. In order to maintain the availability of the priority circuit, called "essential bus", it is possible to select any generator from the flight engineer's sidewall panel to supply the "essential bus".

In normal operation, the "essential bus" is connected to engine n°3 generator. The order of connection priority defined in the emergency drill is 3, 4, 1, 2.

1.6.4 Maintenance

This brief chronological account describes the aircraft maintenance during the last ten years :

. From January 1982 to July 1985, the aircraft (registered G-BFZF) was stored at Lasham (England) under the control of Dan-Air Services, Engineering Division, Lasham Airfield, Nr Alton Hampshire.

. From September 1985 to February 1986, the Dan Air Company carried out maintenance work so as to overhaul the aircraft : "A" ,"B", "C,2C,3C,4C,5C,D" checks, according to the Boeing maintenance program.

These checks happened when the aircraft had accumulated 52 558 flight hours and 15 877 landings. The Civil Aviation Authority issued the Certificate of Airworthiness on 19 February, 1986. The new registration was G-BNGH.

. An important modification was made on 2 May, 1986 : "B707 quiet nacelle installation" (engine cowling modification achieving better sound isolation).

This modification is described as follows in the English documents : "modified engine cowling in accordance with Shannon Engineering Master Drawing List (MDL) number JS1102001, revision B dated 22 February, 1985 or later FAA approved Revision, STC SA 2699NM and FAA-PMA". In the text, this modification is called "HUSH KIT".

. From June 1989, the maintenance was entrusted to the British Company Modern Jet Support Centre (MJSC) at Manston, Kent, England.

. The main works operated are :

- June 1989, A,B,EQ8 checks
- October 1989, A,B,EQ9 checks
- January 1990, B check
- May 1990, C check
- June 1990, left wing minor repair
- October 1990, engines n°1,3 and 4 change at the owner's request
- January 1991, B check
- October 1991, C check
- January 1992, B check
- February 1992, A and B checks.

. The aircraft performed no flights from 24 October, 1990 to 3 March, 1992. It received a Certificat of release to service on 4 March, 1992, with the registration "5N-MAS", from Southend (see paragraph 1.16.4 further on).

Following a burst of the left main landing gear tyres following a ferry flight between Manston and Southend, on 6 March, 1992, induced by an "antiskid" braking system failure, the repair as well as an "A" check were carried out by Heavylift Ltd at Southend, on 8 and 9 March, 1992.

1.6.5 Successive owners and operators

The following table, established from the UK register, gives a list of the aircraft successive owners, from 1978 to 1992, and specifies the registration changes.

Registration	Period	Owner
G-BFZF	from 09/78 to 01/83	SCIMITAR AIRLINES Ltd
	from 01/83 to 01/86	GREYHOUND EQUIPMENT

		FINANCING Ltd
G-BNGH	from 02/86 to 05/86	FINANCING Ltd
	from 05/86 to 12/91	TRADEWINDS AIRWAYS Ltd
	from 12/91 to 02/92	TRANS-AIR SERVICE Ltd
5N-MAS	from 02/92 to 03/92	TRANS-AIR SERVICE Ltd

1.7 Meteorological information

1.7.1 General situation

1.7.1.1 Surface information

At 06 00 hrs, a deep depression centred above England, covered Western Europe. An active cold front was lying from the north of France to the Rhone Corridor and extended towards the Balearic Islands and the Straits of Gibraltar. Over Provence and the Alps, the unsettled weather was characterized by thunder-showers. Hail falls were observed here and there.

1.7.1.2 Altitude information

At 06 00 hrs, at Fl 300 (300 hPa), there was a low pressure area in the west of Britain with a trough extended towards the Iberian Peninsula.

In the front of this trough, a 90 kt south southwest jet stream was lying from the south of Spain to the Balearic Islands,the Rhone Valley and Luxemburg.

1.7.2 Meteorological conditions along the route

The reconstruction of the meteorological situation was achieved for the period between 08 00hrs and 08.35 hrs, corresponding to the overflight period from the central Rhone Valley to Istres where the landing took place.

The cloud layer was composed of 8/8 Ac-As topped by Cs and Ci up to Fl 250-300. Locally, Cb, embedded in the mass, developed up to Fl 330.

Rain and hail clouds, as well as snow clouds in altitude were mentioned over the Drôme area and the upper Provence.

The visibility was nil in the cloud layer. Below the cloud base, around 800 and 1 200 m, the visibility was greater than ten kilometres but was locally reduced to 1 500-3 000 m because of the showers.

Winds and temperatures at altitude were :

. Fl 320 : 200-210°/70 kt, -57°C,
. Fl 300 : 200-210°/70 to 80 kt, -53°C,
. Fl 180 : 180 to 200°/ 50 to 65 kt, -25°C.

The turbulence, moderate to severe, decreased in the atmosphere lower layers.

1.7.3 Particular conditions during the two right engines departing

The studies of the RADAR images and the METEOSAT satellite showed two Cb over the Séderon – Mont Ventoux –Nyons area, triangle over which 5N–MAS was flying. These Cb were embeddedin the cloudy mass and rose up to above Fl 330.

In addition, the flight was performed on the right edge of the 90 kt jet stream.

These two simultaneous particular meteorological conditions generated severe turbulence, confirmed by the crewmembers.

1.7.4 Approach and landing conditions

The conditions were better from Durance and Arles. At Fl 90, the flight was conducted beneath the Ac–As layer. The Istres approach was flown at 3 000 feet at the level of a little developed Sc and Cu peak. The breakdown was achieved at QNH 988 hPa.

The following conditions were transmitted to the crewmembers by the Marseilles Approach controller :

. At 08.22 hrs : Visibility : 6 km
Cloud : 2/8 Sc 500 feet, 3/8 Cb 1 600 feet and 3/8 Cu 2 000 feet.

. At 08.23 hrs : Visibility : 6 km
Significant weather : rain,
Cloud : 2/8 Sc 500 feet, 3/8 Cb 1 600 feet and 3/8 Cu 2 000 feet.

The final approach over Istres, towards the threshold of runway 15, was performed VFR, with a 320°/10 kt surface wind as the controller had advised, then a 320°/8 kt one.

The Istres meteorological information as far as the final approach and landing are concerned was :

. At 08.30 hrs : Wind : 310°/8 kt, gusts at 10 kt,
Visibility : 12 km
Significant weather : none (the rain had stopped at 08.06 hrs)
Cloud : 3/8 Sc 2 600 feet, 4/8 Sc 3 300 feet, 7/8 Ac 9 000 feet,
Temperature : 9,7°C, dew point : 7,6°C,
QNH : 988 hPa
QFE : 985 hPa.

. At 08.36 hrs : Wind : 320°/8 kt, gusts at 12 kt,
Visibility : 15 km

Cloud : 2/8 Sc 2 600 feet, 5/8 Sc 3 000 feet, 7/8 Ac 9 000 feet,
Temperature : 9,2°C, dew point : 6,1°C
QNH : 988 hPa
QFE : 985 hPa

1.8 Aids to navigation

No fault in the radio aids and in the ATC communications used had been reported by the crewmembers or was known by the control organisations' involved.

1.9 Telecommunications

The aircraft was successively in communication with the control organisations mentioned below. The table specifies the periods of time during which transcriptions were made.

These transcriptions are given in Annex 1.

