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MINISTRY OF TRANSPORT AND TOURISM

Official Report

OF THE COMMISSION OF INVESTIGATION

INTO THE ACCIDENT ON 20 JANUARY 1992

NEAR MONT SAINTE ODILE (BAS-RHIN)

OF THE AIRBUS A.320 REGISTERED F-GGED

OPERATED BY AIR INTER

FRANCE

MINISTRY OF TRANSPORT AND TOURISM

Commission of Investigation into
the accident on 20 January 1992
of Airbus A320 F-GGED
near Mont Sainte-Odile (Bas-Rhin)

O F F I C I A L   R E P O R T

into the accident
on 20 January 1992 near Mont Sainte-Odile
(Bas-Rhin)
of the AIRBUS A320 registered F-GGED
operated by Air Inter

-:-:-:-

26 November 1993

- CONTENTS -

SECTION 2. - ANALYSIS.

SECTION 3. - CONCLUSION.

SECTION 4. - RECOMMENDATIONS.

APPENDICES

Appendix 0 : Glossary.
Appendix 1 : Location of accident site.
Appendix 2 : Topographical plan of accident site.
Appendix 3 : Sketch showing distribution of wreckage.
Appendix 4 : Sketch showing distribution of sources of fire.
Appendix 5 : Drawing showing distribution of survivors on board.
Appendix 6 : Arrival and approach procedure charts:
- issued by the SIA
- available to the crew.

Appendix 7 : Graphs showing Quick Access Recorder (QAR) parameter extracts.
Appendix 8 : Extracts from Cockpit Voice Recorder (CVR) transcription.
Appendix 9 : Transcription of Air Traffic Control (ATC) radio communications.
Appendix 10: Transcription of the telephonic communication between the Centre Régionale de la Navigation Aérienne Est (Eastern Regional Centre for Air Navigation), and Strasbourg Approach.
Appendix 11: Radar flight path analysis and associated technical note.
Appendix 12: Flight Management Guidance Computer 1 (FMGC1) flight path analysis and synthesised flight path analysis.
Appendix 13: Meteorological records.
Appendix 14: Tree of potential causes of the accident.
Appendix 15: Description of aircraft control and navigation systems.
Appendix 16: Photographs.

NOTICE

This report sets out the technical conclusions reached by the Commission of Investigation concerning the circumstances and causes of this accident.

In accordance with Annex 13 of the Convention relating to international civil aviation, the analysis and safety recommendations drawn up in this report do not aim to apportion blame or to assess individual or collective responsibility. Their sole objective is to derive from this occurrence the lessons necessary to prevent future accidents.

With this in mind, and because doubt must be of ultimate benefit to safety, some of the recommendations proposed concern points which it has so far not been possible to validate categorically or which occasionally have no direct relationship to the causes of the accident.

Moreover, the analysis and recommendations have been drawn up following exhaustive investigation and are therefore based on an experience and understanding of events which may differ substantially from those prevailing at the precise time of the accident.

Finally, although the people and organisations whose opinions were deemed to be relevant were invited to present their observations at the appropriate time, the Investigation was not conducted in an adversarial manner.

As a consequence, the use of this report for any purposes other than for the prevention of accidents could lead to erroneous interpretations.

- SYNOPSIS -

Date of the accident

Monday 20 January 1992
at 18.20 UTC (*)

Aircraft:

AIRBUS A320
Registration F-GGED

Site of accident

Place known as "La Bloss"
Barr Commune (Bas-Rhin)
(near Mont Sainte-Odile)

Owner:

DIA A.I. France LTD
7-2, YAESU 2-CHOME,
CHUO-KU
TOKYO 104 JAPAN

Type of flight

Scheduled flight
Public transport (passengers)

Operator

The company AIR INTER

Persons on board

2 Flight crew
4 Cabin crew
90 passengers

Summary

During a VORTAC approach, carried out at night and in IMC conditions towards runway 05 at Strasbourg-Entzheim, the aircraft crashed into the mountain known as "La Bloss" during its descent towards the runway, at an altitude of approximately 800 metres and a distance of approximately 10.5 nautical miles from the runway threshold.

Consequences

	Injuries			Equipment	Cargo	Third party
	Fatal	Serious	Slight			
Crew	5	1		100% destroyed	100% destroyed	Approx. 1 hectare of forest destroyed
Passengers	82	4	4			

(*) Times referred to in this report are expressed in Universal Time Co-ordinated (UTC). One hour should be added to give French time on the day of the accident.

ORGANISATION OF WORK

1 - COMPOSITION OF THE COMMISSION OF INVESTIGATION

By Arrêtés (Orders) dated 21 and 27 January 1992, the Ministry of Transport and Tourism established a Commission of Investigation to investigate the circumstances, research the causes and determine the lessons to be drawn from the accident of an aircraft of the type Airbus A320 operated by the company Air Inter which occurred on 20 January 1992 within the territory of the Barr Commune (Bas-Rhin).

The Commission comprised the following members:

M. Alain Monnier, ingénieur général de l'aviation civile, Chairman

M. Paul Arslanian, Head, Bureau Enquêtes-Accidents, Vice Chairman

M. Pierre Bernard, technical investigator, Bureau Enquêtes-Accidents

M. Jean-Louis Chatelain, airline pilot, captain

M. Philippe Gourguechon, Pilot Inspector, Organisme du Contrôle en Vol (Flight Inspection Organisation)

M. Michel Guillaume, conseiller d'Etat

Colonel Guy Lagrange, Chief of Staff of the Direction de la circulation aérienne militaire (Military Air Traffic Directorate)

M. Dominique Marbouty, ingénieur général de la météorologie

Professor Henri Marotte, médecin-chef, centre d'essais en vol (Flight Test Centre)

M. Jean Pariès, Deputy, Bureau Enquêtes-Accidents

M. Frédéric Rico, Deputy, navigation aérienne (Air Navigation Department)

M. Alain Tert, Deputy for Technical Affairs, centre d'essais en vol (Flight Test Centre)

Monsieur Jean Pariès, a member of the Commission, acted as Investigator-In-Charge.

In order to apply the provisions of Annex 13 of the convention relating to international civil aviation, Mr. Robert M. MacIntosh, accredited United States representative in the capacity of State manufacturer (engines), was made an official party to the proceedings of the Commission of Investigation.

2 - METHOD OF WORK

From its first meeting held on 27 January 1992 until the submission of its preliminary report on 20 February 1992, the Commission of Investigation worked collectively with a view to undertaking preliminary investigations and to finalising the terms of the first three safety recommendations presented to the Minister along with the preliminary report and reiterated by the Commission in its final report (three meetings were held on 27 January, 10 February and 17 February 1992).

The Commission of Investigation then created ten working groups made up of experts from Government, manufacturers, the Operator and interested trade unions, whose task was to prepare the material contained in Chapter 1 of this report entitled "Factual Information" and, following this, to carry out the investigations required primarily to set up the accident scenario.

The working groups, whose spokesmen were members of the Commission or of the Bureau Enquêtes-Accidents, conducted their investigations in the following areas:

- Crew
- Conduct of the flight
- 4D Flight path analysis
- Survivability
- Propulsion systems
- Airport information and details of approach procedures
- Aircraft systems and frame
- The Operator and the Civil Aviation Authority (DGAC)
- Navigation and flight control systems
- Recording equipment

These groups operated within the framework of a written mandate given to them by the chairman of the Commission of Investigation. They were required to respect an undertaking to maintain strict confidentiality, which each of their members had agreed to sign.

The activities of a number of these groups (navigation and flight control systems, conduct of the flight) were particularly time-consuming in view of the strict and exhaustive methods adopted by the Commission with respect to all the possible causes of this accident, the number of incidents which were reported after the event and which it was necessary to investigate, and the difficulty of tests and simulations which it was necessary to undertake in an attempt to reconstruct the accident scenario. The work of the final two of these groups ended at the beginning of 1993.

As the work progressed, the Commission used the results to prepare Chapter 1 "Factual Information" and the first part of Chapter II "Analysis of the Accident Scenario" (six meetings were held on 30 March, 18 May, 30 July, 8 October, 23 November 1992 and 14 January 1993). The Commission then worked on the analysis presented in Chapter II of the report and prepared Chapter III - Conclusion - and IV - Recommendations - (five meetings were held on 10 February, 17 March, 8 April, 13 May and 3 July 1993).

In accordance with the provisions of Article 6 of the Ministry of Transport Arrêté (Order) of 3 November 1972 concerning Commissions of Investigation into accidents and incidents affecting civil aircraft, the Commission's draft report was circulated on 23 June 1993 to interested companies and authority bodies, as well as trade union organisations representing the flight crew. The following parties were consulted:

- Civil Aviation Authority (DGAC)
- Air Force Headquarters
- Direction de la sécurité civile (and the Préfet of Bas-Rhin)
- Mr. Robert MacIntosh (NTSB)
- Air Inter
- Groupe Air France
- Airbus Industrie
- SNECMA (CFM International)
- Syndicat national des pilotes de ligne (SNPL)
- Union syndicale du personnel navigant technique (USPNT)
- Syndicat des pilotes d'Air Inter (SPIT)

. Syndicat national du personnel navigant de l'aéronautique civile (SNPNAC)
. Syndicat national du personnel navigant commercial (SNPNC)

All the parties consulted replied. The final response was dated 24 September 1993.

The Commission used these responses largely in the context of reports prepared by study groups chosen from among its number. The reports focussed on the following topics which summarised the comments received:

- professional competence of the crew
- performance data and regulation history of the GPWS
- certification of the Autopilot
- ergonomics of the A320 flight deck
- ergonomics certification procedures
- internal relations among the crew
- search and rescue services
- analysis of alternative scenarios
- data specific to Air Inter
- arrangement of supervision
- the feed-back loop
- air traffic and radar guidance procedures

The Commission's discussions with regard to the responses received in the framework of this consultation procedure gave rise to three working meetings which took place on 9 September, 24 September and 13 October 1993. The final version of the report was agreed by the Commission at a two-day session held on 9 and 10 November 1993. Following a further reading and final corrections, this report was approved unanimously and signed by each of the members of the Commission on 26 November 1993.

SECTION 1

FACTUAL INFORMATION

CHAPTER 1.1. - FLIGHT PROGRESS

On 20 January 1992, an Airbus A320 registered F-GGED and operated by the company Air Inter, made the scheduled connection by night between Lyon-Satolas and Strasbourg-Entzheim using the call sign ITF 148 DA. The aircraft took off from Lyon at approx. 17.20 hours with 90 passengers, 2 flight crew members and 4 cabin crew members on board.

No problems were reported by the crew during the course of the flight. The runway in operation at Strasbourg-Entzheim was 05. After listening to the ATIS announcements, the crew planned to carry out an ILS approach procedure for runway 23, followed by visual manoeuvres for a landing on runway 05.

Before transferring the aircraft to Strasbourg Approach Control, the Centre Régional de la Navigation Aérienne (CRNA) Est (Eastern Regional Air Navigation Centre) in Reims cleared it to descend to Flight Level 70 near the ANDLO way point (see Appendix 6).

At 18.09 hours contact was established with Strasbourg Approach Control. While the aircraft was crossing Flight Level 150 in descent its distance to STR VOR was around 22 nautical miles. Strasbourg Control cleared it to continue its descent to an altitude of 5,000 feet QNH, then, after announcing that it had passed ANDLO, cleared it to a VOR-DME approach to runway 05.

However, the altitude and speed of the aircraft were such that the direct approach procedure could no longer be carried out and the crew informed Control of their intention to carry out an ILS Rwy 23 approach procedure followed by visual manoeuvres for runway 05. Control warned them that this choice would mean a delay, as three aircraft were in the process of taking off from runway 05, using an IFR flight plan. The crew then modified their strategy and advised Control that they would carry out a complete VOR-DME procedure for runway 05.

Control then suggested radar guidance to bring them back to ANDLO, thus curtailing the approach procedure. The aircraft was a few seconds away from STR VOR. The crew accepted and carried out the manoeuvres prescribed by the controller: left turn towards heading 230 for an outbound track parallel to the approach axis, then a reciprocal turn towards the ANDLO point.

At 18.19 hours the Controller informed the crew that the aircraft was abeam the ANDLO way point and cleared them to final approach. The aircraft then commenced its descent, approximately at the distance allowed for the approach procedure, i.e. 11 nautical miles from STR VOR. Thirty seconds later the Controller requested the crew to call back passing STR. The crew acknowledged. This was the last contact with the aircraft.

The wreckage was discovered at 22.35 hours, on a slope of Mont "La Bloss" at a topographical level close to 800 metres (2,620 feet), at a distance approximately 0.8 nautical miles (1,500 m) to the left of the approach path and 10.5 nautical miles (19.5 km) from the runway threshold.

CHAPTER 1.2 - KILLED AND INJURED

Injuries	Crew	Passengers
Fatal	5	82
Serious	1	4
Slight		4

CHAPTER 1.3 - AIRCRAFT DAMAGE

The aircraft was completely destroyed.

CHAPTER 1.4 - OTHER DAMAGE

The cargo was completely destroyed. Approximately one hectare of forest was destroyed.

CHAPTER 1.5 - PERSONNEL INFORMATION

Preliminary note:

The Arrêté (Order) of 5 November 1987 defines the crew as the total number of persons on board employed in the service of the aircraft while in flight, i.e. the flight crew and on-board service personnel.

However, with a view to simplifying the text, the Commission has, except where otherwise stated, used the term "crew" in this report in the reduced sense of flight crew.

15.1 - Flight crew

In accordance with the rules governing the operation of the aircraft, the flight crew comprised two pilots, one a captain, the other a co-pilot. On the flight which led to the accident, the flying pilot (PF) was the captain and the co-pilot carried out the duties for which the non-flying pilot (PNF) was responsible.

Note: the concepts of PF and PNF refer to a principle of allocation of duties which is standard practice in airline companies. The PF is responsible for steering the correct flight path and for navigation, the PNF performs configuration changes and manages telecommunications.

15.11 - Captain

Male, aged 42.
Employed by Air Inter since 7 July 1979.

15.111 - Certificates and licences

- Professional Pilot (PP) certificate and licence N° 5009 of 21 September 1973
- Professional Pilot First Class (PP1) certificate and licence N° 3261 of 3 January 1977
- Airline Pilot certificate N° 2967 of 19 June 1985, corresponding licence valid until 30 June 1992.

Last medical examination taken on 10 September 1991 at the centre principal d'expertise médicale du personnel navigant (CPEMPN) (Principal Medical Assessment Centre for Flight Personnel) in Paris. A study of his medical records brought to light no factors likely to have had any bearing on the accident.

15.112 - Ratings

- Instrument Rating (IR) of 26 October 1973
- International Radiotelephony Rating (QRI) of 24 March 1976
- Type Ratings: F27 in September 1979; SE212 in March 1983; A300 in August 1987; A320 on 9 September 1991.

15.113 - Experience

Number of flying hours (time of the flight leading to the accident not included):

- total number of hours: 8,806, of which 162 were on the A320;
- in the last 90 days: 112, all on the A320;
- in the last 30 days: 38, all on the A320;
- in the last 24 hours: 3h 30 mins, all on the A320;

Experience of the Lyon-Strasbourg route and the airport:

Practical experience of the Air Inter network on Fokker F27s and Caravelles, coupled with flights made on A320s, had given this pilot many opportunities to use Strasbourg airport and fly the Lyon-Strasbourg route.

As far as his specific experience on A320s is concerned, the Commission examined an occurrence which this pilot had reported in December 1991. On

4 December 1991, during a level interception in descent, the A320 F-GHQJ which he was flying was in IDLE/OPEN DESCENT MODE, in the interception phase for the altitude selected. From being nominal at first, vertical speed increased to -5,000 ft/min. The pilot then decided to flatten out the descent, overriding the Autopilot, in order to stabilise the aircraft at the permitted altitude. The investigation conducted by the company and the manufacturer offered no explanation for this occurrence. Two hypotheses were offered, based on the influence of windshear, or on the pilot's action in operating the airbrakes.

15.114 - Flying career

Following his PP/IR training, with around 450 hours flying time, he began his career as a professional pilot on light single-engined and twin-engined aircraft in Africa, and acquired experience in this particular environment.

He took his PP1 course from August 1976 to January 1977.

In view of his inexperience in working as a crew member and his limited flying experience under IFR conditions associated with his work in Africa on single-engined and twin-engined aircraft, the pilot, on his own initiative, took a preparatory course for the PP1. Despite this precaution, during the PP1 course he had to undertake additional training. He nevertheless failed in his first attempt to pass the PP1. After a further 5 hours training he obtained his PP1 at the second attempt.

After obtaining his PP1 certificate, this pilot continued to fly in Africa without being able to apply the training he had received in working as a crew member. He returned from Africa in January 1978 and joined Air Inter in June 1979. He was allowed to fly on Fokker F27s in October 1979. He began training on Caravelle SE212s in March 1983. His level of competence was considered satisfactory and his work to be of a good standard during this period of training.

His airline pilot training began in September 1984. After a few early difficulties followed by significant progress he passed the examination at his first attempt.

He continued his career as a co-pilot on A300s from July 1987 until he was raised to the rank of captain.

In 1988 he underwent a very satisfactory training course to become a captain and was allowed to fly as a line captain on SE212s on 9 May 1988.

Following an A320 Type Rating course during which he was assessed to be above the required standard, he became a captain on this aircraft on 8 October 1991.

On 20 December 1989 he received a disciplinary sanction (suspended) for landing in error on a closed runway at Toulouse airport. The record of the case takes into account several extenuating circumstances. This penalty was the only one in a career lasting approximately 19 years.

It is worth noting that during his flying career this pilot needed an amount of training which was often greater than that scheduled in training programmes. Experience acquired in Africa and the limited amount of structured tuition received during his initial training period explain the necessity for certain additional training to bring him up to the required level.

Nevertheless, from the time he obtained his Airline Pilot's Certificate, this pilot consolidated his position and, in the framework of a structured company, his application and professional qualities overcame the gaps in his initial training. He assimilated, late in his professional career, but effectively and with confidence, the various working practices required by flight crews in the area of public transport.

Evidence from his colleagues and his instructors, together with the notes appearing in his professional record, show that the captain was a dedicated professional. They demonstrate that he was a reserved, calm, cautious man who was reluctant to undertake a task before he fully understood what was involved. This careful, cautious, sometimes even perfectionist side to his nature, allied to a certain slowness, would lead him to pay deliberate attention to last-minute changes in flight preparation, an area where he may possibly have felt more vulnerable.

15.115 - Conditions of work

His conditions of work during the month preceding the accident were in accordance with existing regulations.

15.12 - Co-pilot

Male, aged 37.
Employed by Air Inter since 9 March 1990.

15.121 - Certificates and licences

- Professional Pilot (PP) certificate and licence N° 8104 of 1 October 1979
- Professional Pilot First Class (PP1) certificate and licence n° 4592 of 28 July 1987, corresponding licence valid until 30 September 1992.

Last medical examination taken on 25 September 1991 at the centre d'expertise médicale du personnel navigant (CEMPN) (Medical Assessment Centre for Flight Personnel) in Marseille.

15.122 - Ratings

- Private Pilot (Aircraft) Instructor Rating (ITT) of 21 May 1981
- International Radiotelephony Rating (QRI) of 10 September 1980
- Instrument Rating (IR) of 15 September 1980

- Type Ratings: DA01, 7 June 1990; A320, 30 November 1991.

15.123 - Experience

Number of flying hours (time of the flight leading to the accident not included):

- total number of hours: 3,615, of which 61 hours were on A320s;
- in the last 90 days: 61 hours, all on A320s;
- in the last 30 days: 40 hours, all on A320s;
- in the last 24 hours: 1 hour on the A320;

Experience of the Lyon-Strasbourg route and the airport:

Practical experience of the Air Inter network on Mercure aircraft, coupled with flights made on A320s, had given this pilot many opportunities to use Strasbourg airport and fly the Lyon-Strasbourg route.

15.124 - Flying career

The co-pilot was an ardent air enthusiast who began flying at the age of 17 and obtained his Private Pilot's Certificate in February 1974 aged 19. That same year he began a career as a teacher which he was to abandon 12 years later, in 1986. During this entire period he devoted most of his spare time and resources to flying.

He obtained his Professional Pilot's Certificate in 1979 and at that time had built up a total of approximately 300 hours flying time. The following year, he obtained the Instrument Rating after taking a course during the school holidays and, the year after that, obtained the Private Pilot (Aircraft) Instructor Rating. This allowed him to act as a voluntary instructor and acquire 800 hours flying time.

In January 1986 he left his teaching post and was engaged as chief pilot of his flying club. He twice failed the PP1 assessment test. These failures were linked to his
extremely limited experience of flying under IFR conditions between the acquisition of his IR and the time he took these assessment tests. Following considerable private study and practice, which probably required a major effort in view of his limited previous experience (essentially visual flight on single-engined aircraft), he passed this assessment. He obtained his PP1 at the first attempt.

In November 1987 he was engaged by a charter company as an F27 co-pilot and was promoted to captaincy in

June 1988. He joined Air Inter on 8 March 1990. After taking a Type Rating course on Mercure aircraft he was rated on 7 June 1990 and confirmed in his post on 6 December 1990 following three satisfactory checks. He began an A320 Rating course in October 1991, encountering no particular difficulties. He was cleared for line operations on 26 December 1991.

It is worth noting that this pilot experienced no failures from the point in his career when structured training courses enabled him to profit from his capacity for work. At the beginning of his career he was criticised for being too "academic". This can be explained by the fact that his professional and IFR experience was practically non-existent until he obtained his PP1. Once he became established in a structured environment he proved to be an average pilot, with no exceptional abilities or marked shortcomings.

The evidence of his colleagues and his instructors, together with the comments appearing in his professional record, show that the co-pilot was a rather expansive individual, at ease in relationships and well-versed in assessing the abilities of others (resulting from his previous professional experience). He was a good professional, at home in the environment in which he found himself, well adjusted, probably proud of the fact that he had successfully reverted to a flying career. A hard worker, he was relatively confident of his abilities and capable of recognising his shortcomings, being wary of them and compensating for them when required. The evidence of people who had known him since his arrival at Air Inter demonstrates that he was becoming increasingly content in his career as a pilot.

He was a rounded personality, but a man who in certain circumstances could seem a little condescending towards people he felt were slower to understand than himself.

15.125 - Conditions of work

His conditions of work during the month prior to the accident, including the last 48 hours when he had been on leave, were in accordance with the regulations currently in force.

15.13 - <u>Maintenance and checks of competence</u>

In 1990 and 1991 the periodic training and checks which the two pilots were required to undergo were carried out at the correct intervals in accordance with regulations. They resulted in favourable valuations of their level of professional competence: there were no particular grounds on which they were criticised or called into question.

15.14 - <u>Analysis of A320 Crew Ratings</u>

Note: a more detailed description of the Type Rating programmes can be found in para. 17.23.

The A320 Type Rating course followed by the two pilots was preceded by the course entitled "New Aircraft", a course providing information on new technologies used on modern aircraft.

This Type Rating course was consistent with the programme approved by the DGAC. In particular, two conventional approaches were carried out using a simulator. The course led to a satisfactory valuation of the overall competence of the two pilots. Nevertheless, one criticism levelled at the co-pilot was that he intervened too much during the course of the flight. Even if his interruptions were often justified from a technical point of view, his tendency to "mother" the captain excessively was deemed prejudicial to the smooth running of flights.

The Type Rating course was followed by the course entitled "Technical Support".

Familiarisation with A320 line operations was carried out in accordance with the training programme laid down by Air Inter. Specifically, conventional approaches (VOR, VOR-DME, ILS without GLIDE, ADF) were carried out, three for the captain and four in the case of the co-pilot. The overall valuations are indicative of a high level of competence. However, in the judgment of the instructor responsible for line familiarisation, there was one reservation relating to the co-pilot's strictness in carrying out certain procedures.

15.2 - Cabin crew

In accordance with the appropriate regulations, the cabin crew consisted of four persons.

15.21 - <u>Chief Steward</u>

Female, aged 44;
Safety and Rescue Certificate n° 7192 of 19 April 1974
A320 Approval Certificate of 14 December 1991
Last medical taken on 23 May 1991 at the CPEMPN in Paris.

15.22 - <u>Steward</u>

Male, aged 29;
Safety and Rescue Certificate n° 13021 of 17 July 1986
A320 Approval Certificate of 9 January 1989
Last medical taken on 13 January 1992 at the CPEMPN in Paris.

15.23 - <u>Hostess</u>

Female, aged 25;
Safety and Rescue Certificate n° 19937 of 17 September 1990
A320 Approval Certificate of 20 March 1991
Last medical taken on 17 December 1990 at the CPEMPN in Paris.

15.24 - <u>Hostess</u>

Female, aged 27;
Safety and Rescue Certificate n° 14756 of 6 September 1988
A320 Approval Certificate of 16 November 1988
Last medical taken on 17 May 1991 at the CPEMPN in Paris.

15.25 - <u>Maintenance and checks of competence</u>

Periodic training and checks required for cabin crew were undergone in accordance with the regulations in force.

15.3 - Strasbourg Airport Air Traffic Personnel

Approach Control was carried out from the tower, as were Ground Traffic Control and Airport Circuit Traffic Control. Three Controllers were on hand to perform these functions:

15.32 - <u>Approach Controller, Head of Shift</u>

Male, aged 36, military background
Assigned to Strasbourg since September 1985

First assignment: Mont-de-Marsan airport from January 1977 to September 1985

Operational Controller Rating 27 January 1978
Chief Controller Rating 1 January 1981
Rated "Master Controller" in July 1986

15.321 - Training

- at the Ecole Nationale de l'Aviation Civile (ENAC) (National School of Civil Aviation):

. Air Traffic Controller training course from September 1976 to December 1976

. Chief Air Traffic Controller training course from May 1984 to June 1984.

- internal:

. Ongoing specific training.

15.322 - Experience

. 6,146 hours at post in the tower
. 19,583 aircraft approach movements handled, around 6,500 of which were of civil aircraft.

15.323 - Professional duties in the week preceding the accident

. present for nine hours on 14 January 1992
. present for thirteen hours on 16 January 1992
. present for eight hours twenty minutes on the day and at the time of the accident
. responsibilities held in the hour prior to the the accident: Approach Controller and Head of Shift.

15.324 - Medical fitness

. Last medical examination at the CEMPN in Metz on 27 June 1991
. Passed fit for 2 years.

15.33 - The Tower Controller

Male, aged 25, military background
On his first assignment in Strasbourg, from September 1986
Chief Controller Rating 1 December 1990.

15.331 - Training

. Mont-de-Marsan School of Military Controllers from March 1986 to September 1986
. Ongoing specific training.

15.332 - Experience

. 5,063 hours at post in the tower
. 3,300 aircraft approach movements handled, around 1,400 of which were of civil aircraft.

15.333 - Professional duties in the week preceding the accident

. Present for nine hours on 14 January 1992
. Present for nine hours on 16 January 1992
. Present for ten hours twenty minutes on the day and at the time of the accident
. Responsibilities held in the hour prior to the accident: Tower Controller.

15.334 - Medical fitness

. Last medical examination at the CEMPN in Metz on 15 October 1991
. Passed fit for 2 years.

15.34 - <u>Ground Controller</u>

Male, aged 24, military background
On his first assignment in Strasbourg, from February 1989
Rated Operational Controller since October 1989.

15.341 - Training

. Mont-de-Marsan School of Military Controllers from September 1988 to February 1989
. Ongoing specific training.

15.342 - Experience

. 1,800 hours at post in the tower
. 869 approach movements handled, of which around 300 were of civil aircraft
. 1,019 final approach movements handled, together with 339 ILS approach surveillances.

15.343 - Professional duties in the week preceding the accident

. Present for nine hours on 14 January 1992
. Present for nine hours on 16 January 1992
. Present for ten hours twenty minutes on the day and at the time of the accident
. Responsibilities held in the hour prior to the accident: Ground Controller.

15.344 - Medical fitness

. Last medical examination at the CEMPN in Metz on 15 January 1992
. Passed fit for 2 years.

<u>CHAPTER 1.6 - AIRCRAFT INFORMATION</u>

16.1 - Airframe

- Manufacturer : AIRBUS INDUSTRIE
- Type : A320-111
- Serial number : 015
- Registration : F-GGED
- Certificate of registration: B20275 of 23 December 1988
- Utilisation:
  . since manufacture: 6,316 hours, 7,194 cycles
  . since last complete overhaul on 12 October 1991: 521 hours

16.2 - Engines

- Manufacturer: engines manufactured by General Electric in collaboration with SNECMA and marketed by their joint company CFMI

- Type: CFM56-5-A1
- Serial numbers:
  . left : 731 123
  . right: 731 132

- Hours run and operating cycles at the time of the accident:
  . left : 4,448 hours 5,129 cycles
  . right: 5,412 hours 6,229 cycles

- Hours run and operating cycles since being installed on F-GGED:
  . left (26 July 1991): 869 hours, 1,023 cycles.
  . right (10 May 1990): 3,433 hours, 3,877 cycles.

16.3 - Equipment

An examination of the documentation relating to the aircraft equipment did not show evidence of any discrepancy with respect to French regulations applicable to aircraft used for public transport.

In common with the other A320s operated by Air Inter on the date of the accident, the aircraft was not equipped with GPWS. French regulations did not impose a requirement for this equipment to be carried.

The aircraft was equipped with a Head Up Display (HUD) for the left seat.

The aircraft was linked to the company by the ACARS system (Aircraft Communication Addressing and Reporting System) which allows the transmission and reception of data by VHF link. This system enables the aircraft to be informed of weather conditions, for example, and permits the exchange of information relative to the maintenance of the aircraft or its subsystems. The ACARS messages recorded by Air Inter involving F-GGED on the day of the accident were examined. None of these messages gives cause to suspect a fault.

A description of the A320's control and navigation systems is given in Appendix 15.

16.4 - Certification

Certificate of Airworthiness n° 109620 was issued on 22 December 1988. On 22 October 1991 it was validated until 22 December 1994.

16.5 - Maintenance

Maintenance was undertaken by Air Inter.

The last routine maintenance inspection (Type A) was carried out on 12 December 1991.

The pre-flight inspection was carried out on the morning of 20 January before the departure leg of the round trip.

The document entitled "Technical Log" consists of five items: "Land" condition, tolerances, open or postponed technical items, technical occurrences on the last five flights and specificities.

It was noted that the "Land" condition was operational, that there was no tolerance, that the technical events reported bore no relation to the circumstances of the accident and that the item "specificities" showed that a modified FCU had been installed (see para. 117.22).

The investigators then proceeded to examine the maintenance documents in detail. The outcome of this examination is set out as required in paras. 117.2 and 117.3.

16.6 - Mass and load distribution

At the time of the accident, the aircraft had an approximate mass of 52.5 tonnes and a load distribution of 28.5%. During the entire flight it had stayed within the limits for mass and load distribution.

The aircraft had taken off with an on-board weight of fuel of approximately 5,700 kg.

CHAPTER 1.7 - INFORMATION RELATIVE TO THE OPERATOR AND THE CIVIL AVIATION AUTHORITIES

17.1 - The company Air Inter

17.11 - Brief overview

17.111 - The company Air Inter was founded in 1954. It is a limited company (S.A.) whose principal shareholders are public bodies. It has been part of the Air France group since 22 January 1990. Nevertheless, it has maintained its own structures and original aims within the framework of the group. Its objective is to service the main internal French routes with a specific product, characterised by a policy of low fares (cost per kilometre around 40% lower than the average price charged on French and European routes), based on operating costs reduced by the use of Jumbo jets on many routes, high-density accommodation and simplified in-flight service.

Since 1981 this product has experienced growing competition from high-speed trains (TGV's) and, to a lesser extent, from the liberalisation currently taking place in Community air transport. Despite this, from 1985 to 1990 growth in Air Inter's business was marked (+ 54.4%). In 1990 it was interrupted as a result of the air transport crisis which affected companies across the board. Although the accounts of Air Inter had been in profit since 1975, the company recorded net losses in 1990 and 1991. However, its position remains satisfactory from the point of view of the criteria normally used to assess the financial position of airline companies in France.

17.112 - Air Inter operates 61 domestic scheduled routes and 7 international scheduled routes which, however, represent only 2% of its business. On 1 February 1992 its fleet was made up of 22 AIRBUS A300s, 28 AIRBUS A320s and 8 DASSAULT Mercure aircraft. In 1990, Air Inter carried the third highest total number of passengers of any European airline (16.2 million). In terms of passenger-kilometres flown within Europe it was placed fifth (8.9 billion). Air Inter employed 10,900 people, including 934 flight crew and 2,000 cabin crew.

17.12 - Special characteristics

17.121 - The peculiar nature of its network confers special characteristics on Air Inter's operations. Route stages are short and consequently flight times are reduced. If European journeys are ignored, the average route stage distance is 270 nautical miles, and the average flight time between take-off and landing 40 minutes. Such short flight times make it very difficult to compensate for delays. Turnround times are relatively limited in comparison with European conditions of operation. The shortest periods which can be programmed for A320 turnrounds are 50 minutes (45 minutes in the provinces). Nevertheless, the organisation of turnrounds is built around rapid loading times, added to which the resources made available to ground staff and on-board personnel (third MCDU, ACARS, radio telephones, cockpit refuelling management system) speed up operations in case of technical problems.

17.122 - Businessmen, their main clientele, are extremely sensitive when it comes to the punctuality and regularity of flights, the more so as the short duration of these flights exacerbates the subjective effect of a delay. Adherence to timetables is perceived as being of prime importance in the culture of the company and forms a crucial part of operational organisation. The company culture places high value on the optimisation of flight times, while at the same time following a policy of flight profiles with minimum operational cost. In the case of the A320 this manifests itself in the form of the adoption of a fairly low "cost index". Crews are made aware of the added fuel costs brought about by using Mach numbers or flight levels which deviate from the optimum. Reductions in flight times are therefore achieved by seeking ways to minimise route and arrival procedures and as a result of rapid descents and arrivals likely to secure gains in landing priority. This culture relies on crews having an excellent experience of the network (very high number of repeat flights), the fact that great stress is laid on skill and training, and experience of an aircraft with exceptional speed resorbtion characteristics (the DA01 Mercure) which has induced a certain spirit of rivalry amongst the various airline sectors.

This culture has spread beyond the confines of the company: it is recognised elsewhere, especially by Air Traffic Controllers who, when they are dealing with Air Inter aircraft, expect procedures to be speeded up and occasionally make suggestions to this effect.

In practice, as far as the A320 sector is concerned, 85% of flights are made with less than a 15 minute delay. In 1989 and 1990, Air Inter received the award from Airbus Industrie for the best operational performance of the A320, which endorses its technical reliability.

17.2 - The operation of the A320 at Air Inter

17.21 - Background relative to the entry into service of the A320

17.211 - The first A320 was delivered to Air Inter on 17 June 1988 and put into service on 23 June 1988. Ten other aircraft were delivered between 17 June 1988 and 30 October 1989, and 18 others between October 1990 and February 1992. In Air Inter's case, the most recent entry into service of a new aircraft was in 1974 (Airbus A300). In addition, the A320 was perceived by senior management as an aircraft which was very innovative but at the same time not yet fully developed, particularly in view of the many different types of software on board. The introduction of the A320 was thus perceived by those in positions of responsibility at the company as a difficult operation justifying special measures (see para. 17.22).

17.212 - The social climate surrounding the entry into line service of the A320 at Air Inter was especially problematic. A prolonged dispute involving the workforce, accompanied by considerable enlightening by the media at national level and including repeated strikes by some flight crew personnel, was sparked off by the arrival of the aircraft. Essentially, this followed the decision to operate it using a two-pilot crew. There was a highly-charged atmosphere at the company, and the pilots who had agreed to be part of the team responsible for getting the aircraft ready for operation ("the A team") ran up against serious hostility.

17.213 - The A team pilots took their Type Rating course at Aéroformation, an Airbus Industrie subsidiary set up for crew training, in January 1988.
Subsequent crews continued to be instructed at Aéroformation until June 1989, the date on which Air Inter assumed responsibility for its own instruction .

17.214 - Until January 1991, all the crews beginning an A320 Type Rating course had the choice of whether or not to move on to the A320. They came from the following areas:- A300, Mercure or Caravelle 212. From that date the progressive elimination of the Caravelle sector and the ending of Rating courses on the A300 and Mercure removed pilots' choice in the matter, and assignment to the A320 sector was no longer carried out on a purely voluntary basis.

17.22 - <u>The structure specific to the A320</u>

17.221 - From an aircraft operating standpoint, on 20 January 1992 the company Air Inter was structured in the following way: a Technical and Operational Affairs Directorate was made up of an Operations Department (as well as being responsible for air operations, the Operations Manager is also in charge of flight crew personnel), an Engineering and Equipment Department (responsible for the technical supervision and maintenance of aircraft), and a Transport Department (responsible for the management of the network).

17.222 - The Operations Department was composed of three Divisions: the Flight Crew Division, the Cabin Crew Division and the Engineering Division. The Flight Crew Division included the Flight Crew Training Centre (CIPN), the Flight Crew Flight Centre and the Technical Centre. The CIPN and the Flight Crew Flight Centre were divided into sectors according to type of aircraft, and each therefore included a sector specific to the A320. The Technical Centre was responsible for dealing with incidents and accidents affecting any of the company's aircraft. In particular it had at its disposal an FDR readout service required under French regulations for two-pilot crew operation.

17.223 - The Engineering and Equipment Department itself also included a sector specific to the A320, where the entire workforce specialised in the A320 and handled no other type of aircraft. This sector communicated with the flight sectors via weekly and monthly meetings.

17.23 - <u>Crew selection and training</u>

17.231 - There is no special internal selection process to appoint those pilots who will move on to A320s. They are appointed first of all on a voluntary basis, then on the basis of necessity dictated by fleet conversions.

On the date of the accident the A320 conversion programme for pilots already flying for the company included the following main stages:

17.232 - a specific technical course entitled STAN (Technical Course for New Aircraft)

This preparatory course is intended to broaden and standardise the technical knowledge of ground crews and staff in relation to recent technological developments (modern avionics, airborne computers and digital automatic equipment, electrical flight controls) and their use (flight path and flight management, operation and control of automatic equipment). This course aims to make it easier to acquire technical skills on the aircraft by providing a better understanding of how it operates. At the same time it attempts to instill sufficient confidence to enable trainees to undergo an initial training course: specific innovations are justified and demystified at the same time. This course lasted for seven days.

