MINISTRY OF PLANNING, HOUSING AND TRANSPORT
Final Rapport
CONCERNING THE ACCIDENT WHICH OCCURRED ON 19 SEPTEMBER 1989 IN THE TENERE DESERT (NIGER) TO DC-10-30 REGISTERED N54629

Prepared by Harro Ranter
Source: Official accident report

INVESTIGATION COMMISSION

concerning the accident which occurred on 19 September 1989 in the Tenere Desert (Niger) to DC-10-30 registered N 54629

F I N A L R E P O R T

FOREWORD

Owing to an agreement that was reached between the Governments of Niger and France, an Investigation Commission was set up on 21 September 1989 to investigate the circumstances, find the causes of and release information relevant to, the accident which occurred in Niger, on 19 September 1989, to a UTA DC-10-30 aircraft.

This technical investigation was carried out in compliance with Annex 13 to the Convention on International Civil Aviation (standards and recommended practices as regards investigations of aircraft accidents). Basically, it aims at preventing further accidents. In no way does it try to establish blame or liabilities. A judicial inquiry into the accident is the subject of a separate investigation.

The results of this technical investigation are put forward in this final report which was made up in accordance with the format recommended by the International Civil Aviation Organization (ICAO).

SPECIAL FOREWORD TO ENGLISH EDITION

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

C O N T E N T S

SYNOPSIS

Date of accident: Aircraft:
Tuesday 19 September 1989 McDonnell Douglas
DC-10-30 ;
at 12.59 hrs UTC (*) SN : 46852
Registration: N54629 (US Register)
Place of accident:
Country: Niger Owner:

Area : 16∞54'N 11∞59'E, Interlease Incorporated (Atlanta, Georgia)
in the Tenere Desert, to the north-east of the Termit Massif Operator :
Union de Transports AÈriens (UTA)
Type of flight
Regular flight from Occupants :
Brazzaville to Roissy, with a . Cockpit personnel : 4
stop at N'Djamena . Cabin attendants : 10
Public transport (passenger) . Passengers : 156
Flight No UT 772 Total 170
Radio code : UTA 772

(*) The times given in this report are in universal time coordinated (UTC). Add one hour to obtain time for Niger and add two hours to obtain time for France in use on the day of the accident

Summary : The aircraft took off from N'Djamena for Roissy at 12.13 hrs. A last radio contact was established at 12.34 hrs. Because the crew made no subsequent transmission, the uncertainty (INCERFA), alert (ALERFA) and distress (DETRESFA) phases were initiated starting from 14.30 hrs. Very early the next morning the air search succeeded in locating the scattered wreckage of the aircraft in the Tenere Desert (Niger), nearly 650 kilometres north-north-west of N'Djamena.

Consequences:

	Persons killed	injured	unhurt	Aircraft and cargo	Third party damage
Crew	14	-	-	total loss	none
Passengers	(1) 156	-	-	loss (desert area)	

Third parties 0 - -
(1) According to the boarding documents (flight tickets and boarding cards) 156 passengers were presumed to be on board

COMPOSITION OF THE INVESTIGATION COMMISSION AND SUMMARY OF WORK

Composition of the Investigation Commission
By agreement with the Government of Niger, the Minister of Transport, by order dated 21 September 1989, set up an investigation commission composed of :
Mr. Louis Pailhas Inspector General for Civil Aviation President
Mr. Yerima Allakasso Major
Search and Rescue Service/Niger
Vice-President
Mr. Paul Arslanian Accidents Investigation Bureau/France
Vice-President
Mr. Jean Clauzel Prefect
Vice-President
Mr. Sani Balla Accidents Investigation Bureau/Niger
Mr. J-Frangois Bouisset Commissioned to Security to the Director General o f Civil Aviation
Professor E. Fournier Medical Council for Civil Aviation
Mr. J-Paul Groussard Pilot Inspector
Mr. Michel Guillaume State Councillor (Conseiller d'Etat)
Mr. Bernard Mangane Accidents Investigation

Bureau/France
Mr. Ali Ousmane Accidents Investigation Bureau/Niger
Mr. J-Claude Ripoll Director of the Aeronautic Tests Center of Toulouse
Mr. Barry Trotter, from the National Transportation Safety Board (NTSB), was accredited to the Investigation Commission by the Government of the USA, country of Manufacture and of Registry of this aircraft. Later he was replaced by Mr. James Wildey.
Mr. Mabourouk Gami and Mr. Mahamat Guetti were appointed as accredited observers to the Investigation Commission by the Government of the Chad Republic.
As experts, the following persons were also associated to the work of the Investigation Commission :

* Robert Hildrup, from the NTSB
* Walter Korsgaard and Richard F. Martz, from the FAA
* Margaret Babcock, William Steelhammer and Bernard Annoual (McDonnell Douglas)
* Zigmut Jan Przedpelski, Charles Cutfield and Philippe Turgis (General Electric Aircraft Engines) .

Summary of work
The Accidents Investigation Bureau (BEA) was notified that the DC10 was missing on Tuesday evening, 19 September.

20 September : as soon as the wreckage was located (in the early morning), three investigators from the BEA and the head of the Search and Rescue (SAR) department of the Air Navigation Directorate, together with UTA experts, took the first flight to N'Djamena. As

soon as they arrived, they went to the site of the accident

21 September : an overflight of the site enabled location and identification of the wreckage that was scattered over a large area, in the Tenere Desert, and drawing of a first sketch of its distribution. That same day, the digital flight data recorder (DFDR) was recovered and immediately sent to Paris to be read.

22 September : the cockpit voice recorder (CVR) was recovered and immediately sent to Paris to be read. The General Electric experts examined the 3 engines, declared to be not involved. The detailed examination of various wreckage (aircraft structure scraps, container parts, baggage pieces, etc...) was carried out with the cooperation of FAA and NTSB experts who arrived on that day. This examination gave a strong assumption that an airborne explosion had occurred in the forward cargo bay.

23 September : various wreckage showing evidence of explosion were taken to N'Djamena and were the subject of chemical tests in order to identify the traces of explosive. On the same day the President and the Nigerian Vice-President of the Investigation Commission arrived on the site. The day before, they had held a meeting in Niamey with the Minister of Transport of Niger.

24 September : the detailed map of the distributed debris was drawn thanks to numerous reconnaissance missions and to the observations that were made on the site.

25 September : a meeting was held between the members of the Investigation Commission and the experts who were present in N'Djamena. After collecting and commenting on the observations that had been made since 20 September, it was decided to focus further work on the section of the fuselage located between the rear of the cockpit and the leading edge of the wing. The Commission aimed to collect the pieces of this section with the purpose of having them transferred to Paris.

26 September : A large search and recovery operation was set up with the active participation of French and Nigerian military authorities. That operation - over an area which measured 10 by 6 km - was carried out throughout 27 September. On 28 September, the pieces recovered and grouped together the day before were transported by a lorry to the base camp, after the biggest ones had been cut into sections with a chain saw. Those fragments were then transported by lorries to N'Guigmi (350 kilometres away from the scene of the accident), then by plane to Niamey and Paris.
The investigators returned to Paris on 1st October.
The Investigation Commission met in Paris on 9

October and worked on their preliminary report (which was submitted on 24 October to the Ministers of both France and Niger). They also determined the programme for additional investigations to be performed.
Between early October and mid-December, UTA built a metal framework in a hangar at Dugny Air Base (Le Bourget Airport), on which was reconstitued the section of the fuselage in which the explosion had occurred, using the fragments which had been recovered from the Tenere Desert. That reconstruction enabled to identify the container in which the explosive had been.
Various complementary investigations were also made during the first half of 1990.
All this work was carried out in constant coordination with the work of the judicial investigators, in compliance with the decisions of the interdepartmental directive of 3 January l953.
The last meeting of the Investigation Commission was hold on 17 September 1990.