Control	Frequency	Transcriptions
CRNA/SE	126,7 MHz	08.09 hrs to 08.16 hrs
Marseilles Control	123,9	08.16 hrs to 08.19.30 hrs
Marseilles Approach	120,2	08.19.30 hrs to 08.31 hrs
Istres Tower	123,6	08.31 hrs to 08.37 hrs

The main part of the dialogue relating to this service is summed up below.

CRNA/SE

- 08.11.41 hrs - B 707, flight designator KABO671, sends the first of six MAYDAY messages,

- 08.12.24 hrs - the controller : "I have not no longer radar contact Sir, I am sorry squawk again 7172",

- 08.13.08 hrs - the controller : "...squawk 7700 Sir 7700",

- 08.14.13 hrs - KABO671 : "we need emergency landing both engines missing right wing emergency radar",

Marseilles control

- 08.16.09 hrs - KABO671 sends the message MAYDAY,

-............ - KABO671 advises the nature of its problems:
"two engines missing two engines missing structural request straight in landing",

- 08.16.40 hrs - KABO671 : "priority MAYDAY",

- 08.17.52 hrs - KABO671 :"give me the weather for Marseilles...",

- 08.18.40 hrs - KABO671 : "MAYDAY MAYDAY MAYDAY MAYDAY MAYDAY MAYDAY", 672 request weather",

Marseilles Approach

- 08.19.25 hrs - KABO671 : "Marseilles MAYDAY, Marseilles MAYDAY ..."

-............ - "Marignane UT7209 ...."

- 08.20.46 hrs - the controller : "UT7209 climb radar level 140",

-............ - UTA7209 : "radar level 140 7209",

- 08.21.14 hrs - KABO671 : "This is MAYDAY MAYDAY KABO ..."

- 08.21.50 hrs - KABO671 : "what's the weather, please weather for KABO KABO request weather",

- 08.22.35 hrs - KABO671 : "what's the weather PALMA, weather PALMA ?",

- from 08.23.21 hrs to 08.26.38 hrs, the controller gives the weather conditions in Marseilles,

- 08.30.53 hrs - hand-off to Istres.

Istres tower

- 08.30.56 hrs - the controller : "671, this is Istres Istres I receive you fives Istres 33 runway 33 in use QFE 985 you are cleared for a down wind arrival Sir",

- 08.31.34 hrs - KABO671 : "we make a left hand pattern",

- 08.33.28 hrs - the controller : "671 you have fire on board (twice) I confirm fire on board",

- 08.34.40 hrs - the controller : "you are runway 15 the wind 320 you are on axis you are on axis".

1.10 Istres aerodrome information

The Istres military air base is open to Civil Air Traffic provided that a previous authorization has been given. The airbase has a 3 685 meter long paved runway, QFU 15, oriented 155°-335°, with a stopway that permits in total a 4 000 meter long landing distance available, with a width of 60 meters.

The aerodrome control service was in operation and its equipment was in good working order.

The aircraft was in communication with the tower controller, whose office is in the visual tower cab. This controller has no radar screen, the radar display being operated in the approach room.

This airbase has a major fire brigade (SSIS) since there are Air Force Boeing C 135 aerial tankers, as well as the Flying Test Centre based there.

1.11 Flight recorders

In compliance with the regulation in force, the aircraft was equipped with two crash protected recorders :

. a Plessey PV 1584A Digital Flight Data Recorder, SN CH 2333,
. a Fairchild A100A Cockpit Voice Recorder, SN 25027.

These two recorders were intact.

1.11.1 DFDR read-out

The reading of this recorder should reveal the following parameters : the heading, the roll rate, the IAS, the radio altitude, as well as the EPR indication for each engine.

It was not possible to reveal the IAS, since the corresponding sensor was out of order. Annex 3 gives the history of the other parameters.

It appears that :

. before the recorded time "3 200 seconds", the operation of the engines was normal. In particu- lar, the four power curves of the engines practi cally merged,
. around the recorded time "3 140 seconds", the engine power increased from EPR 1,7 to EPR 2,0 on the four engines,
. at the recorded time "3 200 seconds", EPR3 and EPR4 sensors gave no indication, while, a short time later, the power of the engines n°1 and 2 increased.

Consequently, from the recorded time "3 200", the engines n°3 and n°4 had separated from the right wing.

1.11.2 CVR read-out

The CVR was read with the assistance of a pilot and a flight engineer both belonging to the Flight Control Organisation, qualified on B 707, so as to identify accurately, in particular, the different warning horns.

The transcript of the conversations is in Annex 4.

The main communication between the three crewmembers, the first officer and the control organisation after the loss of the two engines until the landing is reported further on.

In the following text, the abbreviations used are .

captain : Captn

. first officer : F/O

. flight engineer : Fle

Captn : He asks"...? Fire ?"
We can hear sounds indicating physical efforts.

F/O : He reports that "number 4 engine has left the wing!". He sends out the distress call MAYDAY MAYDAY, twice and asks for radar assistance so as to execute an emergency landing.

F/O : He reports that they "have lost both engines".

He checks that the captain is heading south as the CRNA/SE has ordered.

Captn : "I'm trying!"

Fle : He suggests to lighten the aircraft by dumping fuel through the dump valves, which the captain immediately accepts.

F/O : He advises air traffic control of the nature of the aircraft's damage and repeats his request for an emergency landing.

He questions the flight engineer about the execution of the "emergency operating procedure" check-list : "You have cut engines ?"

He transfers to Marseilles.

Captn : The sounds indicating the physical effort to handle the controls gets more and more intense.

During the descent, he asks for the weather in Marseilles.

F/O : He advises the nature of the aircraft's damage and, once more, sends out the distress call MAYDAY.

He asks for the weather in Marseilles.

He orders the gear extension.

Fle : He extends the gear using the emergency method, helped by the maintenance man (the corresponding efforts can be heard by listening to the CVR as well as the aural signal).

F/O : Bothered by the radio traffic between Marseilles and two aircraft (Mike Victor, Delta November Whisky), once more he sends out distress calls MAYDAY and asks for the weather.

Captn : He querries about the defuelling through the dump valves.

He specifies that he has "limited manoeuvring".

F/O : He advises Marseilles Approach that he has limited manoeuvring, and asks for the weather in Marseilles.

Captn : He considers a landing towards Palma.

F/O : He finally gets the meteorological conditions in Marseilles and answers the questions of Marseilles Approach (How many passengers do you have on board ? How much fuel do you have on board ?)

He mentions he can see the airfield.

He say again "this is emergency landing... emergency... full emergency".

He mentions he can see an airfield ahead and asks what that airfield is. Marseilles Approach advises him it is a military airfield.

Captn : He considers that the runway is too short.

F/O : He asks for the length of the runway and gets the answer (4 000 meters).

Captn : "OK"

F/O : He advises Marseilles Approach he can see this airfield and that he can make a left pattern for landing. He gets from Marseilles Approach the frequency of this military airfield (Istres).

He contacts the airfield. Istres tower acknowledges receipt, and advises that the runway in use is runway 33 then gives the QFE.

He asks for a left hand pattern.

The controller agrees.

Captn : "OK ! What is the wind ?"

F/O : "What is the wind ?" He gets the information (wind 330°/10 kt, gusting 14 kt).

He asks the question : "Do you have some radar ?" The controller answers there is no radar and that he has no visual contact with the aircraft.

He advises the captain to keep a minimum speed of 200 kt.

The controller repeats he has no visual on the aircraft, and asks the question : "Do you see my runway ?"

Captn : "Negative, no !"

F/O : (at the same moment) "We are just coming out of the top of the clouds. We come to the west of the field. We see your runway. We are turning on to the west, 3 000 feet". He addresses the captain : "We turn left to land".