17.233 - a Type Rating course proper

This course takes place in four main stages: the study of aircraft systems; the study of normal and emergency procedures; the study of limitations, special procedures and performance data, and of aspects of safety and rescue; simulator "flight" sessions using a Full Flight Simulator (FFS).

The first stage (study of aircraft systems) is carried out in standard crews and lasts for 11 days. It comprises 38 hours of computer-aided instruction (CAI) and uses a set consisting of a full-scale photographic model of a cockpit. The study of each system is followed by a debriefing (17 hours in total) carried out by a Ground Instructor who is an expert in the system. This debriefing enables important aspects to be pointed out and makes it possible to monitor the level of knowledge acquired which, incidentally, is not subject to a formal test. Simulator sessions (a total of 23 hours on a Fixed Base Simulator (FBS)) allow use of the command and control procedures corresponding to each system.

The second stage (study of normal, abnormal and emergency procedures) lasts for six days. It begins with a general briefing on the allocation of duties among
pilots, the use of call/response checklists

and a study of the phraseology specific to the aircraft. Then the procedures are performed on a simulator (FBS) with the help of Ground Instructors. Nine hours are devoted to normal procedures, the same amount of time to abnormal and emergency procedures.

At the end of these two stages, the instructor carries out an evaluation of the knowledge and skills acquired. He then supervises the trainee during the last stage, i.e. the "flight" on the FFS. This evaluation lasts for three hours.

The third stage consists of two days of classroom lessons on the subjects of limitations, special procedures, and twin-engine and single-engine performance data relative to the aircraft. These lessons are given by a qualified instructor. This stage ends with a day devoted to safety and rescue aspects.

The fourth stage is open to trainees who have satisfactorily completed the evaluation on the FBS. It consists of 7 sessions of 4 "flying" hours on the FFS, carried out in standard crews under the direction of an airline training captain, preceded by a 2 hour classroom briefing and followed by a debriefing lasting 1 hour. These sessions deal with basic flying, selecting and managing Autopilot. They look at devices protecting the flight envelope, mode reversions, control laws. LOFT (Line Oriented Flight Training) sessions then cover different types of system failure and emergency situations. Each arrival forms the subject of a different type of letdown (VOR, ADF, LOC, CATI, auto-approaches).

Following these seven FFS sessions, a test session lasting 4 hours is undertaken. It includes a commercial flight that has to be prepared in every detail, during which the crew has to deal with various types of problems and failures. A VOR approach is required for this test.

The fourth stage is completed by a 2 hour session devoted to additional training involving non-conventional take-offs (take-offs with reduced visibility minimums and the use of instrument guidance for tracking) and to auto-approaches.

In the context of this Type Rating course, VOR letdowns are dealt with from the third session onwards. A
special lesson is given by the instructor with the aid of a synoptic diagram showing a conventional approach contained in the Operations Manual, and with the aid of a
specific chart including the vertical profile and photographs of the Navigation Display of each pilot. This special lesson is designed to require the use of the TRK/FPA reference and stresses the importance of the following points: track, speed, regime and aircraft configuration stabilised 1 NM before the descent point (however, FULL flaps configuration, if required, is recommended at 0.5 NM from the descent point - in this case, stabilisation is scarcely possible before the descent); the calculation of estimated vertical speed in relation to wind, and descent updating using DME distances; the announcing of speed deviations, vertical speed and height; the announcing of MDH +200 and MDH +100. Three VOR approaches and one NDB approach are carried out in crew teams during this fourth stage, which means that each of the two pilots is at the controls for two conventional approaches.

17.234 - an off-line handling flight

If the FFS test session is satisfactory, the trainee undertakes a handling flight on the aircraft lasting approximately 45 minutes. This flight forms part of the programme approved by the DGAC (SFACT after advice from the OCV), which has laid down that certain exercises should be included in this flight programme for this aircraft type. Once this flight has been completed the trainee is issued with his A320 Type Rating.

17.235 - a first "technical support" module

This module, which lasts 4 days, is given immediately after the handling flight. Its objective is to deepen trainees' knowledge of systems, structures and procedures associated with maintenance (CFDS, ACARS, practical use of MEL, external pre-flight inspection, knowledge of the various intervenors from the A320 Engineering and Equipment Department), and to examine regulations applicable to precision approaches.

17.236 - line familiarisation flights with an instructor

At the end of the first technical support module, trainees begin line familiarisation, i.e. they carry out commercial flights in their specific role (captain or co-pilot), but accompanied by a Line Training Captain belonging to the Training sector. The number of flights (stages) included in this familiarisation programme depends on the background of the trainee. The first familiarisation programmes on A320s comprised 5 flights of 4 stages. The sixth is the test flight before pilots are allowed to fly commercially. It is carried out by a Line Training Captain attached to the Flying sector.

From mid-1991, as a result of experience gathered from problems already encountered, and following the arrival of a group of pilots who were less motivated and more reticent regarding the change (they were primarily from the Caravelle 212 sector which was being phased out), the length of the line familiarisation programme was extended to 7 flights of 4 stages, the eighth being the test flight before commercial flying was allowed. If he considers the trainee to be insufficiently prepared, the instructor has the option of requiring him to carry out one or several additional flights.

The company's Line Familiarisation Manual recommends carrying out a conventional approach when conditions (weather, air traffic) permit.

17.237 - a second "technical support" module

The objective of this module, which takes place 30 days after the final flight test, is to enable pilots, once they have gained a certain level of personal experience on the aircraft, to continue studying its main systems, some simple operations carried out on turnrounds, and the use of the MEL. This module lasts for 4 days, and includes an FFS session lasting two hours in standard crews, during which there is a test to determine ability to perform non-conventional take-offs and CatII and CatIII precision approaches (including the use of the HUD for captains).

17.24 - Maintenance and checks of competence

The statutory requirements regarding maintenance and checks of competence are as follows: an annual training session to maintain skill levels, an annual test carried out during a commercial flight covering knowledge of and adherence to the Operations Manual, and an annual test carried out in off-line conditions involving Type Rating exercises.

Air Inter has amalgamated the skills maintenance training session and the test carried out in off-line conditions into a single module. This course is entitled "Performance Skills". It is taken once a year. The programme for this course was approved by the DGAC. The objective of the course is to update pilots' knowledge of the A320 along with their ability to handle tasks assigned to them in a crew environment. Above all it provides an opportunity to evaluate incidents which have actually occurred in the course of operation, and to update particular procedures, and abnormal or emergency procedures.

The course lasts for three days. The first is devoted to classroom lessons and the two subsequent days to the simulator: 2 sessions of 4 hours each, preceded by a briefing lasting 2 hours. The first session consists of a LOFT type "flight". The second is devoted to the annual off-line test, carried out on an approved simulator (FFS) in the presence of an Line Training Captain from the company, which covers statutory Type Rating exercises.

17.25 - Factors relating to the line operation of the A320 at Air Inter

17.251 - Crew pairing

On the date of the accident, management of the composition of crews at Air Inter, as in the majority of companies, did not take systematic account of the experience of pilots on a particular aircraft type.

To handle the increase in staff levels and the spiralling number of flight scheduling changes, the company developed a computer tool to aid in the management of flight crews (the AIGLE system). The first applications of this tool, which did not take into account the experience of pilots on a particular aircraft type, were put into operation for flight crews in June 1991.

17.252 - The handling of incidents

French regulations place an obligation on the captain, a member of the crew, or a representative of the owner or the operator of any civil aircraft, to report immediately any incidents which put air safety at risk. As far as serious incidents affecting public transport aircraft are concerned, the captain is required to draw up a report detailing all the circumstances within 48 hours.

The internal organisational structure at Air Inter vests responsibility for handling incidents affecting fleet aircraft in the Technical Centre. The Technical Centre sets up the incident file and takes care of relations with the appropriate government authorities (Bureau Enquêtes Accidents). Two groups of permanent operational staff are set up, one within the Operations Department and the other within the Engineering and Equipment Department, to take charge of events as they happen.

On the date of the accident, however, Air Inter had no specific organisational structure exclusively dedicated to flight safety (e.g: Flight Safety Officer). Notwithstanding this, a flight safety bulletin, including analyses of incidents or accidents, was issued by the Technical Centre.

Practically all operators show a certain reticence to release to the outside world information on incidents they encounter. The tense working atmosphere in which the entry into service of the A320 took place at Air Inter sometimes led to political use being made of incidents which occurred, a situation which reinforced the reticence alluded to above. As a consequence, the dissemination of information to crews, the manufacturer or the civil aviation authorities remained limited. Thus it can be seen that the operating report which Air Inter supplied to the authorities at the end of its first year of operation, in line with a statutory obligation regarding two-pilot crews, makes no mention of any particular operating difficulties, whereas that submitted by Air France points to a "very high" level of technical incidents and provides a full list.

17.253 - Systematic flight analysis program

French regulations make the granting of a licence to operate an aircraft of over 40 tonnes with a two-pilot crew subject to the installation of a systematic flight analysis program using flight parameter recording and flight documents. On the date of the accident, at Air Inter this responsibility was vested in a Flight Analysis Sector, attached to the Technical Centre and thus to the Directorate of Air Operations. This unit performs a computer analysis of the QAR recorder on all A320 flights. Automatic analysis shows up any parameters whose readings exceed a pre-defined threshold or range. The "anomaly" thus detected is then validated manually.

The list of parameters taken into account focusses on flight path monitoring. Contrary to procedure in other airlines, the company agreement does not make provision for flights which have given rise to the detection of major anomalies to be subject to specific and detailed operational analysis, which may include an interview with the crew concerned. Nevertheless such an analysis is possible when the anomaly has been reported by the crew themselves, and only in this case following their written authorisation. A special investigation, possibly including an interview with the crew involved, can then be undertaken. With these exceptions, anomalies detected are thus only subject to general statistical analysis.

The results of systematic flight analysis are circulated internally within the company for the benefit of the Flight Sectors and the Head of Flight Crew Personnel. They are also incorporated in a monthly statistical report. A restrictive interpretation of the company agreement and its provisions concerning respect for anonymity led to a situation in which the information gathered from systematic flight analysis was not being disseminated to the manufacturer, the civil aviation authorities or the Bureau Enquêtes Accidents.

17.3 - The exercise of State supervision

17.31 - <u>Administrative structure</u>

The Civil Aviation Authority exercises supervision over Air Inter through two of its departments:

- The Service de la Formation Aéronautique et du Contrôle Technique (Aeronautical Training and Technical Inspection Department) (SFACT) is the responsible administrative authority. It lays down the regulations applicable to all types of air operation in the public transport sector, specifies particular conditions relevant to their application, issues licences and corresponding approvals and monitors their operation, except in the area of the professional competence of crews.

- The Organisme du Contrôle en Vol (Flight Inspection Organisation) (OCV) carries out inspections of flight crews, either with or without notice, via spot-checks or during special inspections in which it takes part at the request of SFACT. In addition, it is a consultative body responsible for giving opinions and advice to all the departments of the DGAC, particularly to SFACT on questions of operational procedure.

17.32 - <u>The statutory background and its application</u>

The central regulation applicable to all French companies operating in the public transport field is the Arrêté (Order) of 5 November 1987 and its subsequent amendments. This text covers the regulation domain referred to by ICAO Annex 6. It deviates from the provisions of this Annex on the following point: it does not impose a requirement to carry a Ground Proximity Warning System (GPWS). This point is dealt with in more detail in paragraph 1.18.3. This regulation finally includes Arrêtés (Orders) and instructions governing the competence of crews; the issuing of certificates and licences; and Type Rating programmes.

In accordance with this regulation, the Minister responsible for Civil Aviation has granted Air Inter general licences for public transport operation.

17.321 - A licence to operate the A320 using a two-pilot crew was granted on 21 June 1988 in line with the requirements of the Arrêté (Order) of 5 November 1987. Following advice from the OCV, SFACT approved the Type Rating programme, approved the crew training methods and agreed the simulators used for flight training on the Type Rating programme and for the annual off-line test of competency.

17.322 - The process of approving instructors responsible for testing competency took a long time to implement. This procedure requires the company to forward to SFACT the files of instructor candidates for which it is requesting approval. SFACT then evaluates these files according to criteria laid down in the texts of the regulations and relies on the advice of the OCV before granting approvals or not, as the case may be.

The Air Inter company agreement provides for the appointment of instructors according to seniority and for a non-renewable period of four years. These provisions lead to a relatively rapid turnround of instructors and as a result necessitate continuing follow-up work on a considerable number of candidate files to ensure that approvals are issued. Since Air Inter viewed this procedure as being purely formal, it did not submit any files to SFACT before October 1991.

No instructors were therefore officially approved for periodic checks of competence between 1988 and 1992 (compliance with the Arrêté (Order) of 5/11/87 would have involved granting these approvals before 30/11/88).

17.323 - There are no other anomalies to be noted. On the date of the accident no derogations from the regulatory provisions had been granted to Air Inter as far as the aircraft F-GGED and its crew were concerned.

17.324 - In accordance with the Arrêté (Order) of 5 November 1987, the A320 operating procedures used by Air Inter did not form the subject of an official approval but of a description in the Operations Manual. The "operations" section of this manual had been presented to SFACT and the OCV as early as March 1988 and had required a significant amount of updating until June 1988, giving rise to numerous joint meetings between SFACT, OCV and Air Inter. The final agreed version of the manual was lodged with SFACT on 2 June 1988. After that date SFACT passed no further comment on it.

17.325 - Regulations concerning the execution of instrument approach and take-off procedures, in particular those relative to precision procedures, were applied in the normal way at Air Inter. On this basis the company received procedural licences and instructor approvals for precision approaches.

17.326 - With respect to aircraft maintenance, the regulation applicable to any company carrying out maintenance on aircraft used for public transport is the Arrêté (Order) of 8 December 1975. This Arrêté was applied in the normal way at Air Inter: the introduction of maintenance on the A320 led to changes in maintenance specifications which were submitted to SFACT and approved. In applying this Arrêté Air Inter received approvals and licences covering its entire range of maintenance activities on the A320.

17.33 - <u>The conduct of supervision</u>

17.331 - Inspections associated with the granting of the two-pilot crew licence

The regulations applicable (Arrêté (Order) of 20 August 1956, coupled with the Arrêté of 5 November 1987) require that a specific survey be undertaken by SFACT and the OCV whenever an aircraft of over 40 tonnes with a two-pilot crew is put into operation. This survey covers the resources available (flight crew, ground crew; composition and organisational structures of senior management; equipment resources; documentation; Operations Manual). It includes checks by the OCV on the training of flight crews as they are being instructed and during their first line flights, as well as checks on the application of the Operations Manual, performed jointly by SFACT and the OCV.

In this regard, in May 1988 four crews were observed on the simulator by a Pilot Inspector of the OCV who is rated for the A320 (Aéroformation course) as well as being an A300 captain at Air Inter. In August 1988 another Pilot Inspector from the OCV, a captain with another airline, carried out two line flights as part of the "two-pilot crew" survey: one with an Air Inter executive, a pilot with the A team, and the other with a Captain Instructor.

It is appropriate at this point to note that at the end of 1988, during the period when Air Inter were perfecting their own training programme, the Pilot Inspector who was a captain on A300s at Air Inter took a complete Air Inter A320 Type Rating course as a recurrent training on A320s and to get familiarised with Air Inter procedures (cf. para. 17.23).

In addition, during the summer of 1988, SFACT carried out a series of operating checks, both on the ground and in flight (approximately 30 stages) to examine the adequacy of the procedures laid down by Air Inter and how they were being applied.

The decision to authorise the operation of the A320 with a two-pilot crew was matched with a request to Air Inter to draw up an operating report one year after the aircraft had gone into commercial service. This is a regular request.

The DGAC has not laid down any special

demands or expressed any criticisms when examining documents from the report drawn up by Air Inter (cf. para. 17.252.3).

17.332 - Normal inspections

17.332.1 - At the end of the validation period alluded to in the previous paragraph, inspection of Air Inter's methods of operation was incorporated within the normal framework laid down by the Code of Civil Aviation and the Arrêté (Order) of 20 August 1956 coupled with that of 5 November 1987. Their main provisions are:

- the possibility of general or sector-based inspections of the company carried out jointly by SFACT and the OCV;

- verification by SFACT and the OCV of operating methods, and by the OCV of the level of professional competence of crews;

- ground and in-flight inspection of the adequacy of the operating procedures laid down by the company and how they are being applied;

17.332.2 - Air Inter has never been the subject of a general inspection. The last sector-based inspection, concentrating on the system for maintaining the levels of competence of flight crews, and carried out in the context of a national study on the subject, dates back to 1984. This situation is not unique to Air Inter: in practice, very few general inspections of large French companies have been carried out by the supervisory authorities.

17.332.3 - As far as the professional capabilities of crews are concerned, the regulations lay down that these should be specified and checked by the Operator itself at the end of the Type Rating and line familiarisation stages, and during the regulation annual inspections. The effectiveness of this inspection procedure by the Operator itself is in principle, but not always, subject to spot checks by means of OCV flight inspections. In fact, the OCV did not carry out any formal inspections on the A320 at Air Inter between the end of 1988 and the date of the accident (three inspections were carried out, but on other aircraft in the fleet).

However, two sources can be considered likely to have provided the OCV with information on the professional capabilities of Air Inter's crews:

- the first source is the practical flight tests taken as part of the Airline Pilot Certificate, which emanate from the Examining Board chaired by the Head of the OCV. These flight tests are indicative not only of the level of candidates and of their standard of exam preparation, but also of their adherence to operating procedures laid down in the Operations Manual. The results of Air Inter candidates have been similar to results achieved on a national scale.

- in addition, a Pilot Inspector who is a member of the OCV was one of the complement of A320 captains at Air Inter. These twin responsibilities enabled him to experience the daily practicalities of A320 operation on a regular basis. Indeed, he was able to assess the conduct of co-pilots flying as part of his crew at first hand. This conduct did not give rise to any particular criticism on his part, either as far as their crew work or announcements were concerned. This source did not enable the OCV to gather information on the professional level of A320 captains.

17.332.4 - When it came to verifying the adequacy of the company's operating procedures and the way they were being applied, SFACT encountered a number of difficulties:

On the one hand the DGAC has formed a unit of turnround inspectors called Contrôleurs Techniques d'Exploitation (CTE) (Technical Operations Inspectors), whose inspections only cover the condition of the aircraft and its components and the availability of documents required, including flight planning and flight records. The high rate of Air Inter turnrounds at French airports had given rise to a large increase in the number of these inspections, which were often seen as being "interfering". Changes have been made in the way they are carried out so that Air Inter is not subjected to them any more than other airlines.

On the other hand, SFACT has a general power of inspection by authority of the Minister concerned. Accordingly, its agents can carry out any inspections required within the framework of the department's duties. The result is that as soon as a SFACT flight deck inspection is carried out during a flight, all the flight crew contest it. This situation has been the subject of very strict union instructions, leading to a refusal to allow on board any inspectors who are not qualified flight crew personnel to a level at least equal to that of captain. Air Inter flight crews have always stood particularly firm on this point. The consequence has been that SFACT has not been in a position to carry out any operational flight inspections at Air Inter since 1989.

CHAPTER 1.8 - WEATHER INFORMATION

The description of general conditions at altitude and at ground level is based on the network reports of 20 January at 12.00 hours and of 21 January at 00.00 hours. The weather conditions shown refer to the network reports of the 20th at 18.00 hours and 21.00 hours and of the 21st at 00.00 hours and 03.00 hours respectively.

18.1 - General situation

18.11 - Situation at altitude

At altitude, at 500 Hpa and 700 Hpa, the situation was characterised by a fairly strong northeasterly air flow (40 to 50 knots) circulating between an Atlantic ridge - at its height over the British Isles and the North Sea - and a thalweg running from the Ukraine to the Gulf of Lions.

In the lowest layers of the free atmosphere, between 800 Hpa and 900 Hpa, the flow switched to an easterly direction and became moderate (20 to 30 knots).

Above the Rhine plain and the Vosges, average wind speed and temperatures showed the following pattern during the evening of

20 January:

altitude	wind	temperature
5,500 m (500 Hpa)	060°/40 to 50 knots	-28 to -30 $^\circ$C
3,000 m (700 Hpa)	060°/40 knots	-12 to -15 $^\circ$C
2,000 m (800 Hpa)	060° to 080°/20 to 30 knots	-9 to -10 $^\circ$C
1,500 m (850 Hpa)	060° to 080°/20 to 30 knots	-6 to -9 $^\circ$C
1,000 m (900 Hpa)	060°/25 knots	-3 to -5 $^\circ$C

At an altitude of around 1,000 m, the temperature fell to -10 $^\circ$C on 21 January.

18.12 - The situation at ground level

Between 18.00 hours and 00.00 hours a vast area of high pressure dominated Northern Europe (1,039 Hpa in the north of Poland, 1,038 Hpa over the North Sea). A depression linked with a disturbance in the Mediterranean was centred at 1,007 Hpa to the South East of Corsica.

Between these two centres of activity a current developed, within which an active occlusion running from the Alps to the Jura mountains was circulating.

Associated with this was a sky completely covered with rain and snow-bearing clouds, the northern limit of which extended at 12.00 hours from Bavaria to Lorraine and the Limousin region, with rain and drizzle in low-lying areas and snow in the mountains. This entire system drifted back gradually to the South or South West in the French sector and at 18.00 hours the northern limit was still affecting areas extending from the Bavarian Alps to the Vosges mountains and the Auvergne (see Appendix 11).

The north of this unsettled area was dominated by a cold, dry current from the east of the continent: the influx of cold air (air mass at a temperature of -6 $^\circ$C) gradually moved into Alsace and Lorraine by the end of the evening.

18.2 - Information supplied to the crew

18.21 - <u>Written forecast handed to the crew</u>

The flight weather forecast file for the Lyon-Strasbourg route was taken from the Satolas Weather Centre by an agent of Air Inter Operations at 15.20 hours. No special comments were made.

The file contained the following documents (see Appendix):

- the TEMSI EUROC chart for 20 January 1992 at 18.00 hours:

- wind and temperature charts at 300 Hpa (FL 300) and 500 Hpa (FL 180) for 20 January 1992 at 18.00 hours;

- the METARs for 15.00 hours and the TAFs for 15.00 hours to 24.00 hours relating to the departure, arrival and diversion airports.

The weather conditions encountered during the flight and on approach to Strasbourg were very similar to those described in the flight log.

<u>Comment</u>: By virtue of the contractual agreements between Air Inter and the National Weather Centre, wind and temperature charts for 700 Hpa (FL 100) and 800 Hpa (FL 050) do not form a constituent part of the documents which make up weather records for the flights of turbo-jet aircraft which have a cruising altitude of over 500 Hpa (FL 180).

18.22 - <u>Information received in flight by the crew</u>

At 17.56 hours, the crew were listening to ATIS (see para. 1.11.4) from Strasbourg-Entzheim and received the November information recorded at 16.00 hours (see Appendix):

- runway in service 05,
- transition level 50,

- wind 040°/18 knots,
- visibility 10 km,
- cloud: 5/8 at 800 feet, 8/8 at 3,000 feet,
- temperature and dew point: 2°, 1°,
- QNH 1,021,
- QFE 1,003.

At the request of the captain, the co-pilot mentioned the following three parameters: runway in service 05, cloud cover (8/8 at 3,000 feet), and wind speed (18 knots).

The crew listened to ATIS again two minutes later, at 17.58 hours. They received the Oscar information of 18.00 hours:

- runway in service 05,
- transition level 50,
- wind 040°/30 knots,
- visibility 10 km,
- cloud: 3/8 at 1,100 feet, 6/8 at 2,600 feet,
- temperature and dew point: 1°/0°,
- QNH 1,023,
- QFE 1,005.

It was probably during this reception that the crew consulted ACARS at 17.59 hours to obtain the last METAR from Entzheim. It received the METAR of 17.30 hours:

LFST 03019KT 9999 4ST010 4SC030 8AC090 02/M00 1022 NOSIG =

<u>Comments</u>:

1 - The METAR of 18.00 hours, available at 18.01, gave the following parameters:

LFST 03019KT 9999 3ST011 6SC026 01/M01 1023 NOSIG =

2 - Between 17.30 and 18.30 hours the wind gusts measured at the Entzheim weather station fluctuated between 21 and 30 knots, direction 040°.

3 - The 05 runway threshold is the airport's QFE reference. At 16.00 hours the QFEs of runways 05 and 23 were identical (1,003 Hpa). Between 17.18 and 18.06

hours they were different:

- QFE 05 (502 feet): 1,004 Hpa;
- QFE 23 (489 feet): 1,005 Hpa.

After this they were again identical (1,005 Hpa).

At 18.10 hours, at the request of the crew, the Approach Controller confirmed the QFE and QNH pressures (1,005 Hpa and 1,023 Hpa respectively), then, at 18.12 hours, he confirmed the cloud cover figures (3/8 at 1,100 feet and 6/8 at 2,600 feet).

18.3 - Weather conditions encountered on approach

At 18.00 hours the sky associated with the occlusion (para. 18.12) extended over the Auvergne, the Jura mountains and the Swiss and Austrian Alps. Further to the North, in particular between Luxeuil and Strasbourg, the outer edges of the sky were characterised by a layer of stratocumulus cloud, with bases at an altitude of 500 to 700 m and peaks at around 2,000 m, topped by banks of residual altocumulus at approximately 2,700-3,000 m.

The following estimates can be made of atmospheric conditions prevailing between 18.00 and 18.30 hours, during the A320's descent towards ANDLO and then during its circuit at 5,000 feet above the eastern Vosges and the Alsace plain:

- at the time of entry into the layer of stratocumulus at an altitude of around 2,000 m:

. instant wind: 040 to 060°/25 gusting to 35 knots,
. temperature: -9 °C,

- during the circuit at 5,000 feet (altitude 1,500 m) in the layer of stratocumulus:

. instant wind: 050 to 070°/25 gusting to 30 knots,
. temperature: -6 °C.

- during descent from 1,500 m to 800

m, still within the layer of stratocumulus:

. instant wind: 060 to 070^0/20 gusting to 25 knots,
. temperature rising from -6 to -2 ^{0}C.

Within the northeast to easterly current, the orographic effect of the Vosges massif appeared in the form of an accumulation of clouds to windward, an uplift effect characterised by burgeoning peaks and a more pronounced liquid moisture content than above the plain. Wind and temperature readings at altitude, observations on the ground, analysis from parameter recorders and various other forms of evidence gathered allow an accurate picture to be given of the conditions prevailing during approach to runway 05, above the eastern Vosges, between 18.00 and 18.30 hours:

. no stratus to windward on high ground,
. uniform base at 600 m (altitude) of the 8/8 stratocumulus layer,
. average height of the layer: 2,000 m altitude and bubbling up to an altitude of 2,200 m (FL 65 to 70),
. instant wind between the altitudes of 900 and 1,300 m: 070^0/20 knots,
. quantity of liquid moisture present estimated at 0.7 - 0.8g/m^3 between the altitudes of 900 and 2,000 m (-3 to -9 ^{0}C), causing:
. falls of snow or freezing drizzle and ice deposits (observed in the mountains),
. moderate icing conditions during the flight, as evidenced by ice formations noticed by the crews of several aircraft on the edges of their windscreens,
. no major turbulence reported, even at the top of the layer of stratocumulus.

18.4 - Light conditions

The moon had risen at 17.20 hours over the Strasbourg region. At 18.20 hours its position above the site of the accident was:

- azimuth: 78^{0}46' (in relation to True North),

- elevation $+9^{o}18'$.

There had been a full moon the day before.

18.5 - Weather conditions during search and rescue operations

Between 18.00 and 21.00 hours, the influence of the cold, dry air, circulating within the easterly current and following on from the unsettled area which was in the process of drifting to the south, began to manifest itself over the north of the Rhine plain: breaking up of the layer of stratocumulus and disappearance of the banks of stratus. In fact the change in the weather situation, brought about by the influx of Continental air, occurred after 21.00 hours over the Bas-Rhin (Lower Rhine) region and did not reach southern Alsace until the 21st at 00.00 hours. Over the Vosges mountains, in conditions of freezing fog, the cloud cover was to disperse with a time lag of four to five hours compared to the plain.

During the search operations covering the entirety of the forested areas of Obernai and Barr, atmospheric conditions were as follows:

- freezing fog with a visibility of less than 500 m (often a few dozen metres);

- temperature between the altitudes of 600 and 800 m decreasing from -2 ^{o}C at 18.00 hours to -10 ^{o}C at 03.00 hours;

- ground condition: patches of ice, ground snow-covered and subject to frost in parts.

CHAPTER 1.9 - NAVIGATIONAL AIDS

19.1 - Ground-based radio navigation aids

19.11 - General equipment

The published transit, arrival and departure procedures operated by Strasbourg airport are dependent on the following ground-based equipment:

- the "STR" VOR, frequency 115.6 Mhz,

- the "STR" TACAN, channel 103 x (paired frequency: 115.6 Mhz),

- the "SE" locator transmitter, frequency 412 Khz,

- an ILS on runway 23:

. "ST" localizer transmitter, frequency 110.1 Mhz,

. Glide path transmitter, frequency 335.0 Mhz, Glide Slope 3 ^{0},

. Two marker beacons on the 75 Mhz frequency: the Outer Marker (OM) and the Middle Marker (MM).

These installations and equipment were all working at the time of the accident.

19.12 - <u>The "STR" TACAN</u>

19.121 - Equipment history

In November 1991 the presence of water in the TACAN antenna meant that a mobile TACAN beacon had to be set up for the duration of the repair work.

This beacon, reference NRCP 1A, was subjected to a flight control by two Mirage F1 CR aircraft. This control was based on a comparison between the distance measurements provided by the mobile beacon, and those of the beacon due to be closed down as well as those calculated by the inertial units of the aircraft. The results obtained enabled the mobile beacon to be put into operation on 22 November.

In addition to this, a formal request for calibration was lodged at the Commandement Régional des Transmissions de l'Armée de l'Air (Regional Army and Air Force Signals Command HQ) on 2 December 1991. On the date of the accident, this calibration had not yet been carried out; it was not the subject of a NOTAM procedure.

19.122 - Distance measurement accuracy of the TACAN

From the technical clauses contained in the contract between the manufacturer and the Air Force, it appears that the distance measurement accuracy of the TACAN is +/- 90 metres.

The trials and tests carried out before this device was put into service in the Air Force showed that the true distance measurement accuracy of TACAN beacons is +/- 75 metres.

It is this latter figure which has been adopted by the appropriate central technical departments (STTE - DCMAA) and which is given in the "Maintenance manual" for the installation of radio navigation equipment.

19.2 - Radar equipment

19.21 - General equipment

The local military control centre (CLA) of Strasbourg airport is equipped with the following devices to provide radar capability:

- "Centaure" search radar,
- SPAR precision radar,
- an off-set of the radar display from CRNA Est (Eastern CRNA) (VDU 670).

19.211 - The Centaure radar and its videos

19.211.1 - Centaure radar is a primary and secondary search radar system (wavelength 23 cm - antenna revolving 12 times per minute).

The antenna is located on the airfield, between the runway and the taxiway, 400 metres from the threshold of runway 05. The information provided by this radar can be:

- used directly on the radar display units available to the CLA, in the form of primary (raw or filtered) and/or secondary video,

- processed by the STRAPP (STRIDA/Approach) system, located in the technical unit, with a view to generating on the display equipment computed tracks which can either be local in origin or come from STRIDA (the Drachenbronn-based System for the Processing and Representation of Aerial Defence Information with which the Strasbourg STRAPP is connected by a data transmission link),

- used manually via the designation and interrogation system (secondary and Mode C only).

19.211.2 - The primary video

The raw video of the primary radar plays back to the Controller's screen, in the form of primary echoes, the positions of all the aircraft detected as well as the fixed echoes (high ground) located within the radar coverage.

In the "filtered video" position, all or part of the fixed echoes are removed.

The Controller selects the distance scale of the display. This scale applies to all the other videos.

Whichever solution is adopted, aircraft echoes are always perfectly visible when aircraft are manoeuvring above high ground.

19.211.3 - The secondary video

The video of the secondary radar plays back to the Controller's screen the positions of all aircraft equipped with a working on-board transponder and located within the radar's detection range.

At Strasbourg, this video acts essentially as an identification tool for controlled flights, by differentiating between the symbols corresponding to the position of each aircraft.

The Controller matches a particular symbol to the ident code he wishes to identify using a keyboard situated at the side of the display.

Thus the ident (squawk) code 6100, selected by the pilot of F-GGED at the request of the Controller, was displayed on the radar screen by a symbol in the form of a solid rectangle (aircraft on arrival) positioned behind the primary plot.

19.212 - The STRAPP video

STRAPP allows computed tracks to be created and displayed on the screen of the Controller. These tracks are:

- either purely local in origin (primary and/or secondary Centaure detection),

- or local in origin or from STRIDA, depending on the quality index required, when the STRAPP/STRIDA link is activated.

A track is made up of an identification symbol and a velocity vector. To these can be added, if the Controller so desires, a tag which can include all or part of the following elements:

- the flight level (specifying local origin or STRIDA),

- the SSR modes (origin not specified),

- the general number (from STRIDA),

- the call sign (from STRIDA).

19.213 - The computed internal video

The computed internal video permits the display of:

- the circles of distances centred on the origin of detection (position of the radar antenna). These circles either show distances of 10 nautical miles in divisions of 10, with the circles representing distances of 50 miles highlighted, or distances of two nautical miles in divisions of two, with the circles representing multiples of 12 highlighted. The Controller specifies for one or other of the displays,

- the ANDLO way point and the position of the "SE" locator beacon (the position of the "STR" VOR/TAC is not represented),

- the extended centreline of the runway in use,
- any axis line generated at the request of the Controller,

- a direction-finder vector aligned on the radar screen and called up on request.

19.214 - The designation and interrogation system

This system allows the Controller to ascertain the transponder code, and the flight level or the altitude of an aircraft, providing it is equipped with an operational Mode C transponder.

To do this the Controller has to target the aircraft with the aid of a small luminous circle which he moves, displaying changes of position using a trackball situated within easy reach on the desk.

When the Controller has positioned the circle on the secondary video symbol of a targeted aircraft and at the moment when the detection sweep passes over this symbol, the flight level (or the altitude) or the transponder code of the aircraft appear in a window close to the screen.

19.22 - Installation of radar display equipment

Air Traffic Control services are provided from the observation tower and the "IFR room", two distinct entities within local airport control.

The IFR room is only placed on an active footing during periods of military air activity.

Outside these periods the IFR room is deactivated and Approach Control services are delivered from the tower.

Installed in the IFR room are the panoramic display units (approach consoles), the landing radar system screens and VDU 670 screen (off-set of the radar display from CRNA Est (Eastern CRNA)).

Installed in the tower is a complete Approach Control console equipped with a panoramic display screen, offering all the displays and functions outlined in paragraph 19.21 (with the exception of the functions of the VDU 670 available only in the IFR room).

19.23 - Utilisation techniques

19.231 - Principles

To maintain the radar services of General Air Traffic control from the IFR room or the tower, the different video systems available to the Controller are utilised as follows:

- radar identification is established and maintained by correlation between an observed primary echo and a symbol (secondary video) corresponding to the SSR ident code selected by the pilot,

- should the secondary radar or the on-board transponder not be operational, radar identification is performed by checking that the observed primary radar echo is found on the direction-finding position line associated with the radar system,

- radar guidance is performed by using the raw or filtered primary radar video, gain adjustments being carried out in such a way that aircraft echoes appear clearly on the background of charts showing high ground,

- the component units of the STRAPP

tag (possible call sign and especially Mode C) are utilised on the initiative of Control, depending on the situation in the air, essentially with the aim of guaranteeing appropriate vertical separation between aircraft.

19.232 - The day of the accident

At the time of the accident Approach Control services were provided from the tower.

According to the "Register Journal" and the "Register of Faults" (intended for maintenance purposes), and according to the evidence of the Controllers on duty, no faults were reported and all the equipment described above was working normally.

The screen display, and any adjustments to it, are not recorded. Nonetheless, the evidence of the Controller who carried out this function provides us with some indications concerning adjustments to the Approach Control console (see Chapter 1.20).

CHAPTER 1.10 - TELECOMMUNICATIONS

110.1 - Radio communications and ACARS link

During its flight the aircraft made contact successively with the following Air Traffic Control authorities (with their corresponding frequencies):

- Satolas Ground (121.80 Mhz)
- Satolas Tower (120.00 Mhz)
- Satolas Approach (128.50 Mhz)
- Marseille Control (123.80 Mhz)
- Geneva Control (127.30 Mhz)
- Rheims Control (124.95 Mhz)
- Strasbourg Approach (120.70 Mhz)

At no time did the crew report a problem on any of these frequencies.

All the radio and telephone communications of the Control Authorities are recorded.

A track of the magnetic tapes is kept for recording a coded internal clock. When it was reproduced, this coding was read and restored onto a digital clock.

A dated transcription of these communications was made, and the section of this transcription relevant to an understanding of this report is contained in one of the Appendices.

Finally, the aircraft was equipped with an ACARS system (see para. 16.3), designed for the automatic transmission of data by VHF link.

The ACARS messages transmitted by F-GGED during the flight which culminated in the accident were recorded.

110.2 - Radio and telephone equipment operated by the Air Traffic Control Authorities

110.21 - <u>Radio equipment</u>

The Strasbourg-Entzheim Control Tower is equipped with a radio installation allowing transmission and reception on the following frequencies:

- 122.10 Mhz and 118.70 Mhz for Airport Control
- 120.70 Mhz, 125.875 Mhz and 121.35 Mhz for Approach Control
- 121.5 Mhz international distress frequency, permanently manned. Distress beacons (ELTs) transmit on this frequency.
- 126.925 Mhz, for the ATIS frequency.

All frequencies can be controlled independently of the IFR room or the tower.

110.22 - <u>Telephone network equipment</u>

Strasbourg-Entzheim Approach Control is equipped with a network of dedicated direct lines. One of these lines connects it to the Drachenbronn Centre for Co-ordination and Rescue (CCS), another to CRNA Est (Eastern CRNA). This second line is recorded and the transcription of the recording is contained in one of the Appendices.

CHAPTER 1.11 - AIRPORT INFORMATION

111.1 - General points

Strasbourg-Entzheim airport is a military airport open to public air traffic.

It is attached principally to the Ministry of Defence (Air Force) and secondarily to the Ministry of Transport (Civil Aviation).

Air Traffic Control services are provided by Air Force Military Controllers.

Use of the airport by civil aircraft is defined by a protocol agreement drawn up between the two Ministries to which is is attached, dated 1 January 1976 and amended on 1 November 1980.

In winter, the working hours of Air Traffic Control services are: every day from 05.15 hours to 22.00 hours.