1. FACTUAL INFORMATION

1.1. HISTORY OF THE FLIGHT

On Tuesday, 19 September 1989, UTA DC-10 N 54629 performed the regular flight Brazzaville-Paris with a stop at N'Djamena.
The leg Brazzaville-N'Djamena was conducted without problem.
At N'Djamena, nine passengers disembarked and seventy-nine boarded. The stop at N'Djamena was one

hour.
At 12.13 hrs, the aircraft took off from N'Djamena. The flight plan scheduled flight level 350 (*) and the overflight of check-points BOSSO, INISA, DJANET then the standard route to Paris.
At 12.32 hrs, five minutes before the scheduled time for the overflight of point BOSSO, the aircraft reported steady at cruising level.
At 12.34 hrs, another radio fix was made between N'Djamena and UT 772 which was expected to call again at 13.10 hrs at check-point INISA (limit of N'Djamena and Niamey Flight Information Regions).
That call at 12.34 hrs was the last one; that fact was also recorded by the flight data recorder (DFDR) and by the cockpit voice recorder (CVR).
Because it did not receive the position report at INISA, the Flight Information Center of N'Djamena tried several times to come into contact with the DC-10.
As it received no response to its calls and could not get any information from neighbouring centers, at 14.30 hrs N'Djamena initiated INCERFA phase, then at 15.55 hrs ALERFA phase, and finally DETRESFA phase at 16.14 hrs. Night fell at 17.30 hrs.
The investigations that began on the following morning succeeded, at 6.35 hrs, in locating the wreckage of the aircraft in the Tenere Desert, to the north-east of the Termit Massif, on the route scheduled by the flight plan.
The wreckage of the aircraft was spread over a very large area (See Appendix 5).
The track of the aircraft is given in Appendix 1.
(*) *35,000 feet i.e. 10,500 metres*

1.2. INJURIES TO PERSONS

Crew Checked Passengers Third Party
Killed 14 156 0
Injured 0 0 0
Unhurt 0 0

1.3. DAMAGE TO AIRCRAFT

The aircraft was totally destroyed.

1.4. OTHER DAMAGE

The accident occurred in a desert area. So there was no other damage.

1.5. PERSONNEL INFORMATION

The crew included three pilots and a flight engineer. As a matter of fact, a UTA airline pilot instructor was giving a test to the left-seat pilot during the flight.

1.5.1 Captain

* Male, aged forty years.
* Aircraft ratings
* Airline transport pilot licence PL 2458 issued on 25 September 1980; valid to 30 November 1989;
* Equivalent US licence 2 345 893 issued on 27 April 1989;
* Last medical check-up on 24 November 1988.

* Engaged by UTA on 4 October 1976.
* Qualifications :
* Airline transport pilot instructor;
* Type qualifications : DC-8, Super-Guppy, DC-10, B-737:
* DC-10 qualification issued on 24 November 1983.

* Experience :
* total flight hours : 11,039;
* on DC-10 : 2,723 hours.

1.5.2. Left-seat pilot

* Male, aged thirty-eight years.
* Aircraft ratings
* Airline transport pilot licence PL 2833 issued on 23 December 1982, valid to 30 November 1989.
* Temporary equivalent US licence issued on 21 August 1989.
* Last medical check-up on 28 November 1988.

* Engaged by UTA on 14 June 1976.
* Qualifications :
* Type qualifications : DC-8, B 747, DC-10.
* DC-10 qualification issued on 19 August 1989.

* Experience :
* total flight hours : 6,442;
* on DC-10 : 28 hours.

1.5.3. Co-pilot

* Male, aged forty-one years.
* Aircraft ratings:
* - Senior Commercial Pilot licence 3840 issued on 23 March 1981 ; valid to 31 December 1989;
* - Equivalent US licence 2 395 200 issued on 13 May 1988:
* - Last medical check-up on 6 June 1989.

* Engaged by UTA on 31 December 1975 .

* Qualifications :
* Type qualifications : B-707, DC-10.
* DC-10 qualification issued on 11 May 1988.

* Flight experience :
* total flight hours : 8,357;
* on DC-10: 754 hours.

1.5.4. Flight engineer

* Male, aged twenty-eight years.
* Aircraft ratings :
* Flight engineer licence 2669 issued on 19 February 1988;
* Licence valid to 31 July 1990;
* Equivalent US licence 2 411 573 issued on 31 March 1989:
* Last medical check-up on 24 July 1989.

* Engaged by UTA on 2 November 1988.

* Qualifications :
* Type qualifications : SE-210, DC-10.
* DC-10 qualification issued on 31 March 1989.

* Flight experience :
* total flight hours : 597;
* on DC-10 : 180 hours.

1.5.5. Flight attendants

Main purser :

* Male, aged forty-six years;
* CSS No 3780 issued on 4 July 1968; valid to 31 January 1990;
* Last medical check-up on 18 January 1989;
* Engaged by UTA on 20 March 1967.

Purser:

* Female, aged thirty-three years;
* CSS No 9055 issued on 3 August 1978; valid to 31 March 1990;
* Last medical check-up on 24 Larch 1989;
* Engaged by UTA on 11 April 1978.

Stewardess:

* Female, aged forty-two years;
* CSS No 8686 issued on 24 March 1978; valid to 30 June 1991
* Last medical check-up on 9 June 1989;
* Engaged by UTA on 29 March 1971

Stewardess:

* Female, aged thirty-eight years;
* CSS No 6987 issued on 21 August 1973; valid to 28 Feb.1990;
* Last medical check-up on 1 February 1989;
* Engaged by UTA on 13 February 1973

Stewardess:

* Female, aged thirty-three years;
* CSS No 10281 issued on 5 Feb. 1980; valid to 31 October 1989;
* Last medical check-up on 25 April 1989;
* Engaged by UTA on 12 November 1979.

Stewardess:

* Female, aged thirty-seven years;
* CSS No 7223 issued on 31 May 1974; valid to 31 October 1990;
* Last medical check-up on 26 October 1988;
* Engaged by UTA on 3 January 1974.

Stewardess:

* Female, aged thirty-nine years;
* CSS No 5659 issued on 29 December 1971; valid to 30 September 1990;
* Last medical check-up on 7 September 1988.
* Engaged by UTA on 19 October 1971.

Stewardess:

* Female, aged thirty-one years;
* CSS No 12749 issued on 12 November 1985; valid to 30 September 1990;
* Last medical check-up on 9 September 1988;
* Engaged by UTA on 30 September 1985.

Steward:

* Male, aged thirty-one years;
* CSS No 10889 issued on 10 July 1981; valid to 31 January 1991;
* Last medical check-up on 4 January 1989;
* Engaged by UTA on 6 April 1981.

Steward:

* Male, aged thirty-six years:
* CSS No 9718 issued on 18 May 1979; valid to 28 Feb. 1991;
* Last medical check-up on 27 February 1989;
* Engaged by UTA on 5 March 1979.

1.6. AIRCRAFT INFORMATION

Registration : N 54629;
Owner : Interlease Incorporated;
Operator : UTA.

Airframe:

* Manufacturer : McDonnell Douglas;

* Type : DC-10-30;

* Serial number : 46852;
* Delivered first hand to UTA on May 1973;
* Airworthiness Certificate No DAR-9-FS-EU, issued on 21 March 1988 (before that date the aircraft was registered in France).