By listening to the CVR, It is apparent how difficult it was for the captain to achieve this last turn before alignment. The first officer encourages him by repeating six times "left turn".

The Istres controller asks for confirmation of the gear extension.

F/O : "Yes".

At this moment, the controller specifies that the aircraft is on fire : "...You have fire on board, (twice), I confirm fire on board" (it is 08.33.28 hrs).

F/O : "...?..."

Then, listening to the CVR becomes more and more difficult. Different aural warnings keep on sounding. In addition, power cuts - and thus recording cuts - occur and lead to the loss of several sentences in the dialogue.

Afterwards, the CVR again becomes audible. The controller specifies : "Good descent, you are on axis".

F/O : "Roger".

Fle : He annouces the landing touchdown (at 8.35.35 hrs) then "reverse".

Captn : "No".

End of the recording.

1.12 Wreckage information

1.12.1 The aircraft

Most of the damage affects the right wing. The photo n°1 indicates the extent.

The pylons (as well as the engines) n°3 and 4 have disappeared without having caused significant damage to the leading edge.

The electric cable loom routing in the leading edge on the pylon of the right inboard engine was torn, opened, and some electric cables were bruised and burnt.
They showed marks of short-circuits (see photo n°2). By comparison, the cable loom routing in the leading edge of the right outboard engine, on the pylon, did not show marks of short-circuits or of fracture.

The most noticeable damage was that caused by the fire. The wing skin panels above the pylon of the right inboard engine were distorted, warped and cracked. The blackish marks went from the leading edge, above the pylon, and then widened towards the trailing edge (see photos n°3 and 4).

The other main damage was all located on the fuel tank n°4 (tank located between the ribs WS320 and WS733 and the front and aft spars) (see drawing of the wing included in the photo annex, diagram 0).

The skin panels of the upper wing over this tank had straight cracks reaching up to 2,5 meters in lenght (see photo n°4 and diagram 0 in the Annex), the width of the molten and burnt lips being of 12 to 25 millimeters.

These crevices were located exactly above the tank vent pipes (see photos n°5 and 6).

The trailing edge was totally burnt in the area between both engines (see photo n°6).

The inboard and outboard flaps had completely disappear, revealing the burnt operating mechanisms (see photo n°7). The inboard aileron was severely damaged.

Moreover, the examination of the inboard wing box identified the marks of an inner explosion on fuel tank n°4. This explosion seemed to be at the origin of significant deteriorations affecting the wing stiffeness.

This explosion had caused the displacement of the inner ribs of this tank (see photo n°8). The wing stiffeness was particularly damaged on the front and aft spars :

- the lower chord of the front spar was cracked at the pylon of engine n°4, the width of the crack reaching up to 50 millimeters.

- the upper chord of the aft spar was cracked over a length of at least 1,25 meters.

Thus, it appeared that the right wing was severely damaged first because of a fire and then because of an inner explosion at fuel tank n°4.

The fire was intense enough so that the flames licked the rear part of the fuselage, at the back of the trailing edge of the wing. The corresponding cabin windows were cracked, burnt and some were burst. The paint of the rear part of the fuselage, scorched by the heat, showed the structure. The skin of the fuselage was corrugated, at the back of the right rear emergency exit (see photos n°9 and 10), which was the sign of significant distortions.

1.12.2 Engines n°3 and 4

1.12.2.1 Engine n°3

Engine n°3 (right inboard) was found in the area of Séderon, in an uninhabited area, on loose ground, near a forest path. The engine was laid on the left side, in a place close to the aircraft's ground track.

This engine was severely damaged by the ground impact. It was completely flattened, according to a nearly diametrical plan, extending from the points 5 o'clock to 11 o'clock (according to the conventional marking "pilot place").

The photo n°11 depicts its condition.

The four pylon fittings on the wing (described in the paragraph 1.16.1.1 below) were broken. On one of those fittings, the inboard midspar fitting, we could clearly see a fracture with a strange appearance, a fracture which had the shape of a quarter of an ellipse located at the bore for the attachment pin on the wing (see photo n°12).

1.12.2.2 Engine n°4

From the discovery of engine n°3, investigations undertaken with helicopter, following the heading steered by the aircraft, enabled detection engine n°4, 800 meters from the first mentioned, also in an uninhabited area, on the side of a mountain, in an area hard to get to and very rocky. The engine also lay on the left side. Because of the nature of the ground, it had bounced after first impact.

The first impact on the ground and the bounce severely damaged this engine as photos n°13 and 14 show. The rear part separated from the front part, the fracture being between discs n°2 and 3 of the high pressure turbine.

The cowls had released from the engine. The air intake had rolled on the sloping ground. Its general circular shape was conserved except in the left segment from 6 to 10 o'clock. In this area, the front periphery of the air intake showed two impacts very marked at 8 and 10 o'clock. On the first, we could observe mat white marks, parallel to brighter grazing on the soft material (see photos n°15 and 16).

The rear part of the pylon, around the attachment points to the wing, was very damaged. Examination of the fractures of the fittings is mentioned in the paragraph 1.16.1.2 below.

Afterwards, back along the track of the aircraft, a 2,15-meter-long element was collected and identified : this was the rear part of the cowling of the pylon of engine n°4. This light element might have been blown away by the wind coming from the south (wind from 200° to 210° according to the meteorological report).

The track of the aircraft appears on the map in Annex 2, derived from the radar information (Air Force radar System). The impact area of both engines also appears on this map.

1.13 Medical and pathological information

Not relevant

1.14 Fire

Alerted 15 minutes before the landing, fire brigade (SSIS) of the Istres air base intervened to bring the fire under control as soon as the aircraft stopped.

The rescue vehicles were parked on a side strip on the edge of the runway and followed the aircraft during the landing phase, that is to say over approximately 2 500 me-ters. The firemen witnessed the fire on the right wing, the burst tyres of the left main landing gear (under the ef-fect of the emergency braking) and had to get round some debris dropped on the runway.

The fire fighting was operated in three phases :

- fighting the right wing fire, widespread fire, and a second focus on the right main landing gear, fire limited but constantly fed by kerosene leaking from the fuel tank of the right wing, overhanging the landing gear. This phase lasted only 3 minutes, from 08.36 hrs to 08.39 hrs.

- cooling of the main right landing gear, for 1.30 hour.

- surveillance of the wreckage, for 7.30 hours, because of major kerosene leaks coming from the right wing.

The following fire vehicles were used :

- 2 Multivalent Rapid Intervention Fire Vehicles ,

- 2 Multivalent Extinguither Heavy Vehicles,

- 2 Aerodrome Foam Vehicles, which had used extinguishing powder (1 000 Kg), foam (2 000 l of emulsifier liquid), and water (40 000 l).

1.15 Survival aspects

Not relevant

1.16 Tests and research

1.16.1 Expert evaluations of the engine pylons units n°3 and 4

The wreckage of the two engine/pylon units of the right wing were carried to the Parisian area, to "Centre d'Essais des Propulseurs" (C.E.Pr - Propulsion Test Centre) in order to be examined.

1.16.1.1 Expert evaluation of the engine pylon fittings n°3

Diagram 1 illustrates (perspective view and sectional view) the method of attachment of the pylon on the wing, which is composed of 4 fittings :

- one upper front spar fitting,
- two midspar fittings (inboard and outboard)
- one lower spar fitting

The fracture of the inboard midspar fitting (identified as "c" on diagram 2) reveals an evident crack, which has a shape of a quarter of an ellipse, roughly centered on the angle of the upper entrance of the bore (see photos n°12).