The length of single runway 05/23 is 2,400 metres. It is oriented 051/231 degrees Magnetic.

111.2 - Regulations and technical developments

An amendment to the Civil Aviation code (Articles D. 131 - 1 to 10, and more particularly Article 9) dated 25 July 1985 gave Military Control Authorities the statutory powers to provide general Air Traffic Control services in line with performance criteria set out in a Joint Arrêté (Order).

An Arrêté (Order) of 28 July 1986 provides for the creation of a statutory airspace, doubling as a controlled airspace in the Strasbourg region, to allow joint civil and military activity to take place at Strasbourg-Entzheim airport.

An Arrêté (Order) of 24 December 1986 and the issuing of Aeronautical Information enabled this airspace to be put into operation on a twin-status basis along with the corresponding Air Traffic Control services, beginning on 7 May 1987.

A radar sequencing zone was set up inside the controlled airspace. General Air Traffic (GAT) Control,
Flight Information and Alert services are provided inside this controlled airspace.

In the beginning, in view of the non-availability of an adequate radar screen in the tower, radar services could only be provided from the IFR room, to suit military schedules in accordance with the DGAC/Air Force protocol of 1 November 1980.

This double restriction was lifted from 15 October 1987 thanks to the installation in the observation tower of an integral Approach Control console equipped with a Centaure radar display screen, and after an agreement between the military authorities had authorised the Controller to use radar equipment outside military schedules.

When the IFR room is non-operational, Approach Control services are provided from the tower.

The instructions laid down by the Head of the CLA give the Head of Shift complete latitude in deciding how to use this Approach Control console, depending on the situation in the air.

111.3 - Flight control of General Air Traffic at Strasbourg

111.31 - General principles

Strasbourg airspace is included within the airspace for which the Centre Régional de la Navigation Aérienne Est (CRNA Est) (Eastern Regional Centre for Air Navigation) is responsible.

On the day of the accident, this airspace was exclusively reserved for General Air Traffic (GAT) aircraft. Thus only the status of controlled airspace need be taken into consideration.

This airspace includes a radar sequencing zone as well as arrival, departure and transit routes (Appendix 2). Its management is defined in a letter of agreement between the Eastern Regional Centre for Air Navigation and Air Base 124 at Strasbourg-Entzheim.

This letter of agreement specifies the control parameters for General Air Traffic (GAT) aircraft flying according to IFR rules and either flying to or from Strasbourg-Entzheim airport or in transit within the twin-status airspace.

In its appendices it describes:

- means of communication,
- services provided by Strasbourg APP,
- departure, arrival and transit procedures,
- the handling of conflicts between departure, arrival and transit flights.

Strasbourg Approach provides Air Traffic Control, Flight Information and Alert services within the controlled airspace. Radar services are provided as required.

111.32 - Responsibility of control services in relation to the clearance of obstacles by aircraft using IFR

Appendix 4 of the Chicago Convention and DOC444-PANS/RAC define the responsibility of Control services in relation to the prevention of collisions with obstacles. It lays down that, except in the case of radar guidance, it is the responsibility of the pilot to take into consideration the clearance of obstacles and to check that the authorisations he is given do not compromise flight safety in this respect. On the other hand, when he carries out guidance for an aircraft on an IFR flight, the Radar Controller will satisfy himself that the margin of clearance over high ground is sufficient at all times until the aircraft reaches the point at which the pilot can once again resume navigation himself.

As far as French regulations in force on 20 January 1992 were concerned, it was not within the sphere of competence of Air Traffic Control authorities to prevent collisions between aircraft in flight and terrestrial obstacles. The pilot therefore had an obligation to check that clearances from the Air Traffic Control authorities did not compromise flight safety on this point.

However, these regulations specified that when radar control service (guidance and sequencing) is provided for the benefit of an aircraft on initial approach, the instructions given by the Controller must keep it within the radar sequencing zone. This contrives to provide a safety margin for the clearance of obstacles.

111.33 - <u>Arrival procedures at Strasbourg</u>

111.331 - Itineraries

Standard arrival itineraries, i.e. those subject to special approach clearance, are published in AIP France (RAC 4-139).

The first IFR level which can be utilised from the direction of EPL (Epinal VOR beacon and LUL (LUL VOR beacon) is, according to the QNH in force at Strasbourg, level 70, 80 or 90.

111.332 - Co-ordinations

Co-ordinations are defined in the letter of agreement between Eastern CRNA and Strasbourg Approach Control Centre dated 1 July 1990. The reference locator beacon is the SE locator. It is primarily used as a holding fix. Co-ordination is effected ten minutes at the latest before the estimated time of overflight of SE.

Eastern CRNA transmits to the Approach Control Centre the aircraft's designator on arrival and its transponder code.

For arrivals from LUL or EPL, the CRNA must mandatorily respect this ten-minute notice period. In fact, the Approach Control Centre can request it to direct these arrivals straight to ANDLO, with a view to a direct approach towards runway 05.

Approach replies by giving Eastern CRNA the lowest level which can be utilised at 21 NM from the STR VOR, and if need be, the approach time expected.

111.4 - VOR-DME procedure

Note: Strictly speaking, it is a VOR-TAC procedure, because for distances it uses the "distance measurement" part of the TACAN at Strasbourg (cf. glossary). This system can be incorporated into a DME, and the construction of the procedure, as well as how it is practised by crews, are completely identical. Consequently, throughout the remainder of this report the terms "VOR-DME" procedure" and "VOR-TAC procedure" will be used interchangeably.

111.41 - <u>History</u>

Instrument operation of runway 05 at Strasbourg-Entzheim was the subject of an ILS procedure analysis study carried out in September 1977 by the Northern Regional Civil Aviation Authority (DRAC), as well as a study by the Technical Air Navigation Service (STNA) completed in December 1977. The procedure was based on a gradient of 6.25% with a variant proposing a gradient of 8.8% on the middle segment with a final glideslope of 5.5%.

This procedure, which was tested on a simulator, posed problems in terms of the installation's ground location. Taken together with the cost involved, they led to its rejection.

During 1982, the Chamber of Commerce requested a continuation of the usage analysis of runway 05 other than in free visual manoeuvre (MVL). This request led in 1983 to the analysis of a VOR-TAC procedure.

111.42 - <u>The procedure</u>

111.421 - General points

The Strasbourg VOR-TAC 05 procedure is a conventional approach procedure with a visual reference point on final approach.

It consists of a series of segments corresponding to successive stages of the flight. These segments are delineated by reference points (waypoints):

- IAF: waypoint (fix) at the beginning of Initial Approach (for the Strasbourg VOR-TAC 05 procedure, it is the SE beacon;

- IF: waypoint at the beginning of the Intermediate Approach (for the Strasbourg VOR-TAC 05 procedure, it is the ANDLO point);

- FAF: waypoint at the beginning of Final Approach (for the Strasbourg VOR-TAC 05 procedure, it is the fix of the Final Approach segment, 7 NM from the TACAN).

111.422 - Particular design features

111.422.1 - Derogations

The VOR-TAC 05 procedure was set up in accordance with the rules of Order 20754/DNA of 12 October 1982. Three of its points are derogatory and it was explicitly subject to derogations covering:

a) The 5.6% gradient for the Intermediate Approach segment. This allows an identical gradient to be obtained for the Intermediate and Final stages.

As far as the descent gradient is concerned, Order 20754/DNA stipulates that the gradient of the Intermediate Approach segment should be nil because its purpose is to fix the speed and landing configuration of the aircraft to enable it to begin the Final Approach segment. However, if a descent is necessary, the Order specifies that the maximum permissible gradient is 5% and that a level of deceleration should be allowed before Final Approach.

A double derogation is therefore applicable to the 5.6% gradient.

b) The length of segment by dead reckoning on Initial Approach of 11.7 NM. This is the segment included between a point 21 NM from the STR VOR and ANDLO (see chart in Appendix 6).

This enables DME distances, which are identical for the two arrivals, to be obtained by dead reckoning at the start of the Initial Approach.

Order 20754/DNA specifies that as far as the Initial Approach segment is concerned, "guidance onto the flight path is normally required, although a segment by dead reckoning can still be allowed over a distance not exceeding 10 NM".

The length of 11.7 NM of the segment by dead reckoning is therefore derogatory.

These derogations have been agreed by the DNA.

Comment: Neither the request formulated by the Northern DRAC, nor the reply given by the DNA mention the derogation constituted by the absence of a level of deceleration on Intermediate Approach. The diagram appended to the request of the Northern DRAC did indeed show a continuous profile but this did not elicit any comment from the DNA.

On being questioned by the Commission, the DNA indicated that the presence of a

level of deceleration
was difficult to envisage taking into account other
constraints, and that it would have led to the acceptance of other derogations.

111.422.2 - Margin of clearance of obstacles

A margin of 225 m was adopted for the Intermediate Approach segment of the Strasbourg VOR-TAC 05 procedure. This is higher than the statutory minimum of 150 m laid down for this type of procedure. Order 20754/DNA in fact sets out that in mountainous regions it is left to the designer of the procedure to over-estimate the margin of clearance.

111.422.3 - Reverse turn

Designed to allow a half-turn to be made during Initial Approach, this turn is carried out to the north of the approach track in order to maintain the necessary separation with the collective flight paths of Strasbourg Military Air Traffic on the one hand, and the Colmar procedure and the Lahr and Solingen airspaces on the other.

111.422.4 - When it was consulted on the definition of this procedure, the company expressed a positive view.

111.43 - <u>Profile of procedure</u>

**111.431 - IAC Charts of the Aeronautical
Information Service (SIA)**

The SIA is a service of the Air Navigation Authority (DNA) which is responsible for the publication of approach procedures in accordance with the standards and recommendations of Appendix 4 of the Chicago Convention.

The charts published by the SIA relating to the VOR-TAC 05 procedure are reproduced in the Appendix section.

We note that the obstacle at 823 m

taken into account in the formulation of the procedure, which determines the altitude associated with the Final Approach Fix (FAF) located at 7 NM from STR, is not included on the profile of the IAC.

The altitudes prescribed for each waypoint (5,000 feet at 11 NM, 4,300 feet at 9 NM and 3,660 feet at 7 NM from STR) do however offer protection from this obstacle at the FAF level, giving a clearance margin in excess of 50%.

111.432 - Air France charts

For this flight the crew used the aeronautical charts supplied by their company, i.e. the charts published by the Air France group in line with the provisions of the Operations Manual of Air Inter.

It is appropriate to note at this point that the publication of aeronautical charts taken from official cartography is not subject to any official regulation.

From an examination of the charts used by the crew we note that:

- the crew only had access to one set of approach procedure charts.

- the arrival tracks for runways 23 and 05 are placed together on a single sheet and no information is given which allows them to be clearly differentiated. The segment oriented ANDLO-STR-SE (arrival track on clearance or instruction from Approach) is only partially shown. ANDLO and STR are joined by a single stroke without arrowing and the STR-SE segment has been left out.

- the graphical representation of the VOR DME 05 procedure conforms on the whole with the official publication. However, the terms IF (reference point of Intermediate Approach) and FAF (reference point of Final Approach) do not appear. Furthermore, the final track is broken off before the Missed Approach Point (MAPt).

- the flight path shown between ANDLO and FAF was flattened out with the purpose of continuing the gradient with the Final Approach segment.

- the let-down track was noted at 050° (publication of 22 August 1991) whereas the SIA charts give this track as 051° (publication of 3 May 1990).

- the flight path profile for the VOR/DME 05 procedure is derived from the chart.

- the representation of the vertical profile of the procedure gives an indication of possible alerts by the Ground Proximity Warning System (GPWS), symbolised by helicoids at 9 NM from STR on the outbound and inbound tracks.

- the form does not include a chart showing the relationship between the DME distance and the path altitude.

111.5 - ATIS

Strasbourg Approach is equipped with an ATIS (Automatic Terminal Information Service), a system installed by the DGAC for the benefit of General Air Traffic aircraft.

The fundamental objective behind the operation of an ATIS system is to relieve the frequencies of Approach Control from information of a repetitive nature, while at the same time offering users the possibility of obtaining relevant details on conditions of airport use as and when they desire.

ATIS transmissions are intended for both inbound and outbound aircraft.

These messages are identified by the letter following the one used in the previous message, in immediate alphabetical order.

The items of information which follow make up the ATIS message and must be transmitted in this order: runway in service, runway condition, transition level, possible modification to the operational state of visual and radio-navigation aids, special bird-related information, if necessary information concerning the activation of certain areas with a particular status and meteorological information.

Any significant change to one of the items of information contained in the current ATIS transmission must lead to the recording and dissemination of a new message.

The ATIS message must be updated at least every hour. Any message more than an hour old must be considered obsolete and must no longer be transmitted.

At Strasbourg, the preparation, recording and transmission of ATIS messages is the responsibility of the tower.

We note that at 17.56 hours, when the crew listened to ATIS, they received the November information recorded at 16.00 hours.

111.6 - Ground lighting

Runway 05 at Strasbourg airport is equipped with lateral ground lighting, with flashing lights and a VASI approach glidepath indicator. It does not have approach lights.

This equipment complies with the Order of 15 March 1991 relative to approval conditions and to airport operation procedures. In paragraph III.5.3 this stipulates "that the installation of a luminous approach device is not normally required for runways which are not open for precision approaches".

This provision in the French regulations deviates on this point from Appendix 14 of the ICAO, paragraph 5.3.1.1 B (Runway with conventional approach) which specifies:

"Wherever such an installation is physically possible, runways with conventional approach shall be provided with a simple luminous approach device complying with the specifications contained in 5.3.5.2 to 5.3.5.9, unless the runway is utilised solely in conditions of good visibility or adequate guidance is guaranteed by other visual aids".

The French authorities, in common with all the other foreign authorities it must be added, have not notified the ICAO of any difference on this point. In effect it considers that the wording of the paragraph quoted above leaves open the option of not installing a line of approach lighting on a runway with conventional approach, contingent on the adaptation of minimum operational requirements.

To this effect, the order of 12 March 1990 relative to the determination and utilisation of operating minima

(Chapter 3) contains several tables which, for a given MDH, give a VH taking into account the length of the approach line. In particular, table 5 gives VHs for a runway not equipped with approach lighting.

This interpretation is completely accepted and can be found in many airports the world over.

CHAPTER 1.12 - RECORDING EQUIPMENT

112.1 - On-board recording devices

112.11 - Recovery from the wreckage

In accordance with the prevailing regulations, the aircraft was equipped with two protected recording devices. These recording devices were discovered at 00.46 hours on 21 January.

The recorders were situated in the area between the firewall of the Auxilliary Power Unit (APU) and the rear pressure dome of the aircraft. This area suffered badly from the effects of a fire source. The Digital Flight Data Recorder (DFDR) was still on its support mounting, the Cockpit Voice Recorder (CVR) was above it. The two recorders were trapped in a twisted mass of molten metal, the DFDR more so than the CVR. It was possible to salvage them from the hot zone approximately three quarters of an hour after they were found. They were still hot, the CVR less so than the DFDR which burned to the touch, even through gloves.

The manufacturer of the recording devices was LORAL-Fairchild. The Digital Flight Data Recorder was a model F800, reference 17M800-21-1; the Cockpit Voice Recorder a model A100, reference 52799.

In addition the aircraft possessed a non-protected Quick Access Recorder (QAR), manufactured by Schlumberger, reference PC 6033-3-55, S/N 679, designed for the maintenance and the analysis of flights, and recording the same data as the DFDR. This Recorder was discovered on
21 January at approximately 09.30 hours in the avionics bay area.

Finally, non-volatile storage memory located inside various computers on board was found and analysed. The results of this work are set out in para. 1.17.

112.12 - DFDR

The Digital Flight Data Recorder suffered fire damage to the point where its reading system and its magnetic tape melted and fused together. No analysis of the information was possible.

112.13 - CVR

112.131 - Condition of the recorder

Work on opening the CVR and copying the original tape was carried out on the morning of 21 January 1992.

The recorder was fire-damaged over the whole of its external suface. There was no trace of shock damage.

112.132 - Opening procedure

The removal of the outer casing was carried out using wire-cutters, owing to the progressive distortion it had suffered as a result of its exposure to the fire. It was not possible to gain access to the anti-shock box until the recorder's framework and electronic components had been completely removed.

The thermal protection shield showed patches of burning in various places, which indicates that the recorder was exposed to an intense fire source for a long period. Nevertheless, when the last protective cover over the turntable was opened, the magnetic tape was revealed to be in good condition.

112.133 - Magnetic tape

Once out of its spool, the magnetic tape nevertheless showed signs of twisting, characteristic of prolonged exposure to considerable heat. In addition, it was stuck lightly to the capstan, which is the sign of incipient melting.

The tape was cut at the point where it emerged from the turntable support and transferred manually onto a
1/4 inch spool.

112.134 - Copying and use

Two copies were made of the original tape on a 1/4 inch, 4-track tape, and one copy on a 1-inch, 8-track tape. These copies are untreated copies, not subject to filtering or any changes from the time they were originally recorded.

The running speed of the original tape was calibrated by spectral analysis of the interference from the on-board electrical system at 400 Hz. Subsequent synchronisation, made by comparing the relative times of the radio transmissions with the corresponding parameter

of the QAR on the one hand, and the recording of Air Traffic Control on the other, did not present any problems.

Conversations with Control or the cabin crew, recorded directly "at source" on tracks allocated specifically for VHF frequencies and the public address system, could be clearly understood.

The crew did not communicate with each other using headset microphones. Their conversations were recorded via the Cockpit Area Microphone. Understanding certain sentences is particularly difficult. An operation to reduce background noise by digital processing of the most doubtful words or groups of words did not dispel any remaining doubts. Increasing the enhancement between "signal (word) and noise (cockpit noise)" is not sufficient to improve intelligibility on this recording.

Recognition by multi-listener testing did however remove the uncertainties surrounding a number of words.

A transcription of the parts which could eventually be understood, and which are relevant to an understanding of the current report, is contained in the Appendix section.

112.14 - QAR

The recorder showed traces of shock damage and burning over three quarters of its outer surface. After being opened, the magnetic tape appeared seriously damaged, cut and distorted. It was stretched out to a length of around twenty centimetres, corresponding approximately to the last thirty seconds of the flight. In the most affected part its width was no more than one millimetre, and around three centimetres had completely disappeared.

On the damaged section it has not been possible to interpret the magnetic tape with the aid of magnetic reading and computer-assisted decoding techniques. Manual decoding methods have therefore been used to read the binary data contained in the damaged areas. A technique of manual interpretation, involving opti-magnetic reading (see para. 1.19,) has also been used to process two detached portions of tape.

These methods of interpretation have enabled all
the recorded data to be retrieved, with the exception of the last twenty five seconds of the flight (and more

particularly the last nine), where there are elements of dicontinuity in the data recovered.

The extracts from data retrieved from the QAR recording and which are relevant to an understanding of the current report, are included in a series of graphs contained in the Appendix section.

112.15 - Performance of on-board recording devices

112.151 - Strength of materials - scientific tests

As the DFDR tape was destroyed by the fire, and the CVR tape had reached a critical point, scientific analyses were carried out to determine the thermal stresses they had undergone.

The American manufacturer of these items, LORAL, has therefore compared the sets of photographs taken of the opening of the two recorders with its own recorders or related photographs. The company has also carried out tests to determine certain points.

The metallurgical and chemical laboratories of CEPr in Saclay have for their part examined the various pieces of the recorders themselves, as well as the metal matrix that enclosed them. The CEPr also conducted comparative tests on standard cases.

The main results of these scientific tests were as follows:

Duration of the high-intensity fire:

The temperature of burning fuel outside an aircraft is approximately 1,000 to 1,100°C. In these conditions, the external parts made of aluminium, such as the sub-aquatic location beacon and the handle, begin to melt after approximately three minutes. The internal frame structure itself then also starts to melt. After 15 to 20 minutes of total exposure to the fire, all the aluminium components will have melted.

In the case of the F-GGED accident, only some corners of the frame began to melt. The melting temperature of the light alloy is 560 °C. The outer casing of the recorders was therefore subjected to temperatures of less than 650 to 700 °C.

LORAL thus estimates the duration of the general high-intensity fire (temperature above 700 °C) at less than 15 minutes. According to the standard tests, exposure to such a fire for a duration of less than 30 minutes does not lead to the destruction of the tape.

Low-intensity fire:

Following this high-intensity fire which on its own would not have destroyed the DFDR tape, the casings were therefore subjected to a fire of lower intensity over a long period of time.

The magnetic tape itself can withstand a maximum temperature of the order of 200 °C.

Heat tests on a new magnetic tape used in conjunction with parts from the operating mechanism of a new recorder were carried out by the CEPr to produce features identical to those found on the DFDR of F-GGED. In these conditions, the maximum temperature reached inside the DFDR is estimated at 430 °C, for a period of 45 minutes.

It was still necessary to attempt to estimate the duration of the low-intensity fire suffered by the DFDR.

To do this, fire destruction tests on several model F800 DFDR casings were conducted by LORAL with the purpose of ascertaining the damage to the casing from F-GGED. In general, at a temperature of 260 °C, insulation protects the tape for approximately 6 hours.

In the tests carried out, damage at 250 °C proved to be less severe than that observed on F-GGED, while the test at 283 °C showed the damage to be more severe. The average temperature of the long-duration fire was therefore taken to be equal to approximately 260 °C.

The tests were carried out in a temperature-controlled oven. Thermocouples had been placed on the tape and in the internal aluminium casing.

The results of these tests showed that the damage to the DFDR of F-GGED would have required 6 to 7 hours of burning at a uniform temperature of 260 °C.

In view of the initial high-intensity fire, and the temperature of 430 °C noted by the CEPr, the duration of
the low-intensity fire is therefore estimated at approximately 5 to 6 hours.

112.152 - Data recorded on the DFDR

On this aircraft the DFDR and the QAR recorded the same parameter. The comments given in connection with the operation of the QAR in this Inquiry are thus also applicable to the DFDR.

For public transport aircraft of the size of the A320, current French regulations require the recording of 25 parameters. During the Type certification work on the A320, a much larger number of parameters (two hundred and thirteen) was specified. This was therefore the case on
F-GGED.

Innovations with respect to certain flight control systems (electrically-operated flight controls) led to many related parameters being taken into account.

Some Autopilot or automatic flight management modes are recorded.

Except insofar as engine operation is concerned, no target value is recorded.

112.2 - Ground recording devices

112.21 - <u>Radar systems</u>

Radar systems used by Civil Aviation for the purposes of route control are secondary radar systems which utilise the relay transmitter device of an ATC Transponder carried on board the aircraft. When this is interogated by the radar beam, it sends back a response which includes its attributed ident code (mode A) and the pressure altitude of the aircraft (mode C).

112.211 - Radar coverage of the Strasbourg area

This is currently carried out by three radar systems:

La Dole, a radar installed in Switzerland on high ground near Geneva, 138 NM from STR. The Jura mountains obscure its northern horizon, which prevents it from
detecting anything below approximately 8,000 feet over STR.

Chaumont (Cirfontaines en Ornois), a new-generation single-pulse radar sited 87 NM west of STR. The Vosges mountains restrict its horizon to an altitude of
approximately 4,000 feet directly above the STR beacon.

Drachenbronn, a French military radar situated 30 NM to the north of STR. There are no obstacles restricting its horizon towards STR. An aircraft flying at 5,000 feet over STR will, in principle, be detected in good conditions because it is observed at an angle of elevation of 1.5^{0} above the horizon. In contrast, the barrier of the Vosges mountains forms a considerable shield to the south west.

112.212 - Flight paths plotted

The perception of the final part of the flight which led to the accident by the radars mentioned above, to which can be added the German radar installation at Pfalzerwald, produced flight path recordings which have been grouped together on the same scale in the chart contained in the Appendix section. This chart illustrates the scatter corridor of the flight paths as seen by the radars. The same Appendix contains a concise explanatory note on the radar processing system, a general survey of the errors associated with the measures used, and an analysis of the accuracy of flight path plots produced during the final part of the flight.

112.22 - <u>Radiocommunications</u>

A transcription of the recording of the radiocommunications established with the Control Authorities which were responsible for F-GGED is provided in the Appendix section.

112.23 - <u>Telephonic communications</u>

The telephonic communications between Eastern CRNA and Strasbourg Approach are recorded. A transcription of the only communication referring to F-GGED is included in the Appendix section.

CHAPTER 1.13 - DETAILS OF WRECKAGE AND IMPACT

113.1 - Description of the wreckage and the impact site

Note: Appendix 16 contains photos of the site and the wreckage

113.12 - <u>Description of the site of the accident</u>

In the days following the accident, several surveys were carried out:

- a topographical survey of the site of the accident and of the height of the trees cut by the aircraft, included in the Appendix section;

- a diagram showing the distribution of debris, included in the Appendix section;

The site of the impact was on the south west side of "La Bloss" mountain, the height of which is 823 m (see map in Appendix 1). The debris was spread over an area included within 48°25'40" and 48°25'37" North latitude and 7°24'22" and 7°24'15" East latitude, at a terrain altitude between 795 and 810 m in the normal NGF reference system of the IGN.

At this spot the slope of the ground rises. The extent of the gradient varies between 8 and 17%. A coniferous forest approximately 25 metres high covers the entire area. The distance over which the trees were damaged is approximately 120 metres.

Measurements carried out on damaged trees led to the estimate that the aircraft entered the trees at a descent angle of approximately 12^{0} and at an angle of bank of the order of 14^{0} to the left. This angle of bank then increased to approximately 18^{0} some 30 metres further on.

113.22 - Distribution of the wreckage

From the moment it began to hit the trees, sections of the aircraft broke off. The first item found was a piece of the left engine nacelle located near the foot of the first tree damaged. This was followed by a number of pieces of the left wing, the tail section, the fairing panel from the lower fuselage, the landing gear door and parts of the cockpit including a wiper blade and pieces of radome.

The first signs of the aircraft's impact with the ground were located about thirty metres after the first damaged trees. In this area one of the rims of the nose landing gear and its tyre were also found.

Next, a number of small-sized pieces were found; among them, the central windscreen post wedged into a tree stump and a piece of frame 64 (this frame is located at the rear of the last window), as well as the actuating cylinder (ram) of the forward cargo door.

After this debris the first large-sized pieces of wreckage were found.

Situated at a point approximately 40 metres from the first signs of impact with the ground was the rear structure of the aircraft, containing the tail assembly and the tail cone which holds the Auxilliary Power Unit (APU). This was not damaged by the fire which raged in front of its firewall, and is almost intact. The adjustable horizontal stabiliser (PHR) screwjack was found intact. The nut was found at a distance of 24.5 cm (28 threads) from the jack exit bearing. This figure corresponds to a PHR position of 3.7^{0} nose up.

The tail section was severely damaged by the impact and the fire. The structure in the area located between the APU firewall and frame 65 was totally destroyed by the fire. The resins of the composite parts (PHR, fin and rudder) had been completely burned up. The pressure bulkhead was likewise destroyed by the fire. The recorders (CVR and DFDR), which were installed in this area, were discovered there.

The tail unit, to the rear of the APU fireproof surround, was not damaged either by the fire or by the impact.

The rear section of the floor of the passenger cabin, complete from frames 64 to 57, was found a few metres forward of the tail section. Located on this floor were, on the left-hand side, the last seven rows of passenger seats, and on the right-hand side, the last row of passenger seats and the cabin crew seat. The left-side cabin crew seat was no longer on the floor. The passenger seats had suffered a relatively small degree of damage.

The right-side lower quarter of the fuselage normally surrounding these seats was located under this section of floor. The upper quarter of this section of fuselage had been destroyed by the fire. The remaining part was discovered attached to the central section of fuselage.

Located a few metres to the left of the cabin floor was a section of the left wing together with its engine pylon.

Beside the section of the left wing was the left main gear leg which had been broken transversally at the strut level.

To the right of the tail unit, in the same direction as the flight path, were found a piece of the right wing section along with the right main gear leg in the extended position.

Approximately fifteen metres down from the rear cabin floor was the central section of fuselage, complete between frames 35 and 47. From a mechanical point of view this section had undergone little damage. On the other hand, it had been subjected to an external fire, especially over its right-hand part. All the seats that had been situated there, as well as their occupants, had been flung outside towards the front.

Also found in this area of the central section were a cabinet of the avionics bay, a number of computers or parts of computers, and the QAR.

The severely damaged casing of the Emergency Locator Transmitter was also to be found in this area.

The rest of the aircraft, i.e. the largest part, was scattered in a completely dismembered state over the entire area. In particular, the flight deck, and more generally the whole section between the nose bulkhead and frame 35, (the frame located at the leading edge of the wing section) had been broken up by a series of impacts against the ground and the trees. Its components were found scattered over a wide area in a state of considerable fragmentation.

113.13 - Left engine

The left engine was detached from its pylon. It was broken into two parts, with the plane of separation at the interface between the intermediate casing and the high-pressure compressor. The fan casing lay flat, the fan blades pointing towards the sky, the casing extremely buckled. There were no blades missing, some were broken, and most of the others, which were buckled, showed numerous signs of having taken in wood. The variable bypass bleed valves of the low-pressure compressor (VBV) were in the open position. An actuator in the variable stator vanes of the high-pressure compressor (VSV) was in the extended position (VSV closed).

Many of the engine components, fixed to the periphery of the fan casing, had been torn off and scattered over the site.

The rear part (high-pressure compressor, combustor, high- and low-pressure turbines and jet pipe, was jammed under a fuselage component, its axis of rotation clearly horizontal.

The reverse thrust mechanism suffered a large degree of damage, in particular to the mounts attaching it to the pylon, which were buckled and broken. Two of the hydraulic actuators from the reverse thrust control were visible. Their rods were in the retracted position.

The two parts of the engine bore no significant traces of fire.

113.14 - Right engine

The right engine stayed complete, attached to its pylon on a section of wing. Its axis of rotation was clearly horizontal, in the same direction as the flight path.

There were no fan blades missing, some were broken, most were buckled and bore numerous signs of having taken in wood. The variable bypass bleed valves of the low-pressure compressor (VBV) were in the open position and the VSV actuators were in the extended position (VSV closed).

As on the left engine, many of the engine components fixed to the fan casing had been torn off and scattered around the site.

The reverse thrust mechanism suffered major damage. Its rear mounting system was torn off. The right-hand semi-reverser stayed in place, its two flaps closed.

This engine bore no visible signs of fire.

113.15 - Examination of controls, control surfaces and gauges

The flaps lever, found to the front of the central fuselage section, was trapped in a block of ice. It was stuck between marks 2 and 3.

Several rotary actuators from flaps and wing slats indicate that the flaps were down, despite the fact that it was not possible to determine their exact position from a simple visual examination. Precise measurements were therefore taken of these components. Applying the data gathered from an identical aircraft led to the conclusion that the flaps were locked in position 2, or 15^{0}, at the time of the impact.

Measurements were also carried out on slat tracks. Applying the data gathered from an identical aircraft showed that the slats were extended to 22^{0} at the time of the impact.

The spoiler lever was found about ten metres to the rear of the tail section. It was in the "spoilers retracted" position. This control had been twisted by the impact, and the exact position of the distortion shows that it was definitely in the "spoilers retracted" position at the time of the impact.

Several spoiler actuators were found. They do not permit any conclusions to be drawn as to the position of the spoilers on impact. Indeed, when hydraulic pressure is lost, actuators return to their neutral position, which corresponds to the spoilers retracted position. On the other hand, most of these actuators remained attached at least by one part to the sliding panels they controlled, which themselves suffered relatively little damage. Taking into account the break-up of the structure of the wing section, we can surmise that these spoiler panels would have undergone significant damage if they had been deployed at the time of the impact. It is therefore likely that the spoilers had been retracted, or only locked low (roll mode) on impact.

The positioning lever of the landing gear, found to the right of the tail section, was locked in the "extended" position.

The Standby Artificial Horizon, found to the rear of the tail section, was jammed in the 25^{0} nose down position with a 20^{0} left bank.

The Standby Altimeter, discovered to the front of the central fuselage section, was stuck between 1,023 and 1,024 Hpa. Its pointer was broken. The drum, which still appeared to be working, showed between 2,000 and 3,000 feet.

113.2 - General conclusions drawn from an examination of the wreckage

The survey of the wreckage showed that all the extremities of the aircraft as well as all of its mobile parts were present on the site. The aircraft did not therefore undergo any break-up prior to its collisions with the trees and the ground.

The distribution of the wreckage and the traces left on the trees point to the conclusion that the aircraft was being flown manually at the time of impact. The glide path was of the order of 12^{0} and the bank angle approximately 15 degrees to the left.

A comparison between the flight path and the centreline of the main parts of the wreckage, in particular the central fuselage section, shows that after initial impact the aircraft slewed into the trees, skidding to the right.

The rear section of the fuselage was destroyed by lateral force. Its progress was halted by trees and it suffered jolting caused by the repeated break-up of wing components. At the moment of contact with the ground, the nose section disintegrated, as shown by the way in which the cockpit components and the forward part of the cabin were scattered over the entire site. The underside of the front fuselage was gradually torn off as it continued to plough through the trees. The upper part tipped onto the ground before wrapping itself under the central section.

The examination of the wreckage also enabled the following aircraft configuration to be determined:

-gear down.
-flaps extended to 15^{0} and wing slats extended to 22^{0}, corresponding to position 2 of the slats/flaps lever.
- PHR position: 24.5 cm between the nut and the bearing at the electric screwjack outlet. This figure corresponds to a PHR deflection of 3.7^{0} nose up.
-spoilers retracted at the time of impact.

CHAPTER 1.14 - MEDICAL AND PATHOLOGICAL INFORMATION

114.1 - Captain

114.11 - Medical records

An analysis of the Captain's official medical records and the various items of information contained in the Inquiry's files reveals nothing that would support the hypothesis of an incapacity suffered during flight.

114.12 - Toxicological analyses

Identification of the remains of the Captain could only be carried out by genotypical analysis (piecing together fragments from the same body then seeking a possible family connection with its ancestry). Although the body was not completely reconstructed, formal identification was possible.

Several specimens were taken for analysis purposes: a blood sample, a specimen of vitreous humour (eye), a fragment of liver.

The liver specimen was subjected to two forms of toxicological analysis, by immunofluorescence and gas phase chromatography. Neither of these analyses revealed any medicinal or toxic substances from the following groups: benzodiazepines, tricyclical anti-depressants, barbiturates, opiates, cocaine derivatives, amphetamine derivatives, cannabis-related substances.

The dosages of ethyl alcohol were administered by gas phase chromatography complemented by specific detection by mass spectrography, liquid phase chromatography and spectrophotometric detection. This combination of techniques allows the ethyl alcohol to be administered in very precise quantities. In the blood sample, analysis revealed an ethyl alcohol content of 0.28 g/l; conversely, no trace of ethyl alcohol was found in the vitreous humour specimen. This difference can be explained by the formation of ethyl alcohol after death, as a result of the fermentation of sugars contained in the blood during the inevitable processes of fermentation. This mechanism does not exist in the vitreous humour, a tissue which does not contain fermentable sugars. The level of alcohol (nil in this case) found in the vitreous humour some time after death is currently considered to be very close to the blood level at the time of death.

Under these circumstances, it is legitimate to conclude that the Captain showed no known or identifiable cause of sudden incapacity during the flight and that no traces of ethyl, toxic or medicinal poisoning were detected on him.

114.2 - Co-pilot

114.21 - <u>Medical records</u>

The official medical records of the co-pilot point to a few problems, none of which called into question his aptitude for the position: excess weight, moderate dyslipidemy, increase in plasmatic gamma-GTs for at least 3 years, tendency towards progressive high blood pressure.

In the light of these risk factors, the co-pilot took a stress test in February 1991 which, it was concluded, showed no cardiac anomalies. The consultant noted in the report of the examination on 25 September 1991 "to be seen again in three months for a clinical and biological check". There is no record of any further examination being carried out at the CEMPN since that date, although it was not obligatory in nature.

114.22 - <u>Toxicological analyses</u>

The official forensic report makes particular mention of the highly fragmented and partially charred condition of the remains. Seven parts were identified, although this did not enable the whole body to be reconstructed. It was possible to corroborate the reconstruction of the body by undertaking a comparative analysis of the genotypes of the various fragments but identification could not be carried out by next-of-kin. However, identification of the body of the co-pilot was formally established by means of a partial comparison with ante-mortem and post-mortem odontological data, via the jawline of his beard and his clothing effects.

A fragment of striated muscle and a fragment of the stomach wall were removed for analysis. A search for toxic or medicinal substances was carried out under the same conditions as those described above in relation to the pilot. No evidence was brought to light of any of the substances sought.

The search for ethyl alcohol was performed under the same conditions as for the Captain. It produced the following results: 0.90 mg/g (milligrams per gram of moist

tissue) in the muscle specimen and 0.31 mg/g (idem) in the stomach wall specimen.

It is difficult to interpret the results of alcohol dosage on tissue debris which has been host to complex bio-chemical changes. If we interpret them with a large degree of caution, these results enable us to imagine the post-mortem neo-formation of ethyl alcohol in the muscle fragment as a result of the fermentation of sugars originating in the muscular energising substrates. Nevertheless it seems that the quantity of ethanol measured (0.90 mg/g) is too high to be attributed solely to this factor. On the other hand, the concentration measured in the stomach wall, which does not exhibit the same richness as the muscle in terms of energising substrates, seems as though it must be a far better indicator of the blood concentration of ethyl alcohol at the time of death. The Commission cannot therefore exclude the hypothesis that his blood alcohol level was not zero at the time of the accident. This being the case, it is possible to retain the level of 0.30 g/l as being the most probable alcohol level at that instant.

The co-pilot exhibited the metabolic and enzymatic signs generally found among regular consumers of alcohoic drinks, although they were by no means sufficient to give rise to any ruling of unfitness. It is thus possible to surmise that a certain level of consumption of alcoholic drinks by this individual was quite customary.

The available evidence shows, with due deference to caution, that the co-pilot probably consumed a certain quantity of alcoholic drinks on a regular basis and that, at the time of the accident, his blood alcohol level was less than or equal to 0.30 g/l. Based on the hypothesis that his alcohol level was not zero, and taking into account the imprecision of current scientific data, it is not absolutely possible to evaluate what could have been the co-pilot's blood alcohol level at the time he began his duty that day.

CHAPTER 1.15 - FIRE

The anatomical and toxicological analyses performed on the victims allow us to conclude that no fire nor any release of toxic fumes occurred before the impact. In fact no traces of smoke, gas or matter were found in the respiratory systems of these victims.