* Flight hours : 60,267 (on 17 September 1989).
* Number of operating cycles : 14,777 (on 17 September 1989) among which 8,378 hours TAT and 1, 779 TAC since major overhaul.

Engines :

* Manufacturer : General Electric;
* Type : CF6-50C2R;

Engine No 1 (left);

* SN 517493 installed on the aircraft on 30 July 1989;
* 29,969 hours TAT and 7,772 TAC (on 17 September 1989);
* Since last maintenance check : 468 hours TAT, 54 TAC.

Engine No 2 (aft);

* SN 455174, installed on the aircraft on 17 January 1989;
* 44,822 hours TAT and 12,100 TAC (on 17 September 1989);
* Since last maintenance check : 2,418 hours TAT, 537 TAC.

Engine No 3 (right);

* SN 517535, installed on the aircraft on 10 September 1989;
* 26,128 hours TAT and 7 , 2 71 TAC (on 17 September 1989);
* Since last maintenance check : 75 hours TAT, 16 TAC.

Information given on engineering resorts :
Nothing significant through the reading of the engineering reports. The maintenance of that aircraft was carried out in compliance with the regulations in force, by the KSSU group.
Weight and balance :
The mass at the departure from N'Djamena was 187,700 kg of which 49,400 kg was fuel; it was within the allowed limits, as was the balance of the aircraft.
1.7. METEOROLOGICAL INFORMATION
1.7.1. High altitude information:
Over Africa, (to the north of the Equator), subtropical high pressures concentrated on parallel 25∞N for 500 hPa pressure level and went to parallel 18∞N for 300 hPa and 200 hPa pressure levels.
South of these axes, between meridians 10∞ and 20∞ E, winds were settled in the eastern area:

200 hPa : 080∞/10kt to 15 kt, -55∞C to -53∞C (northwards);

300 hPa : 090∞/10kt, -32∞C;

500 hPa : 070∞/15 kt to 20 kt, -9∞C.
1.7.2. Surface information:
The intertropical convergence zone, known on the ground as the intertropical front, that separates the Saharian air masses (dry air) from the Atlantic air masses (wet air) was situated near Lake Chad :

* at 12 hrs, on : 14∞N - 017∞E, 15∞N - 010∞E, 18∞N - 003∞E;
* at 15 hrs, on : 14∞N - 017∞E, 14∞N - 010∞E, 17∞N - 006∞E.

The monsoon effects were not felt further than parallel 10∞N, near meridian 013∞E, and the cloud layer had no activity. The flight data recording confirmed that the aircraft was not subject to turbulence.

1.7.3. Meteorological information along the route :

From N'Djamena to point 10∞N - 013∞E, UT 772 flight was operated in cloudy weather conditions with no significant meteorological phenomenon :

1 to 3/8 Cu until over Lake Chad; bases around 1,200/1,400 metres, peaks 2,000 to 3,000 metres;

2 to 5/8 Ac, growing north of this lake; bases around 4,000/4,500 metres, peaks 6,000 to 7,000 metres;

3 to 7/8 Ci between 7,000 /8,000 metres and 9,000/10,000 metres.

1.7.4. Information given to the crew at the departure from N'Djamena:

The flight file taken at 9.58 hrs by the Air Afrique station personnel and which was given to the crew included

* a significant meteorological chart (SIGMET), valid for 19 September at 12 hrs above flight level 250;
* two forecast charts for winds and temperatures at 300 hPa and 200 hPa:
* a terminal area forecast in clear for N'Djamena,

Roissy and its diversions.

On the SIGMET chart, there were two slight differences in comparison with the actual situation : the line of the intertropical front was around 5∞ too high in latitude, at the east of meridian 005∞E, and the active monsoon area expanded as far as parallel 16/17∞N, i.e. 6 to 7∞ too far to the north. In fact no phenomenon such as cumulonimbus expansion or turbulence was to be anticipated

For this part of the flight, the provided values for high altitude winds and temperatures were consistent with reality (1.7.1.): the flux from the east was steady and brittle, the temperature values did not show any particular discontinuity when climbing to FL 350, and the tropopause was at FL 500.

1.8. AIDS TO NAVIGATION

Not relevant.

1.9. COMMUNICATIONS

Communications were normal to the end of the two-way radio contact. The transcriptions of the radio communications between aircraft and N'djamena Control Center are given in Appendix 2.

1.10. AERODROME INFORMATION

Not relevant.

1.11. FLIGHT RECORDERS

The 5 November 1987 Order (Chapter 2.11) - dealing with the requirements for transport aircraft - makes it compulsory for this type of aircraft to carry a Digital Flight Data Recorder (DFDR) and a Cockpit Voice Recorder (CVR).

DC-10 N54629 was equipped with :

. a Sundstrand 573A DFDR; SN 711612-1174;

. a Sundstrand AV557B CVR; SN 6084.
The DFDR was recovered on Thursday afternoon, 21 September, from amongst the wreckage. It had been damaged by the impact (cracked shield). It was recovered detached from its support.
The CVR was recovered on Friday morning, 22 September, from within the main impact area, detached from its support. The impact had caused no apparent damage to it. Its outer case was not visibly deformed but it had been sooted by the fire.
Those two recorders were transferred to Paris. They were read during the night of 22 to 23 September.
The graphical presentation of the parameters recorded by the DFDR is given in Appendix 3.
1.11.1 DFDR read-out :
The graphics obtained from the reading of the DFDR show a good steadiness of the parameters (normal cruising flight at FL 350), then, a short time before the end of the recording, moderate fluctuations of the engine control parameters as well as peaks in some parameters.
Analysis and explanation of these phenomena are shown in paragraph 1.16. (Tests and research).
1.11.2. CVR read-out
The tape was undamaged and in visually good condition (aspect of a little used tape). It showed no initiation of a significant crack nor specific damage which could have altered its reading.
Conversations were easily heard : until the end of the

recording everything sounded like a normal cruising flight. The radio transmissions were of good quality and the voices transcription did not cause any major problem.
The time of the accident was obtained by the correlation of the CVR recording with the recording of the N'Djamena Control Center communications; the tape speed being set by spectral analysis using the 400 Hz frequency of the on-board alternating current. The accident occurred at 12.59 hrs, while the crew were having lunch and monitoring the flight progress.
The CVR transcription did not provide any significant detail as far as this investigation is concerned.
The end of the recording was submitted to a particular analysis given in paragraph 1.16 (Tests and research).

1.12. WRECKAGE AND IMPACT INFORMATION

The DC-10 fell in a desert area, a fairly flat region, with alternate dunes and hollows with rather f lat. lightly undulating zones . There were no landmarks except a few thorny bushes to the north-eastern part of the wreckage distribution zone.
The in-flight disintegration of the aircraft was very important; the wreckage was spread over a zone whose centreline was 040∞/220∞, nearly 16 kilometres long for the major portions of the aircraft, and nearly 80 kilometres for the lighter pieces that had been subject to wind drift for much longer .
The area over which the major portions were distributed was nearly 6-8 kilometres wide.
The aircraft broke up in flight into four main sections referenced A,B,C, and D (see Appendix 4).
The main wreckage (referenced C) was located in the

most north-eastern part of the wreckage area.
Close by there were elements of the rear fuselage and tail unit (referenced D) : engine No 2, fin and right stabilizer.
The cockpit and part of the cabin (referenced A) were located at 5,100 metres south of the main wreckage.
At a 240∞ bearing from the cockpit a dozen large fuselage panels were found (referenced B) . Because those parts had been widely distributed, they were found using a systematic search.
The plot that shows the various locations of the wreckage is given in Appendices 5 and 6.