The drawing on the diagram 2 shows that this fitting broke exactly across the bore. The attach fitting, which had the shape of an arc of a circle, was found on the wing. It was this part of the fitting which has been examined. The photos n°17, 18 and 19, with increasing magnifying power, give a clear view of the fracture.

The upper part of the attachment fitting broke in a straight line, from a fatigue "half-moon" which started in the inboard side of the bore (on the side of the fuselage). Numerous corrosion pits have facilitated the start of the crack. Beyond the "half-moon", the crack was bordered by a thin shear lip at 45°.

The "half-moon" measured 11mm by 8mm, which represented approximately 18% of the broken surface. It represented two different areas (see photo n°18) :

- the major part of its surface was black, this was probably the result of a significant oxide deposit,

- at the end of the cracking, the area was edged by a clearer band which was approximately one millimetre across.

The crack propagated from 4 areas of initiation, all located in the bore. The bore exhibited a quite important zone of corrosion on the inboard side, especially on two of these areas. The binocular magnifier examination showed that the two other areas were also located on the corrosion pits.

After cleaning of the crack, some crack arrest lines appeared quite clearly (see photo n°19). These lines corresponded very likely to engine cycles.

The electron beam microscope examination had exposed :

- numerous secondary cracks origins in principal crack origin region,

- a very important oxide deposit on all the darker part of the crack, feature which prevented a more accurate observation of this area,

- some quite clear crack arrest lines at the end of the crack, in the clear part. There were more or less 25 to 30 lines which were likely to corres- pond to the same number of flights. Between those lines, a finer striation could be observed, but overall the crack of rest lines were the indica tion of the important strain experienced by the crack.

Beyond the "half-moon", the crack presented the characteristics of a brittle static fracture on a high tensile steel (steel 4330).

The lower part of the attach fitting broke statically under the effect of a bending downward stress (see scheme on the diagram2).

The fractures of the other midspar attachment fitting (outboard) were located forward of the bore of the lug, on the beginning of the two horizontal tangs which framed the structure of the pylon (ruptures identified as "b" on the diagram 2). Those ruptures were static, their similar appearances revealed that they started from the inboard and propagated in parallel towards the outboard.

The fracture of the upper front mounting point broke out on the beam connected to the upper surface of the wing. This beam, with an I-section, broke at two points from the inboard edge of the upper chord towards the outboard edges. This was a fracture in static bending as the forward end of the beam was submited to a movement towards the outboard (ruptures identified as "a", diagram 2).

The lower fitting of the diagonal brace broke up on the bores of the two yokes of the brace . The examination of the fractures (with a static nature) also showed that their orientation was from inboard to outboard (see scheme with the following legend : "lug of the diagonal brace, diagram 2").

The schemes on the diagram 2 present the different aspects of the fractures of the fittings. These observations permitted assessment that engine n°3, free on its left-side, had drifted to its right side. The remaining fittings broke and the released engine carried on its movement to the right.

1.16.1.2 Examination of the engine pylon fittings n°4

Photos n°20 and 21 reveal the important distortions of these fittings, the forward part of the pylon around them was highly damaged.

None of the fittings presented evidence of fatigue fracture. These fractures occured on the two midspar fittings axes and the beam of the overwing fitting. The fracture of the lower spar fitting is located on the diagonal brace forward end, at the root of the clevis lugs. The cause of the fracture was a torsion at stress. The upwards movement of the lug on the inboard side corresponded to a rotation of the engine around the axis of the brace.

The upper front spar fitting lug was little damaged. The fracture of this fastener was the result of the shear of the pin at the interfaces of the double lugs of the attach fitting and the overwing beam, as well as the partial tearing of the lugs. These fractures were due to a forward tensile static stress of the engine.

1.16.1.3 Expert evaluation of the engine air intake n°4

Photos n°15 and 16 of the outboard engine air intake give prominence to :

- the existence of an impact on the inboard side, a little bit below the engine axis of rotation,
- matt whiteish marks, parallel to brighter grazing on the soft material .

The analysis of these whiteish marks had revealed that it was a paint deposit.

In order to compare, some pieces of white paint from the cowl of engine n°3 were analysed.

These two analysis revealed that the deposit collected on engine air intake n°4 and the pieces of paint of the engine n°3 were of the same nature (polyurethane-based paint).

1.16.1.4 Examination of the engines

The wreckages of engines n°3 and 4 were inspected by a Pratt and Whitney company expert who also had a copy of the engines powers recording from the DFDR.

The examination of the engines through the air intakes did not reveal fractures of the fan blade in operation. On the other hand, the examination of the visible cowls or casings did not reveal evidence of instability of the rotating sections nor a rupture of the turbine disc.

On examining the hot sections parts, no trace of metallization of the turbine stages was noticed.

On the basis of these examinations and the study of the engine data given by the DFDR, the Pratt and Whitney expert had come to the conclusion that :

- these engines had run normally until the moment they separated from the aircraft,
- there is no evidence of an engine failure which would not have been contained or of an external fire as long as the engines were on the wing,
- there is no evidence of an engine defective operation which could have prevented them from developing power,
- the engine fittings on the pylons were unbroken.

1.16.2 Texts concerning the periodic monitoring of the engines fittings

1.16.2.1 Texts in force at the time of the accident

CASES OF THE INBOARD ENGINES

The 88-24-10 airworthiness directive (AD) (dated 1988 according to the American coding system) concerns the pylons fittings'periodic monitoring for engines n°2 and 3.

This AD is part of the "Boeing Supplementary Structural Inspection Document" (SSID) program, reference 54-A45-02. It is effective from a 12000 hours/4300 cycles ageing of the airframe and a 1500 hours/600 cycles reccurence frequency. It consists of "carry out of a close visual inspection for cracks in both midspar fittings in the upper tang root area and in the exposed surfaces of the lug" (visual inspection method).

This AD 88-24-10 replaced a previous AD (AD-77-09-03) of the same nature. In fact, these two successive ADs ratify the BOEING Service Bulletin n°3183, issued in June 1975 and developped over time. This Service Bulletin describes the midspar fittings periodic visual inspection method and specifies that it is possible to replace the cracked fittings by reinforced fittings.

The AD in force is justified by the existence of a repetitive technical defect. In fact, since 1965, 46 crack cases on the midspar fittings have been recorded. In 4 extra-cases (the present accident included), a loss of at least one engine during flight had happened.

Only 3 cases among the 46 cases quoted above concern aircraft which have undergone the "HUSH KIT" modification for sound insulation of the engines (the modification procedure began in 1986).

Among the 4 cases of engine loss during flight (the first case dated May 4, 1977), 2 aircraft were modified for "HUSH KIT".

The Service Bulletin and the AD can be found in Annex 5.

CASES OF THE OUTBOARD ENGINE S

A similar inspection must also be done in order to monitor periodically the outboard engines fittings, without any existing AD, in this case. This inspection is not in the scope of the BOEING Service Bulletin 3183 and is integrated in the SSID program under the 54-A40-02 reference. This periodic inspection (which could be found in Annex 6) is effective from 19000 cycles and at the frequency of 500 cycles. It consists in a visual inspection of the two midspar fittings for cracks on the upper tang level and in the fitting lugs area.