Three fire sources were discovered on the site of the accident (see the sketch in Appendix 4).

The aircraft's flight log allows us to estimate the quantity of fuel still present in the tanks at the time of the accident at approximately 4,500 litres. Part of the kerosene could have been atomised at the site when the wings were torn off.

Although it has not been able to be identified formally, the most probable origin of the fire sources was the ignition of the kerosene coming into contact with heated parts of the engines.

In its vapour state, kerosene can be ignited in

the presence of a flame or a spark as soon as the temperature reaches 42 ^{0}C ("flashpoint"). In its liquid state, in contact with a source of heat at a temperature above
250 ^{0}C, kerosene self-ignites.

In relation to the spread of the fires, the one located in the forward area was the most significant. It probably broke out at the time of the impact or very shortly afterwards. Tests carried out on pieces of titanium-based alloy and aluminium-based alloy mixtures demonstrated that the maximum temperature to which these parts of the wreckage were subjected was of the order of 700 ^{0}C.

The fire located in the central area, to the right of the fuselage, appears to have spread by delayed action, as a result of the discharge of fuel which undoubtedly came from the remains of a tank in the right wing. In fact, a survivor whose ankles were seriously injured gave evidence that he was burned well after the crash despite his efforts to get away from the fire that was in progress. It would appear, also according to his evidence, that two passengers who survived but were very seriously injured, were overtaken and burned alive by the spread of the burning fuel.

The fire in the rear section was less extensive than the first fires. It seems to have been fed essentially by the fuel intended for the APU. The CVR and DFDR recorders were found in this area. The tests carried out on these recorders (see para. 112.15) enabled the temperature reached on one side of the DFDR casing to be estimated at 700 ^{0}C. Analysis of a cluster of aluminium alloy in which some copper wires were wedged, together with an aluminium plate, allowed the further estimate to be made that locally in the rear section, the maximum temperature attained was somewhere between 500 and 800 to 1,000 ^{0}C.

CHAPTER 1.16 - QUESTIONS RELATIVE TO THE SURVIVAL OF THE OCCUPANTS

116.1 - Aspects relative to the cabin

116.11 - Instructions and procedures relative to the cabin crew

The instructions and procedures relative to the cabin crew (PNC) and flight crew (PNT) set out in the following section are extracted from the Operations Manual in force at Air Inter at the time of the accident.

The actions of the cabin crew are controlled by the actions of the flight crew. Before the descent, the flight crew announce over the public address system that the descent is imminent. When passing level 100 during the descent, the pilot at the controls (AP) announces 10,000 feet, the pilot not at the controls (NAP) places the "Fasten Seat Belts" switch in the "ON" position. Before landing, the lighting of the "No Smoking" sign is operated by the downlock of the landing gear (when the "No smoking" switch has been placed on AUTO by the flight crew).

116.111 - Statutory composition of the cabin crew

For less than 200 passengers the basic cabin crew is made up of 4 members, one of whom is a Chief Steward (C/S), allocated as follows:

. C/S seat A1 forward left entrance
. PNC A2 cabin crew member seat A2 forward left entrance
.PNC A3 cabin crew member seat A3 rear cabin, in the aisle next to the last row of seats
. PNC A4 cabin crew member seat A4 rear left entrance, in the rear vestibule.

116.112 - Procedures followed by the cabin crew

. <u>Descent</u>

When the "Seat Belt" sign is illuminated C/S makes the specified announcement or ensures that it has been made. A2 and A3 check that all the passengers are seated with their seat belts fastened and that all the overhead luggage lockers are closed, then A2, A3 and A4 check the potentially hazardous areas (rubbish bins, ashtrays, Cabin Attendants' Panel, water heater power cut-off, toilets), A1 checks that the "Caution" light is extinguished, A2, A3

and A4 notify the Chief Steward, who in turn reports to the Captain.

.<u>Before landing</u>

When the "No Smoking" sign is illuminated C/S makes the announcement "Please place your tables in the upright position" or ensures that it has been done. A2 and A3 check that the tables have been placed in the upright position, that the toilets are free, and that there are no objects blocking the aisles or impeding access to the overwing exits. A2 and A4 check that the galleys are locked, A2 and A4 open and secure the curtains, A2 and A3 open the mobile curtain.

All the cabin crew must be seated with their seat belts fastened by the time the C/S calls over the intercom, at the latest.

116.12 - <u>Cabin configuration during descent and at the time of impact</u>

According to the CVR transcription, the announcement by the cabin crew that descent had begun was made 12 mins 31 secs before final impact. It does not appear that there was any kind of announcement by the flight crew over the public address or the intercom.

Two minutes later, the cabin crew requested the passengers to fasten their seat belts. This announcement seems to have followed the action of the flight crew in illuminating the "Fasten Seat Belts" sign. The aircraft passed level 100 during descent, the co-pilot executed his checklist and announced "Seat belts on".

The landing gear extension lever was activated 55 seconds before impact, the announcement by the cabin crew to check that seat belts were fastened and tables in the upright position began 43 seconds and ended 11 seconds before impact.

The stewardess in the A4 position had her seat belt fastened. According to her evidence, her colleague, seated normally in the A3 position, offered to carry out the cabin check while she, before putting on her seat belt, finished clearing away and locking the galley.

It appears that all the procedures were followed within a relatively short space of time.

All the passengers most probably had their seat belts fastened at the time of impact.

116.13 - <u>Distribution of the accident survivors on board the aircraft</u>

Eight passengers and a stewardess survived the accident. Out of these nine survivors eight were located in the extreme rear section of the cabin. The ninth survivor was sitting in row 14 next to the window in the middle of the left wing section (see diagram of the distribution of survivors in Appendix 5). This passenger, the victim of multiple fractures to his ankles, seems to have been ejected at the moment of impact (he remembers perfectly being strapped a little loosely in his seat belt, and regaining consciousness outside the aircraft).

116.14 - <u>Causes of death</u>

The victims suffered an extremely violent frontal impact. In addition, a certain number of them were either completely or partially burned to death.

No traces of soot or pulmonary oedema were found when examining the upper air passages and the lungs, factors which would have been the sign of a fire or an explosion before impact.

All the victims had experienced multiple traumatisms. Certain lesions were frequently noted in the areas of the head, the pelvic girdle and the extremities of the lower limbs by the doctors who examined the bodies. According to these doctors, the lesions observed in the head area could have been due to the impact against the structure of the seat back situated in front of the passenger. The lesions in the pelvic girdle were probably due to the safety belts which, as far as can be ascertained, were not torn off. The lesions in the extremities of the lower limbs could have been accounted for by the lower part of the seat structure and by the fixtures attaching the seats to the floor of the aircraft.

According to the report of the Institute of Forensic Medecine in Strasbourg, these various lesions caused the immediate deaths of eighty one victims (included in this category were the two presumed victims whose remains were not identified). The same report states that, of the six victims whose death occurred after impact, two would probably have survived if the emergency services had arrived within the first two hours (they died
while being taken to ambulances. The four others might perhaps have had a chance of survival if the emergency services had arrived within the first thirty minutes.

116.15 - <u>Resistance of seats and seat belts</u>

116.151 - Material tested

Although a selection of seats and seat support rails was made at the site of the accident for official testing purposes, only one part of these items was able to be examined. Seats located to the front and the middle of the aircraft which had been selected for subsequent testing were not correctly separated from the rest of the wreckage and were destroyed.

The only items preserved were the three seats from row 29 left and a rear support of a seat whose position on the aircraft is unknown.

116.152 - Reminder of seat resistance standards

The seats with which F-GGED was fitted were designed, in accordance with prevailing standards, to withstand the following G load factors in a static position:

2 g from above (g=9.81 m/s^2)
9 g from the front
1.5 g in lateral
4.5 g from below.

116.153 - Results

The outcome of the analysis on the seats from row 29 left was as follows: the fracturing and distortions observed were probably caused by bending stresses under the effect of a load factor exerting itself primarily along an axis horizontal and parallel to the longitudinal axis of the aircraft, and applying itself to a row of seats which was loaded dissymetrically (only one passenger sitting next to the window: see the diagram in Appendix 5 showing the distribution of the survivors on board the aircraft).

The outcome of the analysis on the rear seat support was as follows: the support broke by flexing, probably under the effect of torque forces. It should be noted that the stresses sustained were multidirectional and greater than those sustained by row 29, whose rear supports were not apparently distorted.

These tests do not allow a precise evaluation to be made of the load factors to which the seats were subjected, all the more so as the stresses could have been applied along different directions between the moment the aircraft hit the ground and the time it came to a standstill.

Neither do they offer any significant additional reasons to explain the number and the distribution of the survivors.

It is appropriate to note at this point that as far as the seat characteristics are concerned, specifications have since changed. This type of seat is no longer used for commercial reasons and because it contains too much polycarbonate-based upholstery, dangerous in the case of impact. In addition, new toughness standards have been laid down for seats fitted to the new types of aircraft: the load factors applied during static resistance tests have been increased for certain directions of application (e.g. 4 g laterally, instead of 1.5 g), while resistance conditions for seats subjected to dynamic tests have been introduced and criteria relating to survival conditions on impact have been reinforced. The type of seat fitted in
F-GGED, successfully undertook tests to demonstrate conformity with the new standard with respect to Head Injury Criteria (HIC).

116.2 - Organisation of searches

116.21 - <u>Statutory considerations</u>

The organisation and operation of search and rescue services for aircraft in distress during peacetime are laid down by the interministerial order of 23 February 1987.

This order assigns overall authority for operations to the responsible Centre for Co-ordination and Rescue (RCC) within the geographical area concerned. This body is subject to the area control of the Air Force Operational Command.

In particular the RCC determines the probable accident area and the areas to be searched. It is responsible for the overall conduct of search operations and directly controls aerial resources, whereas the conduct of terrestrial emergency service operations is delegated to the Prefect of the Department.

The organisation of, and the procedures applied by the Air Alert Service are fixed by the Air Traffic Order (RCA 3-7 & 5-6). In the event of simultaneous loss of radio and radar contact, the lead times before emergency procedures are set in motion are respectively five minutes for ALERFA and ten minutes for DETRESFA.

The order of 23 February 1987 is backed by the SATER protocol agreement of 8 September 1987 which specifies how the various stages of ground search operations are to be organised.

The procedures involved are respectively SATER/1 (request for information not implying any shift in position), SATER/2 (ascertaining an area from the local population specified in the maximum possible detail) and SATER/3 (thorough searches on the ground when the sector in which the aircraft is being sought is pinpointed with sufficient certainty). The triggering of SATER/3 leads to the establishment of a permanent liaison between the RCC and the relevant Prefecture.

116.22 - <u>Progress of searches</u>

The Commission has reconstructed in summary form information on search and emergency operations taken from reports drawn up by the RCC at Drachenbronn and the Prefecture of Bas-Rhin (Lower Rhine), along with evidence gathered by the police.

The alert was activated at 18.31 hours by Strasbourg Approach who informed the Centre for Co-ordination and Rescue (RCC) at Drachenbronn, the Reims Control Centre (Eastern CRNA) and the Prefecture of Bas-Rhin (18.34 hours).

At 18.34 hours, the RCC set in motion the SATER/2 plan in conjunction with the Prefecture, in an area centred on Mont Sainte-Odile. This procedure was confirmed to the Director for Civil Defence and the Strasbourg Police Division at 18.39 and 18.43 hours respectively. At 18.56 hours, the Prefecture asked amateur radio enthusiasts to look for a possible transmission on the distress frequencies (121.5 and 243 Mhz).

At 19.09 hours, the Prefecture, at the request of the RCC, set in motion the SATER/3 procedure in a primary search sector between Mont Sainte-Odile and Andlau. At 19.30 hours this was extended to a four-sided area bounded by Mont Sainte-Odile, Barr, Andlau and Le Hochwald.

An Alouette III of the Civil Security based at Strasbourg-Entzheim airport, took off at 19.13 hours. This aircraft performed visual searches to the west of a line joining Barr with the Chateau de Landsberg. This area was within the specified four-sided area but did not totally cover certain mountain-tops, including Mont Sainte-Odile and La Bloss, which were covered by cloud formations.

At 19.20 hours the amateur radio enthusiasts reached Mont Sainte-Odile. They heard no ELT distress signals. In consequence, twelve teams of two radio amateurs spread out over the area to take part in ground searches.

The RCC gave orders to two Puma helicopters equipped with night-vision binoculars to take off at 19.40 and 21.32 hours respectively. In view of the flight conditions encountered (night flying in mountains with sharp ridges and risk of icing), these searches, which were ultimately fruitless, were carried out clear of cloud below 600 m QNH.

At 18.41 hours the RCC requested that the Drachenbronn radar recording be restored and similar steps were taken by Eastern CRNA. The corresponding recordings were not made available to the RCC until 20.10 and 22.04 hours respectively, given the techniques which existed for restoring radar flight paths in these Centres on the date of the accident and the prevailing procedures governing their implementation. These factors only allowed the RCC to redefine and reduce very gradually the range of ground searches from the extent specified at 19.09 and 19.30 hours.

Search operations were thus carried out primarily using ground-based resources directed from an operational command post (PCO) which was installed at 20.45 hours in the Barr police headquarters. The resources with which these operations were conducted grew in relation to the data available to the PCO and the RCC. Their main components were as follows:

- from 19.40 to approximately 21.00 hours, 24 police patrols combed, by road, the first four-sided area bounded by the Andlau and de Ville valleys and the Obernai-Ottrot sector.

- from 20.00 hours, the rescue centres of Ville, Schirmeck and Urmatt carried out search operations within a sector situated to the west of Mont Sainte-Odile for approximately 5 km.

- at 20.15 hours, the RCC confirmed the search area specified at 19.09 hours, requesting that investigations be concentrated in the Buchenberg region. Two police patrols were despatched to the area; their searches proved fruitless.

-as a result of the indications given to the PCO by two Air Inter representatives concerning the spot overflown by the A320 when it last had radio contact (Breitenbach), three search areas 3 km on each side were defined at 20.45 hours, arranged in descending order of priority.

Area N°1 was centred on La Bloss and the intention was to deploy the forces of the Mobile Guard as soon as they arrived, in an operation to comb this sector with the aid of firefighters and mountaineering guides from the Club Vosgien.

Deployment of the various search teams within this area was carried out from 21.00 to 21.35 hours:

-at 21.25 hours, the RCC requested the stepping-up of search operations along a line radiating at 320° from the Chateau de Landsberg towards point 826 (La Bloss).

-at 22.04 hours, the RCC gave the Prefecture the co-ordinates of the last plot recorded by the Eastern CRNA (48° 25' 37N; 007° 24' 42E), stating that the aircraft could be located at hill 826 (La Bloss).

-at 22.10 hours, an Army regiment (200 strong) was asked to begin combing area N° 2 (mission cancelled at 22.20 hours as a result of the latest evidence received which confirmed that search operations were being focussed on the La Bloss mountain area).

An able-bodied survivor was able to reach the road and point out the exact site of the wreckage. This enabled a detachment of Mobile Guard to reach the wreckage at 22.35 hours.

It must be pointed out that a considerable number of private vehicles converged very quickly on to all the roads leading to Mont Sainte-Odile, as a consequence, it would appear, of news announcements broadcast by the media (especially local radio).

Note: Resources utilised:

- Police (Mobile Guard and Territorial Police): 350 persons,
- Air Force and Army: 400 persons,
- State Security Police (CRS): 100 persons of which 24 were motor cycle police responsible for controlling traffic and access to the site,
- Civil Security: 100 persons,
- Radio amateurs: 24 persons,
- Two Puma helicopters from the ALAT,
- One Alouette III Civil Security helicopter.

116.3 - Organisation of emergency operations

116.31 - <u>Statutory consideration</u>

In pursuance of the law of 22 July 1987 relative to the organisation of civil security, Prefectures must draw up an emergency plan called the "Red Plan".

The Red Plan in force in Bas-Rhin, approved by a prefectorial Order on 11 June 1990, covers the deployment of emergency resources and medical aid in circumstances where normal resources would rapidly be exhausted but which do not necessitate the implementation of the ORSEC plan.

116.32 - Progress of emergency operations

The Red Plan was put into action at 18.40 hours. Organisation of the operational command post (PCO) was carried out under the following circumstances:

- the PCO was set up at the Barr Police Constabulary. The sub-prefect, director of emergency services, the superintendent colonel controlling emergency operations (COS) and the colonel in charge of the police detachment remained exclusively at this command post.

- the mobilisation of emergency medical resources, in accordance with a procedure laid down by the Departmental Red Plan, was carried out at the Obernai Emergency Centre, designated as the Point of First Destination (PFD) for all services.

These localities were chosen in view of their position close to the search area covering the two main access routes to the mountain (Barr and Ottrott).

When the wreckage was discovered, first aid was administered by those first to arrive, i.e. the police Mobile Guard who are all qualified first aid personnel. They were quickly joined by three military doctors and one or two civilian doctors. Reinforcements were urgently requested and the survivors were all located by 23.00 hours.

Before the arrival at approximately 23.20 hours of the first column of emergency aid vehicles from Barr, four people who according to the military doctors were fit enough to be transported were evacuated by the police Mobile Guard to the La Bloss car park, where the first emergency vehicles were stationed, either on men's backs or arms or even with the aid of makeshift stretchers.

Seven other people were evacuated between 23.20 and 00.15 hours by similar means. Some of them were examined and given medical treatment on the site by military doctors.

The second column of emergency aid vehicles coming from Obernai via Ottrott and carrying stretchers arrived approximately 45 minutes after the first. After a difficult climb due to the condition of the roads and congestion caused by curious onlookers, the siting of the vehicles was complicated by the presence of a large number of other vehicles (other emergency services, public order officials, idle onlookers, journalists).

On their way up the mountain to the site of the accident the doctors and first aid personnel passed the column of vehicles on its way down. The injured were accordingly transferred onto stretchers and transported to the rescue headquarters where the ambulances were located.

From approximately 01.30 hours onwards the operation to transfer the victims to hospitals in the region began.

Two victims died during the initial evacuation (from the site of the accident to the ambulances).

CHAPTER 1.17 - TESTING AND RESEARCH

117.1 - Technical analysis of propulsion systems, the APU, and the fuel

117.11 - Technical analysis of engines

Detailed technical analysis of the two engines was carried out at SNECMA, in its technical facility at Villaroche.

Dismantling operations consisted of separating the forward and rear modules (i.e. the fan module from the low pressure turbine module) and of disassembling the high pressure module.

The relevant findings are summarised in the following section and are applicable to both engines.

117.111 - Low pressure (LP) rotors: fan, LP compressor and LP turbine

During the phase when the aircraft was ploughing through the trees, the LP rotors were revolving, as demonstrated by the widespread presence of the air duct by vegetation debris (especially sawdust) up to the level of the exhaust flange. This general contamination had spread to the LP compressor, the combustion chamber, the HP (high pressure) diffuser and the LP turbine.

On impact with the ground, the LP rotors had rapidly decelerated and were either no longer rotating or were turning at very low speed. In fact:

-most of the fan vanes were buckled in the direction of rotation and towards the rear.

This was the result of the distortion of the fan casing following the collision with the ground,

-the blades and/or fixed blades of the LP turbine were buckled and/or snapped exclusively to the right of the distortions in the casings. This damage proves that there was not enough power in the rotors to force the vanes to move to the right of the distortions in the casings.

117.112 - High pressure (HP) rotors

The blades in the compression stages were either broken or buckled in the direction opposite to the

direction of rotation, as a consequence of radial friction on the casings. This finding enables us to confirm that the HP rotors were revolving during the entire phase in which the aircraft was ploughing through the trees.

117.12 - <u>Reverse thrust mechanism</u>

As far as the reverse thrust mechanism is concerned, analysis of the ACARS and QAR data shows no anomalies, whereas any major failure would have appeared in the form of a "Class 2" malfunction message, transmitted by ACARS.

In addition, X-ray analysis was carried out on two of the hydraulic actuator controls in the reversers. These confirm that the actuators were in the locked position (reverse thrust mechanism non-active).

117.13 - <u>Technical analysis of the APU</u>

The APU was practically intact. The air intake duct and the air intake screen were clean and clear of any sign of the ingestion of branches or pine needles.

At the site, the air bleed valve was found in the closed position. The fact that the APU was clean (unlike the engines) and the air valve closed shows that the APU was not in operation at the time of impact.

The company's flight instructions do not allow for its utilisation in flight except in emergency conditions or on landing in very specific circumstances. No such conditions or circumstances prevailed in Strasbourg on that day.

117.14 - Fuel

According to the weight and load distribution sheet completed by the crew, the weight of fuel on take-off from Lyon was 5,700 kg. Air Inter had replenished the tanks with 2,800 litres at the airport.

An analysis of the fuel - kerosene type "JET A1" -sampled at Lyon, was carried out at the Propulsion Test Centre (CEPr) in Saclay. This fuel meets the required technical specifications.

Among the parameters recorded in the QAR is the fuel flow (FF) which measures the consumption of fuel by each engine. This consumption, at constant altitude, is a

function of the power rating of each engine. An analysis of the QAR during the stage before the projected landing, (for example, from QAR time 2628 to QAR time 2980) indicates that the two FF parameters of the two engines were perfectly in keeping with the N1 parameters designating the power ratings of the engines.

The engines were therefore supplied quite normally with fuel for the entire duration of the flight. Estimates made of consumption put the quantity of fuel remaining at 3,700 kg.

117.2 - Technical analysis of components from ATA 22, 27, 31, and 34

117.21 - General method

The search for a possible failure of a system from ATA 22, 27, 31 and 34 was carried out using the following documents and recordings:

- documents relating to F-GGED in particular:
  - the ACARS of the Lyon-Strasbourg flight
  - the PFRs of the preceding flights
  - the CRMs and TSAs (technical facts)
  - the Technical Log
  - the last Type A inspection

. the incident reports drawn up by the captains and chief stewards.

-documents relating to the A320 used by Air Inter:

. NIT, CRM and TSA (technical facts), database.

-documents relating to the A320 in general:

. Flight Manual, FCOM, OEB, TR, AOT, TFU, CN, SB, the certification document "System Safety Assessment of the Flight Management and Guidance System".

-the available recordings:

. QAR, CVR;
. Non-volatile memory (CFDIU, FMGC, VOR, DME);
. ACARS, PFR;
. ATC frequency, radar;

-items from the wreckage:

. FCU rack, PHR screwjack,...;

-aeronautical information documents (AIP, NOTAM):

. List of radio navigation stations declared inoperative, verification of beacon co-ordinates contained in the database.

-simulations

. (for example to determine flight mode, not recorded on the QAR)

-The reports from in-flight inspections of radio navigation stations.

-occurrences notified by Operators.

All these documents were supported by specific test notes supplied by the Civil Aviation administration, the Operator, the manufacturer and equipment suppliers at the request of the Commission.

117.22 - <u>ATA 31 equipment. Electronic display systems</u>

117.211 - Electronic Flight Instrument Systems

The QAR and ACARS recordings show that the component parts of electronic display equipment for flight and navigation purposes (EFIS) were in their rated configuration and no faults were detected. The

CVR transcription contains no mention of any malfunctioning of the display systems (EFIS).

117.212 - The HUD (Head Up Display)

Five minutes before the accident, the HUD OHU/IDHUD message was transmitted by the ACARS system. This message can mean that the HUD has been made 'live' but has not yet been displayed, or that an internal problem in the viewer lens, has, for example, manifested itself by the disappearance of the symbolology. However, this message does not indicate a fault likely to cause the display of erroneous information. Listening to the CVR provided no additional information.

117.22 - <u>ATA 22 equipment</u>

117.221 - The FCU

117.221.1 - F-GGED was equipped with the FCU S/N 200.

An historical record has been drawn up of the modifications carried out on the FCU S/N 200 together with the maintenance operations it had undergone since its delivery to Air Inter:

This FCU was installed on F-GJVE on 12 August 1991. It was taken out on 14 September 1991 following a problem with speed selection (whatever the selection, the display window only showed a white point followed by dashes signifying a managed parameter). Installed on F-GJVB on 8 October 1991, the FCU was taken off on 11 December 1991 to allow for the application of the SIL (Service Information Letter) procedure, which is designed to remove the risk of interference on certain VHF frequencies. Re-installed on 13 December 1991 on F-GGEB, it was removed on 15 December 1991 as a result of interference to certain VHF frequencies. It was re-installed on 19 January 1992 on F-GGED, as a replacement for the FCU S/N 143 which showed evidence of a lighting fault connected with a rotary knob for selecting map scales.

The application of Service Bulletin (SB) instructions relating to the FCU was checked subsequently by Sextant, the equipment manufacturers: the Bureau Veritas examined the entire follow-up file on this equipment. No anomalies were found.

In particular, modifications carried out to raise it from the "K217 AAM5" to the "K217 AAM5 ABC" standard complied with the definition approved by the official authorities and became effective on 20 November 1990.

The technical report on F-GGED, dated 20 January 1992, mentions the recent installation of this FCU on F-GGED. On the day of the accident, the FCU totalled 597 flying hours, 8 of them since its installation on F-GGED.

117.221.2 - The sole components of the FCU recovered from the site were the forward panel and two of the integrated circuit boards belonging to its computers: the ARINC board of the FCU1 computer which does not contain any non-volatile memory, and a CPU board whose EEPROM component was destroyed.

The panel had been seriously damaged by the accident. The positions of some rotary switches and selector knobs had been noted on-site by the investigators:

- the ND1 display mode selector switch was in the VOR ROSE position, the ND2 display mode selector switch in the PLAN position;

- the scale selector switches on sides 1 and 2 were in the 10 NM position;

- on the captain's side, the n° 1 ADF/VOR selector switch was missing; the n° 2 ADF/VOR switch was on VOR;

- on the co-pilot's side, the n° 1 ADF/VOR selector switch was in the neutral position, whereas the n° 2 switch was on VOR.

The FCU was tested at Sextant, the equipment manufacturers, in the presence of an investigator from the BEA.

117.221.3 - It was found that:

- The Liquid Crystal Displays (LCDs) and the encoders were badly damaged or absent. It must be noted that it is not possible to ascertain the values displayed after a long interruption to the power supply.

- The mechanical components were damaged or absent. The VS (or FPA) vertical speed selector switch was jammed. It must be noted that the position of this button is in no way indicative of the last parameter value selected.

- The other rotary selectors were broken or not jammed. On the captain's side, the display mode selector switch was in the "ILS" position and the scale selected was 20 NM. On the co-pilot's side these switches were on "PLAN" and 10 NM. It was noticed that the position of the selector switches varied between the time they were noted down at the site (see above) and the time when the FCU was examined at the equipment manufacturers. It is not possible to confirm that the VOR/ADF selector switches, the display rotary selectors for the navigation screens and the scale selection rotary selectors stayed in the same positions they were at the time of the accident.

- The HDG-VS, TRK-FPA mode selector button was submitted to a test which demonstrated that electrical supply from the circuit-breaker was continuous but could not prove that the system operated correctly when this button was pressed.
- The EEPROM component of the CPU card was destroyed by the accident.

In conclusion, it was not possible during these evaluations to establish either the display mode or the scale selected by the non-acting pilot (NAP). Neither was it possible to make a judgment as to whether, just before the accident, components of the flight mode acquisition and processing mechanism, together with the assigned value selected by the pilot were actually functioning.

117.222 - CFDIU equipment

The S/N 393 CFDIU (Centralized Fault Data Interface Unit) had been recovered at the site of the accident. It was subjected to an examination at the premises of the equipment manufacturer in the presence of a BEA representative.

Damage incurred made the reading of its non-volatile memory impossible.

117.223 - FMGC equipment

117.223.1 - F-GGED was equipped with two FMGC computers. Their serial numbers were as follows:

FMGC side 1: S/N 126
FMGC side 2: S/N 79.

These items conformed to the most recent standard (ISB: Intermediate Standard N° 8).

117.223.2 - Examination of the FMGC computers

Among the few items recovered at the site and identified as part of these computers, only the EEPROM component of the COM card of FMGC2 could be read.

An analysis of this memory unit provided no further information than that obtained by analysing the QAR. This information is set out in the section below.

117.223.3 - Analysis of the QAR recording

Except during the last few seconds of the flight, when the recording medium was too damaged to be analysed, the QAR indicates that neither of the two FMGCs was stated to be faulty.

The positions calculated by FMGC1 were recorded on the QAR. The maximum margin found between the FMCG1 flight path and the so-called synthesised flight path (see para. 117.8) was approximately 0.15 NM. To give this an order of magnitude, when the updating method for the FMS position is "DME/DME", the position can be calculated with an accuracy estimated at better than 0.28 NM.

117.223.4 - Examination of the DATABASE

Characteristics (especially geographical co-ordinates and range) of the VOR and DME ground-based radio navigation stations are contained in the DATABASE used by the FMS to select and operate these methods of navigation. The characteristics of the stations likely to have been used during the flight were investigated.

In addition, it was noted that the Strasbourg VOR and TACAN stations were stated in the DATABASE to be "non co-located".

F-GGED was equipped with pin-programming, which automatically removes at the end of a flight any waypoints set up during this flight. This eliminates the hypothesis that a waypoint spelt ANDLO, created by the MCDU during a preceding flight and allocated with co-ordinates adjoining those at the published point, could have been included in the DATABASE.

117.223.5 - Examination of the ACARS messages

None of the ACARS messages makes mention of any malfunctioning of an item of equipment within ATA 22.

117.223.6 - Examination of the CRMs of F-GGED

The investigators had initially retained for further analysis the CRMs reporting transitions in Speed-VS mode in Idle/Open Descent mode.

Such a malfunction is not relevant to the accident, as the figures produced by a number of the parameters recorded show that the aircraft was not in Idle/Open Descent.

As far as the radio altimeters were concerned (ATA 34), CRMs reported certain malfunctions which led to the sending of an associated ACARS message. This was not the case here.

In the case of the FMGC computers, one CRM reported that it was impossible to select the display of VOR

read-outs on the Navigation Display screen from the left-hand panel (the EFIS control panel). This malfunction is not relevant to the accident as the QAR indicates that the pilot on the left was in VOR Rose mode.

Other CRMs notified instances of "Time Out". In such a case, the AP1 would have been disconnected and the occurrence would have been recorded on the QAR.

117.223.7 - Technical failures encountered:

As far as control of the descent by the pilot is concerned, possibile technical failures encountered are as follows:

- faulty operation of the reference control selector button for the HDG-VS <---> TRK-FPA trajectory;

- faulty operation of the rotary selector switch for the VS or FPA consigned value;

- fault in one or several segments of the display window;

- untimely mode activation: for example, engaging descent mode by simply rotating the selector without performing the action of first pulling on this switch.

As far as acknowledgement of the descent command
and its transmission to the FMCG is concerned, possible technical failures encountered involve all types of corruption of data processed, such as for example corruption causing the Autopilot to execute a command at variance with the one selected by the pilot (see para. 117.63).

117.23 - <u>ATA 27 equipment</u>

The ATA 27 documents relating to F-GGED and those relating to the A320 in general were examined. None of the malfunctions which form the subject of these documents were accepted as possible causes of the accident.

The circumstances of the accident prompted the investigators to examine in more detail the systems employed in monitoring the longitudinal flight path: the elevator control surfaces mechanism, the control mechanism for the adjustable horizontal stabiliser, the leading edge slats, the flaps and the spoilers.

An examination of the wreckage, the technical analyses undertaken, the parameters recorded on the QAR, the transcription of the CVR and the ACARS recording demonstrate that:

- the spoilers were operating correctly;

- the position of the wing slats and the flaps corresponded to the configurations selected and announced by the crew;

- the adjustable horizontal stabiliser and the elevators were at all times in positions which were consistent with the commands of an Autopilot which was flying according to the parameters of the flight path which were actually being implemented by the aircraft, their main objective being to maintain a constant vertical speed. The hypothesis that there was some kind of corruption specific to an ATA 27 system, to an operating parameter of the Autopilot, is therefore ruled out.

-the ELAC2 computer which controls the pitch control was not found to be faulty. (In the event that this computer is faulty the ELAC1 replaces it).

In conclusion, no evidence was found of a malfunction of an ATA 27 system.

117.3 - Technical analysis of radio navigation equipment on board

117.31 - <u>General method</u>

The crew and the FMS utilised the VOR and DME methods of radio navigation during the last turn and the final approach. The information provided by these systems was presented to the crew in the form of raw data and was also used by the FMS to calculate the position of the aircraft. Investigations into possible failures of these systems were conducted using the same methodology as that described in para. 117.2 in relation to the systems of the elevator mechanism. They chiefly consisted of the analysis of malfunctions identified up to December 1992.

The ILS and ADF systems were not examined in the course of the Inquiry.

117.32 - <u>Collins-700 DME equipment</u>

117.321 - F-GGED equipment

F-GGED was equipped with two Collins-700-020 DME devices:
DME side 1: S/N 1613 installed on 12 July 1991,
DME side 2: S/N 1683 installed on 9 August 1991.

This type of DME was specially adapted for installation in the A320 and other new-generation aircraft (e.g. the B747-400), so that it could be integrated into the maintenance systems by means of an interface with the CFDS system.

DME distance data are displayed on the Navigation Display screens and on the DDRMI. They are not recorded.

117.322 - Modifications since certifkcatkon

Since the date of certification of this equipment, modifications carried out to the hardware and amendments made to its operating procedure have been as follows:

- -on 20 June 1991, Collins distributed to all Operators of aircraft equipped with Collins-700 DME devices the Service Bulletin (SB) DME-700-
  34-20. This SB N°20 describes the modification which should be carried out to prevent an operating fault known as "SLEEPING MODE".

- -On 14 August 1991, the Operators Information Telex (OIT) N° ST/999.0140/91 recommended the application of SB N°20.

- -The Operations Engineering Bulletin (OEB) N°91/1, distributed in August 1991, outlined a monitoring procedure for DME data, until such time as SB N°20 covered by the modification N°22638 was applied.

- -The Temporary Revision (TR) N°113 of the Master Minimum Equipment List (MMEL), distributed in August 1991, demanded that the procedure described in OEB N°91/1 be applied, but solely in the case of flight with an FMGC.

- -On 22 August 1991, Modification N°22638 was approved, which made SB N°20 mandatory for A320s.

- -In September 1991, TR N°112 of the MMEL demanded that two items of DME equipment be operational at flight departure.

- -In March 1992, OEB N°91/2, dealing with sleeping mode and deaf mode, superseded OEB 91/1.

- -In September 1992, OEB N°91/3, dealing with sleeping mode, deaf mode and jump mode, superseded OEB N°91/2.

The processing of OEBs led to the issuing of Technical Information Notes (TIN) by the Flight Sector at Air Inter and the TRs were transferred in the form of corresponding Temporary Revisions into the Operations Manual.

117.323 - Examination of DMEs S/N 1613 and 1683 installed on F-GGED

As the two items of equipment had been recovered from the site, the non-volatile memory of the BITE in these two DMEs was read at the premises of the equipment manufacturer in the presence of a BEA representative. During the flight which culminated in the accident, none of the faults which might have been expected to be recorded were stored in this memory.

117.324 - Examination of documents relating to F-GGED

The aircraft's CRMs contained no information which raised doubts as to the operating quality of the DME processing system of F-GGED during the flight which led to the accident.

117.325 - Examination of the DATABASE and the NOTAMs in effect on the day of the accident

The investigators examined the features (in particular geographical co-ordinates and range) of the DME and TACAN stations contained in the DATABASE which are likely to have been used during the Lyon-Strasbourg flight (in France, Switzerland, Germany and Belgium).

In addition the NOTAMs relating to means of radio navigation were examined in order to identify any ground stations undergoing maintenance operations.

Finally, the military authorities confirmed that no aircraft carrying an on-board TACAN station was flying during the hour which preceded the accident.

None of the facts discovered in the context of these investigations was of a kind to cause an error in calculation during the approach.

117.326 - Evaluation of the hypotheses of malfunctions identified as sleeping mode, deaf mode and jumping mode

Comment: Data (frequency, distance, identification of ground station) is transmitted on five pre-assigned channels. One of these channels is reserved for display (EFIS and DDRMI screens). The FMGC computers do not perform any probability tests on the DME distances which are carried by this channel.

117.326.1 - "Sleeping mode" phenomenon

The fault known as "sleeping mode" is likely to affect any item of Collins-700 DME equipment which has not undergone the modifications of the Collins SB N°20, irrespective of the type of aircraft on which it may be installed.

This phenomenon is explained by the fact that every 33.5 seconds the DME distance value is recycled using the figure calculated at the moment the fault appeared. Furthermore, it is impossible to tune the DME to the frequency of another ground station.

When it detects sudden changes of distance greater than 0.35 NM, the FMCG linked to the defective DME automatically switches to pure inertial navigation mode.

In addition, if the positions calculated by the two FMCGs differ by more than 5 NM, the crew is informed via the message "FMS1/FMS2 POS DIFF" displayed on the MCDUs.

OEB N°91/1 (repeated and amplified in March 1992 in OEB 91/2) describes the operational procedure applicable by crews. This procedure recommends that the two DMEs are tuned into the same frequency and that a cross-check is made at regular intervals of the distance data displayed on the Navigation Screens and on the DDRMI.

When the phenomenon is detected, one re-initialisation (reset) can be attempted by actioning a reset of the circuit-breaker for the DME at fault.

Collins has laid down that SB N°20 (covered on the A320 by Modification N° 22638) is applicable for the correction of sleeping mode.

SB N°20 had not yet been applied to the Collins-700 DMEs installed on F-GGED.

Note: (The figures quoted below were given to the Commission by the equipment manufacturers in the middle of 1992).

Collins estimates that around 20 of the faults reported may be cases of sleeping mode, but that only six
of them have been able to be confirmed. An analysis by the company of the number of hours flown by the entire fleet of aircraft equipped with the Collins-700 has enabled it to predict that the probability of a fault

occurring is 10^{-5} per flight hour (i.e. one case in a hundred thousand flight hours). This statistic gives an idea of the order

of magnitude, although its accuracy is difficult to evaluate given the lack of certainty that all the cases of "sleeping mode" have indeed been discovered and then reported by crews.

No provision is made for this malfunction to be recorded on the data recorders (DFDR, QAR). Added to this, the CVR transcription includes no references by the pilots to the DME distances. Finally, the BITE software used by the Collins-700 DME devices was not capable of detecting or recording these malfunctions.

BITE is a software program designed to ensure that the equipment is self-monitoring and to facilitate maintenance operations upon it. It is therefore programmed with the particular object of detecting certain anomalies in the functioning of the operational program. The memory allocated to protect items of information relating to the anomalies detected is non-volatile memory, arranged into tables in which this data is ordered. The address of this physical protection is calculated by the BITE software. In the case of the sleeping mode phenomenon, the BITE software procedures do not detect that a storage address is taking up an excessive amount. An item of data relating to BITE is then logged in the memory reserved for the operational program, which causes it to malfunction.