1.12.1 Main wreckage (referenced C):

The main wreckage included the wings, Nos l and 3 engines and the section of the fuselage between frame No 1159 (ahead of wing root) and frame No 1986.
It was located in an area oriented north-south, 100 metres wide by 200 metres long. It fell on the ground inverted and mostly burnt at the impact. Some elements of aft fuselage, such as the stabiliser main box and a fragment of the left stabilizer were not destroyed by the fire.
The DFDR was recovered at the western limit of the fire zone. It was not damaged by the flames. The CVR was located at nearly 50 metres from the DFDR, within the burnt area. It had been sooted.
Numerous bodies were still inside that part of the wreckage in which the fire had been very fierce.
Within the fire zone the following main pieces were identified:

* scattered pieces from the main and central landing

gears;
* left and right wings with detached components;
* scattered parts from slats, flaps, engine cowlings, fan cowls, fuel tanks;
* cabin door, undercarriage doors;
* Nos l and 3 engines broken into various units. At ground impact, their rotating parts had a low rotation speed. The blades of the fans of those two engines showed characteristic traces of ingestion of solid foreign objects and were badly damaged, some being broken. The compressors blades were also very damaged. This damage occurred while the engines were rotating at high speed. There was no evidence that the cases had been penetrated by rotating parts.

Also, within the same zone, but unaffected by the fire, the following items were found :

* lower part of aft fuselage;
* stabilizer main box;
* part of left stabilizer;
* aft section of the fuselage with elements of the auxiliary power unit (APU);
* aft cargo door (shut and locked);
* aft cargo hold floor.

The position and distribution of the above items confirmed that the section of the aircraft situated between the wings root and the forward end of the tailplane crashed inverted, as a single section.

1.12.2. Flight deck and fore section of the cabin (Referenced A)

The forward section of the fuselage was located 16∞54'N by 011∞59'E, at a l87∞ bearing nearly 5 kilometres from the main wreckage.
It lay on the ground on its right side and did not burn. The pilots', flight engineer's and a steward's bodies were still inside

1.12.3. Fuselage tail section (Referenced D) :

The fuselage tail section, broken near frame 1986, had broken in flight into various items which included :

a.)
* The forward section of No 2 engine air inlet duct;
* The aft section of that air inlet duct and a major part of the fin:
* The upper part of the fin;
* The vertical rudder;
* Items of secondary structure and of No 2 engine cowling;
The leading edge of the fin showed traces of impacts by metallic items which occurred during the in-flight disintegration of the aircraft.

b.)
* No 2 engine which detached from the structure before reaching the ground With its nozzle, it was located in the most northerly position of the items quoted above. Most of the damage to that engine resulted from ground impact. The visual examination showed that, at that time, the engine had a low rotational speed. There were some marks on the fan blades which showed that it had ingested foreign items whilst rotating at significant speed.

No penetration of the case by rotating parts was to be seen.
All elements quoted under a) and b) were at nearly one kilometre from the major wreckage at a 80∞ bearing

c.)
* The right stabiliser, whose leading edge showed impact traces similar to those of the fin, was located at a 230∞ bearing from the major wreckage, at 2.3 km.
None of these elements burned.

1.12.4. Forward cargo hold and fuselage section (Referenced B)

The section of the fuselage situated between elements referenced A and C was composed of the forward cargo hold and part of the passenger cabin. On an intact aircraft it is a 14 metre-long cylinder. It broke into a dozen large panels, recovered in an 8 kilometre-long by 6 kilometre-wide zone. The centre of that area was at a 237∞ bearing, 7 kilometres away from the cockpit and its centreline axis was 045∞/225∞.
The largest section of these parts was a panel which included 12 cabin windows together with the forward cargo hold door. The cargo hold door which was on the right side of the fuselage was still in place, shut and locked.
That panel was situated roughly between frames Nos 824 and 998/1019. It was located at a 200∞ bearing, 3.3 kilometres from the cockpit.
Between that last point and the most south-western part of the area there were the other major elements of this

section of the fuselage:

* a panel situated between frames Nos 999 and 1099 that included 4 complete cabin windows, the left landing headlight and the left wing illumination light;
* A panel nearly 3 by 5 metres panel, situated roughly between frames Nos 755 and 879, that included No 12 lower door frame (left side of the fuselage), water panel and static ports. That panel showed relevant perforation traces by one or several elements from inside the aircraft
The sealing sheets showed characteristic distortions as a result of a high overpressure inside the fuselage.
Within that area other items were also recovered:

* pieces of fuselage skin of various sizes, separated from the structure,
* structure pieces (unskinned frames and stringers), nearly 1.5 metres by 1 metre:
* cabin floor structure items;
* container items together with electrical equipment and cabin equipment (seats, galleys, trolleys, baggage containers, water heater, etc. . .)
* numerous baggage and clothes.

None of the items recovered in that area had burnt.
Most of the fuselage debris of that section (frames 595 to 1099) were recovered and reconstructed. Those recovered items represented nearly 90% of the fragmented section of the aircraft

1.12.5. No 1 engine air inlet duct - Escape slide

Between the major wreckage and a point approximately

situated at a 220∞ bearing and at 9.2 km from that wreckage were recovered from south to north:

* No 1 engine air inlet duct, whose rims showed impact traces:
* one escape slide;
* items from flaps and leading edge slats.

1.12.6. Light items

Most of the aircraft lightest items (composite decorative panels, papers, etc...) were sub Sect to wind drift and distributed within a 10 to 15 km-wide and 50 km-long zone in the southern part of the area described in 1.12.4. During the aerial search (aircraft and helicopters) no significant item from the aircraft was found among those light elements.

1.12.7. Characteristic elements

In the proximity of the investigation area defined above (area in which Part-B fragments were located) and more precisely around a place situated at a 245∞ bearing 7.5 km from the cockpit the following items were recovered:

* container and cargo hold floor pieces; some of which showed characteristic evidence of explosion (small craters with melted metal); and others which showed distortion that could not be the result of the crash;
* pieces of wooden box riddled with metallic fragments;
* torn up clothes with holes and baggage pieces, distorted and burnt in places.

According to the loading plan, these things were located in the forward cargo hold.

The fact that they were located among debris that did not burn can only be explained by an in-flight explosion. The laboratory examinations and analyses which were carried out for the judicial inquiry established subsequent evidence of significant traces of explosive substance (penthrite), particularly on a baggage fragment. It was established that there was at least one kilogramme explosive.

1.13. MEDICAL AND PATHOLOGICAL INFORMATION

When the airframe broke at high altitude, all passengers and cabin crew instantly experienced, in addition to the shock wave due to the explosion, a sudden depressurization, a very rapid cooling (the outside temperature was nearly -45∞C) and a lack of oxygen which caused immediate loss of consciousness.

1.14. FIRE

The fire in the wreckage major section was due to ground impact. The fire was fed by the aircraft's fuel.

1.15. SURVIVAL ASPECTS

1.15.1. Survivability

This accident was not survivable.

1.15.2. Emergency services

The aircraft took off from N'Djamena at 12.13 hrs. It estimated point BOSS0 at 12.37 hrs, the limit of the N'Djamena/ Niamey FIR (point INISA) at 13.10 hrs, the limit of the Niamey/ Alger FIR (point KIRMI) at 13.40 hrs.