According to the information given by the National Transportation Safety Board (N.T.S.B), BOEING has recorded 9 cases of inboard midspar fitting fractures, including the Miami incident (paragraphe 1.16.5 below). The distribution of the fractures between the HUSH KIT modified aircraft and the unmodified ones is unknown.

1.16.2.2 Development of the Publica tions following the present accident

This development only deals with the case of the inboard engines pylons fittings.

Following the 5N-MAS accident and another one, which occurred on 25 April, 1992 in Miami, the American Civil Aviation Authorities took the following measures :

- the N.T.S.B issued a safety recommendation on 25 April, 1992 (n°A92-38) asking the "Federal Aviation Administration", (F.A.A.) to proceed to the review of the AD 88-24-10 described above to increase its efficiency by reducing the time between inspections and by improving the inspec tion process.

- the F.A.A. :

. published in the "Federal Register", on 23 September, 1992 a draft amendment 39-83-73, AD 92-19-15 by which it explains the aim of the AD 88-24-10 (Service Bulletin 3183) and calls for comments of the concerned parties by 23 November, 1992.

. following the comments made during this first consultation, published on 27 January, 1993 a modification to the AD 92-19-15 in order to reduce the time between inspections of the fittings and to remind that a reinforced fitting is required to replace the cracked fittings.

. then published in the Federal Register of the 4 June, 1993 the AD 93-11-02 which amends the AD 92-19-15 :

  . the periodic inspections of the fittings are maintained,

  . in case of crack discoveries, the fittings are replaced by reinforced fittings. Then, periodic inspections are no longer necessary.

The AD 93-11-02 concerns, according to the estimations of the F.A.A., approximately 50 B 707 aircraft all types, modified for HUSH KIT or not.

These documents are in Annex 5.

1.16.3 The 5N-MAS up-to-date maintenance

The investigation was conducted, at the BEA request, by the A.A.I.B. (Air Accidents Investigation Branch) which investigated the Modern Jet Support Centre (MJSC), company in charge of the aircraft maintenance since June 1989.

The investigation results, centred on the accomplishment of the operations relative to the pylons fittings checks (SSIC 54-A45-02 - inboard engines and SSID 54-A40-02 - outboard engines) are summarized below.

Inboard engines pylons fittings'inspection

The lastest inspection (according to the SSID 54-A45-02) was performed on 10 October, 1991 at 60779 hours/ 17873 aircraft cycles.

Both works requests and the two corresponding execution reports are presented in the pages B11 to B14 of Annex 6.

The B11 and B14 pages correspond to the description of the requested works : visual inspection for cracks in the midspar fittings (carry out close visual inspection for cracks in both midspar fittings in the upper tang root area and in the exposed surfaces of the lug).

The B12 and B13 pages are the execution reports for the works achieved on respectively engines n°2 and 3 (cards E3 0557 and E3 0547). These cards only report one single correction action : retightening of the two midspar fittings bolts. On the left engine as on the right one, the visual inspections did not reveal any defects.

It should be noted that the previous inspection had been performed by the MJSC on 23 May, 1990 at 59947 hours/17686 cycles, that is to say only 832 hours/187 cycles before the accident, when this inspection had to be performed only every 1500 hours/600 cycles. The A.A.I.B. had been able to prove that the most recent one - on 10 October, 1991 - had been performed, on the owner-seller request, in order to give the aircraft maximum lifetime before any new maintenance.

To sum up :

- the inspection of the inboard engines pylons midspar fittings was performed twice within 17 months, at a clearly lower interval to the interval imposed by the AD (832 hours/187 cycles for 1500 hours/600 cycles asked).

- the last inspection, performed only 116 hours/34 cycles before the accident did not reveal the cracks.

Outboard engines pylons fittings'inspection

The lastest inspection (according to the SSID A54-A40-02 program), was performed on 21 June, 1991 at 17873 cycles. The B10 page reproduces the work request (numbered 588) certifying the inspection of engines n°1 and 4, inspection which did not result in the discovery of defects.

1.16.4 The 5N-MAS recent utilization

It is noted that the aircraft performed no flights between 24

October, 1990 and 3 March, 1992.

Afterwards, between 4 March and 31 March, it performed 116 hours in 34 flights (that is to say as many cycles), without including the flight duration relating to the accident.

Note that on 4 March, that is to say the very day of its aerial activity resumption, the aircraft suffered a heavy landing in HongKong which caused a bounce and the bursting of two tyres of the left main landing gear.

1.16.5 The similar recent accidents/incidents

The accident of Miami :

On 25 April, 1992, the Colombian B 707 - 324C, registred HK-3604-X, cargo aircraft, took off from Miami. During the take off, the right inboard engine separated from the wing and hit the pylon and the engine air intake n°4, which however remained hooked up to the wing. The aircraft landed without any other incident.

The examination of the engine pylons fittings n°3 revealed the existence of a fatigue crack on the inboard midspar fitting (it is on the same fitting that a fatigue crack was found for the 5N-MAS . However, this crack was not located on the same place). Annex 7 presents the substance of the information asked for by the B.E.A. of the N.T.S.B., given the similarities between the two events.

This B 707 had a total of 53257 flight hours and 20399 cycles. It had also undergone the modification of sound insulation of the engines (HUSH KIT) and, like the 5N-MAS, was to follow the AD 88-24-10.

According to the report of the N.T.S.B., the fatigue crack could have initiated from a burn during rectification (in this case, the rectification is a machining operation realized after chrome plating).

The incident of Miami :

On 2 June, 1992, on the B 707 - 351C, cargo aircraft of the Cordoba Air Airline, registred N8091J, during inspection before flight, a defect was discovered on the engine pylon fittings n°4.

Close examination revealed the existence of a double fracture of the inboard midspar fitting. The upper tang and the lower tang had broken from the development of fatigue cracks whose causes, according to the sketchy information we actually have, could present analogies with those of the Miami accident described previously (rectification crack).

This aircraft had a total of 54175 flight hours and 20651 cycles. It was modified for HUSH KIT. The last inspection of the midspar fittings, in the frame of the SSID inspection program (A 54-A40-02), had been completed in November 1990, at the aircraft life of 50049 hours/19773 cycles.

1.16.6 Fuel circuit examination

The left wing fuel circuit scheme is on diagram 3. As the right wing fuel circuit was perfectly symmetrical, the indications identified 1 and 2 become respectively 4 and 3.

The shut off valve of the engine n°3 and the two transfer valves of the engines n°3 and 4 were located in an inboard dry bay reached by an access panel in the wing skin near engine n°3.

The shut off valve of engine n°4 was located in an outboard dry bay near engine n°4.

These 4 valves were identical. They were electrically operated and equipped with an indicator lever whose position on the wing it had been possible to mark, as their dry bay had not been damaged.

- the shut off valves were in the off-position (lever in the up position)
- the transfer valves were open (lever in down position)

These positions corresponded to those of the instrument panel switches of the fuel circuit in the cabin (shut off valve : off-contact - transfer valves : on-contact).

The 4 valves were removed and tested in a laboratory. Supplied with 28 Volts DC, the shut off closed entirely during every manoeuvre.

Therefore, we had to come to the conclusion that the respective conditions of the 4 valves were in agreement with the instrument panel and corresponded to the testimony of the flight engineer who indicated he had manipulated the shut off valves.

In this context, the fuel leakage on the leading edge of engine n°3 could not have been caused by a closing failure of the shut off valve. Damage of the pattern following the pylon detachment could be the cause. The exact location of the leak could not be detected.

1.16.7 The path of the aircraft

The path of the aircraft was determined from the radar fixes and is in Annex 2.