However, after examining the content of the non-volatile memory stores of the DME devices, Collins came to the conclusion that there had been no sleeping mode during the approach. Their argument rests on the simultaneous non-occurrence of three criteria which distinguish the phenomenon. The hypothesis of a malfunction associated with sleeping mode can thus be refuted by a simple technical demonstration.

The validity of this demonstration was confirmed by an independent technical evaluation performed at CEAT (Toulouse Centre for Aeronautical Testing) at the request of the Commission. CEAT found inconsistencies and corruptions in the data recorded by the BITE software in non-volatile memory. Also according to CEAT, this program showed evidence of design faults which lead to the spillover of tables. Verification and testing procedures carried out on the Collins 700 DME BITE software did not show up these disorders before this equipment was put into service.

117.326.2 - "Deaf mode" phenomenon

This fault is likely to affect any Collins-700 DME device which has not been modified in accordance with the requirements of Collins SB N°24, irrespective of the type of aircraft on which it has been installed.

Although this fault was identified after the date of the accident, the investigators considered it to be a hypothetical failure relevant to the circumstances of the accident.

The fault occurs in the following way:- when the equipment is subjected to a voltage, five of its memory zones are not initialised. However, their contents are utilised to manage the scheduling of the six tasks (Input, Output, Receiver Manager, Monitor, Distance, Background) executed on each of the five channels of the DME.

When the fault occurs, it prevents the execution of one (or several) of the six tasks on one (or several) of the five channels. It is not a temporary malfunction.

The equipment manufacturer has confirmed that deaf mode can only occur when the equipment is once again subjected to a voltage after the DME's power supply has been cut off for at least one hour.

It is possible that the fault is only detectable in flight, for example if the FMGC or the crew attempt to change frequency when the task concerned (Input) cannot be executed on the channel concerned.

The OEB dated March 1992 describes deaf mode and recommends an operational procedure for detecting the fault. Should this be necessary, the crew will attempt to reinitialise by actioning a reset of the circuit-breaker for the DME at fault.

Collins has laid down that SB N°24 (covered on the A320 by modification N° 23196) is applicable for the correction of deaf mode.

The investigators were only aware of two cases: the first was encountered in the laboratory, the second during a flight on 15 February 1992.

The occurrence of this fault cannot be detected on QAR or BITE recordings.

On the other hand, it was not normally possible for the fault to occur on the Lyon stopover where, on account of its short duration, the power supply to the F-GGED equipment (in particular the DME) was not, in all probability, interrupted.

117.326.3 - "Jumping mode" phenomenon

This fault was identified following the accident. It is peculiar to Collins-700 DMEs, irrespective of the type of aircraft on which they are installed.

According to research carried out by Collins, the fault should only occur at low DME* speeds, less than 35 knots approximately. The maximum probability of occurrence is obtained when DME speed is nil.

(Note* : the DME speed is the radial speed of the aircraft in relation to the ground-based DME station. If the aircraft is at a constant distance from the station (for example during the execution of an "DME Arc" procedure), its DME speed is equal to zero.)

"Jumping mode" can affect any of the DME's channels:

In the case of a channel used for display purposes, the fault manifests itself in terms of a sudden jump in distance between -4.25 and -5.45 NM (the distance displayed is thus less than the true distance) for 14 seconds, after which time the DME software will have detected the discrepancy and recalculated the true distance.

In the case of a channel used for the calculation of FMS position, the fault can manifest itself in the form of a drift from the position calculated. Above FL 200 this drift is filtered and consequently does not have an effect on the FMS position. Below FL 200, the time constant of this filtering is less, which can lead to a drift from the FMS position. At its worst this drift does not exceed 2 NM.

OEB 91/3 of September 1992 outlines an operational
procedure based on the cross-checking of DME data.

SB N°25 sets out the modification specified by Collins for correcting jumping mode.

This malfunction is not recorded on the data recorders (DFDR, QAR).

The CVR transcription contains no comments by the pilots relative to DME distances.

The QAR recording provides heading and ground speed data as well as the positions of the aircraft calculated by FMGC1. This flight path analysis was

validated by comparison with a reference flight path analysis (see para. 117.8).

It can be noted that:

- coming out of a turn at 5,000 feet, the speed and heading values were such that the DME speed was above 160 knots.

- from QAR time 2980, and right up to the instant when it was put into descent (disengagement of ALT HOLD mode at QAR time 3005), the apparatus was approaching the ground DME station on a heading clearly equal to the QDM (approximately 060^{0}). As the aircraft was then practically in a headwind, the route followed was clearly equal to the QDM. In these conditions, the DME speed is close to the ground speed, i.e. 170 knots.

- the same is true during descent when heading and ground speed data are almost constant.

Therefore, more than thirty seconds before the aircraft was put into the descent and during descent itself, DME speed was much higher than the speeds at which jumping mode can occur.

The jumping mode hypothesis can thus be eliminated.

117.326.4 - Other malfunction

One fault reported at a date subsequent to that of the accident could not be classified with certainty under any of the three headings described above. It manifested itself in the form of erroneous DME distances alternately
affecting the two units in a temporary fashion. The fault was detected both by the crew and the FMGC, following which the computer rejected the DME in question. BITE did not include any mention of faults on this flight. No technical explanation of this discrepancy was available at the date this Investigation concluded.

117.33 - Collins-700 VOR equipment

117.331 - Equipment

F-GGED was equipped with two Collins-700-020 VOR receivers:

VOR side 1: S/N 842 installed on 20 June 1989,
VOR side 2: S/N 894 installed on 12 July 1991.

This type of receiver was adapted to allow for integration of the interface with the A320 maintenance system (CFDS).

According to the system of display selections operated by the crew, data prepared by the VOR receivers were liable to be shown on the navigation screens and on the DDRMI. These VOR data were not recorded.

The conduct of the approach, especially their method of alignment on the approach track, implied that the crew were using bearing indications with respect to the Strasbourg VOR station as well as deviations in relation to the 231° radial of the same station. As a result of this, the databases and the system used for calculating VOR indications on board were subjected to special tests.

117.332 - Modifications since certification

Since the date of its certification, modifications to the equipment and modifications to its operating procedure have been as follows:

- the introduction of a filtering system for VOR bearing information displayed on the navigation screens. The time constant of the filter is 0.8 seconds.

- TR N°124 of FCOM (July 1991) concerning Collins-700 VORs. This revision requires that VOR approaches are carried out in Navigation mode and that Go-Around is initiated if the VOR deviations are greater than 1/2 dot (reminder: a deflection of 1 dot in the Course Deviation Indicator signifies a deviation of 5° from the selected track).

- TR N°143 of FCOM (January 1992). This revision extends the application of the operational procedure outlined in TR N°124 to all types of VOR receivers.

-TR N°151 of FCOM (February 1992). This revision cancels and supersedes TR N°143. It outlines the operational procedure in the event of fluctuations and/or erroneous bearings.

-TR N°156 of FCOM (April 1992). This revision cancels TR N°151 in the case of aircraft which have undergone a cowling modification and earthing of the VOR antenna (SB N°34-1044, Modification N° 22956).

117.333 - Examination of the NOTAMS in effect on the day of the accident

An examination of the NOTAMs did not bring to light any anomalies likely to have affected the accuracy of VOR data during approach.

Reminder: In the database the Strasbourg VOR and TACAN stations were stated to be non co-located. Consequently the FMS did not use the STR VOR.

117.334 - Examination of ACARS messages

During the flight, twenty five and three minutes before the accident respectively, the ACARS system transmitted the message "VOR1 - No data from control source" and the message "VOR2 - No data from control source". The meaning of these messages has no connection with any possible erroneous VOR indications.

117.335 - Examination of the QAR: frequencies selected

The two VOR receivers were tuned in to the frequency of the Strasbourg station.

The fact that the VOR frequency is recorded on the QAR shows that the equipment's monitoring software had not detected any operating fault.

117.336 - Examination of the S/N 894 VOR installed on F-GGED

Only the VOR S/N 894 receiver was recovered from the site of the accident.

The non-volatile memory of its BITE software was read at the premises of the equipment manufacturers in the presence of a BEA representative.

Among the information available, it was found that the only message recorded during the last few flights was "No data from control source". The origin of this message forms the subject of Service Bulletin N°10. It does not indicate any erroneous VOR indication.

The BITE software of Collins-700 VOR equipment permitted neither detection nor recording of the malfunctions analysed in the following paragraph.

117.337 - Analysis of malfunctions identified as "VOR bearing errors" and "VOR indication flutter"

Two types of hazardous malfunctioning characterised by erroneous and/or fluctuating VOR indications have been reported regularly since the time the aircraft was brought into service (mid-1988).

The first is known as "Bearing errors", the second "Indication flutters".

117.337.1 - The phenomenon of "VOR bearing errors"

This phenomenon is characterised by highly erroneous VOR indications. It has only been reported on A320s equipped with VOR receivers made by an equipment manufacturer other than Collins.

This phenomenon is essentially due to the attenuation of the radio-electric signal by excessively heavy bonding of the fairing of the VOR antenna. The filtration of antenna signals at the input of the Collins VOR receiver is different to that applied at the input of VORs made by the other equipment manufacturer.

The probability that this phenomenon was present on F-GGED during its approach to Strasbourg is therefore extremely low.

117.337.2 - The phenomenon of "VOR indication flutter"

When this malfunction occurs, the omni-bearing indicator, along with the angular deviation bar, are subject to flutter, the amplitude and frequency of which vary according to the cases reported.

Among others, this discrepancy affects Collins-700-200 equipment. The manufacturer has attributed the cause essentially to the attenuation of the radio-electric signal by excessively heavy bonding on the fairing of the VOR antenna.

As in the case of the phenomenon of bearing errors, a modification consisting primarily of protective metallised coating to counteract lightning on the fairing of the VOR antenna has been made to the entire A320 fleet to correct this fault. This modification had not been applied to F-GGED.

This fault cannot be detected "a posteriori" on the QAR or BITE recordings.

It is therefore not possible to eliminate the hypothesis that there were such VOR indication flutters during the approach to Strasbourg.

117.34 - Evaluation of data displayed to the crew on the navigation screens

117.341 - Operation of the systems

The CVR transcription includes no mention of any discrepancy.

The QAR recording indicates that neither of the two FMGCs was declared to be faulty.

The QAR, ACARS and CVR recordings show that the components of the electronic displays for flight and navigation (EFIS) were in their nominal configuration, with no detection of faults monitored.

117.342 - Evaluation of the quality of the FMGC1 trajectory

The maximum deviation found between the FMGC1 trajectory and the reference flight path (see para. 117.8) was approximately 0.15 NM. (To give this an order of magnitude, when the current mode of the FMS position is "DME/DME", calculation of the FMGC position is performed with a level of accuracy estimated to be better than 0.28 NM).

A flight simulation (of final turn and placing in descent) showed a good correlation between the

FMGC1 trajectory and the trajectory obtained by selected flight mode. (see para. 117.5).

Note: If the aircraft cannot receive two DMEs correctly, the FMGC switches to pure inertial navigation mode, maintaining the divergence "inertial position - radio position" previously calculated. In this way the transition from "Radio-Inertial" to "Pure-Inertial" is not accompanied by a shift of position.

117.343 - Examination of discrepancies identified in relation to navigation maps shown on Navigation Display screens

The hypothesis of a discrepancy (discrepancies) in the navigation maps shown on navigation screens was considered. The different cases considered are set out in the following paragraphs.

117.343.1 - Shifting of the map with an exact FMCG position

Two distinct phenomena have been isolated:

a. "Map shifting"

In this case the position calculated by the FM is exact (managed navigation is correct) but a part of the trajectory presented on the ND shifts suddenly. This phenomenon is only encountered when certain identified approaches are being executed. It results from a particular combination of segments and points which define the FMS flight path.

Such combinations do not exist for the Strasbourg 05 VORTAC approach. Moreover, they cannot be created manually. The hypothesis of map shifting from the exact FMGC position is therefore ruled out.

b. Discrepancy of presentation in 10 NM scale

This phenomenon, discovered at a date subsequent to the accident, is the subject of TFU N° 22720019, opened in April 1992. Only a few cases have been reported since the A320 was put into service. This discrepancy is manifested by the incorrect positioning of symbology: i.e. the graphical representation of the active flight plan is erroneous.

The hypothesis of a discrepancy of presentation in 10 NM scale (only on co-pilot's side) cannot be eliminated for purely technical reasons.

117.343.2 - Shifting of the map from the false FMGC position

Note 1: The QAR recording does not include the positions calculated by FMGC2. This map discrepancy was examined to cover the eventuality that the co-pilot may have selected a particular map mode display, while the flight path shown was the one produced by FMGC2.

Note 2: Due to the absence of a recording, it is not possible to compare the positions calculated by FMGC2 to the reference flight path. Nothing can therefore be said about the quality of the FMGC2 trajectory but we note that the CVR transcription includes no mention relative to the existence of any display message signifying a difference of more than 5 NM between the positions calculated by the two FMGCs.

The phenomenon known as "shifting of the map with an exact FMGC position" was reported on a VORTAC 29 approach to Bordeaux. It was probably due to the fact that the FMGC was using data from the VOR co-located with the TACAN which had been degraded on reception by an excessive metal spray coating on the fairing of the VOR antenna.

However, the conditions under which FMGCs used ground stations were not the same at Strasbourg. Indeed, the STR VOR and TACAN were stated in the DATABASE to be non co-located. Because of this, although the two VOR receivers had been tuned in to STR, the FMGCs never used the data from this VOR. Even during the final phase they never moved into mode update "VOR/DME".

The hypothesis of a map shift linked to a false FMGC1 position is therefore excluded.

117.343.3 - Frozen ND symbology

In November 1992, the only case reported dated back to March 1992. According to the crew report, all the ND data were frozen and it was not possible to recover the normal indications by using the mode and scale selectors and the VOR/ADF select switches of the FCU.

117.4 - Testing and research with respect to ground-based radionavigation installations

117.41 - Introduction

With respect to the operational condition of ground-based radionavigation installations, the investigators examined the inspection reports on these stations as well as the results of measures effected on 23, 24 and 28 January 1992.

In fact, following the accident, the BEA had entrusted the STNA with the task of carrying out an in- flight inspection of the quality of the radio-electric aids that F-GGED had been able to use during its approach towards Strasbourg-Entzheim. This in-flight inspection had the following aims:

- checking the operation of the Strasbourg VOR;
- recording of DME or TACAN stations received during the procedure;
- checking the quality of distance data received;
- detection of possible jammers.

With this in mind, a measurement test bench installed on board the aircraft, together with specific installations on the ground to provide the reference trajectory, were put into operation.

It should be noted at this point that the entire VOR infrastructure is periodically subject to in-flight inspections.

With respect to DME stations, the STNA lays down that the permanent integrity test for these stations is performed out over the entire processing system, from reception of the aircraft's interrogation until broadcast of the ground station response. This mechanism renders in-flight inspection of the reliability of the test pointless. Before stations are placed in service, only DME reception data are supplied on request to technicians on the ground by an aircraft in flight, to correct the phenomenon of blind spots.

The upper limit of errors due to the TACAN station and to multi-tracks is estimated at 450 m (0.25 NM).

117.42 - **Analysis of the results of in-flight and ground inspections**

117.421 - Strasbourg VOR station (STR)

117.421.1 - Flight inspection of 24 July 1991

The average error recorded on the approach track was 0.5°. The rate of modulation was within the tolerances.

Note: In France it is recommended that the alignment error of a radial axis aid for an approach procedure is less than +/-1.5°.

A "high altitude" inspection had been carried out in November 1991: the average error found was 0.4°.

117.421.2 - Inspection performed on 23 January for the needs of the Investigation

It was noted that there was no inspection in the month preceding the accident.

An initial series of measurements was performed while flying in an orbit around the VOR at a distance of approximately 4 NM and at 1,300 feet, i.e. at an elevation of 3°. The average error found was of the order of 0.1°. The difference in comparison with the figure obtained during the "high altitude" inspection, can be explained by the fact that the procedures were not carried out at the same distance from the station, or at the same time. They are all within tolerances.

Note: The ICAO does not specify tolerances applicable to the average error measured at a given distance over 360° around the station. In France, stations are set up to maintain an average error of less than +/-1°.

The average measured "30 Hz Var" rate of modulation was within the ICAO tolerances.

As far as the "9960 Hz Ref" rate of modulation was concerned, this was found to be outside ICAO tolerances. A simulation of this phenomenon showed that the error induced in the indication was of the order of 0.1°.

Further series of procedures were performed on the radials 251, 241, 237 and 231° at an altitude of 5,000 feet, from 20 NM to the VOR. It was found that there was no loss of VOR data and that the characteristics of the radials (average error and rate of modulation) were within the prescribed tolerances.

The average error found on the 231° approach radial was +0.9°.

Note: Taking into account the sign convention adopted, this means that by selecting QDM 051°, maintenance of a nul angular deviation appears in the form of a ground trace of the aircraft located approximately at QDM 052° from the station, to the left of the published Final Approach track.

Finally, procedures were carried out on radial 311° which corresponds to the track STR VOR - GTQ VOR. The characteristics of the radials of these two VORs were within the prescribed tolerances.

In conclusion, inspection of the STR VOR station proved that errors of track alignment in approach procedure 05 and on the radials inspected comply with ICAO standards, despite the fact that the "9960 Hz Ref" rate of modulation is outside prescribed tolerances.

Irregularities were discovered between 9 and 8 NM from the station. They were again seen during the execution of the approach. They are attributable to multi-tracks (composition of the direct signal and signals reflected by an obstacle such as surrounding high ground).

From the viewpoint of ICAO standards, which require that irregularities measured on the VOR radials must be less than +/-3°, it is appropriate to remind ourselves that this figure was produced in 95% of cases. Points found on the recording which reach +/-4° are of very limited duration and are thus not sufficient to categorise this radial as being "outside standards".

However, such irregularities can cause instability in the VOR indication. This low-frequency interference has the appearance of a sine curve. Its maximum amplitude is between 3 and 4°.

A simulation computer for the Collins-700 receiver enabled an evaluation to be made of this receiver's response to a signal such as the one

recorded on 23 January. The response curve obtained shows that the
oscillations of the input signal are reproduced at the receiver's output. They are slightly attenuated and out of phase, predictable given the filtering applied.

In addition, the flight path of F-GGED was lower than that of the flight inspection aircraft and, in the very last seconds of the flight, F-GGED, obscured by

La Bloss mountain, was below the radio horizon of the STR VOR station. The nature of this 'eclipse' was such as to cause a further alteration in the VOR indication.

Finally, it should be pointed out that the signal is reflected differently, depending on whether the reflection surface is snow-covered or not. Although the inspection flights were carried out in snowy conditions similar to those encountered at the time of the accident, it is not possible to confirm that the VOR signal received by F-GGED was identical to that recorded during these inspection flights.

In summary, although we are not in a position to confirm that on the day of the inspection flight the conditions affecting the reflection of the VOR signal were identical to those encountered by F-GGED on its flight path, it is very probable that the irregularities in the signal manifested themselves in the form of movements in the VOR pointer and the VOR deviation bar of comparable amplitude.

117.422 - Strasbourg TACAN station (STR)

Alongside the inspection of VOR radials a parallel check was carried out on board the aircraft into the validity of distance data.

In addition, the aircraft executed a complete racetrack circuit starting from STR VOR at an altitude of 5,000 feet, then a fresh circuit aligned to QDM 057° of the VOR after a procedural turn and descent from 5,000 feet to overfly the accident site at low altitude. No loss of TACAN data was noted and the distances given were valid.

In conclusion, the reception of distance data from STR TACAN was satisfactory within the range of space investigated.

Procedures relating to the Grostenquin DME (GTQ): no interference due to the GTQ DME or any other

DME was ascertained during the 05 approach. Added to this, no information was received on the GTQ frequency when the station was cut off by technical service personnel for the purposes of this test.

An inspection carried out on 28 February 1992 as part of the normal programme of ground-based inspections of the TACAN station, showed that the "distance measurement" part of the TACAN was operating in the prescribed way. Two military aircraft validated the beacon data.

117.423 - Information received during the execution of approach

During the approach procedure, the flight control system utilised allowed for the reception of valid data from 12 different DME or TACAN stations*. Among these, between 11 and 3 could be received simultaneously (3 at an altitude of 500 feet on the approach path).

These data were of good quality and no jammer was detected. No radiation from any unknown station was found.

(*): Alphabetical list of the DME or TACAN stations received during the flight on 28 January:

BGT (TACAN Bremgarten, Germany), BLM (VOR/DME Basle), CLR (TACAN Colmar), GTQ (VOR/DME Grostenquin), HOC (VOR/DME Hochwald, Switzerland), LHR (TACAN Lahr, Germany), MCY (DME Etain, Meuse), NAY (TACAN Nancy-Ochey), PB (DME Phalsbourg, Moselle), SAA (TVOR/DME Saarbrucken, Germany), SLN (TACAN Sollingen, Germany), STR (VOR/TACAN Strasbourg).

117.5 - Research into Autopilot vertical mode during Final Approach

117.51 - <u>Introduction</u>

In "selected" mode, the automation of the aircraft in lateral and vertical flight offers two possible flight path references, which link the corresponding lateral and vertical modes: the reference "HEADING/VERTICAL SPEED" (HDG-VS) and the reference "TRACK/FLIGHT PATH ANGLE" (TRK/FPA). Knowledge of the reference actually used by the crew of F-GGED during the last turn and final descent is an important factor in understanding the accident. This information, however, is not recorded on the QAR (or

on
the DFDR). Moreover, no part of the CVR recording reveals this reference.

An attempt has therefore been made to establish by logical means the specific reference used, utilising data available on the QAR.

117.52 - <u>Simulation display</u>

A numeric simulation was undertaken of that part of the flight extending from QAR time 2900 (the aircraft was at the end of its outbound track on heading 231) to QAR time 3035 (the aircraft was stabilised during descent at

3,300 ft/mn). Using a numeric model of the aircraft's flight, this simulation consists of calculating the values of parameters representing the flight path obtained with the aid of different hypotheses: HDG-VS or TRK-FPA reference, hypotheses concerning the selection of command parameters by the crew. These parameters were compared with those recorded on the QAR of F-GGED, and a hypothesis was established leading to the optimum correlation between values calculated and values recorded.

Note: This simulation was halted at QAR time 3035, the moment when the airbrakes were deployed, as the effect of the progressive deployment of airbrakes is difficult to model with a sufficient degree of precision in the simulation used, where the parameters (vertical speed or angle of descent) are constantly changing.

117.53 - <u>Examination of the hypothesis of a change in the flight path reference between the start of the last turn and the moment of the accident</u>

An analysis of how the Autopilot operates shows that by design, any change in mode causes the command (heading and, if the mode has been activated, vertical speed, with the reference HDG-VS; track and, if the mode has been activated, angle of descent, with the reference TRK/FPA;) to be identified with the instantaneous value of the parameter being considered at the time when the mode is being changed.

If the flight path is not stable and rectilinear, this will manifest itself in the form of a jolt on the aileron deflection and the bank attitude, or on the elevator.

By way of example, let us consider the case of a 90° right turn in TRK mode coming out of a northerly route. The command "TRK 90°" has been selected and the aircraft is turning to the right. If in the course of the turn the pilot goes into HDG mode, the Autopilot instruction instantly changes to the value of the heading at the moment the mode was changed, for example "HDG 52°". However, as the aircraft is in a manoeuvre, this heading tends to be overshot by inertia, and the Autopilot will have to initiate a correction, which takes the form of a jolt on the aileron deflection in the opposite direction to the turn, so that it can seek out the target heading established at the moment the mode was engaged. Similar reasoning applies to the vertical plane, during the dynamic phase when the aircraft is put into descent mode.

In the case of F-GGED, no jolt of this type was found on the QAR recordings, or on the bank attitude for the duration of the turn, or on the elevator at the time when the aircraft was put into descent mode.

An analysis of the QAR recordings therefore leads to the conclusion that no change in flight path reference could have occurred from the time the aircraft was put into its last turn.

117.54 - <u>Determination of vertical flight mode</u>

Once it has been demonstrated that this reference is permanent, it remains to be determined which of the two couples, HDG/VS or TRK/FPA, was most probably utilised by the crew in this phase of the flight.

The analysis rests on two arguments.

The first concerns the degree of conformity, following the adopted reference, of the values calculated and the values recorded, for the representative parameters: heading or track, vertical speed.

The second concerns the exact times the aircraft came out of a manoeuvre, as defined by the Autopilot command values on the approach.

117.541 - Comparison between values calculated / values recorded for flight path parameters

The first parameter it is necessary to determine is the wind (intensity and direction). To do this we

calculated the vectorial difference between the true speed
(V_{TAS}) and the ground speed (V_{GS}) derived from IRS data available on the QAR.

V_{TAS} is not recorded on the QAR. It is determined by applying a density correction to the air speed V_{CAS}, which is recorded. On the day of the accident, the temperature at 5,000 ft was 10^{0} lower than the standard temperature.

By tracing on the same diagram the coefficients of the true speed thus calculated and of the ground speed read from the QAR, a point is found at which the two curves intersect: the ground speed and the true speed are equal in terms of their coefficients at the exact QAR time of 2937. The aircraft heading is then 161^{0} and the track 116^{0}. By completing a triangle of the speeds it can be deduced from this that the wind is coming from 074^{0} and that its intensity is 20 knots.

This value is confirmed at QAR time 2900: heading 230, V_{CAS}=231 knots, V_{TAS}=242 knots; taking into account the wind determined above, a figure of V_{GS}= 260 knots is obtained, which conforms with the QAR data.

Note: The preceding calculation does not take into account the error in ground speed. This error is due to the drift from the cetral inertial unit (IRS1). This is a vector of direction and magnitude which is constant over the scale of time considered (a few minutes). In the following section we evaluate the effect of such an error by breaking it down into a vector parallel to the approach path and a normal vector along this axis.

The simulation begins with the following initial parameters: heading 231, pressure altitude 4,750 ft, air speed V_{CAS} 230 knots. It is carried out on the one hand using the TRK-FPA reference, on the other using the HDG-VS reference. It takes account of the following events, while keeping exactly to the time intervals found on the QAR:

- change of heading or track command selected (probably to the value of 090^{0}) (QAR time 2902);
- deceleration from 230 knots to 180 knots (QAR time 2912);
- transition to configuration 1 (slats 18^{0} /

flaps 0^{o}) (QAR time 2927);

-further changes in heading or track commands selected to rejoin the extended centreline of the runway (QAR time 2945, 2986);

-transition to configuration 2 (slats 22^{o} / flaps 15^{o}) (QAR time 3000);

-selecting descent in V/S or FPA mode (QAR time 3006);

-landing gear extension (QAR time 3010).

With respect to lateral mode, it was found that the plots relating to heading, track, bank attitude and aileron deflection obtained by simulation in HDG mode were perceptibly nearer the plots taken from the QAR than those obtained by simulation in TRK mode, especially the lateral incline from the maximum figure of 25^{o} when coming out of a turn.

As far as vertical mode is concerned, it was likewise found that the plots obtained in VS mode concerning vertical speed, pitch attitude and elevator deflection were closer to the plots taken from the QAR than those obtained by simulation in FPA mode. In particular, in FPA mode, it is essential to select the maximum possible angle of descent value which can be displayed (9^{o} 9) in order to approximate the aircraft recording, but the maximum vertical speed reached (of the order of -3,050 ft/mn) is still far from the recorded figure of a variation (200 ft/mn) which is appreciably greater than the rated accuracy with which the Autopilot follows the parameter (+/- 50 ft/mn).

117.542 - Determination of the instant of desaturation from Autopilot vertical mode

In analysing the structure of the control laws in VS mode, it can be seen that the variation in pitch attitude controlled by the Autopilot is firstly proportional to the variation between the aircraft's vertical speed and the value selected by the pilot (command), and then constant when this variation exceeds a certain limit. It is then said that the flying loop is "saturated".

In the case of the flight which led to the accident, this saturation value of the order of attitude excursion was -1,050 ft/mn. In fact, transition to configuration 2 had, by means of a lift augmenting effect, induced a positive vertical speed of more than 500 ft/mn at the same time that the crew were ordering a descent. In such a case the authority of the Autopilot is increased (the standard saturation figure is 350 ft/mn).

This saturation principle has the following consequence: whether one selects (as in this case) a negative vertical speed of 1,050 ft/mn or 6,000 ft/mn (the maximum figure which can be selected), the speed at the beginning of descent mode is identical, and descent will take place with the same vertical acceleration, although the aircraft is not being flown in G-load factor during this phase (the variation in the G-load factor is close to 0.12/0.13g in this case). The sole difference will be in the acceleration time.

As the selected value is approached, the Autopilot orders an attitude excursion in the opposite direction to the preceding one. The Autopilot loop is then said to be "desaturating". This desaturation thus occurs 1,050 ft/mn before the target value, i.e. at -2,250 ft/mn if the value selected was -3,300 ft/mn. It manifests itself in the form

of a jolt on the elevator, the appearance of a sudden rapid variation of approximately +0.1 g in vertical acceleration, a break in the speed of the trim and a rounding off in the vertical speed curve.

Note: The vertical speed recorded on the QAR is a barometric vertical speed. In order to obtain this parameter, the barometric vertical speed calculated by the simulation is obtained by assigning the geometric vertical speed the coefficient of temperature correction: $[1 - (T^0\text{-TISA}) / T^0]$.

An analysis of the structure of the control laws in FPA mode leads to comparable findings. The variation in pitch attitude controlled by the Autopilot is 'saturated' when the difference between the current angle and the angle selected exceeds a certain limit.

In the case of the flight which led to the accident, this saturation figure of attitude excursion was in the order of 585 deg*knot. In effect, transition into configuration 2 had led to an angle of climb of more than 1.5^0 at the same time that the crew were ordering a descent. As in VS mode, the authority of the Autopilot is increased in such a case; otherwise the standard saturation figure is 195 deg*knot.

Desaturation thus occurs under the same conditions 585 deg*knot before the target value, or 3.4° before the angle selected (given a ground speed of 170 knots). If the figure selected was $9^{\circ}9$ and if this data was converted into vertical speed, it would be found that the theoretical point of desaturation in FPA mode corresponds to a Vz of 1,965 ft/mn. This point will be accompanied by the same phenomena as desaturation in VS mode: a jolt will be noticed on the elevator, and there will be a sudden rapid variation in vertical acceleration of approximately +0.1 g.

Numerical simulation consequently predicts that desaturation point will occur considerably earlier in time in FPA mode (Vz= -1,964 ft/mn) than in VS mode (Vz =
-2,250 ft/mn). The error calculation shows that this differentiation resists possible errors (one shift in a calculation cycle in the control law (180 ms) leads to an error of 36 ft/mn; one error of +/- 5 knots in the module of the ground speed leads to an error of 80 ft/mn).

Note: The computer derives the angle of descent (FPA) from the baro-inertial vertical speed using the following formula:

Tangent (FPA) = VzBI/Vgs

where Vgs is the ground speed of the aircraft calculated by combining the accelerations measured along the "north" axis and the "east" axis by the IRS.

The baro-inertial vertical speed is not recorded. However, the method by which it is calculated is such that this vertical speed is equal to the barometric vertical speed for slow dynamics. This is the case between times 3015 and 3035 and the vertical speed recorded on the QAR is thus comparable with that taken into account when calculating the FPA.

The desaturation point which corresponds to the factors described above can be pinpointed on the QAR recording at time 3027. The average vertical speed close to this moment is of the order of -2,250 ft/mn (or even higher). This point thus corresponds to the simulation prediction for VS mode.

117.4 - Testing and research with respect to ground-based radionavigation installations

117.41 - Introduction

With respect to the operational condition of ground-based radionavigation installations, the investigators examined the inspection reports on these stations as well as the results of measures effected on 23, 24 and 28 January 1992.

In fact, following the accident, the BEA had entrusted the STNA with the task of carrying out an in- flight inspection of the quality of the radio-electric aids that F-GGED had been able to use during its approach towards Strasbourg-Entzheim. This in-flight inspection had the following aims:

- checking the operation of the Strasbourg VOR;

- recording of DME or TACAN stations received during the procedure;

- checking the quality of distance data received;

- detection of possible jammers.

With this in mind, a measurement test bench installed on board the aircraft, together with specific installations on the ground to provide the reference trajectory, were put into operation.

It should be noted at this point that the entire VOR infrastructure is periodically subject to in-flight inspections.

With respect to DME stations, the STNA lays down that the permanent integrity test for these stations is performed out over the entire processing system, from reception of the aircraft's interrogation until broadcast of the ground station response. This mechanism renders in-flight inspection of the reliability of the test pointless. Before stations are placed in service, only DME reception data are supplied on request to technicians on the ground by an aircraft in flight, to correct the phenomenon of blind spots.

The upper limit of errors due to the TACAN station and to multi-tracks is estimated at 450 m (0.25 NM).

117.42 - **Analysis of the results of in-flight and ground inspections**

117.421 - Strasbourg VOR station (STR)

117.421.1 - Flight inspection of 24 July 1991

The average error recorded on the approach track was 0.5°. The rate of modulation was within the tolerances.

Note: In France it is recommended that the alignment error of a radial axis aid for an approach procedure is less than $+/-1.5^{\circ}$.

A "high altitude" inspection had been carried out in November 1991: the average error found was 0.4°.

117.421.2 - Inspection performed on 23 January for the needs of the Investigation

It was noted that there was no inspection in the month preceding the accident.

An initial series of measurements was performed while flying in an orbit around the VOR at a distance of approximately 4 NM and at 1,300 feet, i.e. at an elevation of 3°. The average error found was of the order of 0.1°. The difference in comparison with the figure obtained during the "high altitude" inspection, can be explained by the fact that the procedures were not carried out at the same distance from the station, or at the same time. They are all within tolerances.

Note: The ICAO does not specify tolerances applicable to the average error measured at a given distance over 360° around the station. In France, stations are set up to maintain an average error of less than $+/-1^{\circ}$.

The average measured "30 Hz Var" rate of modulation was within the ICAO tolerances.

As far as the "9960 Hz Ref" rate of modulation was concerned, this was found to be outside ICAO tolerances. A simulation of this phenomenon showed that the error induced in the indication was of the order of 0.1°.

Further series of procedures were performed on the radials 251, 241, 237 and 231° at an altitude of 5,000 feet, from 20 NM to the VOR. It was found that there was no loss of VOR data and that the characteristics of the radials (average error and rate of modulation) were within the prescribed tolerances.

The average error found on the 231° approach radial was +0.9°.

Note: Taking into account the sign convention adopted, this means that by selecting QDM 051°, maintenance of a nul angular deviation appears in the form of a ground trace of the aircraft located approximately at QDM 052° from the station, to the left of the published Final Approach track.

Finally, procedures were carried out on radial 311° which corresponds to the track STR VOR - GTQ VOR. The characteristics of the radials of these two VORs were within the prescribed tolerances.

In conclusion, inspection of the STR VOR station proved that errors of track alignment in approach procedure 05 and on the radials inspected comply with ICAO standards, despite the fact that the "9960 Hz Ref" rate of modulation is outside prescribed tolerances.

Irregularities were discovered between 9 and 8 NM from the station. They were again seen during the execution of the approach. They are attributable to multi-tracks (composition of the direct signal and signals reflected by an obstacle such as surrounding high ground).

From the viewpoint of ICAO standards, which require that irregularities measured on the VOR radials must be less than +/-3°, it is appropriate to remind ourselves that this figure was produced in 95% of cases. Points found on the recording which reach +/-4° are of very limited duration and are thus not sufficient to categorise this radial as being "outside standards".

However, such irregularities can cause instability in the VOR indication. This low-frequency interference has the appearance of a sine curve. Its maximum amplitude is between 3 and 4°.

A simulation computer for the Collins-700 receiver enabled an evaluation to be made of this receiver's response to a signal such as the one recorded on 23 January. The response curve obtained shows that the oscillations of the input signal are reproduced at the receiver's output. They are slightly attenuated and out of phase, predictable given the filtering applied.

In addition, the flight path of F-GGED was lower than that of the flight inspection aircraft and, in the very last seconds of the flight, F-GGED, obscured by

La Bloss mountain, was below the radio horizon of the STR VOR station. The nature of this 'eclipse' was such as to cause a further alteration in the VOR indication.

Finally, it should be pointed out that the signal is reflected differently, depending on whether the reflection surface is snow-covered or not. Although the inspection flights were carried out in snowy conditions similar to those encountered at the time of the accident, it is not possible to confirm that the VOR signal received by F-GGED was identical to that recorded during these inspection flights.

In summary, although we are not in a position to confirm that on the day of the inspection flight the conditions affecting the reflection of the VOR signal were identical to those encountered by F-GGED on its flight path, it is very probable that the irregularities in the signal manifested themselves in the form of movements in the VOR pointer and the VOR deviation bar of comparable amplitude.

117.422 - Strasbourg TACAN station (STR)

Alongside the inspection of VOR radials a parallel check was carried out on board the aircraft into the validity of distance data.

In addition, the aircraft executed a complete racetrack circuit starting from STR VOR at an altitude of 5,000 feet, then a fresh circuit aligned to QDM 057° of the VOR after a procedural turn and descent from 5,000 feet to overfly the accident site at low altitude. No loss of TACAN data was noted and the distances given were valid.

In conclusion, the reception of distance data from STR TACAN was satisfactory within the range of space investigated.

Procedures relating to the Grostenquin DME (GTQ): no interference due to the GTQ DME or any other DME was ascertained during the 05 approach. Added to this, no information was received on the GTQ frequency when the station was cut off by technical service personnel for the purposes of this test.

An inspection carried out on 28 February 1992 as part of the normal programme of ground-based inspections of the TACAN station, showed that the "distance measurement" part of the TACAN was operating in the prescribed way. Two military aircraft validated the beacon data.

117.423 - Information received during the execution of approach

During the approach procedure, the flight control system utilised allowed for the reception of valid data from 12 different DME or TACAN stations*. Among these, between 11 and 3 could be received simultaneously (3 at an altitude of 500 feet on the approach path).

These data were of good quality and no jammer was detected. No radiation from any unknown station was found.

(*): Alphabetical list of the DME or TACAN stations received during the flight on 28 January:

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117.5 - Research into Autopilot vertical mode during Final Approach

117.51 - <u>Introduction</u>

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An attempt has therefore been made to establish by logical means the specific reference used, utilising data available on the QAR.