The last contact with the ground was established at about 12.34 hrs on radio frequency 128.1 MHz when the crew announced to the N'Djamena Flight Information Center that the aircraft was about to overfly point

BOSSO. The next contact, still with N'Djamena, was to be established at about 13.10 hrs on HF radio frequency 8,903 kHz. Between 12.34 hrs and 12.36 hrs, the crew established a radio contact with another aircraft for the N'Djamena Control Center.
Because the crew made no call at the time estimated for crossing of the FIR limit, the N'Djamena and Niamey Control Centers initiated several SELCAL calls on frequency 8903 kHz.
Kano and Alger Centers were contacted but could not give information about the flight. Radio contacts with Centers able to provide information were sometimes difficult to establish
Messages which initiated INCERFA (*) and ALERFA phases (*) were respectively sent at 14.30 hrs and at 15.55 hrs. DETRESFA phase (*) began at 16 . 14 hrs and the N'Djamena Search and Rescue Center started preparing the emergency operations. As night fell at about 17.30 hrs, the air search began on the following day using a French Air Force Transall that took off at 4.45 hrs. The wreckage was located at 6.35 hrs.

(*) *Within non controlled airspace, uncertainty phase (INCERFA) must be initiated if two compulsory consecutive messages are not received.*

1.15.3. Emergency beacon

Because regulations in force did not make it compulsory, the aircraft equipment did not include an emergency location beacon aircraft (ELBA) that works automatically at ground impact.
Nevertheless the SARSAT/COSPAS Mission Control Centre of Toulouse was consulted by N'Djamena at

17.22 hrs but was obviously unable to give any information about the location
Alert phase (ALERFA) is initiated forty-five minutes after uncertainty phase initiation.
Distress phase (DETRESFA) is initiated forty-five minutes after alert phase initiation.

1.16. TESTS AND RESEARCH

Between 20 and 23 September 1989, the investigators worked successively on recovering the recorders on the engines condition, on the closing of the cargo hold doors and on the general scatter of the debris of the aircraft. This last observation enabled them to note that Part-B of the aircraft had been distributed in a dozen fragments whereas forward section (A) and aft section (C) had fallen to the ground as entities. During that examination, characteristic elements, as described in 1.12.7., were recovered.
As a consequence, the investigators decided to focus their effort on searching for and recovering Part-B debris before the sandy wind made it difficult.
A combing operation over a rectangular area of desert, (10 by 6km), was made on 27 September by sixteen civil investigators, about thirty Nigerian soldiers and thirty French paratroopers, together with four helicopters belonging to the Army (ALAT) and all-terrain lorries. For the whole operations security and radio coverage were provided by a Breguet-Atlantic aircraft from the French Fleet Air Arm
That combing operation made it possible to recover around 90t of the Part-B structure together with several items showing blast evidence. Those pieces were transferred by lorries to N'Guigmi (350km), then by a

French Air Force Transall to Niamey and by an UTA flight to Paris.
The Investigation Commission met in Paris on 9 October 1989 and worked on their preliminary report which concluded : "An explosion occurred in the forward cargo hold and led to the destruction of the aircraft
The Commission also determined the programme for additional research:

* decision to have Part-B of the fuselage reconstructed so as to locate the seat of the explosion as accurately as possible and to describe the disintegration sequence;
* decision to make a particular analysis of the end of the DFDR and CVR recordings;
* referring to Annex 17 to the Convention on International Civil Aviation (*), decision to study security measures in force for flight 772.

(*) *Annex 17 : Safeguarding International Civil Aviation against acts of Unlawful Interference.*

1.16.1. Reconstruction of fuselage, Part-B

The debris recovered from the Tenere Desert included large pieces of fuselage skin, pieces from the forward cargo hold floor, containers (or container fragments), together with a pallet.
Those items were put in a hangar at Dugny Air Force Base (Paris-Le Bourget aerodrome). The reconstruction of the fuselage section were done by UTA personnel. In the first place it was necessary to build a framework strong enough to support the fifteen-tons of metallic items which constituted the fuselage section

The initial work aimed at identifying the various parts of the fuselage, of the cargo hold floor and of the containers. This was achieved by placing them side by side on the ground
The pieces belonging to the belly section were then assembled onto the framework, then the same for the left and right side pieces, including the forward cargo hold door.
The upper part of the fuselage section was closely inspected. Because it exhibited no particular feature of interest to the investigation and the understanding of the disintegration sequence it was not assembled on the framework. Its components were simply laid out on the hangar floor.

1.16.2. Location of the explosive charge

The examination of the reconstructed portion of the fuselage made it clear that the blast made three major apertures located in a vertical plane which created a 50∞ angle with the pressure hull longitudinal axis (see Appendix 7). This observation led to consideration of the propagation of the shock wave destructive effects in a conical way as sketched in Appendix 7 and it Established a possible location for the seat of the explosion.
The apertures in the fuselage (see Appendices Nos 8a, 8b and 8c) were caused by the blast which provoked an intense overpressure, with the pro Section against the was is of the items that were inside the cargo hold . Those items (baggage, containers, pallets) had been dislocated, fragmented and projected with high energy. Damages to the right side of the aircraft were among the most important. They were consistent with the

damages to the cargo hold floor and to the containers which were on the same side. Damage on the left side was the result of the mechanical effects of the blast along the cone axis
Photos of fuselage reconstruction are given in Appendix 8.
The examination of the containers and the comparison between their distortions with those of the cargo hold floor (Appendix 8d) and of the fuselage skin gave evidence that the explosion occurred in container No 7044 RK (*). This container was in the 13 right location (13-R, see loading map at Appendix 7), which matches the above observations.
Only baggage checked at Brazzaville airport for Paris was inside this container. It was out of reach during the N'Djamena stop.

(*) *At the time the accident occurred UTA and Air Afrique (RK) containers were undifferentiated.*

1.16.3. Breaking up sequence

The rupture sequence of forward fuselage had been much too complex to be precisely and accurately described. However, examination of the breaks made it possible to establish that the cockpit folded on the left side of the fuselage.
There were three types of fuselage ruptures :

* breaks related to the rivet lines, either at panel reattachments or in "full skin", according to the direction of the fuselage main axis.
* breaks along the skin panels showing a crockery-like sketch, enlarging outwards.

* breaks affecting the most bulky sections and the edges of the two parts which remained together (junctions of Part-B with the cockpit and with the central section).

Those latter breaks did not seem to be due to the direct blast effect but rather to a tearing process caused by significant aerodynamic effects.
The condition of some fuselage pieces (crumpled aspect over large areas) revealed a compression on weakened parts after the detachment sequence of the forward part of the aircraft
Elements from the cabin floor, from the forward cargo hold ceiling and from the cabin interior upholstering were missing. This fact was attributed to their lightness (honeycomb and laminated structure). Their fragmentation and distribution due to the wind effect while falling had been important.
In short, the disintegration sequence was rather complex; it lasted probably longer than a simple shock wave.

1.16.4. Pressure hull condition

The detailed examination of the fuselage section during reconstruction work and the observations on the site of the accident assert that the DC-10 hull was in very good condition; in particulars it did not show any trace of corrosion.

1.16.5 Analysis of the end of the DFDR recording

It was indicated in 1.11.1 that, a short time before the end of the DFDR recording,

* slight fluctuations of engine parameters (see Appendix 3, curves 1), and

* abnormal peaks for some other parameters (see Appendix 3, curves 2)

appeared.

1.16.5.l. Analysis of the fluctuations of engine parameters

A few minutes before the voice recording ends, the pilots were speaking together about Speed bugs" tuning. It is well-known that a slight shifting of these bugs leads to an automatic adjustment of the engine parameters by the autothrottle.

It is probable that the observed fluctuations of the engine parameters were the result of the pilots adjusting the speed bugs slightly whilst they discussed them.

1.16.5.2. Analysis of the peaks observed for some parameters

The abnormal values of some parameters a few seconds before the end of the DFDR tape could lead to various kinds of questions or suppositions.