The legend on the map was derived from the CVR dialogue and the ATC communications with the concerned control organisations.

1.17 Additional information

1.17.1 On board

After the accident, the crewmembers described how the event took place. The following indications can be deduced from their respective actions :

Captain

First of all, the accident was evident as double bang and severe turbulence. The captain concentrated on the piloting in order to keep control of the aircraft. In his statement, he praises the self-control and the professionalism of his crew.

First officer

The first officer indicated that, before starting the climb to flight level 330, the aircraft, at flight level 290, met quite severe turbulence. The loss of the two engines occurred during this climb.

He also specified that, in Istres, given that the aircraft was capaple of limited manoeuvring, it was not possible to make a left turn to come properly to the QFU 33 circle to land, as the controls were fully held to the left. Therefore, the captain made a big left pattern to land down wind.

On the other hand, on the ground, the aircraft tended to turn to the right.

Flight engineer

The flight engineer emphasised the problems caused by the continuously ringing "engine fire" and "depressurization" warning horns. He did not manage to switch them off despite his numerous efforts on the control panel.

He specified the following points :

- the navigation radar which had been working before the loss of the two engines, failed,

- he closed the right shut off valve of the pressurization circuit to deal with the problem of the loss of pressurization induced by the departure of the two right engines,

- he closed the fuel shut off valves of engines n°3 and 4,

- he closed the hydraulic pump supply shutoff valve of engine n°3 and verified on the engineer instrument panel the state of the hydraulic services. He confirmed that the rudder power unit was working normally,

- he dealt with the problem of the electrical power supply by connecting the essential bus to the A.C generator n°1 (engine n°1),

- he sent the cargo supervisor to examine the right wing from the cabin windows (note : the cargo supervisor specified that the two right engi nes had really disappeared, the leading edge was unbroken and that there was a fuel leakage).

- he had some difficulties in executing the lightening procedures of the aircraft by fuel dumping. Actually, after he manipulated the dump valves of fuel tanks n°1 and 4, he noticed that n°1 fuel tank dumping did not occur, a fact which increased the problems of assymme- try of the aircraft. He stopped the operation and selected the dumping of the centre tank. Afterwards, he noticed that the breaker of the dump system of tank n°1 had popped. He reconnected it and was able to dump symetrically both tanks,

- in the landing circuit, he lowered the flaps in accordance with the emergency drill (electrical energy). This drill was slower than the normal one (in hydraulic mode), it was not possible to lower the flaps entirely (38° instead of 50°).

1.17.2 <u>On the ground</u>

Several people on the ground saw the landing. Two testimonies particularly hold attention.

The first person is a member of the military staff of the air base. He looked at the B 707, coming from the west and flying over the runway. He asserted that the aircraft was not on fire at this time.

Afterwards, he had lost sight of the aircraft and saw it again later, coming from the east and making its last turn. He asserted that the right wing was on fire at this time, "the fire was small at first and then it became a huge fireball".

The second person is a member of the base fire brigade (SSIS). He asserted that, then over the base, "no part of the aircraft was on fire and he identified under the right side a sort of fog". Then, when the aircraft turned left to line up, he saw orange flames on the right wing.

On the other hand, the right wing fire, just before the landing, was confirmed by the controller who advised it to the crew (see Annexe 1).

2. Analysis

2.1 Loss of the two right engines

The examination of the pylon fittings of engine n°3 identified, on the one hand, the existence of a fatigue crack on the inboard midspar fitting mount, and on the other hand, the appearance of the static fractures of the other three fittings as the engine drifted rightwards.

The examination of the wreckage of engine n°4 and its pylon indicated that the fractures of the fittings were all of a static type.

Moreover, the examination of the engine air intake n°4 identified the existence of an impact on the inboard side as well as white paint marks of the same nature of those of the engine case n°3.

Finally, the examination of the engine power data given by the replay of the DFDR indicated that from the recorded time "3200", the power sensors of engines n°3 and 4 stopped transmitting indications. So, we had to come to the conclusion that the two right engines separated almost at the same moment.

Considering all these elements, here is the final scenario for the loss of the two engines, (see diagram 4):

- as engine n°3 was running at the climb power (EPR = 2.0) and was torn off the wing because of the initial fatigue fracture of its pylon inboard midspar fitting and the consecutive fracture of the other fittings, it was propelled to the out board. The fittings fracture process was probably assisted by the increased strains induced by the turbulence reported by the crew.

- after spinning round approximately 3/4, following its longitudinal axis, it hit engine n°4 on its air intake and then swung over it.

The violence of the shock induced the tensile fracture of the forward engine fitting n°4. The midspar fittings broke in turn, then the aft fitting, the engine eventually separated from the wing by swivelling around it.

This sequence was consistent with the evidence of the crew (the "double bang" heard), the position of the engines on the ground in comparison with the flight path (before the beginning of the turn) and with the start in right roll attitude of the aircraft induced by the massive assymmetry of the left engines thrust only.

On the other hand, it was essential to compare the present accident with the Miami accident which occurred on 25 April, 1992.

2.2 <u>Development of the inboard mispar fitting fatigue crack of engine n°3</u>

In the paragraph 1.16.1.1, it appears that the examined fatigue "half-moon" includes two different areas:

- the major part of its surface is black, result of significant oxide deposit,

- at the end of the cracking, the area is edged by a clearer band which is approximately one millimetre across. This difference of colouring is certainly linked with a prolonged storage of the aircraft, corresponding to the limit of the two clear and dark areas.

These observations permit precise assesment of development of the crack with time :

- birth of the crack at a date located noticeably before the prolonged storage of the aircraft (that is to say before 24 October 1990),

- the crack progressed slowly until the cessation of the flights. Then, during the ground period this area became oxidized.

- at the resumption of the flights, the crack continued to propagate, but the crack had no time to become oxidized. This part corresponds to the clear area.

On the other hand, the electron microscope examination of the clear area (that is to say at the end of the cracking), enabled to count 25 to 30 stoppage lines. This number is consistent with the recent activity of the aircraft (34 flights).

2.3 Monitoring of the pylon fittings

The AD 88-24-10 (SSID 54-A45-02) imposed the checking of the inboard engine pylons fittings. The maintenance operation SSID 50-A40-02 imposes the checking of the outboard engines.

The last checking of the inboard engines was carried-out on 10 October, 1991, the life of the aircraft was 60779 flying hours/17873 cycles.

The penultimate checking dated back to May 23, 1990, the aircraft had then 59947 flying hours/17686 cycles.

It is convenient to note that these two checkings are separated by only 832 hours/187 cycles whereas the recommended frequency is 1500 hours/600 cycles.

However, according to the metallurgic examination it appeared that on 10 October, 1991, date of the latest AD 88-24-10 execution, the crack existed, its propagation surface was corresponding then to the black oxidised area: consequently, the recommended check appeared to be ineffective because it did not allow detection the existence of the crack.

On the other hand, even though the date of the "birth" of the crack is unknown, it was probable that the crack was already existed during the penultimate check, on 23 May, 1990. It is then possible that the penultimate check had also not allowed detection of the crack.

So, it seems that the inspection method recommended by the AD is imperfect because of a difficult operating method.

It consists of a visual inspection of the visible parts of the attachment fittings. Nevertheless, in the case of the accident, the crack is located on the bore. Consequently, it is masked by the inboard clevis lug of the wing and escaped a visual inspection. In these conditions, only dismantling of the pylon from the wing could have permitted its detection.