117.52 - <u>Simulation display</u>

A numeric simulation was undertaken of that part of the flight extending from QAR time 2900 (the aircraft was at the end of its outbound track on heading 231) to QAR time 3035 (the aircraft was stabilised during descent at

3,300 ft/mn). Using a numeric model of the aircraft's flight, this simulation consists of calculating the values of parameters representing the flight path obtained with the aid of different hypotheses: HDG-VS or TRK-FPA reference, hypotheses concerning the selection of command parameters by the crew. These parameters were compared with those recorded on the QAR of F-GGED, and a hypothesis was established leading to the optimum correlation between values calculated and values recorded.

Note: This simulation was halted at QAR time 3035, the moment when the airbrakes were deployed, as the effect of the progressive deployment of airbrakes is difficult to model with a sufficient degree of precision in the simulation used, where the parameters (vertical speed or angle of descent) are constantly changing.

117.53 - <u>Examination of the hypothesis of a change in the flight path reference between the start of the last turn and the moment of the accident</u>

An analysis of how the Autopilot operates shows that by design, any change in mode causes the command (heading and, if the mode has been activated, vertical speed, with the reference HDG-VS; track and, if the mode has been activated, angle of descent, with the reference TRK/FPA;) to be identified with the instantaneous value of the parameter being considered at the time when the mode is being changed.

If the flight path is not stable and rectilinear, this will manifest itself in the form of a jolt on the aileron deflection and the bank attitude, or on the elevator.

By way of example, let us consider the case of a 90° right turn in TRK mode coming out of a northerly route. The command "TRK 90°" has been selected and the aircraft is turning to the right. If in the course of the turn the pilot goes into HDG mode, the Autopilot instruction instantly changes to the value of the heading at the moment the mode was changed, for example "HDG 52°". However, as the aircraft is in a manoeuvre, this heading tends to be overshot by inertia, and the Autopilot will have to initiate a correction, which takes the form of a jolt on the aileron deflection in the opposite direction to the turn, so that it can seek out the target heading established at the moment the mode was engaged. Similar reasoning applies to the vertical plane, during the dynamic phase when the aircraft is put into descent mode.

In the case of F-GGED, no jolt of this type was found on the QAR recordings, or on the bank attitude for the duration of the turn, or on the elevator at the time when the aircraft was put into descent mode.

An analysis of the QAR recordings therefore leads to the conclusion that no change in flight path reference could have occurred from the time the aircraft was put into its last turn.

117.54 - <u>Determination of vertical flight mode</u>

Once it has been demonstrated that this reference is permanent, it remains to be determined which of the two couples, HDG/VS or TRK/FPA, was most probably utilised by the crew in this phase of the flight.

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The first concerns the degree of conformity, following the adopted reference, of the values calculated and the values recorded, for the representative parameters: heading or track, vertical speed.

The second concerns the exact times the aircraft came out of a manoeuvre, as defined by the Autopilot command values on the approach.

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The first parameter it is necessary to determine is the wind (intensity and direction). To do this we calculated the vectorial difference between the true speed
(V_{TAS}) and the ground speed (V_{GS}) derived from IRS data

available on the QAR.

V_{TAS} is not recorded on the QAR. It is determined by applying a density correction to the air speed V_{CAS}, which is recorded. On the day of the accident, the temperature at 5,000 ft was 10^0 lower than the standard temperature.

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This value is confirmed at QAR time 2900: heading 230, V_{CAS}=231 knots, V_{TAS}=242 knots; taking into account the wind determined above, a figure of V_{GS}= 260 knots is obtained, which conforms with the QAR data.

Note: The preceding calculation does not take into account the error in ground speed. This error is due to the drift from the cetral inertial unit (IRS1). This is a vector of direction and magnitude which is constant over the scale of time considered (a few minutes). In the following section we evaluate the effect of such an error by breaking it down into a vector parallel to the approach path and a normal vector along this axis.

The simulation begins with the following initial parameters: heading 231, pressure altitude 4,750 ft, air speed V_{CAS} 230 knots. It is carried out on the one hand using the TRK-FPA reference, on the other using the HDG-VS reference. It takes account of the following events, while keeping exactly to the time intervals found on the QAR:

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- deceleration from 230 knots to 180 knots (QAR time 2912);
- transition to configuration 1 (slats 18^0 / flaps 0^0) (QAR time 2927);

-further changes in heading or track commands selected to rejoin the extended centreline of the runway (QAR time 2945, 2986);

-transition to configuration 2 (slats 22° / flaps 15°) (QAR time 3000);

-selecting descent in V/S or FPA mode (QAR time 3006);

-landing gear extension (QAR time 3010).

With respect to lateral mode, it was found that the plots relating to heading, track, bank attitude and aileron deflection obtained by simulation in HDG mode were perceptibly nearer the plots taken from the QAR than those obtained by simulation in TRK mode, especially the lateral incline from the maximum figure of 25° when coming out of a turn.

As far as vertical mode is concerned, it was likewise found that the plots obtained in VS mode concerning vertical speed, pitch attitude and elevator deflection were closer to the plots taken from the QAR than those obtained by simulation in FPA mode. In particular, in FPA mode, it is essential to select the maximum possible angle of descent value which can be displayed (9° 9) in order to approximate the aircraft recording, but the maximum vertical speed reached (of the order of -3,050 ft/mn) is still far from the recorded figure of a variation (200 ft/mn) which is appreciably greater than the rated accuracy with which the Autopilot follows the parameter (+/- 50 ft/mn).

117.542 - Determination of the instant of desaturation from Autopilot vertical mode

In analysing the structure of the control laws in VS mode, it can be seen that the variation in pitch attitude controlled by the Autopilot is firstly proportional to the variation between the aircraft's vertical speed and the value selected by the pilot (command), and then constant when this variation exceeds a certain limit. It is then said that the flying loop is "saturated".

In the case of the flight which led to the accident, this saturation value of the order of attitude excursion was -1,050 ft/mn. In fact, transition to configuration 2 had, by means of a lift augmenting effect, induced a positive vertical speed of more than 500 ft/mn at the same time that the crew were ordering a descent. In such a case the authority of the Autopilot is increased (the standard saturation figure is 350 ft/mn).

This saturation principle has the following consequence: whether one selects (as in this case) a negative vertical speed of 1,050 ft/mn or 6,000 ft/mn (the maximum figure which can be selected), the speed at the beginning of descent mode is identical, and descent will take place with the same vertical acceleration, although the aircraft is not being flown in G-load factor during this phase (the variation in the G-load factor is close to 0.12/0.13g in this case). The sole difference will be in the acceleration time.

As the selected value is approached, the Autopilot orders an attitude excursion in the opposite direction to the preceding one. The Autopilot loop is then said to be "desaturating". This desaturation thus occurs 1,050 ft/mn before the target value, i.e. at -2,250 ft/mn if the value selected was -3,300 ft/mn. It manifests itself in the form

of a jolt on the elevator, the appearance of a sudden rapid variation of approximately +0.1 g in vertical acceleration, a break in the speed of the trim and a rounding off in the vertical speed curve.

Note: The vertical speed recorded on the QAR is a barometric vertical speed. In order to obtain this parameter, the barometric vertical speed calculated by the simulation is obtained by assigning the geometric vertical speed the coefficient of temperature correction: [1 - (T^0-TISA) / T^0].

An analysis of the structure of the control laws in FPA mode leads to comparable findings. The variation in pitch attitude controlled by the Autopilot is 'saturated' when the difference between the current angle and the angle selected exceeds a certain limit.

In the case of the flight which led to the accident, this saturation figure of attitude excursion was in the order of 585 deg*knot. In effect, transition into configuration 2 had led to an angle of climb of more than 1.5^0 at the same time that the crew were ordering a descent. As in VS mode, the authority of the Autopilot is increased in such a case; otherwise the standard saturation figure is 195 deg*knot.

Desaturation thus occurs under the same

conditions 585 deg*knot before the target value, or 3.4° before the angle selected (given a ground speed of 170 knots). If the figure selected was 9°9 and if this data was converted into vertical speed, it would be found that the theoretical point of desaturation in FPA mode corresponds to a Vz of 1,965 ft/mn. This point will be accompanied by the same phenomena as desaturation in VS mode: a jolt will be noticed on the elevator, and there will be a sudden rapid variation in vertical acceleration of approximately +0.1 g.

Numerical simulation consequently predicts that desaturation point will occur considerably earlier in time in FPA mode (Vz= -1,964 ft/mn) than in VS mode (Vz =
-2,250 ft/mn). The error calculation shows that this differentiation resists possible errors (one shift in a calculation cycle in the control law (180 ms) leads to an error of 36 ft/mn; one error of +/- 5 knots in the module of the ground speed leads to an error of 80 ft/mn).

Note: The computer derives the angle of descent (FPA) from the baro-inertial vertical speed using the following formula:

Tangent (FPA) = VzBI/Vgs

where Vgs is the ground speed of the aircraft calculated by combining the accelerations measured along the "north" axis and the "east" axis by the IRS.

The baro-inertial vertical speed is not recorded. However, the method by which it is calculated is such that this vertical speed is equal to the barometric vertical speed for slow dynamics. This is the case between times 3015 and 3035 and the vertical speed recorded on the QAR is thus comparable with that taken into account when calculating the FPA.

The desaturation point which corresponds to the factors described above can be pinpointed on the QAR recording at time 3027. The average vertical speed close to this moment is of the order of -2,250 ft/mn (or even higher). This point thus corresponds to the simulation prediction for VS mode.

CHAPTER 1.18 - SUPPLEMENTARY INFORMATION

118.1 - Certification of the ergonomics of the A320 flight deck

118.11 - Statutory objectives

The requirements of airworthiness relative to the flight deck, in common with those which cover other areas of certification, do not aim to achieve the best possible arrangement, (to the extent to which this concept is meaningful), but to define minimum objectives, which are essentially:

- to secure a level of comfort (especially in regard to adverse weather conditions), which allows the crew to carry out their duties without undue effort, concentration or fatigue;
- to ensure adequate exterior visibility.
- to minimise the risks of misunderstanding in the utilisation of commands, chiefly through standardisation of the form and transmission of primary flight commands;
- to minimise ambiguities in information supplied to the crew;
- to enable a minimum flight crew complement to carry out its duties without excessive workload (fatigue, concentration).

118.12 - Principal statutory references

The Airbus A320 was certified by the French, English, Dutch and German authorities on the basis of a common framework of certification requirements, or "common bases of certification", including Order JAR 25 up to Amendment 11 (except for the remainder of JAR 25.207 up to Amendment 10) and the corresponding ACJSs, complementary technical conditions (JAR AWO), and special conditions including points open to interpretation.

The statutory requirements applicable to the ergonomic aspects of the A320 flight deck examined in the context of the current Investigation are essentially outlined in the following extracts from these common bases of certification:

- JAR 25.771. Flight compartment

"(a) Each flight compartment and its equipment must allow the minimum flight crew (as specified by JAR 25.1523) to accomplish its duties without undue concentration or fatigue."

- JAR 25.777. Flight cabin controls

"(a) Each of the flight cabin controls must be positioned to allow for convenience of operation, and to avoid confusion and inadvertent use." (See ACJ 25.777 (a))

"(g) Control switches must be shaped in such a way as to prevent misunderstanding. switches must be of the same colour and this colour must contrast with the colour of control switches used for other purposes and with the surrounding flight cabin."

- JAR 25.1303. Flight and navigation instruments

"All flight and navigation instruments must have features which are suitable for use on the particular aircraft in question. Display must be clear and unambiguous."

- JAR 1309. Equipment, systems and facilities

"Warning information must be supplied to alert the crew to a system showing evidence of any dangerous operating conditions and to enable them to take the appropriate action required. Monitoring and warning systems and controls, together with their related facilities, must be designed to reduce to a minimum the errors of the crew which might give rise to additional sources of danger."

- AMC 820. Electronic Instrument System

This document lays down Acceptable Means of Compliance for the certification of EFIS equipment. It contains general requirements valid for all CRT (Cathode Ray Tube) screens which relate to legibility, stability, brightness, colorimetry, image reliability and reconfiguration of displays in case of failure. The symbology is examined in section 2.1.4 of this document. Displays which relate more particularly to flight and navigation parameters are discussed in Section 3 of this document. This section pays particular attention to qualitative provisions concerning the presentation of information.

- Special condition S30 Autoflight system

"Means must be provided of indicating to the crew the active mode and all the modes armed by the pilot. The position of the mode selection button is not an acceptable means of such indication."

118.13 - <u>Means of Compliance which may be utilised</u>

This regulation lays down requirements which may relate either directly to the design of the aircraft (i.e they define how such or such a component should be designed), or the result to be achieved (i.e. they define overall objectives to be met).

Compliance with direct design requirements (for example: shape of a switch, direction of movement of a control) is in general quite simple to assess because it leaves little room for interpretation. It is determined by direct verification from plans or descriptions, by the examination of mock-ups or by cockpit inspections by engineers and pilots.

The objectives of the regulations are to achieve certain general results (e.g.: JAR 25.777 (a) "Each flight deck control must be located in such a way as to allow for convenience of operation and prevent confusion and inadvertent use.").

Determination of compliance with this type of requirement today relies on qualitative assessments based on experience, using the opinions of several longstanding pilots. A "static" evaluation of the flight deck is therefore complemented by a dynamic "in-situ" evaluation. To achieve this, a series of realistic operational scenarios made up of a combination of simulated failures and internal (e.g.: pilot incapacity) and external events (e.g.: track diversion) is introduced on line flights, actual or simulated, carried out by crews of test pilots and/or line pilots familiar with the aircraft.

Assessment of compliance under these conditions calls upon the judgment of these same pilots, as well as the judgment of qualified observers who follow the flight taking note of any significant facts. In order to give a weighted value to these assessments, each scenario is played out several times with different crews. These evaluations are supported by findings made during other certification flights, especially those involving certification of the Autopilot system.

118.14 - Certification of the A320

For the certification of the A320, the means of assessing compliance described above were applied in the following way:

118.141 - Flight deck inspection

A flight deck inspection was carried out on aircraft number 3 (in Toulouse on 15 December 1987) and number 4. Its conclusions are recorded in the document entitled "Cockpit Inspection Report", reference
000190P0002/C07.

These conclusions indicate that the examination of aircraft number 3 demonstrated compliance with most of the referenced requirements of the regulations, except for a few points requiring modification or for which additional investigation was necessary. This was the case for the FCU, assessment of which was deferred until the programme of flights using minimum crew levels. The results obtained on these flights enabled the certification authorities to decide on the acceptability of the FCU (see results below).

118.142 - Certification flight tests

The ergonomics of the flight deck was evaluated by crews consisting of a pilot from the manufacturing company and a pilot from one of the four certification authorities, during trials conducted in-flight and on a simulator in a wide variety of operating conditions. The conclusions of these evaluations are recorded in the document entitled "Cockpit Flight Report", reference 000190P004/C06.

118.143 - Demonstration flights carried out by the minimum flight crew

The certification demonstration by the A320 with its minimum flight crew gave rise to a programme consisting of 20 simulator flights and 50 actual flights, performed by 4 different crews and using a dozen scenarios each capable of generating a significant workload (introduction of malfunctions and rigorous operational conditions).

The conclusions of these evaluations are recorded in the documents entitled "Dynamic Workload Analyses - Simulator Programme - Analytical Workload Calculations" (reference 00D102A0001 C0S) and "Dynamic Workload Analyses - Flight Programme - Analytical Workload Calculations" (same reference).

Each flight is described in terms of the content of the scenario, a histogram of the workload evaluated by the crew and the observer, and a log of significant events.

An analysis of the errors made by the crews is contained in the CEV report n°14/CEV/IS/SE/AV.

"Crew errors" recorded were actions (or non-actions) by crews deviating from those normally recognised as complying with the state-of-the-art of the profession in that area. According to the document quoted, the analysis of these errors was undertaken with a view to detecting those which could warrant corrective action in terms of procedures, checklists or the aircraft.

With this in mind, errors recorded during simulator or actual flights were classified according to the following two criteria:

- the criterion of gravity:

  M: minor error; I: important error; S: error affecting flight safety.

- the criterion of causality:
  - **.Class A:** error due to oversight or clumsiness on the part of the crew which can take place in everyday practice on all types of aircraft.
  - **.Class C:** error due to inadequate knowledge of the machine or procedures or even to being unaccustomed to flying as part of a two-man crew.
  - **.Class E:** error which is avoidable by a correction or a modification either in procedures, or in relation to the aircraft.

Over the entire number of 50 actual flights carried out, 81 errors were noted by the observers, classed as follows:

- 63 errors classed as M (78.8%)
- 17 errors classed as I (21%)
- 1 error classed as S (1.2%)

Following analysis, the origins and causes of these errors were classed as follows:

- 37 errors classed as A
- 16 errors classed as C
- 11 errors classed as A/C
- 12 errors classed as E
- 5 errors unclassified

Over the entire number of 20 simulator flights, 16 errors were noted by the observers, with the following classification:

- 13 errors classed as M (81.3%)
- 3 errors classed as I (18.7%)

Following analysis, the origins and causes of these errors were classed as follows:

- 3 errors classed as A
- 2 errors classed as C
- 2 errors classed as A/C
- 1 error classed as C/E
- 7 errors classed as E

This record of errors made by the crews, as well as comments and observations gathered during flights and at debriefings carried out after each stage by pilots and observers from the official bodies, were utilised to clarify, make more precise and improve the presentation to crews of procedures, ECAM checklists and messages and of MMEL.

On the other hand, the analysis which was made of these errors did not call into question the ergonomics, or certain aspects of the ergonomics, of the flight deck used during certification.

In particular, it did not bring to light any errors or misunderstandings in the utilisation of flight modes or in data presented to the crew which could have been ascribed to unaccustomed features of the ergonomics of the flight deck, including at times when the workload resulting from the scenarios evaluated was high.

Nevertheless, looking at all the certification documentation available, it is still not possible to restore with absolute certainty the modes utilised during trials.

118.144 - Endurance flights

Special condition G17 "Operational proving flights" stipulates that "all test flights considered necessary by the authorities must be carried out with the aim of determining whether there is a reasonable degree of assurance that the aircraft, its constituent parts and equipment are reliable and function correctly."

To satisfy this special condition, an endurance programme consisting of around 100 flights was carried out by pilots belonging to client companies in actual operational conditions, on an aircraft close to the series standard. This programme enabled the views of a group of line pilots to be assessed before certification, but still did not form the basis of a summary report. The results obtained did not lead to any aspect of the ergonomics of the flight deck being called into question.

118.2 - Controlled flights into terrain and avoidance systems

118.21 - Introduction

Collision with the ground or water by a controlled aircraft is one of the major causes of loss of life in transport aviation. 'Controlled flight' is here defined as any flight during which the crew has not lost control of the aircraft, which remains technically and aerodynamically airworthy. The probability of surviving such an accident is very low, owing to the high level of kinetic energy and the concentrated force of the impact.

An American study notes that 2,705 lives were lost in controlled flights into terrain (CFIT), out of a total of 5,675 fatalities during the decade 1979-1989:

(DIAGRAM)

(Source: Sundstrand)

The size of the problem led to a search for specific solutions designed to warn the crew of a potential accident when the other safety mechanisms, i.e. procedures utilised, on-board instrumentation, existing alarms associated with the vigilance of the crew and Control, have not proved effective.

Solutions utilised are designated under the heading 'Ground Proximity Warning Systems'. A distinction is made between on the one hand on-board equipment such as APS, GPWS (see para. 118.22) and GCAS (see para. 118.23), and on the other ground-based systems for the use of Controllers such as MSAW (see para. 118.24).

The aim of these automatic systems is to trigger an alarm when an aircraft gets dangerously close to the ground.

118.22 - The GPWS (Ground Proximity Warning System)

118.221 - The concept and its development

At the end of the 1960's radio altimeters, required for CAT II and CAT III precision approaches, were installed on a large number of transport aircraft.

The radio altimeter is a self-contained on-board device which measures the height of the aircraft in relation to the ground.

This sensor unit (radio altimeter) allowed communication with a warning computer which, using second-by-second radio-altimetric data (height at any given moment of terrain being overflown), would supply a "prediction" of future height above terrain with the aid of envelopes. The concept of the GPWS (or APS, 'Avertisseur de Proximite du Sol') was launched by the Scandinavian company SAS in 1969 and developed by a large number of equipment manufacturers who, for a wide variety of reasons (in particular the fact that the patent was lodged by Sundstrand) pulled out. Only the Sundstrand GPWS continued in production, which allowed it to acquire a de facto monopoly.

In 1975, after a Boeing 727 accident in Washington, the entire American fleet was equipped with GPWSs in line with the FAR 121.360 regulation of 1974. According to American studies, and giving due regard to difficulties inherent in this type of analysis carried out as it was, a posteriori, a reduction in the number of accidents classified as "controlled flights into terrain" could in part be attributed to the GPWS, despite its initial defects.

More specifically, over the five years prior to 1975, an average of 2.8 accidents per year of the CFIT variety had occurred in the United States. The period during which the fleet was equipped extended approximately from mid-1974 to the end of 1976. The number of accidents of this type then fell appreciably: 0 in 1975, 2 in 1976 and 1977, 1 in 1978, and 0 from then on with the exception of 1985 (1) and 1989 (2).

These results in terms of safety led the ICAO in 1979 to include among its standards the requirement to carry a Ground Proximity Warning System. Schedule 6, covering technical aircraft operation, in fact stipulates that when "the original individual Certificate of Airworthiness was issued on 1 July 1979 or after that date, all turbo-engined aircraft with a certified maximum take-off weight exceeding 15,000 kg, or which are authorised to carry more than 30 passengers must be provided with a Ground Proximity Warning System". (Reminder: the A320 comes into this category of aircraft).

If the original individual Certificate of Airworthiness was issued before 1 July 1979, the carrying of a GPWS is only recommended.

The terms of Schedule 6 of the ICAO lay down the general specifications that must be met by the on-board Ground Proximity Warning System: it "must be able, automatically and in reasonable time, to give the flight crew clear warning when the aircraft finds itself in a situation which may be dangerous on account of the proximity of the ground surface".

According to a study by the equipment maker Sundstrand, at the time of the F-GGED accident approximately 95% of the world fleet meeting the criteria of aircraft required to carry a GPWS as defined by the ICAO were in fact equipped with one.

(DIAGRAM)

(Source: Sundstrand)

From January 1983 to April 1991, the confidential ASRS (USA) system of gathering incident reports, enumerated 64 reports of crews which had experienced a GPWS alert. In at least 35 cases it was the GPWS warning which enabled the accident to be avoided.

In its earlier versions the equipment suffered problems involving alarms which sounded too late, or conversely alarms which sounded at the wrong time or were spurious, all of which led crews to be suspicious of alarms produced by the equipment. One or other of these factors prevented the GPWS from playing its full role as a protection of last resort with respect to accidents or incidents involving aircraft on which it was installed.

To restore credibility to GPWS alarms, Sundstrand was forced to improve its product. By modifying the envelopes, reprogramming alarms and adapting to new technologies, it went on to produce successively the Mark I, Mark II and Mark VII versions (analogue), and Mark III and Mark V versions (digital). Steps were also taken in the United States to adapt Air Traffic Control procedures to the requirements of the GPWS.

According to the equipment maker, flight trials showed an average avoidance reaction time on the part of crews of 5 to 6 seconds after the alarm was triggered, in the case of the MK II and III models, and for pilots who had not been trained on a simulator in the use of the GPWS.

118.222 - The situation in France

A programme of GPWS equipment trials had been carried out by the CEV (Flight Test Centre) in 1975. This programme had been conducted without any attempt to fashion procedures to reduce alarms occurring at the wrong times. Given, among other factors, the speed regression capability during approach of the aircraft used (the 'Mercure'), there were numerous occurrences of alarms not indicative of dangerous situations.

As a consequence, and taking into account particularly the level of spurious alarms which had been encountered, the French government concluded that the GPWS afforded safety gains which were considerably less positive than those claimed by its promoters.

Further, it found Sundstrand's marketing strategy highly aggressive, and did not wish to make the carrying of a device protected by an industrial patent and for which a manufacturer therefore had a de facto monopoly, mandatory.

This is the thrust of the letter sent to the ICAO in 1977 which states that the carrying of a GPWS should have "at most the status of a recommended practice", and not of a standard. As the ICAO had nevertheless taken the decision to include the carrying of a GPWS among its standards, in 1978 France notified an exception. Following a subsequent inquiry by the ICAO into national variations, France replied, in error, that its regulations did not contain any exceptions from Schedule 6. For this reason, the note indicating a French derogation on this point was removed from Schedule 6.

In 1990 JAA (Joint Aviation Authorities) began the task of drawing up common European operational regulations. The draft texts specify an obligation to carry GPWS systems from 1 March 1993.

At the time of the accident, French regulations did not make the carrying of a GPWS obligatory.

As of 31 December 1991, approximately 75% of the aircraft operated by French transport companies and meeting the criteria for carrying a GPWS as defined by the ICAO were equipped with such a system.

Air Inter was one of the few French companies not to have GPWS systems on its aircraft as specified in the ICAO standard.

On 16 December 1991, in a letter addressed to Air Inter and signed by the Head of the Aircraft Operations Bureau, SFACT expressed its surprise that this company's A320s were not equipped with GPWS systems and questioned the company on the policy it would adopt with regard to the carrying of GPWSs on the A320 as well as on the other aircraft in its fleet: "(..) A recent inquiry has just confirmed to me that none of your aircraft is equipped with a GPWS detection system. I share the viewpoint of the Flight Inspection Organisation, which has expressed concern over this situation and regrets that your AIRBUS A320 aircraft, despite possessing the necessary controls and wiring as standard, are not equipped with such systems.

Finally, although the regulations as they exist at present do not impose an obligation to carry these devices, the GPWS as represented in its latest versions has proved to be an essential factor in the prevention of accidents. I would remind you that the ICAO in Schedule 6 considers it to be an obligatory part of standard equipment in heavy aircraft and that this rule will be reiterated in the JAA

regulations which are soon to appear. I would be grateful if you would inform me of the factors which prompted you to take this decision, as well as outlining to me your future policy on the use of the GPWS for the whole of your fleet (..)". This letter remained unanswered as of the date of the accident.

Air Inter had undertaken evaluations of the performance characteristics of GPWS equipment available in the 1970's. The company had taken part in trials carried out by the CEV in November 1975. An evaluation of the equipment had been carried out on Mercure and A300 aircraft, by crews and over the company network, in 1976 and 1977.

In view of the fact that it had been observed that alarms were sounding at inappropriate times during these evaluations of the initial GPWS versions, and given the absence of any statutory obligation, Air Inter chose not to equip its fleet with them.

However, following technical improvements to the GPWS, at the end of the 1970's Air Inter acquired the necessary preliminary equipment on the A300 and Mercure aircraft. It had also retained this preliminary equipment on the A320.

118.23 - <u>Other type of on-board equipment: the GCAS</u>

The GCAS (Ground Collision Avoidance System) was developed during the 1980's for military applications.

Its operating principle is based on one hand on the analysis of data relative to terrain (database) and the position of the aircraft, and on the other on a prediction of the aircraft's flight path.

Development work has been going on since 1992 on a project to apply this system to the needs of civil aircraft.

118.24 - <u>The MSAW (Minimum Safe Altitude Warning)</u>

In France, on the date of the accident, responsibility for avoiding collisions with terrain did not rest with ground control organisations. However, faced with the gravity of this problem, air navigation organisations sought to see whether they could offer air operators some kind of preventive assistance in the event

of danger, taking the form of flight information under the auspices of the radar service, but without altering their respective spheres of responsibility.

Out of this concern was born the concept of MSAW (Minimum Safe Altitude Warning) developed first of all by the F.A.A. (United States Federal Aviation Administration), as a complementary procedure to the GPWS. The concept was taken up by France where a similar system is being studied.

The principle is as follows:

The "en-route" radar processing system knows the position, flight level, horizontal speed and vertical speed of each aircraft in radar contact and equipped with a "mode C" transponder.

This system is thus in a position to determine the position of an aircraft in relation to the terrain it is overflying or towards which it is heading providing it holds in its memory the topography of this relief. The same process could be used to position aircraft in relation to special status zones.

Describing the volumetric contour of the zones presents no difficulties. As far as modelling of the terrain is concerned, the National Geographical Institute has access to a digitised database of the terrain which satisfies the required conditions. It is the source from which the system can construct its own internal geographical database.

Each time the radar information is changed, the monitoring system determines the area within which each aircraft is flying in order to assess, on the basis of predefined or estimated criteria, whether it will be coming into contact with any danger in the near future.

The effectiveness of the system depends essentially on a reliable and sufficiently well anticipated prediction of the aircraft's flight path. Care must be taken to avoid generating spurious alarms which would detract from the credibility of the system, while at the same time adopting adequate safety margins which allow the crew to react in time.

The Air Navigation Authority had already been able to assess in 1991 that the MSAW could provide help to the Controller in the area of monitoring special status zones.

It is continuing this activity and carrying out an in-depth evaluation of the software in order to assess if a monitoring function of this type is practicable in the current operational context, especially on the approaches to an airport or in low-level manoeuvres.

It is also directing its attentions toward improving radar coverage, performance characteristics of the radar processing system, the method of presentation and the dissemination of data to Control positions.

118.3 - The Emergency Locator Transmitter

118.31 - <u>General points</u>

F-GGED was equipped with an Emergency Locator Transmitter designed to operate automatically on impact (RBDA).

This ELT, a Jolliett JE2 model, was located on the rear bulkhead of the flight deck in the top part of the coat compartment.

The ELT did not function. It was discovered in the debris, beneath the forward part of the aircraft, crushed and ripped open, its antenna broken away from the casing.

118.32 - <u>Statutory aspects</u>

118.321 - Obligation to carry an ELT and approval

With respect to international commercial transport aviation, Schedule 6 of the ICAO (technical operation of aircraft), contains no standard or recommendation concerning the carrying of an Emergency Locator Transmitter with automatic activation on impact (RBDA). The carrying of this equipment is only recommended for international general aviation flights and for international helicopter flights. Schedule 10 (Aeronautical Telecommunications) sets out the technical specifications of these devices (frequency, power and auditory signal) but includes no provisions on their positioning and on their resistance to shock loads and fire.

As far as French regulations are concerned, the

Order of 28 August 1978 makes it obligatory for all General Air Traffic aircraft (chiefly therefore for public transport aircraft) to carry an ELT with automatic acivation on impact (RBDA). This equipment must comply with the standards and specifications laid down in Appendices 6 and 10 of the Chicago Convention and must be of an approved type. This approval is given by the Minister with responsibility for civil aviation (STNA), with reference to approved international standards (EUROCAE, RTCA or FAA).

Two complementary directives dated 27 July 1979 and 2 January 1980 stipulate that in terms of installation the user is free to choose between a fixed ELT with an external antenna and a portable ELT with an internal antenna set up in front of a porthole or a panel window on the flight deck. In addition, the Order of 5 November 1987 relative to the conditions of utilisation of aircraft operated by an air transport company exempts aircraft with a certified maximum weight on take-off of above 20,000 kilos and permanently equipped with at least two approved survival beacons from carrying an ELT on flights over water. Should they be equipped with only one beacon they are exempt from carrying an ELT on flights over designated terrestrial areas.

118.322 - Certification of the installation on board the aircraft

Regulations applicable in France to certification of the installation of radio-electric equipment on board aircraft relate both to regulations involving basic airworthiness (such as for example standard AIR 2051, FAR 25 or, since recently JAR 25) and specific rules contained in a document issued by the STNA and entitled the "CGCE" (standing for "General Conditions to be Satisfied for the Issue of an Operating Certificate").

As far as regulations concerning basic airworthiness are concerned, on 8 March 1979 SFACT and the Certification Bureau wrote and widely disseminated via the Documentation Section of the Bureau Veritas the statement that the only rules to be followed with respect to airworthiness when it came to the installation of an ELT "consisted of ensuring that an aircraft so equipped continued to satisfy the relevant conditions relating to certification of airworthiness"... and that moreover "the non-operational condition of an ELT, for whatever reason, does not constitute a case of unfitness for flight in terms of the application of the Order of 17 March 1978 relative to the maintenance of aircrafts' fitness for flight.

As far as specific rules are concerned, the CGCE document of the STNA (addition to the CGCE distributed on 11 December 1978 and modified on 13 May 1980) lays down that, to comply with the 1978 Order, aircraft must be equipped with an ELT of either a "fixed automatic" or "portable automatic" variety. ELTs of the portable automatic variety can be mounted without an antenna fixed permanently on the outside of the aircraft and the installation must be carried out in such a way as to be very easily accessible to survivors and easily dismantled without the use of tools; this dismantling must allow for the removal of the casing and the disconnection of the antenna feeder, should one exist. It is only with respect to ELTs of the "fixed automatic" variety that the CGCEs lay down that they must be located, as far as is reasonably possible, in the rear section of the aircraft, possibly in the lower part of the vertical stabiliser.

118.33 - <u>F-GGED equipment</u>

118.331 - Equipment installed

Air Inter chose to equip its aircraft with the JOLLIETT JE2 ELT. This transmits on the frequencies 121.5 Mhz and 243 Mhz. It can be made to work either automatically as a result of an impact, or manually using a switch.

The JOLLIETT JE2 beacon was approved by ministerial ruling N°20919 STNA of 26 October 1978, with reference to standards TSO 91 and RCTA DO 147. Tests carried out after the F-GGED accident showed that the specifications of this equipment were well in line with these approval standards.

118.332 - Certification of the installation

On all the A320s operated by Air Inter, the beacon and its mounting are installed in the ceiling of the crew's coat compartment in the left-hand vestibule of the cockpit. Its controls are directly accessible by the flight crew. A coaxial cable approximately 1.5 m long exits the beacon towards the left side rear window panel. The last 60 cm of the coaxial are exposed and are fixed vertically on the window panel without a bonding strap. This constitutes the antenna. The accelerometric switch of this beacon, which is aligned in a direction +- 15° of the fuselage centre line, automatically operates the ELT following an impact greater than 5g on the aircraft, along its longitudinal axis. The location of the ELT and its conditions of operation are not visible to the passengers.

This installation is described in Modification Record n°20243 presented by AIRBUS INDUSTRIE on 15 February 1988. This modification 20243 was approved by the Bureau Veritas on 26 March 1988 following a judgment by STNA.

The record does not include the results of tests on the homing range and on the omni-directionality of the radiance in the horizontal plane. Such tests are not required in the context of the certification of the equipment. The only test required is a qualitative transmission check (presence of a radiated field) and this was performed.

118.34 - <u>Tests involving the ELT</u>

The ELT with which F-GGED was equipped was destroyed on impact and more than four hours were required to locate the wreckage of the aircraft at a time when there were survivors. The Commission of

Investigation was concerned to know, in the event that the ELT had functioned, if the wreckage of the aircraft could have been discovered sooner, using readings from the SARSAT satellite system, airborne aircraft and amateur radio enthusiasts.

An experiment therefore took place on 9 April 1992 at 18.20 hours UTC in order to ascertain a satelite configuration and the availability of amateur radio enthusiasts such as they would have been on the day of the accident. The beacon was located on Mont Saint-Odile at approximately 300 metres from the site of the crash, in a wooded area. All the participants played their normal role during an alert but the SATER plan was not launched. The sky was clear. In these conditions, a little less than three hours were required to find the beacon.

The Commission of Investigation is conscious that the choice of site, and the fact that the SATER plan was not launched and helicopters not used to reconnoitre the search area, could have impaired the realism of this simulation. In the circumstances, the Commission did not feel that it could draw any definitive lessons from the results as they were presented.

118.4 - Statutory developments with respect to DFDR and CVR recorders

118.41 - <u>Protection</u>

The LORAL-FAIRCHILD recording devices (DFDR and CVR) installed on F-GGED are of an identical generation. The principles of protection governing the operation of these two protected recording devices are identical in terms of impact, fire and chemical attack. Their protective casings are physically identical.

The offical Rating requirements applicable to this generation of recording devices (TSO-C84 of 2 September 1964 for the CVR, TSO-C51-A of 5 February 1966 for the DFDR) specify in particular that, with respect to fire resistance, the recorder must be exposed during trials to a flame of 1,100°C, enveloping at least 50% of the external surface of the recorder for a continuous period of 30 minutes. After a series of tests representative of an accident, the contents of the protected recording support must be still be readable. In normal operation, the maximum temperature expected is 55°C.

The new regulations referring to the documents EUROCAE ED 55 (for DFDRs) and ED 56 (for CVRs, in the course of being updated as ED 56A) modify the accident test requirements with regard to fire by increasing the area exposed to flame to the entire surface of the recorder. The heat flux is quantified. The duration of the trial is kept at half an hour. It should be noted that these tests do not allow for exposure to low-intensity fires over a prolonged period.

The Fairchild F800 and A100 models installed on F-GGED comply with the fire resistance tests of the new American TSOs 123 and 124, which are adaptations of the EUROCAE standards ED55 and ED56.

On 28 May 1992 the National Transportation Safety Board (NTSB) issued a recommendation to the Federal Aviation Administration (FAA), advising them to set aside the old TSOs C84 and C51-A, to carry out studies to improve the standards of fire resistance laid down in
TSOs 123 and 124, and then to set aside these later TSOs which had become obsolete. The reasons adduced by the American recommendation make mention of the fact that the older or more recent standards do not take into consideration fire of long duration at low intensity. A study was carried out of known cases of the destruction of recorders by fire since 1966. It emerges that of 90 recorders that were damaged by fire:

-14 out of 45, certified by TSOs C84 or C51A, were damaged to the point where the tape was destroyed,

-4 out of 45, known to the NTSB as having complied with the tests laid down by the new TSOs, were damaged to the point where the tape was destroyed.

<u>Comment</u>: It is the function of recordings such as the QAR (Quick Access Recorder) and non-volatile memory, with which certain computers are equipped, to assist in the maintenance and analysis of flights. They are not designed for post-accident inquiry purposes and are therefore not subjected to specific resistance requirements.

118.42 - <u>Data recorded</u>

118.421 - The CVR

The CVR records communications between crew members, between the command post and the cabin or Air Traffic Control, in essence the general noise of the flight deck.

Actual experience shows that the recording of this general atmosphere is sometimes inadequate in understanding conversations exchanged between crew members, due to the non-specific nature of the microphone used which is necessary to capture all the sounds of the flight deck. On the other hand, recordings of conversations on tracks allocated for the purpose are of good quality.