It was, then, important to analyse them completely and precisely so as to find an explanation.

That accurate study was performed by specialists working for the BEA. It is to be found in Appendix 3.

It demonstrated that the abnormal values detected were not due to variations of the recorded parameter values but followed from problems in reading-out the tape which was badly damaged in several places by the shock given to the DFDR at the ground impact. This damage gave way to de-synchronisation of the signal from the tape while replayed. As far as the recorded parameter values were concerned, they had the values and stability consistent with a normal cruising flight at

FL 350.

1.16.6. Analysis of the end of the CVR recording

Besides the voice transcriptions, investigations were made on the end of the recording to try to find possible evidence of an explosion.

The spectral analysis of the final transient showed a vibratory wave initiated by the blast and transmitted by the aircraft structure. No trace of a shock ware transmitted by air was to be found.

1.17. ADDITIONAL INFORMATION

The investigations mentioned in paragraph 1.16. made it possible to assert that:

* the explosion occurred inside a container located in the forward cargo hold, in location 13-R (see Appendix 7);
* this container, loaded up at Brazzaville, contained only baggage checked at Brazzaville airport for Paris;
* the door of this container, as it was positioned in 13-R, could not have been opened at the N'Djamena stop. To open it, it would first have been necessary to shift the container itself as well as the one which separated it from the cargo hold door (location 14-R). The hypothesis of that double handling cannot be accepted. Somebody would have noticed it during the one hour stop, daytime, at N'Djamena.

Therefore, the Commission believed that the most probable hypothesis was an explosive charge, located in baggage embarked at Brazzaville with destination to Paris.

To protect air traffic against such risk, and to define the

necessary and reasonable level of security measures to enforce at airports, standards and recommended practices are prescribed by Annex 17 to the Convention on International Civil Aviation, and guidances are given in the ICAO "Security Manual" (DOC 8973).
Referring to these texts, the Commission decided that it was their responsibility to get information about the security measures in force at Brazzaville airport for departing international flights, at the time of the accident. So they perused the main observations made in October 1989 by the French experts, sent for that matter to the concerned Congolese authorities :

a. inside the terminal, passengers and baggage for departing international and domestic flights could be checked simultaneously in the same area. Passenger and baggage traffic between the free access and the restricted areas was not sufficiently regulated and controlled. In particular, it was easy to have access to the conveyor belt carrying checked baggage.
Moreover, the terminal dimensions, not adapted to the number of passengers and relatives at the time of several simultaneous departures, made rather questionable the enforcement of a strict supervision.

b. at passenger's request, it was possible to have hold baggage pre-checked, from the hotel, the day before departure.
Between pre-checking and cargo loading, the baggage was left at the airport for around 12 to 24 hours in a container with insufficient protection or watch.

c. any passenger could have his baggage checked by one of his employees. That habit (usually called "protocol-checking") did not exclude the possibility of baggage substitution (or addition) without the passenger's knowledge
d. as final precaution, when checking operations are over, it is an efficient security measure to make the passengers recognize their hold baggage before boarding, in front of the aircraft. That measure was not in force in Brazzaville at the time the accident occurred.

Consequently, the following three hypotheses could be considered plausible:

* baggage with fraudulent tag for Paris, either put down on the baggage conveyor belt or into the container that, temporarily, collected pre-checked baggage;
* baggage accepted by a deceived passenger, or checked without passenger's knowing, using "protocol-checking";
* baggage checked by a passenger who disembarked at N'Djamena whereas his destination (and that of his baggage) was Paris.

Furthermore, with the last two hypotheses, it was to suppose that the explosive device was hidden inside the baggage so as not to be noticed by hand control (done just before checking).
As far as the third assumption was concerned, the Commission took notice of the observations made by the same experts in N'Djamena in October 1989, relative to an important aspect: was it possible for a

Brazzaville-Paris passenger to disembark and remain unnoticed at the transit stop ? The answer was : that hypothesis cannot be ruled out in spite of the controls operated over disembarking passengers by the Chad border police.
While in N'Djamena, the French experts were also informed that, on 19 September, during the one-hour stop, the DC-10 was constantly under the control of three armed guards and that the different persons who had to work on the aircraft knew one another. That corroborated the hypothesis considered the most likely by the Commission (explosive loaded at Brazzaville).

2. ANALYSIS AND CONCLUSIONS

* DC-10 flight UTA 772, Brazzaville N'Djamena - Paris, was destroyed by an explosion on l9 September 1989, forty-six minutes after take-off from N'Djamena, while cruising at flight level 350 in totally normal conditions.
* That destruction was due to an explosive charge placed in a container in location 13-R in the forward cargo hold.
* The Investigation Commission assert that the most plausible hypothesis is that the explosive charge was inside baggage loaded at Brazzaville Airport.
* Observations made shortly after the accident on Brazzaville Airport made it clear that, at that time, the airport security measures in force were not in accordance with the ICAO standards and recommended practices (Annex 17 to the Convention

on International Civil Aviation and Civil Aviation Security Manual (DOC 8973)).

3. RECOMMENDATIONS

3.1. On 4 October 1989, at the joint proposal of the Niger delegation and the French delegation, the ICAO general assembly adopted resolution A-27-9 about acts of unlawful interference aimed at the destruction of civil aircraft in flight.
After a vigorous condemnation of criminal acts against civil transport aircraft, that resolution:

* urges States to intensify their efforts to implement fully the Standards, Recommended Practices and Procedures related to aviation security developed by ICAO and to take any appropriate additional security measures whenever an increase in the level of threat so requires;
* requests increase of technical, financial and material assistance to States which need it to ensure universal application of these provisions;
* urgently requests States to accelerate studies and research related to security equipment and to the detection of explosives and to take an active part in the development of an international regime for the marking of explosives for detectability.

THE INVESTIGATION COMMISSION RECOMMEND THAT THIS RESOLUTION BY

ICAO GENERAL ASSEMBLY BE PUT IN FORCE ACTIVELY AND FIRMLY BY ALL STATES.

In this respect, the Commission observe that several actions to reinforce passenger and baggage control at Brazzaville Airport have been taken by the Congolese civil aviation authorities, in compliance with ICAO prescriptions.

3.2. Security measures as prescribed by ICAO cannot be fully efficient when a terminal capacity is not adapted to the number of its passengers because of its insufficient dimensions and its internal lay out.

THE INVESTIGATION COMMISSION RECOMMEND THAT SECURITY REQUIREMENTS AND OBJECTIVES BE TAKEN INTO CONSIDERATION AND BE STATED AS HAVING HIGH PRIORITY WHEN DES IGNING OR ENLARGING A TERMINAL USED FOR INTERNATIONAL FLIGHTS.

3.3. Under present current operations, it is not impossible for a passenger checked for a different destination to disembark during a transit stop without drawing anybody's attention.

THE INVESTIGATION COMMISSION RECOMMEND THAT, AT ANY TRANSIT STOP, TEE AIRLINE AT ARRIVAL SYSTEMATICALLY COUNT PASSENGERS WHO DISEMBARK AND THEN, BEFORE DEPARTURE, COUNT ALL PASSENGERS ON BOARD (TRANSIT PASSENGERS TOGETHER WITH NEWLY EMBARKED PASSENGERS) .