In the case of the Miami accident, the crack was also located under the inboard clevis lug and was also hidden in the same way and cannot be visually detected.

Besides, we observe that :

- the pylon midspar fittings on the wing have, since entry into service of the B 707, shown weaknesses which have resulted in about fifty fatigue cracks,

- the midspar fittings structural weakness concerns the inboard engines first of all, but also, and to a lesser extent, the outboard engines,

There are good grounds for saying that this phenomenon is connected with the life of the aircraft. In fact, we must note that "5N-MAS" and the two other aircraft in Miami had a total of more than 50000 flying hours and more than 17000 cycles. On the other hand, the HUSH KIT modification might have had a negative effect on the resistance of these fittings (see Annex 5, the F.A.A. commentaries in the successive AD).

2.4 Right wing fire

The two witnesses on the ground asserted that, when over the base, the wing when the aircraft was coming from the West was not on fire. One of them was sure that he saw, under the right side, "a kind of fog".

This fact corroborares the testimony of a passenger who went to verify the condition of the right wing and noticed a fuel leak.

It should be noticed that the fire marks on the upper surface of the wing went from the leading edge of the pylon of engine n°3 and widened towards the trailing edge whereas there was no fire mark on engine n°4. The fuel leak which was at the origin of the fire, was consequently located on this place.

It is reasonable to think that as a consequence of the closing of the two fuel shutoff valves of engines n°3 and 4, the fuel leak of the engine n°4 stopped whereas the leak of engine n°3 persisted as a consequence of a system damage induced at the moment of the pylon tearing away.

During all of the descent at a variable but always greater than 220 kt speed, it is probable that the fuel leak carried on without the fuel catching fire, as the conditions of ignition (depression of the upperwing, speed...) were not achieved and the vaporized fuel was not in contact with the electrical short-circuits of the damaged cabling loom located on engine n°3 leading edge.

These conditions changed during the last turn in consequence of the semi-extension of the flaps. The speed reduced (between 220 and 190 kt), the depression on the upper wing and the turbulence increased. Then, it was possible that under the effect of the electric arcs of the short-circuits quoted above, the fuel ignited, as the conditions of the kerosene-air mixture became optimal for burning.

This fire was violent as the condition of the upper wing demonstrated, particulary at the trailing edge. This intense fire had destroyed the trailing edge as well as the flaps and left evidence of overheating on all the right aft part of the fuselage.

The Istres controller advised that the right wing was on fire at 08.33.28 hrs and the landing touchdown occured at 08.35.35 hrs. Consequently, the right wing fire lasted more than two minutes without the possibility of being more precise on this point.

It is more difficult to understand the process which provoked the explosion of tank n°4, an explosion which had seriously damaged the front and the aft spar of the wing.

The most likely hypothesis seems to be the following:

- the intense fire on the upper wing brought the soft material skin panel up to a high temperature, diminished its mechanical resistance, a fact which explained the crazing, the blisters in all the area blackened by the fire and more particularly in the nearest fuel leak .

- as a result of the difference of pressure between the outboard and the inboard of the wing, the overheated soft material plate broke, inducing the noted crevices .

- by the crevices created this way, and given the kerosene vapors of the breather system, the fire progressed little by little and provoked the explosion of tank n°4. The drawing, diagram 0, which detailed the damage of the right wing showed the position of this tank. It was the most exposed tank because it was located in its most inboard part, on the level of engine n°3.

The explosion in the wing probably occurred during flight, a short time before the landing if we consider the fireball mentioned by a witness.

2.5 Distress piloting

Listening to the CVR and the testimonies collected have permitted outline of the behaviour of the crew in this distress situation.

The captain

He maintained the handling of the aircraft. Immediately after the loss of the two right engines, he went to the essential and tried to keep control by counteracting on the controls. The rudder power unit worked normally, the aileron and the pitch controls were intact.

However, the CVR indicated an intense physical effort. Therefore, it seemed that this major effort in order to "maintain" the aircraft was the consequence of the imbalance due to the weight between the two wings and of the assymetric thrust of the two left engines.

During the descent, the captain limited thrust by lowering the flaps as late as possible.

At the same time, he gave brief orders and took quickly the required decisions. Thus, he agreed straight away with the flight engineer's proposition of lightening the aircraft by defuelling through the dump valves. He was concerned about the weather conditions and asked the first officer to report that the aircraft had limited manoeuvring.

Then, he decided to land on the Istres airfield, fortunately located on the track and whose runway is very long. The landing approach and the final turn were performed by left turns, the conventional rule, which gave preference to the turn performed on the working engines rather than on the broken engines, was respected.

The first officer

First he just noticed the loss of the outboard engine. He was in charge of the radio traffic and guided the captain to the intended runway thanks to the headings given by the ATC control and asked the flight engineer for the execution of the "emergency operating procedure" checklist.

Finally, when he saw the Istres runway, he asked for information on the nature of the ground and the length of the runway. Conscious that the aircraft had limited manoeuvring, he suggested operating a counter QFU circuit to the left. He advised the captain to keep a minimum 200 kt speed and helped during the landing by holding the left engines power handles.

For the completion, he also had time to take a picture, in flight, of the right wing leading edge where engine n°4 had disappeared ...(Flight International 4/10 November 1992).

The flight engineer

He successfully completed the following actions :

He resolved the depressurization problem by insolating the right circuit by closing the shut off valve of the circuit.

He closed the fuel shut off valves of engines n°3 and 4.

He isolated the hydraulic system of engine n°3 by closing the hydraulic shut off valve.

He resolved the problem of the emergency electrical energy by connecting the "essential bus" to A.C. generator n°1.

He sent a passenger to check the condition of the right wing from the passenger cabin windows.

He suggested lightening the aircraft by the rapid fuel dump in flight system. As the captain agreed, he dumped fuel despite the difficulties on fuel tank n°1.

Helped by the maintenance man, he extended the gear by the emergency system and verified its complete lock.

During the last turn, he lowered the flaps in accordance with the emergency procedure.

Finally, noticing that the captain, because of the normal brake system failure (hydraulic mode), used the emergency brakes (pneumatic mode), he selected "reverse" on engine n°2.

General comments

During approximately the last 24 minutes, during which the manoeuvre was operated, the crew was bothered by several warning horns that the flight engineer did not manage to switch off.

The crew had no emergency operating procedure corresponding to the present case. As a result, the crew used the procedure corresponding to the "Engine fire, severe damage or separation" checklist (card 5).

However that may be, the execution of this emergency operating procedure proved to be efficient, as the aircraft remained manoeuvering until the landing and preserving the essential of the necessary emergency ancillaries :

. the hydraulic rudder booster worked normally in emergency,
. the normal braking was inoperative, but the (pneumatic) emergency braking worked,
. the electric power enabled to fuel dumping, lowering of the flaps in emergency and ensured the normal operation of the ATC radar beacon system and communications.

The major workload associated with this exceptional event was remarkably well shared between the crewmembers and this good organization led undoubtedly to the success of the manoeuvre.

2.6 Control assistance

Listenings to the ATC communications and the CVR enabled analysis of the successive phases of the dialogue between the crew of the distressed aircraft and the controllers.

CRNA/SE

The first two distress calls were timed at 08.11.41 hrs and 08.11.48 hrs. At 08.11.53 hrs, the controller of the CRNA/SE answered : "say your level and position Sir". He repeated his question at 08.12.20 hrs advising that he did not have radar contact.