When an accident or incident occurs, in order to improve collective security through an understanding of all the aspects of human involvement, as well as flight security through the use of clear communications, the concept of a permanent microphone (hot mike) was developed. It was incorporated into the EUROCAE ED 56 standard and is based on recording each conversation on a dedicated track by a specifically allocated microphone.

In some countries, such as the United States and the United Kingdom, use of the hot mike by crews is mandatory during certain flight phases. France, on the contrary, has not incorporated it into its statutory code.

118.422 - DFDR data

Current French regulations require the recording of a minimum of 25 parameters for public transport aircraft.

During work to prepare the A320 for certification provision was made for the recording of a much greater number of parameters (213) on this aircraft.

Innovations in certain types of flight control systems led to many associated parameters being included.

On the other hand it is noticeable that except for engines, target flight figures selected by the crew and a number of Autopilot or flight management modes are not recorded.

For aircraft which are subject to JAR certification the recent EUROCAE ED 55 standard requires "an appropriate combination of discretes" offering "Autopilot situation, auto-throttle, CADV mode and engagement". It is also specified that "the discretes must show which systems are engaged and which primary modes are utilised in controlling the flight path and the speed of the aircraft".

Discretes are required for alarms: "a discrete must be recorded for the general alarm". Each "red" alarm (including smoke in the toilets) must be recorded if the reasons for the alert cannot be determined using other parameters or the cabin recorder".

In addition certain details specific to the aircraft in question which give rise to the recording of data must be evaluated. Thus lists are given of target figures selected by the crew, barometric displays, chosen display formats (for the two crew members), distances measured by the DMEs, the status of the head-up site, etc.

In practice, certification work, or statutory upgrading for aircraft which are already certified, determine the way this new standard is applied depending on the aircraft type.

118.5 - Co-ordination of the administrative and judicial inquiries

118.51 - General points

In France, when any aircraft accident occurs, generally speaking two different types of procedure are initiated, one judicial and the other administrative. The object of the first is to identify responsibilities and, if necessary, errors from a a criminal and a civil standpoint. Initially it takes the form of a preliminary judicial investigation or inquiry. The aim of the second is to study the circumstances of the accident, to isolate the causes and to learn the relevant lessons in order to improve the safety of air transport. In the first few hours it is conducted by investigators from the Accident Enquiry Bureau of the Civil Aviation and Meteorological Inspection Authority. In the case of major accidents it is then continued by a Commission of Investigation set up by the Minister responsible for Civil Aviation.

These two procedures, the outcomes of which are different, need to use a collection of basic materials, especially the tapes recording the flight data and communications exchanged on the flight deck, where relevant. Co-ordination between them is governed by the interministerial Order of 3 January 1953 covering the co-ordination of the preliminary judicial investigation and technical and administrative inquiry in the event of an aircraft accident. This was complemented by a letter of 10 July 1989 to Attorney Generals which lays down that "black boxes must, with the agreement of the responsible magistrate, be handed over (to the civil avaition investigators) without delay and in exchange for release documents".

In addition, given the controversy that had arisen after the accident at Mulhouse-Habsheim in regard to recorders, the administrative and judicial authorities were particularly conscious, in the case of the Mont Sainte-Odile accident, of the extreme importance of rigorously carrying out initial procedures on the site.

118.52 - Co-ordination of the inquiries into the F-GGED accident

118.521 - Initial steps taken at the administrative and judicial levels

Notified at 22.30 hours that he was responsible for a preliminary investigation into the causes of death following the F-GGED accident, the judge arrived at the accident site at around 23.30 hours on Tuesday 21 January with the Public Prosecutor from the COLMAR County Court. At 00.45 hours he nominated and briefed two judicial experts.

With respect to the administrative inquiry, the first two investigators from the Accident Enquiry Bureau arrived in Strasbourg by plane at around 21.50 hours and on the site of the accident at around 00.15 hours on Tuesday 21 January.

118.522 - Discovery of the recorders and measures taken

The flight recorders (DFDR and CVR) were located at 00.46 hours in the rear part of the wreckage. These two devices, placed one on top of another, were burning and partially covered with ash. It was difficult to recover them immediately on account of their temperature and the presence of a fallen burning tree which lay across the wreckage.

After the area was photographed by a police team, removal was undertaken at 01.30 hours and the two items of equipment were taken down to BARR brigrade headquaters where they were placed under seal. They were then taken in the presence of the Judge to the CEV and BEA analysis laboratories, where, during Tuesday 21 January they were opened and the CVR was first listened to in the presence of the Judge and his experts.

According to the Judge, the QAR recorder was discoverd on 21 January at 09.30 hours and taken by a policeman to the CEV were it arrived the same evening at 22.30 hours.

118.523 - Continuation of investigations on the site

The on-site investigations were then conducted by investigators from the Accident Inquiry Bureau in the presence of the judge and his experts or the police, as appropriate. They were characterised by a considerable concern for detail in the judicial actions carried out.

This concern for detail nevertheless had to be relaxed by the judge several times as problems were encountered on the site. The fact that the procedures were so rigorous could in certain cases have prevented the BEA investigators from carrying out effectively the task of collecting and piecing together important elements for the continuation of the inquiry.

On the other hand, given the number, complexity and geographical distribution of the activities being undertaken, quite clearly they could not all be followed by the judge and his experts without the risk of endangering the integrity of essential evidence.

118.524 - Co-ordination between the two inquiries

The judge and the Chairman of the Commission of Investigation met regularly to establish the ways in which the two inquiries should be co-ordinated, to resolve certain problems involving access to evidence or the conduct of the technical analyses, and to ensure the smooth progress of the two procedures.

118.6 - The feed-back loop

118.61 - <u>General structure</u>

118.611 - The general structure for the feed-back loop, and by feed-back loop we mean the acknowledgement of failures encountered in daily operation involving safety principles practised within the air transport system, hinges on two key concepts: the concept of accident and the concept of incident.

Schedule 13 of the ICAO gives a definition of the concept of accident based on a threshold of injury to human life or material damage, or the complete destruction of the aircraft. It gives the following definition of incident: "an event, other than an accident, associated with the operation of an aircraft, which compromises or could compromise the safety of this operation". In another connection, a note refers to the 'Manual of the Notification of Accidents and Incidents' (Doc 9156) which contains a list of incidents considered by the ICAO as being of particular benefit in relation to the prevention of accidents. Finally, a draft amendment to Schedule 13 following on from the AIG/92 meeting, specified the addition of the following definition: "serious incident: an incident, the circumstances of which indicate that an accident narrowly failed to occur".

118.612 - The preceding provisions relate to a initial category of events which largely corresponds to the field of investigation of permanent structures of inquiry into accidents and incidents. However, this collection of events does not amount - far from it - to the entire flow of information supplying the feed-back loop in civil aviation. A second category of events, which represents a considerably higher volume in global terms, is actually handled within the framework of operational follow-up and continuing airworthiness between Operators, manufacturers and their technical supervisory authorities.

118.613 - At the ICAO the statutory provisions concerning the feed-back loop relating to ongoing airworthiness checks are contained in Annex 8, para. 4.2.4, which stipulates:

"With respect to aircraft of a certified maximum take-off weight greater than 5,700 kg, the state of registry must ensure that there exists a system enabling transfer to the organisation responsible for the design of this type of aircraft, information with respect to faults, operating malfunctions, defects and other instances which have, or which could have, an unfavourable effect on the type's continued airworthiness".

In short these provisions enable the state of registry to ensure the existence of a system of directing information towards the manufacturer.

General indications of the concept of "faults, operating malfunctions, defects and other instances" are contained in part 2, Section 1, Chapter 3 of the Technical Manual of Airworthiness (Doc 9051).

Some states have set up mandatory systems for the communication of similar information to their Airworthiness Authority.

118.614 - As far as Operators are concerned, the ICAO regulations (Schedule 6) do not make the notification of incidents obligatory, irrespective of whether they relate to airworthiness or operation.

118.62 - <u>Structure of French regulations</u>

118.621 - With regard to the notification and reporting of incidents, the Civil Aviation Code contains the following two provisions:

- Article R.142-2 (Book I "Aircraft", Heading IV "Damage and Responsibilities") imposes an obligation upon the captain to report any incident "affecting or capable of affecting the safety of an aircraft". This incident report must be forwarded either to the Manager of the nearest airport or to the Regional Control Centre with which a flight was in contact;

- Article R.425-1 (Book IV "Flight Crew", Heading II "Professional", under the chapter entitled "Discipline") imposes an obligation upon the captains of transport aircraft and aircraft carrying out aerial work, to provide a detailed report within 48 hours on any incident which may have serious consequences, or any infraction of air traffic regulations and operational regulations. This report must be sent to the directors of the company, who forward it to the Accident Enquiry Bureau, which in turn ensures that it is distributed to interested bodies.

118.622 - With respect to public transport aircraft, the Order of 5 November 1987 (Chapter 12) imposes on the Operator an obligation to inform the Minister responsible for civil aviation of any incident,failure or fault of a nature which would place in jeopardy the airworthiness of the aircraft, or knowledge of which is of benefit in relation to the improvement of safety in the design, utilisation and maintenance of the aircraft.

Reports must be sent to the Accident Enquiry Bureau within a month. They can be sent either as an internal technical report, or on a specific form drawn up by the manufacturer or the Operator, or on forms drawn up by the DGAC known as 'Report on an Incident Occurring during Operation' (CEE) and 'Established Operational Serviceability of Equipment (CIM), all of which bear the references of SFACT.

The same text recommends that Operators keep manufacturers informed of all incidents which have to be reported.

118.623 - Finally, in an Appendix dealing with conditions associated with authorisation to operate an aircraft of more than forty tonnes with a crew which does not include a flight engineer, this text stipulates:

"The Operator must adopt a system of flight analysis based on the systematic utilisation of on-board documentation and/or flight data recordings. This analysis must be carried out anonymously and used in such a way as to guarantee respect for the rights of the persons involved and to prohibit any kind of repressive use.

On the first anniversary of authorisation, the Operator must send a summary report on the operation of aircraft covered by the authorisation, in particular the overall results of flight analysis and the lessons drawn".

118.624 - In addition, French regulations in this area include the Order IGAC/300 of 3 June 1957 "concerning the measures to be taken in the event of an irregularity, incident or accident in the field of aviation". This Order defines two types of occurrence which overlap with the concept of incident as defined in Schedule 13 of the ICAO: "operating irregularities" (defined as one of the following occurrences: delay in departure of more than two hours, return to base, landing at an airport not specified in the flight plan), and "incidents" (defined as "any infraction of air traffic regulations or operational regulations, or any event having exposed persons or equipment to risk, even if this did not bring about an operational irregularity").

With respect to these occurrences, this Order imposes the following obligations:

- on a public transport Operator, to notify "operating irregularities" and to draw up a quarterly survey for the General Inspection Authority for Civil Aviation, for SFACT, and for the Air Navigation

Authority;

- on the captain, a member of the crew, or a representative of the owner or the Operator, to report any "incident" to Local Airport Control or to the local civil or military authority. This obligation can be compared with the one laid down by Article R.142-02 of the Civil Aviation Code;

- on the captain of a transport aircraft or an aircraft carrying out aerial work, to draw up a detailed report within 48 hours on any incident which may have serious consequences, or any infraction of air traffic regulations and operational regulations". This report must be sent to the directors of the company, who forward it to the Accident Enquiry Bureau, which in turn ensures that it is distributed to interested bodies. This obligation is identical to that laid down by Article R.425-1 of the Civil Aviation Code.

118.625 - Finally, the arrete (statute) of 11 July 1962 relating to the organisation and powers of the Accident Enquiry Bureau specifies in Article 8 that the Accident Enquiry Bureau and the directorates and departments of the central administration for civil aviation should disseminate to each other all the information they receive concerning incidents and irregularities of operation affecting civil aircraft.

118.63 - Practical operation

In practice, the various intervening parties do not adhere to the strict statutory arrangements. In particular, although there is no statutory requirement in this regard, Operators generally address the incident reports they send to the Accident Enquiry Bureau to SFACT, and also inform the manufacturers. Nevertheless, a large number of documents conveying technical or operational information are seen neither by SFACT nor by the Accident Enquiry Bureau. The same is true for documents such as TFUs (Technical Follow Up).

Over and above the statutory provisions, the manufacturers in general and Airbus Industrie in particular have set up their own system for gathering and processing incidents during operation.

For the system set up by Airbus Industrie, information comes from its representatives, operating separately within user companies, from the companies themselves, from the systems set up by the supervisory bodies in the various states, or from other less formal sources.

Each incident is analysed by the design departments responsible for the design of systems which were involved or actually caused the incident. This analysis is carried out in conjunction with the user(s) concerned and may attempt to discover additional information using, for example, available recordings.

Depending on the outcome of this analysis, different steps can be taken: modification of the maintenance programme or procedures, inspection of the fleet concerned, initiation of an aircraft modification study, modification of operational procedures, temporary instruction, briefing of the staff involved, development of training programmes.

Briefing the user concerned, as well as all user companies, will be done via various specific documents, or by temporary or definitive modifications to documents whether approved or not (FCOM, maintenance programme...). Additionally, symposium meetings bringing together all the user companies contribute to the dissemination of information.

Finally, when the manufacturer is informed of an incident, Airbus keeps its supervisory authority (the DGAC) informed. Events are reviewed between the manufacturer and the supervisory authority during "Airworthiness Review Meetings". Following these meetings the DGAC decides, or not as the case may be, to reinforce the corrective actions of the manufacturer by the expedient of issuing an Airworthiness Directive.

DIAGRAM:

1. **French regulations**

2. obligation

3. recommendation

4. practice

5. irregularity: delay > 2 hours
   return to base
   landing at an airport not specified in the flight plan

6. incident: infraction
   risk

7. BEA

8. Statute of 11 July 62
   Art. 8

9. customs

10. address "error"

11. CEE/CIM

12. "DTA"

13. SFACT

14. customs

15. address "error"

16. CEE/CIM forms

17. incidents

18. airworthiness

19. report 1 month

20. Order
    15 June 79

21. Manufacturer

22. recommended

23. Statute 5 Nov 87

24. IGAC 300
    Art. 13

25. IGAC 300

26. Art. 8 aerial work and air transport
    Art. 9

27. quarterly report on "irregularities"

28. Operator

29. R425.1 + IGAC 300 Art. 12

30. Statute 5 Nov 87 = airworthiness incidents

31. serious incidents

32. R425.1 detailed report 48 hours
    IGAC 300 Art. 11.2

33. Airport Manager
    CCR

34. declaration

35. R142.2

36. Captain

37. declaration

38. IGAC 300 Art. 11.1

39. Local Air Traffic Control;
Civil or Military Local Authority

CHAPTER 1.19 - SPECIAL INVESTIGATION TECHNIQUES

119.1 - Introduction

The object of this Chapter is to present new investigation techniques into aviation accidents which have been implemented for the purposes of this Investigation:

- Optical reading "by garnet" of a magnetic tape enabled certain sections of the QAR magnetic tape to be analysed, even though traditional techniques had proved to be ineffective (see para. 1.19.1).

- Genetic analysis was one of the methods of identification of the accident victims (see para. 1.19.2).

119.2 - Optical reading by garnet

119.21 - Objectives

In the case of the F-GGED accident the objective was to try to extract the final seconds which had been recorded on the QAR tape, which the damage caused by the fire had made impossible to decipher with the aid of a conventional recorder. Three pieces of tape, each a few centimetres long, were subjected to detailed analysis.

For this purpose the investigators called upon a technique developed by the company Schlumberger Industries, known as magnetic tape reading by garnet.

This technique enables a large number of tracks to be viewed on the tape at the same time. Furthermore, unlike other processes such as ferro-fluids, it is the only non-destructive method available for recordings.

119.22 - Preparation of pieces of tape for technical analysis

In order to analyse a greater part of the damaged tape, each piece was smoothed out as much as possible. To do this, the method adopted was to attach the back of the tape with self-adhesive tape onto graph paper, smoothing it out delicately using wooden square rulers. This meant that the tape was on a support which was easier to manipulate. In addition, better contact was obtained with the garnet, giving rise to improved display of the data.

A binocular magnifier and a tool enabling the piece of damaged tape to be flattened against the garnet with the aid of a piece of felt were used. The low magnification of this equipment makes it possible to view the entire width of the tape simultaneously (1/2 inch).

119.23 - Preliminary checks

The determination of the track of the accident was carried out on a sample of "simulated" tape, then on the piece of the QAR tape recorded before the accident.

An examination of the tape on the feeding spool covering the time of the accident showed that track 10 was missing. On the other hand the receiving spool contained the recording of track 10.

This initial experiment proved that track 10 on the piece of tape corresponding to the last seconds of the flight could be viewed and analysed using this process.

119.24 - Photography of the track to be analysed

The equipment used was fitted with an observation window 2 mm wide. The optical part of the test bench format was equipped with magnification adapted to view a single track at a time, as well as with a 24 x 36 camera; this equipment enabled photographs of track 10 to be taken.

The running speed on the QAR PC 6033-3-55 is 1.18cm per second and the recording rhythm is 768 bits per second. Using the chosen procedure, one second of recording corresponds to 36 photographs with an overlap of at least 30% between each photograph to guarantee correct analysis.

119.25 - Principle of optical reading by garnet

Garnets are double silicates of different metals. They possess magnetic and optical properties. Their natural structure in magnetic areas is very sensitive to an external magnetic field. In addition, these areas, possessing alternately opposed magnetism, can be observed under the microscope in polarised light (magneto-optic effect known as the Faraday effect).

The reading principle consists of displaying the data recorded on the magnetic tape through a layer of garnet. The magnetic transitions between the bits of data recorded create escape fields which affect the magnetic structure of the garnet. The garnet's magnetic areas line up with these transitions, making them visible. They can then be photographed. They appear as a succession of lines comparable to a bar code, alternately dark and light (see figure below).

(Caption: Disclosure by garnet of tape recorded data)

119.26 - <u>Decoding of the recording</u>

Coding of data on this type of recorder is of the two-phase M variety. It is characterised by a change of state (a magnetic transition) at the start of each cell ("the cell" corresponds to the coding of a bit), the 1 being represented by a second transition a half-cell after that, whereas the 0 corresponds to the absence of this intermediate transition.

The figure below shows a coded sequence together with an equivalent illustration of the transitions which can be viewed with their primary spacings. These appear alternately dark and light and between two transitions of the same colour only three spacings are possible: a, 3/2a or 2a.

Figure: two-phase M code and relationship between transitions which can be viewed using a garnet

(Diagram:) Cell

According to the settings used at the time of the reading, a rising front can correspond to a dark transition or a light transition. In the case under consideration the rising fronts correspond to the dark bands.

After the photographs were printed off, they were numbered and classified. Manual decoding was carried out by measuring the distances between the light transitions. When the spacings were known between the descending fronts of a sequence, all that had to be done was to complete the sequence with the rising fronts, following the definitions of the two-phase M coding to reconstruct the binary message.

119.3 - Victim identification techniques

119.31 - Introduction

Identification of the victims was performed by the Strasbourg Institute of Forensic Medicine (IML). For the first time in the context of an air accident, this team used the technique of analysing genetic imprints, as much to reconstruct the bodies as to secure reliable identification when morphological tests were found wanting.

119.32 - Standard methods and results

The standard methods employed by this Institute during the early stages of its work enabled it to identify 67 out of the 87 victims after ten days.

For the record, these methods are:

- the thorough retrieval of bodies, human debris and objects surrounding them, from individual square sections of the site;

- the search for means of identification from the families, doctors and dental surgeons who had treated the victims;

- the examination of bodies and the search for anatomical peculiarities, especially via radioscopic examination and fingerprint analysis;

- forensic autopsy, in particular the comparative study of ante and post-mortem dental records, and tissue samples with a view to subsequent toxicological and genetic investigations.

119.33 - Analysis of genetic imprints and results

In the pursuit of its work the Institute carried out various genetic investigations. At the beginning these investigations consisted of determining the genotype of each body or fragments of body by gene magnification of the HLA DQ alpha and DI S80 laws. This is a technique which can be performed rapidly and which is sufficiently discriminatory to enable fragments originating from the same individual to be brought together. It enabled the remains of the two flight crew, two cabin crew and thirty six passsengers to be brought together. During a second phase, genetic analysis was applied to the human remains for which it had not been possible to establish formal identification using conventional morphological methods. The process consisted of researching a possible family connection between the ancestors or the descendants of a non-identified victim and fragments not yet attributed, with the aid of single cell molecular probes exploring highly polymorphic areas of the human genome.

Categorisation by gene magnification, combined with the search for family connections , enabled the identification procedures to be continued by piecing together either totally or partially 18 of the 87 victims listed by the authorities as missing (the pilot, two cabin crew, and fifteen passengers). For the two non-identified victims, no biological trace of their presence could be formally established, probably due to the fact that their bodies had been almost totally incinerated in the fire.

CHAPTER 1.20 - WITNESS EVIDENCE

120.1 - Introduction

In the course of its work the Commission solicited numerous statements concerning the various aspects of the Investigation.

A number of these statements were taken a long time after the event.

An understanding of the circumstances and possible causes of the accident did not require these statements to be taken into account in their totality nor, in the case of those considered relevant, to be transcribed word for word.

120.2 - Statements taken from survivors

Neither the passengers nor the stewardess can recall any impression of a problem regarding the flight in the moments before the accident. Most of them have no recollection of the impact and found themselves either still in their seat or on the ground beside the wreckage.

They have no exact recollection of the precise location and extent of the sources of fire. To withstand the biting cold some of them gathered near the fire which had started at the rear of the aircraft.

The stewardess remembers hearing the noise of a helicopter. An attempt to find flares in the wreckage (to signal their location) was fruitless.

They are not able to specify the time at which the first help arrived. According to one statement, the first rescuers who arrived on the site of the accident had no emergency equipment. For example they had to fashion stretchers from pine branches and their jackets.

According to their evidence, some of the injured had to wait more than an hour before the ambulance in which they had been placed took them to CHU Hautepierre.

120.3 - Statements taken from persons who were close to the site of the accident at around 7 p.m.

People who were present in the Mont Sainte-Odile convent indicated that the fog was very dense towards the end of the afternoon (visibility reduced to a few dozen metres).

120.4 - Statements taken from persons who took part in search and rescue operations

The Civil Defence helicopter took off from Strasbourg Airport at around 8.00pm. The cloud base was at an altitude of approximately 600 m, which prevented overflight of Mont La Bloss.

When assessing the progress of the emergency operations, the Commission used statements which formed part of the report drawn up locally under the jurisdiction of the Prefect as well as statements gathered by the Police.

120.5 - Statements taken from the Eastern CRNA Controller and the Strasbourg Approach Controller who had F-GGED on their frequency

The Eastern CRNA Controller kept F-GGED on his frequency until it had crossed with an Air France flight departing Strasbourg. Then, in line with what had been negotiated during co-ordination with the Strasbourg Approach Controller, he directed F-GGED to ANDLO on descent towards level 70.

The Strasbourg Approach Controller had asked that F-GGED be directed towards ANDLO to allow it to carry out a direct VOR DME 05 approach. Given the way in which the situation developed, he suggested radar guidance to ANDLO to shorten F-GGED's approach. The Controller indicated that the equipment (in particular radar) was not subject to any malfunction. He had selected the following settings on the Approach Control console:

- the radar image was centred on the screen;

- the distance display scale was set to 50 NM with range markers of 2 NM x 2 NM;

- the extended centreline of runway 05 was displayed on the computed internal video. This line extends from the runway up to the outer edge of the screen;

- the ANDLO waypoint was marked on the screen;

- during the entire sequence, before and during guidance, the primary echo and the mode C associated with the STRAPP tag were readable on the screen;

- from the moment the crew displayed the ident code 6100, the symbol associated with this code (filled rectangle) was added to the elements previously mentioned.

120.6 - Statements taken from persons who met the crew

120.61 - <u>During the Orly stopover</u>

The co-pilot came to the pre-flight briefing room very early to examine the file of the planned turnround. One hour before departure, he made the pre-flight inspection of the aircraft.

The captain arrived at the aircraft around thirty minutes before the planned departure time.

The atmosphere on board was very sober.

120.62 - <u>During the flight from Orly to Satolas</u>

An Air Inter pilot who knew the captain came on this flight as a passenger on the flight deck. He observed that the verbal exchanges between the crew were strictly limited to those necessary for the conduct of the flight. Each of them was immersed in his own work and the atmosphere was "strained".

During this flight the captain discussed with him an incident which he had experienced a short while before on an A320. The circumstances of this incident, which had left a mark on the captain, are described in para. 15.11.

120.63 - <u>During the Satolas turnround</u>

No technical problems were reported.

According to the statement of the co-ordinator, after carrying out the various tasks for which they were responsible, the two pilots ate side by side without engaging in conversation. They appeared very guarded.

A traffic agent noticed that the two pilots displayed an indifferent attitude towards each other.

120.7 - Statements taken from Air Inter pilots

Air Inter pilots who had worked with the captain and the co-pilot (in the role of instructor, Controller or co-pilot) supplied relatively similar statements with respect to the social interaction and the work practices of each individual.

It emerged that the captain was rather reserved. He took his work and his responsibilities as captain very seriously and was cautious in his approach to flying.

The co-pilot was of a rather relaxed and expansive disposition. He appeared to be "at ease" on A320s.

Information supplied in these statements is described in greater detail in para. 1.5.

SECTION 2

ANALYSIS

CHAPTER 2.1 - ACCIDENT SCENARIO ANALYSIS

Warning:

The following analysis should be read taking into account the limits within which a technical enquiry into an accident is normally conducted. In particular:

- existing channels for providing feedback of experience constitute the sole available basis for evaluating the order of magnitude of the frequency of an anomaly. This reference is unreliable insofar as it suffers from the effects of systematic bias which always tends towards an under-estimation of the frequency of occurrence.

- for obvious reasons of time constraints imposed on the enquiry, the 1st December 1992 was the cut-off date for reported anomalies or incidents used for the purpose of this analysis.

21.1 - Principles and Elements of the Analysis

21.11 - General method of presentation

21.111 - The term "accident scenario" is used throughout this report to mean the factual sequence (not interpreted) of significant events leading to the accident. The information available to or gathered by the enquiry was insufficient directly to establish the scenario in this case. The commission was therefore constrained to employ indirect methods. For this reason, it has attempted to determine as exhaustively as possible the likely scenarios and subsequently to select the one/s more pertinent to its conclusions on possible safety recommendations.

Nevertheless, in order that this exploration should remain within acceptable bounds, the commission has taken note that not all the constituent events of a given scenario bear the same weight. **For example, in the case of F-GGED, it has identified in particular a determining event a full understanding of which would supply a decisive lead towards a full understanding of**

the accident. That event is:

the onset of and failure to correct a mean rate of descent of 3300 feet per minute on the approach instead of 800 feet per minute which would have permitted an approach angle of 3.3° to be maintained at normal approach speed.

Hereafter this event is described as "the pivotal event" in the scenarios, and the commission has concentrated its systematic investigation on this specific event. However, an explanation for this one event, however critical its nature, will not provide a full understanding of all the factors directly contributing to the accident. The accident arose as a result of the interaction of other events, other conditions and other circumstances which globally make up the whole scenario.

21.112 - Initially (para 21.2)therefore , the commission was careful to explain this pivotal event in terms of a sequence or coincidence of primary events, such as malfunctions or errors, linked to it by a direct relationship of cause and effect. Hereinafter, such a sequence will be termed an accident "generator".

In an effort to determine the generator of this accident, all potential generators were listed in the form of a tree diagram. Using a dichotomy principle, and starting from the pivotal event, its possible causes were divided into two complementary branches each of which was again divided into two more complementary branches and so on until a sub-group was reached which was either indivisible or about which it was possible to establish a true state or estimate the overall probability.

The tree was then "pruned" using the information gathered by the enquiry: flight-recorded data, information arising from the examination of and expert reports on the wreckage, analysis of known defects, eyewitness reports etc.

21.113 - For each branch, the analysis selected one of the following three conclusions:

- generator refuted: the proposed hypothesis (malfunction or error) could not have occurred, and/or could not have contributed to the pivotal event;

- possible generator: the hypothesis could have occurred and its potential contribution to the pivotal event would have been direct and primary.

- possible contributory factor: the hypothesis could have occurred, but its potential contribution to the pivotal event would have been indirect and secondary. It would only have contributed within a context favouring the occurrence of the pivotal event or some other event within the scenario.

21.114 - Later (para 21.3), after the generator tree had been pruned, the commission evaluated in detail the accident scenario/s judged to be possible. In this way, it sought to take account of the other contributory events and to establish the coherence of the proposed hypothesis employing all the available information.

21.12 - method of selection of possible generators

21.121 - The generator tree

Annex 14 is a tree diagram showing the hypotheses explored as possible explanations for the pivotal event (onset and maintenance of a rate of descent of 3300 feet per minute on the approach instead of a reference value of approximately 800 feet per minute).

Note: The research in certain cases concerns itself more with how the descent was initiated than how it was maintained. The most rigorous line of enquiry focused on establishing what processes could have led to the initiation of such a descent rate and to what extent they were capable of creating an anomaly which was difficult to detect.

The tree diagram has been constructed in accordance with the following principles:

- each branch represents a group of hypotheses and two branches stemming from the same parent are complemetary;

- the ranking (R1,R2, etc) of a branch indicates the number of dichotomies that have preceded, starting from the pivotal event;

- the branch number of a given ranking **n** is formed by adding to the end of the number of the parent ranking (n-1) the numeral "0" if the left-hand branch is taken, and the numeral "1" if it is the right-hand branch (looking into the diagram).

The construction of the tree begins by defining two main branches:

- the "0" branch incorporates all the hypotheses in which the high rate of descent is the result of a normal response of the aircraft to the actions of the crew on the controls;

- the "1" branch incorporates all the hypotheses in which the rate of descent is not the result of a normal response of the aircraft to the actions of the crew on the controls.

21.122 - Composition of branch "0"

21.122.1 - In this first group, which subsequently was called "rate of descent actually initiated by the crew", and including all the cases where the aircraft responded normally to the actions of the crew on the controls, all intentional commands were first identified (branch 00), and then all unintentional commands (branch 01), that is to say those about which

the crew had no accurate perception of the effect that their actions on the controls was actually having on the aircraft (manual and automatic).

21.122.2 - Developing branch 00, the following were studied separately:

- (branch 000); all the hypotheses in which an intentional command to begin a high rate of descent would result from a positional error induced by an anomaly in the navigation data presented to the crew by the aircraft instruments, and itself brought about either by an error associated with ground stations (branch 0000) or on-board equipment (branch 0001).

21.122.3 - Developing branch 01, particular attention was paid to:

- cases where the crew had a correct perception of the vertical mode selected on the auto-pilot (branch 011). An unintentional command to begin an abnormal rate of descent therefore presupposes an incorrect interpretation of the rate actually requested, and an attempt was made to identify possible sources higher up in the branch hierarchy.

- cases in which the opposite applied and where the crew's perception of the vertical mode selected was not that which was selected in reality (branch 010). Here, two separate error processes were identified and analysed: failure to change mode (branch 0100), and an incorrect execution of the mode change (branch 0101).

21.123 - Composition of branch 1:

21.123.1 - In this second group, embodying all the hypotheses in which the high rate of descent did not result from the normal response of the aircraft to crew actions on the controls, those cases were isolated (branch 10) where an abrupt and steep vertical descent would result from a malfunction of one of the control systems affecting the longitudinal flight path (height control channel and engines).

An investigation of branch 10 first identified cases of loss of power (branch 100) for the other hypotheses. These, grouped under branch 101, concern malfunctions in the height control channel, from the auto-pilot mode selection control panel through to the servo-controls themselves. These malfunctions were systematically investigated using the nomenclature ATA and examining on the one hand (branch 1010) the functional components in the height control channel up-stream of the receipt of the control command (VS or FPA by the FMGC, and on the other hand (branch 1011) the functional components located down-stream responsible for processing and executing the control command.

21.123.2 - The complementary branch (11) groups together all other possible causes for an abrupt and steep vertical descent: loss of aerodynamic control (branch 110), and all other causes (essentially structural failures in flight)(branch 111).

21.13 - Review of essential technical information

From all the available documents and recordings, as well as the studies, trials and research carried out and reported in chapter 117 of this report, it has been possible to establish the following concerning the radar control and final approach phase:

- the QAR and CVR show that the captain was at the controls(PF) and that No.1 auto-pilot was engaged up to the moment of the accident. Auto-thrust SPEED mode remained engaged.

- the auto-pilot mode was a selected mode (as opposed to a "managed" mode). In fact, the actual speed in flight did not correspond to the programmed optimum speed in managed mode prior to lowering the flaps at an altitude of 5000 feet and for the cost index 55 almost certainly used by the FMS (value written in the COROUTE. It should be noted that this speed is the same as the managed cruising speed for the transit to Strasbourg.

- the studies reported in § 117.5 show that the auto-pilot mode was not changed during the final turn and commencement of the descent (except to deselect ALT mode to make the control command to begin the descent, and that the mode selected during this phase of the flight was almost certainly HDG-VS ;

- the crew conversation on play-back of the CVR makes no explicit mention of any anomaly in the aircraft's performance, the navigation aids, or the aircraft instruments (see CVR transcript in annex);

- the QAR recording shows that neither of the FMGCs had been declared unserviceable;

- it has been possible to reconstruct the flight-path of F-GGED with great accuracy using in particular the radio-altimetre recording (see § 117.8). The FMGC1-recorded flight-path has a maximum lateral displacement from this reference flight-path of 0.15nm. Bearing in mind the accuracy of the FMGC calculation of position in DME/DME mode, this is an indication that FMGC1 was functioning correctly for horizontal flight (see § 117.342).

- the database used by F-GGED indicated that the VOR and TACAN were not co-located. For that reason, the FMGCs did not make use of the Strasbourg VOR to calculate position in the final approach.

- the QAR recording showed that the two VOR receivers were tuned to STR during the procedure turn, that the captain had ROSE VOR selected on his navigation display at the start of the procedure turn, and that this remained selected apart from a period of some ten seconds when he switched briefly to ARC NAV mode, having just been told by the ground controller "...you are 4 nm from the inbound radial ......left of the radial"

21.2 - Analysis of branch 0: hypothesis for a flight path under the effective control of the crew.

21.21 - <u>Branch 00 : flight path flown intentionally</u>

21.211 - branch 000 : intentional control command following a positional error induced by data presented to the crew

21.211.11 - The serviceability of the TACAN ground installation was flight-tested a few days after the accident (see § 117.4), and this failed to reveal any anomaly. Furthermore, a majorant of errors attributable to the ground installation (systematic delay error, multi-path errors) was evaluated as 0.25nm.

An error of this order of magnitude over distance cannot have contributed to the accident. This permits the hypotheses included in branch 000 01 of the generator tree to be refuted.

21.211.12 - The serviceability of the VOR ground installation was also flight-tested a few days after the accident (see § 117.4), and this showed that the installation characteristics were within ICAO tolerances. However, an examination of the modulation rate and error graphs recorded during the test flight from 10nm out to on top the VOR revealed the following:

- the mean error on the 231° radial transmitted by the VOR was 1° : radial 231° was in fact on radial 232°, that is to the left of the published inbound radial in the direction of approach;

- there was signal interference on the inbound radial, most probably caused by a mixing of the direct-path signal and signals reflected by obstacles between 9nm and 8nm from the ground emitter. The interference was sinusoidal, low frequency and had a maximum amplitude of 3° to 4°. It was capable of creating oscilllations of the aircraft's VOR indicator whose strength depended upon the filter characteristics of the signal-processing channel. A simulation revealed (see § 117.421) that interference of this kind on the input signal is reproduced at the output of a Collins-700 VOR receiver slightly attenuated and phase-shifted.

It should be also be noted that in the very last seconds of the flight, the aircraft was very close to the transmitter horizon of the ground installation, and even perhaps below it, because of the masking effect of Mont la Bloss. This might have caused a fluctuation of the aircraft indicator.

It has been established as fact that there was a discrepancy between the aircraft's position as plotted on the reconstructed flight-path shown in para 1.17.8 and what the VOR was indicating to the co-pilot at QAR time 3049 when he called " on the inbound radial ", and then at 3054 when he said " coming up to the inbound radial...a half-point off the inbound radial".

At that moment, on the reconstructed flight-path, the aircraft was on radial 236°, that is to say 4° off the mean reference radial as measured by the calibration aircraft during the flight test. So the indication "a half-point off the inbound radial" means that the deflection bar on the navigation display was indicating a total angular deviation of 2.5° in relation to the selected final approach bearing. There was therefore a discrepancy of 4° when he called "on the inbound radial" and 1.5° when he called " a half-point off the inbound radial." These calls may be taken as accurate instantaneous readings of the navigation display indications. In this case, the indications were affected by a fluctuation of at lease half a point in a few seconds. The call " on the

inbound radial" can equally be interpreted as an anticipation of a result, repeated immediately afterwards as " coming up to.....".

In that same moment, the aircraft was 8.7nm from the Strasbourg VOR, that is to say in the received signal distortion zone which we have seen can cause fluctuations up to 4° and which may be responsible for producing needle oscillations.

Consequently, the characteristics of the received signal may themselves explain the discrepancy measured between the actual position of the aircraft at that moment and the VOR indication on board F-GGED.

Note: The supplementary hypothesis of VOR indicator fluctuations being produced by on-board equipment will be dealt with later.

The probable fluctuations of the VOR indications received by the aircraft cannot however have influenced directly the initiation and maintenance of a high rate of descent. It has been shown that the FMGCs were not using the Strasbourg VOR and, when carrying out a procedure of this type, the crew would not have used the VOR for longitudinal positioning of the initial descent point. Branch 000 00 can therefore be rejected as a possible generator of the accident.

Moreover, the commission also looked at the possible effect of VOR fluctuations on the work load. Two aspects should be considered here. Firstly, the mean error displacing radial 231° to radial 232° has only a minimal effect on the alignment geometry, and actually tends to assist capture because the aircraft was turning too tightly.

On the other hand, the distortion occurring between 9nm and 8nm, as the crew were preoccupied with lining up on the inbound radial, may have complicated their task without their being aware of it by presenting unstable indications.

The foregoing factors enabled the commission to exclude as possible generators all significant positional errors produced by the ground systems and consequently to refute branch 000.0 of the generator tree. Nevertheless, the commission did not rule out the possibility that the instability of the VOR received signal between 9nm and 8nm might have been a factor contributing to the crew's failure to detect the anomalous rate of descent by increasing their work load during the capture phase of the inbound radial.

21.211.2 - Branch 000 1: Origin in the on-board systems.