3.4. The DC-10 wreckage was located seventeen hours after the accident .

Considering that everything must be done to reduce the time necessary to locate an accident,
Considering also that the international satellite tracking system SARSAT-COSPAS is operational and makes accurate location of an accident possible within a period of a few minutes to four hours at the very maximum,
THE INVESTIGATION COMMISSION:
RECOMMEND THAT AN EMERGENCY LOCATION BEACON AIRCRAFT BE MANDATORY ON BOARD PUBLIC TRANS PORT AIRCRAFT THAT OVERFLY INHOSPITABLE AREAS REGULARLY:
RECOMMEND PERIODIC SEARCH AND RESCUE EXERCISES BETWEEN NEIGHBOURING FIR CENTERS TO CHECK THE COMMUNICATION EQUIPMENT AMID PROCEDURES TEAT HANS IT POSSIBLE TO ACTIVATE THE EMERGENCY PHASES.

4. REPORT APPROVAL

The present report was unanimously approved by the members of the Investigation Commission on 17 September 1990.
The accredited representatives and observers indicated that they also agreed with this report.

APPENDICES

MINISTRY OF PLANNING, HOUSING AND TRANSPORT
Final Rapport
CONCERNING THE ACCIDENT WHICH OCCURRED ON 19 SEPTEMBER 1989 IN THE TENERE DESERT (NIGER) TO DC-10-30 REGISTERED N54629
APPENDICES

APPENDICES

5. Distribution map of the debris.
6. Distribution map of the major parts of the main wreckage.
7. Position of the containers inside forward cargo hold.
8. Reconstruction of the fuselage section - main damage to the pressure hull.
9. Glossary of the abbreviations.
10. Photographic documents

APPENDIX 1

Dc-10 Route

APPENDIX 2

TRANSCRIPTION OF RADIOCOMMUNICATIONS BETWEEN N'DJAMENA AND THE DC- 10

12.00 UT 772 N'Djamena UTA 772
NDJ UTA 772 N'Djamena
UT 772 Yes, we are ready to start-up to Paris.
NDJ Roger, start up, temperature 33, dew point 22, Fox Echo 9. 7.5. and QNH 1010, the 23, report to taxi.
UT 772 Yes, starting up, call you back to taxi UT 772. We'll take the 05 if possible.
NDJ OK for 05, report to taxi.
UT 772 Willdo.
N24RM N'Djamena N 24 RM evelling at 095.

NDJ 124RM report TMA out.
N24RM ....
12.02 UT 772 Last wind for UT 772.
NDJ 220 240 6 to 8 knots.
12.08 UT 772 N'Djamena UT 772 we are ready to taxi.
NDJ 772 taxi mid-taxiway, enter and back track.
UT 772 So, we taxi via mid-taxiway and back track 05.
NDJ OK for 05.
12.10 NDJ 772, clearance.
UT 772 Go ahead Sir.
NDJ Left turn after take-off, initial climb to 280 by BOSSO.
UT 772 Roger left turn after take-off and climb to 280 initially BOSSO UTA 772.
NDJ Correct and report lined up to take-off.
UT 772 I call you lined up.
...
...
12.12 UT 772 N'Djamena UTA 772 to take off.
NDJ 772 Clear to line up and take off 240,6 knots.
UT 772 772 taking off runway 05.
12.16 NDJ UTA 772 take-off at 13 call back for estimates.
UT 772 Roger.
12.17 UT 772 Ready for estimates ?
NDJ Go ahead.
UT 772 Well BOSSO at 12.35 hrs FIR flying out at 13.10 hrs arrival at Paris Charles de Gaulle at 17.19 hrs one seven one nine, we pass level 70 climbing to 280 initially.
NDJ Roger 772 report passing 240 to climb.
UT 772 Affirm report passing 240 to 280.
12.22 UT 772 N'Djamena UTA 772 approaching 240 to 280

FREQUENCY 128.1

12.23 UT 772 N'Djamena Info UT 772 good day approaching 240 to 280 initially.
NDJ UTA 722 good day report 280.
UT 772 Roger. Request higher.
NDJ Yes. Giving you a traffic information, Air Zaire 002 flying from Kinshasa to Brussels is at level 310 and ENBUT point estimated at one two two five at 12.25 hrs, INISA at 12.57 hrs, it is a DC-10, you report approaching 280 for higher.
UT 772 Ok thank you.
NDJ You estimate BOSS at 35 correct?
UT 772 BOSSO at 34.
NDJ 34 Roger. For the time I have no contact, report approaching 280.
UT 772 Roger.
NDJ Zaire 002 N'Djamena
AZR 002 Right N'Djamena we are checking ENBUT at level 310 .
NDJ Roger report INISA.
AZR 002 Read you 002.
NDJ UTA 772 N'Djamena
UT 772 Yes Sir, go ahead
NDJ Report crossing 300 to 350.
UT 772 Roger report crossing 310 to 350.
12.27 NDJ 002 checking ENBUT at 25 to INISA.
UT 772 Roger contact with it. OK report three one zero to three five zero.
AZR 002 Yes, for your information Air Zaire maintaining 310.

NDJ Wilko, thank you.
NDJ UTA 772 N'Djamena
UT 772 Yes I read you.
12.28 NDJ Did you check KANO FIR boundary inbound point?
UT 772 Affirmative.
NDJ At what time ?
UT 772 At 25.
NDJ 25 thank you.
UT 772 UTA 772 crossing 310 to 350.
12.29 NDJ UTA 772 report leveling 350.
UT 772 OK, report 350 steady .
12.32 UT 772 UTA 772 steady level 350 BOSSO within 2 minutes.
NDJ Roger, report passing FIR.
UT 772 Roger.
NDJ UTA 772 N'Djamena
NDJ UTA 772 N'Djamena
12.34 UT 772 N'Dgamena UTA 772
NDJ 772 I request coordinates of the outbound point on FIR boundary N'Djamena
UT 772 Confirm ?
NDJ Coordinate of FIR outbound points.
UT 772 All right, that will be 18.07 north 11.30 east.
NDJ Roger report passing the FIR on 8903.
UT 772 Wilko. Making a relay for you.
NDJ OK, transmit thank you.
UT 772 Well it's S.A.Z. 01 flying Zurich-N'Djamena level 410. Checked TUMMO at 7 and estimates N'Djamena at time 13.42.
NDJ Read well read thank you very much.
NDJ He call me back DIRKOU.

UT 772 DIRKOU ?
UT 772 Sierra Alpha Zulu
N24RM N'Djamena 24 Romeo Mike.
NDJ 24 Romeo Mike N'Djamena.
N24RM 24 RM we'd like descend from flight level 095 to 3,500 feet.
NDJ Roger call maintaining 3,500 feet.
N24RM OK 24 RM.

APPENDIX 3

Curves 1 (208 Kb!)

Curves 2 (195 Kb!)

ANALYSIS OF THE ABNORMAL VALUES (PEAKS) NOTED FOR SOME PARAMETERS OF THE DFDR

A detailed study of the DFDR read-out shows that these peaks were not due to variation of the actual values during the flight but rather to de-synchronisations of the signal during read-out.

1. How a DFDR works

To explain this de-synchronisation phenomenon, it is necessary to review DFDR data acquisition and read-out. Sensors on board the aircraft enable to get various data. The data is transmitted to computers that deduce the value of a number of parameters which are characteristic of the flight.