Comments The reconstruction of the radar traces performed by the CRNA/SE confirmed the momentary disappearance of the secondary image of 5N-MAS between 08.10.50 hrs and 08.12.20 hrs (see Annex 2). Thus, during 1 minute 30 seconds, the controller was not able to identify the aircraft from the radar. This disappearance of the trace was explained by the fact that the electrical power supply of the transponder was supplied by the "essential service bus", connected with engine n°3 at the moment of the separation of both engines. The transponder no longer transmitted because it was no longer electrically supplied. It got back to transmit - and the secondary image reappeared - when the flight engineer connected the essential bus with engine n°1.

Then, the controller identified the aircraft undoubtedly from the rereading of the strip. The controller asked the captain to get the aircraft at flight level 200.

The controller asked the crew to confirm the landing in Marignane. After the answer ("Anywhere landing immediate"), he requested the display of the transponder distress code 7700 and ordered the crew to turn southwards, towards Marignane.

The crew advised the control of the nature of the troubles at 08.14.13 hrs : "We need emergency landing emergency landing both engines missing right wing emergency landing radar". It should be noted that this sentence could be understood in two different ways. There is no doubt that the crewmembers wanted to warn the controller about the detachment of two engines. In fact, it is highly probable that the controller understood that the crew wanted to land because of inoperative engines. The aircraft was transferred to Marseilles Control.

Marseilles Control

As soon as the hand-off was made, the new controller tried to get pieces of information. At 08.16.22 hrs, he asked : "Ah Roger proceed direct to Mike Romeo Sierra. What the nature of your problem ?".

The answer of 5N-MAS is more accurate : "Two engines missing two engines missing structural request straight-in landing". However it might have been interpreted by the controller as a double engine failure if the word "structural" was not perceived or understood.

At 08.17.14 hrs, the controller repeated his question, which seemed to confirm that he had not understood : "How many engines on failure...671 ?". The answer ("Two engines missing ...") did not remove the ambiguity. At 08.17.51 hrs, KABO 671 asked the meteorological conditions in Marseilles.

The conversation with 5N-MAS was hindered by the radio traffic of the controller with other aircraft on the same frequency. At 08.18.40 hrs, KABO 671 specified once more the reality of its distress call :"MAYDAY

MAYDAY
MAYDAY MAYDAY MAYDAY MAYDAY 671 request weather". Then the aircraft was transferred to Marseilles Approach, requests for information on weather at Marseilles not obtained.

Marseilles Approach

As soon as 5N-MAS was transferred to the frequency of Marseilles Approach, the controller gave the crew the heading 240 and specified that the runway in service was runway 14. On the same frequency the UTA 7209 flight, just taking off from Marseilles, signalled that it was "climbing towards 3000 ft".

At 8.20.33 hrs, KABO 671 specified once more the reality of its distress call :"Roger request all assistance possible we have two engines broken from the airplane only running on one and two". The controller answered "Roger I understand" (in fact and always for the same reasons, he might have not understood the real situation of the aircraft).

Then, KABO 671 mentioned that the aircraft had limited manoeuvering and specified that they wanted the meteorological conditions in Marseilles. It is at this very moment that, doubting the good meteorological conditions in Marseilles, the crew considered to re-route towards Palma and asked for the corresponding meteorology. The follow-up of the dialogue revealed that the crew quickly forgot this idea; they finally got the detailed meteorological conditions in Marseilles, answered the questions of the controller about the number of people and the quantity of remaining fuel. Then the controller gave the heading 180° in order to direct the aircraft towards runway 14 (see path in Annex 2).

The dialogue with 5N-MAS was hindered by the radio traffic of the controller with other aircraft on the frequency.

The controller got the aircraft turned left to the heading 110. A short while later, 5N-MAS asked :"KABO we have an airfield ahead what is that airfield ?". It was the military airbase of Istres, with its 4000 meters long runway. The crew suggested to land there ("4000 m I can land there ?"). The controller gave the landing clearance. The aircraft was transferred to Istres Tower.

This analysis reveals that the various people in contact with 5N-MAS became aware only gradually of how serious the situation really was and without, moreover, perhaps ever identifying its real cause. Notably, the urgent calls and MAYDAY did not suffice to produce this realization. The service provided was not adequate for the seriousness and urgency of the plane's distress.

We might note, among other things, that the repeated requests for frequency changes and the continuation of exchanges with other aircraft

increased the crew's workload. When the plane signalled that it was in distress, requesting permission for an emergency landing, no analysis was made of the airfield and means of assistance available. Also, when the plane, whose diminishing ability to manoeuver was known, approached Marignane to land on 14, take-
offs were continued with no allowance apparently made for this factor. Lastly, there was no reply to requests for information on weather conditions until relatively late. And yet a reply, even to hold, would have spared the crew the impression that their calls were falling on deaf ears, which added to their nervous tension.

None of the above can be undertaken lightly, particularly in an emergency situation. The ability to respond properly to such situations, when they arise, depends on being prepared and trained for them. Flight-controller personnel, however, does not systematically receive this type of training.

3.Conclusions

3.1 Data given by the inquiry

The crew had the certificates, the licences and the necessary qualifications for the operation of the aircraft.

The maintenance operations recommended were performed according to the instructions in force.

Climbing in turbulent air, following the fracture of the fittings because of a crack propagation, engine n°3 was propelled outboard and hit engine n°4, inducing its tearing away.

The fracture of the fittings of the pylon of engine n°3 started from an inboard midspar fitting fatigue crack. This crack was not detected during the double execution of the AD which imposed the periodic visual inspection of the midspar fittings. The visual inspection described by the AD was not sufficient to permit this detection.

The distressed aircraft control assistance revealed some defects in the preparation to the handling of emergency situation. However, in this case, those defects were not at the origin of the accident. There did not lead neither to worsened consequences.

The crew succeeded in forced landing, right wing on fire, on the Istres runway.

The efficiency of the fire brigade (SSIS) of Istres avoided the complete destruction of the aircraft and its freight.

3.2 Causes of the accident

The accident resulted from the fracture of the right inboard engine pylon fitting, in such conditions that this engine came to hit and tore away the outboard engine.

The AD, imposing periodic monitoring of the midspar fittings, proved to be insufficiently efficient.

4. Safety recommendations

4.1 The B 707 pylons fittings

This accident brought to light the weakness of the B 707 pylons fittings. This structural weakness provoked four cases of loss of engines in flight.

The successive AD in force since 1977 shows that this problem is not recent. Because they are limited to visual verifications without dismantling, they failed to detect hidden fatigue cracks, such as those described in the present report.

On the other hand, it is not impossible that the HUSH KIT modification is an aggravating factor, increasing the probability of crack developing.

Consequently, the B.E.A. recommends that :

- in order to ensure the safety of the flights, the inspection of the current midspar fittings of the pylons of the engines be modified in order to enable the detection of the hidden cracks, or that these fittings be systematically replaced by reinforced fittings.

Comment : these reinforced fittings should undergo an examination in order to respond to the new conditions which could be induced by the sound insulation modification of the engines.

4.2 Control

This accident revealed defects in the management of the distress. They are linked to the unusual nature of the situation (break in the routine) and to the sudden nervous tension (stress) due to the distress situation of the aircraft. If the Air Traffic controllers are prepared for this kind of situation during their initial training, they do not have afterwards a specific periodic training.

Consequently, the B.E.A. recommends that :

- the controllers be trained to face up to the distress and emergency situations, thanks to the theoretical study of possible cases and the practical corresponding exercises.