Those parameters (in analogic form) are then coded, digitised and multiplexed by a job-oriented computer, the Flight Data Acquisition Unit (FDAU) and

transmitted to the recorder itself as a sine wave form signal.
Multiplexing consists in presenting one after the other (in the form of a continuous signal) various parameters which are obtained simultaneously.
As far as the DFDR is concerned, all parameters are given in frame format, each parameter being repeated at the same place (or same "word") in each frame. The frame used by the FDAU of the DFDR is a four-second one, each frame being itself divided into four one-second sub-frames. Each sub-frame must contain 768 bits (0 or 1), i.e. sixty-four 12-bit words, and must begin by a specific word called "synch word".
At DFDR read-out, a series of computers decode the data in the reverse way they were recorded. So, after the signal is read, a computer cut it and convert it into bits and words. Then those words are demultiplexed so as to be finally translated by one more computer into actual values (the flight parameters).
During the demultiplexing operation, there is a verification of the binary signal: the demultiplexing computer searches for all the synch words (as defined above) and verifies that the number of bits between them is correct. If, for any reason, (damaged tape, bad reading, etc...) a synch word is not to be found at the right place, the computer will warn that there was de-synchronisation when that sub-cycle was concerned; in such a case, the conversion of the binary signal into actual values will be altered and the listings and graphics obtained subsequently will show abnormal values. There will be synchronisation again as soon as the computer detects two synch words that define two

consecutive sub-frames, separated by the right number of bits.

2. Analysis of the de-synchronisations

Let (tf) be the last recorded second of the flight; a first de-synchronisation is noted at (tf-14 seconds). A more accurate analysis of the binary signal read at that second makes it clear that 2 bits are missing in the sub-frame (766 instead of 768 bits) and that these bits were lost at the beginning of the sub-frame (starting from the fifth word). All actual values calculated later on are therefore distorted (more than 90% of the data contained in that second are lost).

A second de-synchronisation occurs at times (tf-11s) and (tf-10s). These two seconds are de-synchronised because the computer has not found the synch word which is between the two sub-frames. Nevertheless, the analysis proves that the first 46 words (out of 64) at second (tf-11s) are consistent; so are the last 60 words at second (tf-10s). Therefore something wrong happened between the forty-seventh word of time (tf-11) and the fourth word of time (tf-10).

Finally, a last de-synchronisation occurs at time (tf-5s). During that sub-frame, the computer counted 770 bits (i.e. two additional bits). As early as the sixth word of that frame, there is inconsistent information (one additional bit at that moment). If we make the assumption that it is one bit too many, consistent data is to be found again, through manual calculation, until word '9, and then there are again abnormal values.

In this way we note that, several times along the fourteen seconds before the end of the recording, the binary signal calculated by the DFDR shows alterations

that bring about a translation in actual values that is utterly wrong and in no case representative of the actions of the aircraft at these moments.
Another reading of the DFDR was made with a different tension of the tape on the playback heads. It was then noted that two out of the three de-synchronisations of the tape end had disappeared (those at times tf-14s and tf-5s). The parameters recovered for those two seconds were perfectly consistent with the rest of the flight. De-synchronisations on one listing, partial recovery of consistent data on another ones are the proof, if needed, that these problems are due to the bad condition of the tape.

3 . Explanation of these de-synchronisations

The DFDR recovered after the accident was particularly damaged (impact evidence, rounded sides,etc). When it was opened, BEA specialists noted that the thermal insulation was damaged and, furthermore, that the outer loop of tape was severed, that it showed folds and that is had come out of the roller transport guides. We may suppose that that section of the tape was cut at the ground impact, because it was less protected, and that the tape slackened suddenly and hit mechanical parts (rollers, playback head, etc...) The signal on the tape may have then be damaged; this deterioration of the sinusoidal signal may have led to a defective binary transcription.
This DFDR works in such a way that the last recorded seconds are precisely located between one of the erasing heads and the corresponding far left roller. Between those two points, the tape Ad about 30 cm long. Since the tape recording speed is 0.43 in./s the last

twenty-seven seconds, or so, are on this section.
To investigate that problem, BEA carried out an extensive analysis of the end of the original tape . The use of a detector material on that tape section made the following apparent :

The beginning of the detected blank space precisely corresponds to the end of the flight recording . 5.2 cm before, (i .e . a 4. 7 s. recording), an important folding enables an explanation of the de-synchronisation found at time (tf-5s) on the first listing. Then, 11.1 cm before the end of the flight (i.e. a 10.2s recording),, the tape was cut, which is an indubitable explanation to the de-synchronisation between times (tf-10s) and (tf-11s). Lastly, 15 cm before the end of the flight (13.7s), the fact that the tape was slightly creased also explains the de-synchronisation at time (tf-14s) in the first listing.

APPENDIX 4

Model showing aircraft detachment

APPENDIX 5

Distribution map of the debris

APPENDIX 6

Distribution map of the major parts of main wreckage
(Referenced C Appendix 4)

IDENTIFICATION OF THE MAJOR PARTS OF MAIN WRECKAGE

1 Lower fuselage skin
2 No 3 engine turbine compressor and cowl parts
3 Lower fuselage, fuel components
4 Drip No 9
5 Upside down right wing
6 Drip No 7
7 Engine cowls and pod
8 Slat part
9 Not engine component
10 Not engine drive
11 Fuel indicator
12 Main landing gear part
13 Cowls
14 Gear truck
15 Central landing gear door
16 Fuel tank
17 No 3 engine case and fan
18 Electric generator
19 No 3 engine component
20 Central landing gear door
21 No 1 engine turbine and combustion chamber
22 Wheels
23 Slat part
24 Main landing gear part
25 Gear truck
26 Landing gear box
27 Landing gear part

28 No l engine fan and compressor
29 Left wing tip
30 Upside down left wing
31 Landing gear doors
32 DFDR
33 CVR
34 Part of aft fuselage from cargo hold level
35 Stabilizer component
36 Part of fuselage, tail cone, APU
37 Aft cargo hold floor
38 Stabilizer: central section and left part
39 Hydraulic tank

APPENDIX 7

Position of the containers inside the forward cargo hold

APPENDIX 8

a. Reconstruction of the fuselage section
(Reference B Appendix 4)
b-A. Reconstruction of the fuselage section
(Reference B Appendix 4)
b-B. Reconstruction of the fuselage section
(Reference B Appendix 4)
c-A. Belly aperture
(Reference B Appendix 4)
c-B. Belly aperture
(Reference B Appendix 4)
d-A. Reconstruction of container 7044 RK

(Reference B Appendix 4)
d-B. Location of container 7044 RK floor on cargo hold floor
(Reference B Appendix 4)

APPENDIX 9

GLOSSARY OF THE ABBREVIATIONS

APU Auxiliary Power Unit
BEA Bureau Enquetes-Accidents
CEAT Centre d'essais aÈronautique de Toulouse (Toulouse Aeronautic Test Center).
CSS Certificat de sÈcuritÈ sauvetage (Safety and rescue certificate)
CVR Cockpit Voice Recorder
DFDR Digital Flight Data Recorder
DGAC Direction GÈnÈrale de l'Aviation Civile (Directorate General for Civil Aviation)
DNA Direction de la navigation aÈrienne (Air Navigation Directorate)
FAA Federal Aviation Administration
FDAU Flight Data Acquisition Unit
FIR Flight Information Region
ICAO International Civil Aviation Organization
KSSU KLM-Swissair-SAS-UTA Group
NTSB National Transportation Safety Board
RK Air Afrique designator
SIGMET Significant Meteorological chart
SELCAL Selective Calling
UT UTA designator

UTC Universal Time Coordinated

APPENDIX 10

1. Forward section (Appendix 4, referenced A)
2. Reassembled elements of fragmented section (Appendix 4, referenced B)
3. Main wreckage fire area (Appendix 4, referenced C)
4. Scattered elements Right stabilizer (Appendix 4, referenced D)
4. Scattered elements No.2 engine: air intake central section with fin (Appendix 4, referenced D)
5. Scattered elements No.1 engine air intake (Appendix 4, referenced D)
6. Evidences Metallic impact in wooden box cover
7. Evidences Torn clothes with holes

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