21.211.21 - As a consequence of the foregoing it was necessary to examine the hypotheses which would explain a voluntary initiation of the descent in terms of a response to erroneous positional information originating in the on-board systems.

It is known that the captain had ROSE VOR mode selected on his navigation display throughout the procedure turn and final approach, except at QAR time 2959 when he selected ARC NAV/20nm mode for some ten seconds. Apart from this brief period, he was therefore using VOR bearing and radial offset information on the one hand, and DME range information with respect to STR on the other, for approach line up and commencement of final descent. An analysis was conducted(branch 000 11) of anomalies that might have affected the raw data and their possible contribution to the accident pivotal event. Because it was not known what mode the co-pilot had selected, the possible effects of anomalies in the maps presented by the navigation displays in ROSE NAV and ARC modes were also examined. (branch 000 10)

In examining possible anomalies affecting the raw data, VOR and DME information was treated separately.

21.211.22 - VOR Information (branch 000 110) :

F-GGED was fitted with twin Collins-700 receivers. The QAR recordings show that both were tuned to the Strasbourg VOR frequency and that no fault had been detected by the self-check facility.

At this point, un-monitored anomalies that might have affected the information supplied to the crew were examined, as well as those discussed earlier concerning the received signal. Anomalies of this type, affecting equipment, are reviewed in § 117.32.

The hypotheses of a stable but erroneous bearing indication, as postulated in branch 0001101 of the generator tree, can be ruled out at once. In fact, this fault has only been found in receivers produced by a manufacturer other than Collins who attributes the difference in the processing of the received VOR signals to the different characteristics of the filters used by the two manuafacturers.

However, the Collins-700-200 is susceptible to fluctuations of the needle and displacement bar caused by excessive metallization of the aerial faring, and this was made the subject of an investigation under branch 0001100 of the generator tree.

It is not possible to show technical evidence that an anomaly of this type did or did not occur during the approach phase. The CVR transcription shows no sign that the crew detected any such irregularity. The frequency of fluctuations could have been so small that a momentary movement of the indicator would not have been picked up by a cursory glance at the instrument. But the CVR transcription shows that the crew was paying great attention to the VOR raw data during the interception and line-up phase. There are several references made which are all consistent with the reconstructed flight-path, save for those at QAR times 3049 and 3054 discussed earlier concerning the quality of the VOR ground station transmissions.

In particular, at QAR time 2983, the co-pilot says "... we should have come out on 070 (in other words, the co-pilot is telling the captain he ought to have completed the turn on a heading of 070°). At time 2985, the captain replies " yeah, yeah ", and at 2987 the co-pilot adds "at least". These comments are perfectly consistent with the position of the aircraft which was in fact turning inside the ideal flight path. Finally, at QAR time 3054, as the aircraft is coming back on to inbound radial, the co-pilot - probably referring to the earlier discrepancies, says: " there you are, it was sixty, it's OK, you see. " This statement by the co-pilot can be interpreted as an allusion to the start of the descent, which was in fact begun on a bearing of 060° from STR.

Consequently, if there had been fluctuations in the VOR indicator, they occurred sufficiently infrequently not to have been detected or at least not to have caused an attentive crew to pass comment. And they were sufficiently weak not to have prevented an accurate perception of the dynamics of the interception of the inbound radial.

Finally, as regards the vertical element of the procedure, the crew was not using the VOR for longitudinal positioning of the initial descent point. In the lateral plane, the initial line-up difficulties experienced by the captain were the direct result of the positioning of the turning point at the end of the outbound leg, and of his selection of headings which prevented him from intercepting the inbound radial at the desired point. The fact that the co-pilot picked this up quite quickly and commented on it, and that the captain agreed, shows that the VOR indications the crew were receiving were not being affected by any anomaly

sufficient to have significantly altered their perception of the aircraft's relative position.

The commission therefore considers the hypotheses of fluctuations of the on-board VOR equipment, presented under branch 000 1100, to be very improbable. Moreover, had such fluctuations occurred, they could not have contributed directly to the pivotal event and therefore this hypothesis cannot be an accident generator. If, however, they had occurred, but had not been detected, they could have represented a contributory factor by slightly increasing the work load on the crew during the capture phase of the inbound radial prior to and immediately following commencement of descent.

21.211.23 - DME information (branch 000 111) :

Note : the distance-measuring ground station at Strasbourg is a military TACAN beacon. The information supplied by this type of beacon can be used by on-board DME equiment.

An error in the Strasbourg TACAN range presented to the crew could have translated itself into an under-estimation of the true range and might have led the crew to believe that they were closer to STR than they actually were and therefore, taking their height into account, to think that they were above the published descent path for the approach. In this hypothesis, the pilot could have been trying to regain a 3.3° descent path by increasing his rate of descent. During the course of a temporary height adjustment, a range error might also have given the crew an incorrect perception of their position in relation to the reference path. Possible technical failures of the on-board DME equipment were therefore examined.

F-GGED was fitted with twin Collins-700-020. An analysis of know defects likely to have affected the raw range data supplied by this equipment was carried out and reported in § 117.31.

By reading and interpreting the content of the non-volatile memory of the BITE in both pieces of equipment recovered from the site, it has been possible to show that neither could have been affected by the fault know as "sleeping mode".

As far as "deaf mode" and "jumping mode" faults are concerned, the hypothesis of their occurrence has been refuted on technical grounds (see § 117.325.2 and § 117.325.3).

The two foregoing paragraphs consequently permit branch 000 111 0 of the generator tree to be refuted.

However, another fault which could have produced erroneous DME range information was identified after the accident (see § 117.325.4). The hypothesis for an occurrence of this fault cannot be discounted given the facts available as this report goes to press. In a more general sense, it is not possible formally to produce absolute technical proof that the DME receivers on board F-GGED were working correctly.

However, several factors mitigate against the hypothesis that such a failure occurred, or at least that it could have contributed to the initiation of an excessively high descent rate.

At QAR time 2382, at the request of the ground controller, the co-pilot reports a DME range of 22nm from Strasbourg which corresponds to the actual position of the aircraft. Subsequently, the crew makes no reference to delaying the commencement of descent, or to any need to change the briefed rate of descent. They did not question the controller when he reported their position as " right of the inbound radial" (when in point of fact the word "right" was not appropriate at that particular moment) at QAR time 2991. They began the descent at 11.2nm from STR, that is to say the nominal range for the procedure, fifteen seconds after being cleared to do so by the ground controller. It is highly unlikely that the captain would have authorized the commencement of descent for a VOR DME approach without first taking note of the DME range and, in so doing, that he would not have noticed a discrepancy in the read out.

Consequently, any possible contribution to the accident of a defect in the on-board DME equipment is limited to the failure to detect the excessively high rate of descent. A fault in the instruments of the pilot making a height adjustment (of which there was no mention) occurring at the moment he was making it would then have prevented him from being aware of the abnormally low altitude of the flight path.

The commission therefore considers the hypothesis presented under branch 000 111 1 to be extremely improbable. In addition, if indeed a defect in the on-board equipment had occurred, it could not have contributed directly to the pivotal event. This hypothesis cannot therefore have been an accident generator, although it might have been a contributory factor in the subsequent loss of height/range control.

21.211.24 - Faulty navigation display maps (branch 000 10)

The commission conducted a detailed analysis of known map display faults at the time of the accident. This analysis (see § 117.34) permits all known

defects to be ruled out with the exception of two. The first affects only the 10nm scale and produces a positional error in the flight path symbology. The second results in the symbology on the navigation display being frozen.

*Note: As was indicated at § 117.221, it was noted at the site of the accident that the 10nm range scales were selected. But when the FCU study was carried out, the captain had the 20nm range scale selected. It is therefore not possible reliably to ascertain what selections were at the moment the accident occurred.

Furthermore, it should be noted that the use of the 10nm is very unlikely for this approach, because neither STR nor the runway would then have been visible on the map at the commencement of descent.

The only way in which it could have been possible for a faulty map to have contributed to the accident would have been if the co-pilot had selected a map mode and the captain had used the map by turning his head, or else had made use of unheard information (there is no trace of it on the CVR) passed to him by the co-pilot and taken from his map.

But, during the final turn and interception of the inbound radial, the crew were calling out aircraft headings and VOR read outs. Every one of the comments made by the co-pilot about the lateral movement of the aircraft refers to raw data concerning displacement and bearing, and is perfectly consistent with the true position of the aircraft. The two pilots expressed agreement about the interpretation of these data, and showed that they were perfectly aware that the turn was too tight. At no time did they mention the map selected for some ten seconds on navigation display 1 and,in particular, made no reference to any discrepancy between a map and raw radio-navigation data.

There are no reasonable grounds to support the hypothesis for an intentional descent at four times the nominal rate on the basis of a scenario such as that depicted above, particularly given that the DME range information was correct.

Having regard for all these factors, the commission is therefore led to reject a faulty map (branch 000 10) as a possible generator of or factor contributing to the accident.

21.212 - branch 001: intentional command, for reasons other than a positional error induced by data presented to the crew.

21.212.1 - In attempting to discover reasons, other than those associated with a positional error, why the crew might have been led into making a decision to commence a final descent at a rate of 3300 ft/min, a study was first made of those that could be linked to a misunderstanding or faulty execution of the procedure itself.

Branch 001 10 postulates the hypothesis that the rapid descent was deliberately initiated to the MDH, in order, for example, to gain visual contact with the ground as quickly as possible and to avoid the risk of reaching that height too late to land successfully. This first of all suggests that there was confusion in the minds of the crew between the intermediate approach fix (IF) on the inbound radial located 11nm from STR and the final approach fix (FAF) located 7nm from STR. Bearing in mind the special requirements of this procedure (constant angle of descent from overhead the ANDLO beacon), such confusion is impossible. Nevertheless, the hypothesis also implies that the two pilots either forgot, or deliberately broke the rule governing descent by means of minimum range/height pairs, and here in particular the pair 7nm STR/3660 ft.

This hypothesis is however highly improbable for the following reasons:

- the CVR contains not the slightest reference to such a course of action, which would have been very much contrary to that decided at briefing, and which would have called for either some prior warning from the captain, or a query on the part of the the co-pilot;

- the rate of descent adopted was far too high: almost three times the customary rates used in such a situation. And the crew were perfectly aware that they were not yet on the inbound radial (cf CVR), and were also well aware that there was a major obstacle below their flight-path.

Consequently, the commission considers the hypothesis that a rate of descent of 3300ft/min to the MDH was intentionally initiated highly improbable.

21.212.2 - Branch 001 110 of the generator tree postulates the hypothesis that there was a calculation error of the rate of descent (in VS mode), for the 5.5% descent slope shown on the procedure chart.

The commission considered this hypothesis to be highly improbable because the difference between the rate set and normal final approach vertical speed rates was too great for a calculation error of that order to have escaped the notice of the pilots.

Branch 001 110 of the generator tree postulates, among other possibilities, the hypothesis that the pilot at the controls was confused between the Strasbourg DME range and the range to the runway threshold. It should be noted that the TAP chart used by the crew includes a scale of ranges to runway threshold. If it had been a case of confusion, the crew would have had the impression that they were late for the descent.

Finally, the hypothesis was put forward that an optical illusion had led the pilot at the controls to increase the slope of the descent path substantially after making visual contact with a (bad) point of reference on the ground. This hypothesis was examined under branch 0010 of the generator tree and was refuted on the basis of available meteoroglogical information and other factors (landing lights extended but not illuminated...), demonstrating that the commencement of descent and final descent were carried out with no visual contact with the ground.

The combination of these factors led the commission to discount all the hypotheses within branch 001 as a possible generator of or a contributory factor to the accident.

21.22 - <u>Branch 01: Unintentionally flown flight-path</u>

21.221 - Branch 010: Unintentional command resulting from a lack of awareness of the vertical mode

This branch groups together all the hypotheses associated with a loss of crew awareness of the auto-pilot vertical reference, in this case the VS mode, and in particular by the captain. The initiation of an excessive aircraft descent rate would then be the result of the selection on the FCU of a flight path angle (FPA) of 3.3°, that the automatic pilot would interpret, in accordance with the selected reference, as a vertical speed(VS) command.

The selection characteristics would in this case lead the auto-pilot to assume a command value of 3300 ft/min.

The commission identified two error processes that might have given rise to a situation of this kind:

- forgetting to change reference (branch 0100): after executing a turn in HDG mode, the pilot selects a 3.3° FPA and activates it without changing reference, either because he purely and simply forgot the intermediate action, or as a result of confusion about the HDG-VS and TRK-FPA correlations.

- a mistake in the execution of the change of reference mode (branch 0101), and in particular confusion of buttons: instead of pressing the button which switches between HDG-VS and TRK-FPA modes, the pilot presses the button which switches the altitude reading from metres to feet located further to the right on the FCU fascia.

The hypotheses grouped together under branch 010 are error processes of a classic kind and a fairly high frequency of this type of error has been reported during training. Their operational residual frequency is not known and they are generally quickly detected and corrected. However, reported incidents (see para. 1.17.6) would tend to suggest that errors of this sort that remain undetected by the crew for some time have a frequency of the order of 10 to the minus 5 per flying hour.

This led the commission to take the view that the hypotheses grouped under branch 010 were possibly, and even probably, an accident generator.

21.222 - branch 011: unintentional command with a correct awareness of the active vertical mode

An unintentional commmand to execute an abnormal rate of descent by a crew aware of the active vertical mode selected on the auto-pilot presupposes an incorrect awareness of the actual value selected. The commission identified two possible processes which might have led to a command for an abnormal vertical speed being given unbeknown to the captain:

21,222.1 - the first process (branch 011 0) is based upon a practice sometimes employed to commence a descent during a high work-load phase: with a rapid, single turn of the rotary switch, the pilot selects a very rough value which he refines later. The value selected by this initial movement can be too high, either because of hastiness, or deliberately

with the intention (illusory) of accelerating the descent in order to counter the lift generated as a result of extending slats and flaps, or finally because the hand is jolted by the effect of turbulence as the selection is made.

In this case, forgetting to carry out a subsequent check would lead to an abnormal flight path being flown. The selection of a value of 3300 ft/min in one single movement requires slightly more than one turn of the rotary switch in VS mode (one turn equates to 32 clicks and corresponds to a selection increment of 3200ft/min), and more than three turns in FPA mode (where at least 9.9° must be selected).

Trials have shown that, in the second case, the required movement is difficult to execute, and also extremely unnatural, making it very unlikely. Since there is very little likelihood that the FPA mode was selected (cf para. 1.17.5), this hypothesis can be ruled out. In the case of VS mode, on the other hand, (considered here as intentional), the movement is possible. However:

- it is assumed that VS mode was selected as a result of a deliberate choice (if not it was the wrong mode), and therefore of a change of plan from that which was briefed. A change that was neither announced nor commented upon;

- the inexperience of the captain on type and his personality do not at all mitigate in favour of such a movement;

- the "random" selection corresponds exactly with the nominal numerical selection. It is therefore necessary to consider the conditional probability of selecting exactly 3°3;

- a procedure of the " very rough selection/refine later" type demands considerable short-term recall ability in relation to the second element. The hypothesis " the captain had completely forgotten to refine his selection" is therefore less probable than the one, "having gone back to refine his selection, he was pleased to see that a value of 3°3 was showing, or a value quite close which he then adjusted slightly." At this point, one is back to a slightly different variation of the hypothesis of lack of awareness of an inconsistency between the selected units/active vertical mode.

This led the commission to conclude that the hypothesis was a possible, but not very probable generator.

21.222.2 - the second process (branch 011 10) brings to light a more complex error sequence: the execution of an action which was part of an earlier plan but had not been updated. In this scenario

the captain is well aware of the vertical flight mode (VS), but selects the required value mechanically, drawing on his memory of the value calculated earlier and announced in his briefing (see QAR time 2741), that is 3°3. In other words, he selects a dimensionless number, without checking to verify its significance.

This method of working is very economical of mental resources and enables maximum attention to be paid to coping with a problem perceived as priority. An error of this kind is consequently plausible in the sense that the prevailing focus of attention on the flight deck at the critical moment was on the lateral flight path and aircraft configuration.

This led the commission to conclude that this hypothesis, under branch 011 10, was a possible and quite probable accident generator.

21.3 - Analysis of branch 1: hypothesis for a flight path not under crew control

2.31 - <u>Branch 11</u>

21.31 - From an examination of the wreckage (see § 113.2) it was possible to establish that the aircraft had suffered no damage to or loss of its moving aerodynamic surfaces prior to impact with the trees and the ground.

This enabled the commission to rule out the hypotheses under branch 111 of the generator tree.

21.312 - The examination of the wreckage, analysis of debris scatter, reconstruction of the flight path as it struck the trees, analysis of QAR parameters respresentative of the vertical flight path and a comparison of the latter with an aerodynamic model of the aircraft all show that it suffered no loss of aerodynamic control before impact.

This enabled the commission to refute the hypotheses grouped under branch 110 of the generator tree.

21.32 - <u>Branch 10: malfunction of one of the means of controlling the vertical flight path</u>

21.321 - Loss of thrust

The examination and expert analysis of the engines, as well as the analysis of the appropriate QAR parameters, revealed that the engines were functioning before impact at a speed compatible with flight idle, and that this speed corresponds to the normal thrust

setting for the aircraft's configuration and flight path applied via the auto-thrust control unit (A/THR). This enables the hypotheses under branch 100 of the generator tree to be ruled out.

21.322 - Malfunction in the height control channel

21.322.1 - The analyses presented under this paragraph lead to a general conclusion ruling out the hypothesis for a flight path not under crew control, with the exception of the cases examined under branch 101 which incorporates all possible malfunctions in the height control channel.

The height control channel includes all those elements listed under the heading ATA22 (Auto-pilot, Flight Director, Auto-Thrust, Flight Augmentation Computer, Flight Management and Guidance System, Autoflight System Bite) and those listed under the heading ATA27 (THS, Spoilers, ELAC, SEC,...).The full list of possible malfunctions in the functional channel was divided into two, separating those upstream of the receipt of control command data by the FMGC from those downstream.

21.322.2 - Malfunction upstream of the receipt of command data.

Examination of possible malfunctions upstream of the receipt of control command data by the FMGC, grouped under branch 1010 of the generator tree, was discussed in § 117.22.

Possible technical malfunctions considered were those involving either the vertical flight mode, or the system interpretation of the values selected by the crew.

The following possible malfunctions were examined under the heading of **vertical mode.**

- malfuntioning of the mode selector button: despite the fact that the crew pressed the button, switching from HDG-VS to TRK-FPA mode, no change occurred (branch 101 000 1). As the research reported at § 117.63 indicates, there are known cases of malfunctions of this nature, and a possible occurrence of a similar fault cannot formally be ruled out.

  The commission was therefore led to conclude that the hypothesis under branch 101 000 1 was a possible accident generator.

- inadvertent and unintentional mode change (branch 101 000 0): after changing mode from HDG-VS to TRK-FPA there was an inadvertent and unintentional switch back to the initial mode.

Since it has been demonstrated that there was no mode change (see § 117.5), the hypotheses under branch 101 000 0 can be refuted.

- inadvertent and unintentional mode change: as the value is being set on the rotary selector switch, an inadvertent and unintended descent mode is engaged which is not actually selected by a movement of the rotary switch (branch 101 001). There have been cases of similar faults and therefore this hypothesis cannot be excluded. However, the contribution to the accident of an event of this kind would be nil to marginal. In fact, the descent was initiated at the specified range (11.2nm) and followed about 15 seconds after clearance was given by the final approach controller. In consequence, everything points to a descent under the control of the crew.

The following possible malfunctions were considered in relation to selected command values:

- failure of a luminous segment of the selector scale resulting in an incorrect selection being made. This postulates a situation in which the crew select FPA mode and wish to select the briefed descent path angle of 3°3. They make a rapid turn of the rotary selector without initially paying heed to the values selected and overstep the desired value by a considerable margin. As a result the final selection is actually 9°3 although the read-out is 3°3 because of the faulty first selector scale segment.(A double failure selecting 9°9 for a read-out of 3°3 can be ruled out as too improbable).

This hypothesis, under branch 101 010, has been refuted for the following reasons:

. the selected mode was almost certainly VS mode;
. the vertical speed that would have resulted from a selection of 9°3 in FPA mode is substantially less than the one recorded by QAR;
. the movement of the rotary switch needed to select 9°3 is substantially greater than that required to select 3°3;

- corruption of the control command value fed by the FCU to FMGC1 (branch 101 011): the crew correctly selects the desired value compatible with the nominal descent slope (about 800 ft/min in VS mode). The correct value appears in the scale window, but the value actually registered by the FMGC1 is different (and greater).

There is a known case of an FCU fault of this nature leading, eight months after the accident, to three cases of abnormal reaction by the aircraft in flight. The enquiry was not able to collect sufficient data to permit it formally to rule out an occurrence of a fault which could have produced a stabilised vertical speed of 3300 ft/min for a selected value of 800 ft/min. However, the known frequency of occurrence for such an event is very low. In fact, at the end of December 1992, operators of the A320 had flown one million four hundred hours, during the course of which a single fault had been identified, affecting the same FCU (Air Inter incidents in September 1992, see § 1.17.6.3).

Having due regard for the foregoing, the commission concluded that the hypothesis under branch 101 011 was a possible accident generator but not a very probable one.

21.322.3 - Malfunction downstream of the receipt of command data

The examination of possible malfunctions downstream of the receipt of command data by FMGC1 (branch 101 1 of the generator tree) was reported at § 117.23.

A full examination was able to show that the horizontal flight control system including all height control surfaces were at all times in positions consistent with the commands of an auto-pilot functioning normally and controlling the aircraft in accordance with parameters consistent with the flight path actually flown, with in particular a constant vertical speed setting of 3300 ft/min.

Furthermore, the position of the slats and flaps corresponded to the configurations selected and referred to by the crew. The spoilers were working normally and the ELAC2 computer, exercising height control, had not been declared unserviceable.

The initiation and maintenance of a very high rate of descent cannot therefore have been caused by a malfunction in the height conrol channel as listed under branch 1011 of the generator tree.

21.4 - Conclusion concerning uneliminated hypotheses

21.41 - <u>Principles of selection</u>

It can be seen from the preceding analyses that this was a very difficult enquiry and, despite considerable effort, it was not possible to identify an accident scenario with any certainty.

Even when concentrating on seeking an explanation for a pivotal event, the commission was not able to establish the validity of a single hypothesis to the exclusion of all others.

As a result, the commission has had to choose, from a number of unrefuted hypotheses, those that it considers give grounds for reflection concerning specific safety implications. Within this framework, it has selected on the one hand those considered to be the most probable (although no more than very general orders of magnitude have been assigned to these probabilities), and on the other, those which, even if their connection with the accident is unlikely, seem to raise serious questions with regard to important safety issues.

21.42 - <u>Preferred hypotheses</u>

On the basis of the foregoing, the commission identifies the following preferred scenarios as explanations for the pivotal event:

21.421 - Hypothesis No. 1:

the abnormally high rate of descent was the result of an unintentional command on the part of the crew because they believed the vertical mode selected on the auto-pilot to be other than that which was actually selected.

Having flown the outbound leg and executed an inbound turn under radar control with HDG mode selected, the crew commenced the descent still in HDG-

VS mode and selected "33" in the FCU window:

21.421.1 - Variant 1A: a descent at an (FPA) angle of 3°3, in the belief that FPA mode had been selected, but having in fact forgotten to change mode, or having forgotten/made a mistake about the HDG-VS association;

21.421.2 - Variant 1B: a descent at an (FPA) angle of 3°3, in the belief that FPA mode had been selected,

but having mistakenly pressed the wrong button (in fact the height units change-over button).

The commmission is of the view that Hypothesis No.1 is quite probable.

21.422 - Hypothesis No. 2:

The abnormally high rate of descent was an unintentional command on the part of the crew, resulting from an incorrect perception of the selected numerals.

Having flown the outbound leg and executed an inbound turn under radar control with HDG mode selected, the crew initiated the final descent having decided to remain in HDG-VS mode, and selecting "33" in the FCU window because it was the briefed value.

The commission is of the view that Hypothesis No.2 is quite probable.

21.433 - Hypothesis No. 3:

The abnormally high rate of descent was the result of:

21.423.1 - Variant 3A: a malfunction of the FCU (faulty mode selector button);

21.423.2 - a malfunction in the command control channel feeding an erroneous value to the FMGC.

The commission is of the view that Hypothesis

No.3 is not very probable.

21.5 - Reconstruction of the most probable scenario

The following paragraph establishes the sequence of significant events leading up to the accident. This sequence obviously includes the pivotal event, with the different hypotheses put forward in para. 21.4. shedding further light. It also includes other events having causal links with the accident of varying degrees of importance and directness, as for example those relating to the lateral flight path or workload. Finally, it includes purely contextual elements: environment, circumstances, coincidences, etc.

21.51 - Flight Preparation

The flight during which the accident occurred had been preceded by an Orly-Lyons flight. Preparation had begun at Orly and was completed during the stop-over at Lyons. For both flights, the enquiry was able to

establish from collected information that the procedures followed by the crew were those accepted by the company as standard.

A witness saw the crew eating in Lyon. Both pilots ate at least a partial meal.

Information available to the enquiry leads it to conclude that the crew selected a COROUTE of "LYSSXB" on the FMS with an ILS 23 arrival.

21.52 - <u>Initial stage of the flight</u>

Take off from Lyon-Satolas was at 17h39mn01s on runway 36. The captain was the pilot in control(PF). At 17h41mn01s, the ILS frequency changed from 110.7Mhz (frequency for the Lyons-Satolas ILS runway 36) to 110.1Mhz (frequency for the Strasbourg ILS runway 23). This means an ILS approach on runway 23 had been programmed into the FMS before take-off. On reaching flight level 180, the frequency for the Strasbourg SE beacon was selected on the ADF. The transit was flown at this flight level with the No.1 (AP1) auto-pilot engaged. Indicated airspeed was 327kts, corresponding to the managed speed at that flight level and for a cost index of 55 (value specified by Air Inter).

Radio contact was established with Reims Control at 17h53mn55s. The controller instructed the crew to " proceed via Luxeuil for a standard arrival Strasbourg" and the co-pilot read back. There are in fact two possible arrival routes to which this radio instruction could apply: LUL-ANDLO-STR and LUL-OBORN-SE.

21.53 - Preparation for arrival: ILS 23 option

At the captain's request, from 17h56mn38s the co-pilot was listening to the Strasbourg ATIS and advised him of the active runway at 17h57mn13s: " the active is 05". The ATIS advised him of the active runway but did not specify the approach procedure in force. The captain questioned the co-pilot: " zero five? What wind are they giving?" and received no reply. He continued: " Get me the weather, will you? What cloud base are they giving?" The co-pilot's response is uncertain (" eight eighths at three thousand, I'll have to get it again.") It is probable the captain then read the notes jotted down by the co-pilot when he was first listening to the ATIS.

At 17h57mn57s (QAR time 1705), according to the QAR recording, runway 05 was fed into the MCDU (ILS frequency 110.1Mhz disappeared). This

input is not mentioned. In view of the subsequent dialogue, it can be assumed that the co-pilot fed a VOR 05 arrival into the F-PLN (Flight Plan) page of the MCDU and updated the PERF APPR page (approach phase performance).

At 17h58mn48s the captain commented on the wind (on 050 degrees) that the co-pilot has just confirmed for him: " eighteen knots...hah! Unlucky." He then asked the co-pilot to confirm the minima for runway 05 and the co-pilot did so for a VOR/DME approach on 05. The captain then asked: " Is there a visual approach procedure from overhead?" The co-pilot passed him the indirect approach minima : " visual approach at night (...) eight hundred feet and two thousand eight hundred metres".

The weather conditions reported by the ATIS (eight eighths at eleven hundred feet, ten kilometres visibility) were better than these minima. At 18h56s [sic], the captain decided: " Depending on traffic, we'll try an ILS approach." He described the indirect approach procedure on runway 05 for a right-hand turn outbound from the ILS approach, and started to explain the reasons for his choice: " if we go for the 05 procedure...ah well we'll...(whistles)". He asked for the minima for an indirect approach procedure to be input and corrected what the co-pilot was doing by specifying the requirement for an MDH (Minimum Descent Height).

At 18h01mn45s, the captain continued with: " you know, I'm going to select the 23 runway, otherwise I shan't be able to make an ILS approach! I'll set 23 again, eh? When the co-pilot queried this, with - " you're setting two three?" he confirmed: " yep! that's it...for an ILS arrival." At the same moment, the aircraft overflew the Luxeuil (LUL) VOR and turned on to a heading of 043° for the OBORN reporting point. Ten seconds later the frequency for the Strasbourg ILS appeared again on the QAR recording: the 23 runway had therefore been re-input into the MCDU in place of 05. The captain then gave his arrival brief for an ILS arrival on runway 23. The frequency 115.6Mhz was selected on VOR1, the frequency for VOR STR Strasbourg. At 18h02mn33s and for about a minute, navigation display 1 was switched from ARC NAV 80nm mode to PLAN mode: this corresponds almost certainly to the captain checking the flight plan program down to break off, in accordance with Air Inter standard operating procedures.

In the following seconds, the co-pilot says: " I don't know why you don't try a 05 VOR DME ." The question suggests that he is referring to a straight-in VOR DME approach on 05 but is not very clearly expressed. The captain answers by referring to the complete VOR DME procedure: " because for a VOR DME you have to fly inbound here, then outbound..for god knows how far and then inbound again...so it would be just as quick

to...". Then he adds: " otherwise we'll have to fly 11 outbound from STR, eleven point two two nautical miles to be precise...that's another ten minutes flying time.. so that's why...that". The co-pilot appears to agree: " yep, we'll have to do a...".

At 18h04mn15s (QAR time 2083), the STR frequency 115.6Mhz is selected on VOR2. It was probably the captain who made this selection, because 54 seconds later he says to the co-pilot who has identified the SE arrival beacon: " I've set the STR return inbound radial for you...zero five zero".

21.54 - <u>The descent and flight path to the ANDLO beacon</u>

At 18h05mn29s the captain commences his pre-descent checks, prior to descent at 18h08. At the request of the co-pilot, the aircraft is cleared to descend to flight level 130. AT 18h06mn27s, the ground controller requests the crew to set heading for the ANDLO reporting point. This point does not figure in the flight plan for a standard ILS arrival on 23, and was therefore not showing on the navigation display. Having got the co-pilot to confirm this instruction with the controller, the captain says: "ANDLO, now they're starting to mess me about....".

The aircraft turns right towards the ANDLO beacon (or perhaps SE) on the heading of 053° that the ground controller has requested they maintain until further notice (to maintain separation from a departing aircraft). The co-pilot passes a negative remark about this restriction. At 18h07mn24s, the controller clears them down to flight level 70. The co-pilot reads back saying: "Continuing to descend to FL70." In fact, the aircraft had not yet left its transit flight level: the descent begins two seconds later.

According to the FMGS co-ordinates, the aircraft was then 22.9nm from the ANDLO beacon. The co-pilot announces that he has selected IDLE/OPEN DESCENT mode in accordance with comapany procedures, but does not mention the selected level. The speed drops to about 315kts, which appears to be a managed speed value and indicates that EXPEDITE mode was not being used.

At 18h08mn56s, the heading restriction is lifted and the aircraft changes frequency to Strasbourg approach.

21.55 - Arrival under the control of Strasbourg approach

On initial contact, the Strasbourg approach controller asks the aircraft to turn towards the ANDLO beacon and gives the range (22nm from STR) and clearance to descend to 5000ft on the QNH. He does not specify the runway in use, nor the approach procedure to be used, neither does he give clearance beyond the ANDLO beacon, and the crew does not ask him how they should proceed beyond this reporting point. Furthermore, in order strictly to comply with the clearance given by the controller to overfly the ANDLO beacon at 5000ft, it was necessary to increase the descent rate. This correction was not made,and there is no evidence that the crew gave the problem any thought, which seems to suggest that they did not see the instruction as jeopardizing in any way their intention to carry out an ILS approach on runway 23.

At 18h09mn52s (QAR time 2420), the aircraft is passing flight level 115 in the descent and its indicated airspeed increases to a maximum (322kts) and then drops back to 254kts at flight level 97, very likely as a result of the automatic activation of the speed limiter restricting the speed to a maximum of 250kts below flight level 100. The crew carries out the altimetre checks after changing to the QFE. Whilst doing this, the co-pilot discovers the captain has made an incorrect setting (1008 instead of 1005 as they had been informed) and he corrects it. The co-pilot reads the "initial approach" check list on his own initiative (Air Inter procedures specify that the pilot in control must ask for them, in this case the captain).

At 18h11mn32s (QAR time 2520), the aircraft passes overhead the ANDLO beacon at 9480ft on the QNH. The airspeed is 257kts increasing (to 312kts),as is the rate of descent. The captain had probably overriden the speed limiter (250kts/FL100): there was no Air Inter instruction about this at the time of the accident, nor was there anything in the Strasbourg procedures governing the approach. At 18h11mn42s, the co-pilot reports to the controller: "passing overhead the ANDLO". The aircraft is 9.6nm on a bearing of 054° from STR. The controller answers: "....you're number one for a VOR DME on zero five, call the VOR on finals." This is the first time that the procedure they are expected to carry out - a VOR DME approach on 05 - is mentioned by the controller. However, the call could have been interpreted by the crew in two ways:

either a direct aproach, or a full procedure. The fact that the aircraft is requested to call passing overhead the VOR on finals suggests that it was not expected to carry out the full procedure, although the controller does not tell them that they may not do so. The aircraft is now 8.6nm from STR, that is to say 11nm from the runway threshold, airspeed 292kts at an altitude of 7600ft: at this juncture a direct approach is no longer feasible.

At 18h12mn05s (QAR time 2553), SPEED mode (acquisition and maintenance of desired speed by auto-thrust) and ALT STAR mode (desired altitude capture) are engaged. The vertical speed is -4800ft/mn. The commanded N1 increases progressively, as does the vertical speed. The desired speed must have been in the order of 310kts, because the speed reaches 312kts at 18h12mn26s and then falls back.

At 18h12mn11s, the co-pilot suggests: " We could ask him to confirm the current cloud ceiling, (....) nautical miles?", thereby suggesting perhaps that they should respond to the ground control clearance by carrying out a VOR DME direct approach.

Either because that is what he understood the co-pilot's response to mean, or because he was reacting directly to the ground control clearance, the captain demurs: " ten nautical miles...tell him that's no good, we'll do a....". However, the co-pilot asks the controller to confirm the ceiling, as he himself had suggested. In response to the controller's reply (three eighths at a eleven hundred feet and six eighths at two thousand six hundred), the captain says: " fine", which in all likelihood means that these conditions are satisfactory for an ILS approach on 23 followed by a visual on to 05. The co-pilot advises the controller of the captain's decision at 18h12mn29s: " yes, we are proceeding to the SE for an ILS approach followed by an indirect on to 05." This is the first time the crew has made any clear and explicit reference to the controller about their intentions.

During the course of this exchange, the commanded and actual N1 values have decreased to IDLE, very probably corresponding to a selection of a new desired speed (260kts) by the captain. He makes no comment about this selection.

At 18h12mn34s (QAR time 2582), a single stroke chime sounds, the PRESS page appears on the ECAM, and an ACARS message is recorded: this is the LO DIFF PRESS alarm which is activated as a result of a high rate of descent. The captain asks for the alarm to be de-activated: the aircraft being on the point of levelling out at 5000ft, there is no risk of a cabin depressurisation.

At 18h12mn45s, the captain asks the co-pilot for the temperature. The reply is interrupted by a message from the controller who tells the crew that in view of the approach they have requested, they may have to hold to allow three aircraft to take off on runway 05. He does not say for how long. The captain then decides to change his mind, abandoning his plan for an ILS approach on 23 for a VOR DME on 05. The controller is advised of this and gives clearance.

At 18h13mn10s, the captain says: " It won't be much fun descending in India Mike; if they'd warned us earlier, but it'll be a hot arrival." (India Mike: instrument meteorological conditions). This is an oblique comment for the controller and perhaps the co-pilot. He justifies his earlier refusal to carry out the VOR DME straight-in approach on 05 as cleared by the controller, and which would have meant a rate of descent incompatible with a normal approach procedure in IMC.

21.56 - <u>The outbound leg</u>

AT 18h13mn28s, as the aircraft is approaching STR, the controller suggests radar guidance to bring them over the ANDLO beacon and thereby avoid the necessity for them to fly the full procedure of an outbound leg and inbound turn. The captain accepts. The aircraft passes north of STR at 5025ft on the QNH (QAR time 2646). Its speed is steady at 260kts. The controller tells them to squawk new code 6100 to identify them as the inbound aircraft and to turn left on to heading 230°. The crew turns left, probably selecting the new heading, and sets a new target speed (250kts). The altitude maintenance ALT mode is engaged. There is no verbal reference to the selection of the new heading or ALT mode, contrary to company regulations.

At 18h13mn52s, the captain says: " I'm setting the 05 again ", and thirteen seconds later the ILS frequency for runway 23 is deselected (QAR time 2673). This means that the crew very probably input the details for a VOR 05 arrival into the FMGS. The enquiry (in particular the simulator study reported at §1.17.7) was not able to establish what type of arrival was actually input (NO STAR or STAR LUL 05, or VIA SE, or NO VIA). In view of his earlier remark, it was probably the captain who input the essential details of the procedure. The simulation results referred to at §1.17.7 tend to indicate that an input of runway 05 after passing STR would most probably have required the runway heading to be set as well as the inbound reporting points, particularly STR07 (7nm STR) and perhaps the ANDLO.

At 18h14mn12s (QAR time 2680), a command to reduce N1 indicates that a new target speed (approximately 215/220kts) is selected. The captain gives the appropriate briefing for the planned new approach procedure. In particular he mentions the initial descent point at 11nm from STR, which he seems to think is different from the ANDLO: " we overfly the ANDLO on the inbound radial and start the descent at 11 STR". He confirms the passing heights at 9nm and 7nm but makes no specific reference to the STR passing height.

At 18h15mn04s, the ACARS indicates that the HUD is now switched on.

At 18h15mn06s, the controller advises their position: " six nautical miles on the 290 radial from Strasbourg". This position does not correspond to the aircraft's position established by the enquiry. At that moment F-GGED was at range 4.5nm on the 340 radial from Strasbourg, and 4.5nm on the 301 radar radial from Strasbourg. The study of the flight path reported at § 1.17.8 and the technical note concerning the radar plot reported in annex give an explanation for this discrepancy which is within the tolerance of the radar.

Continuing his briefing for a VOR DME approach, the captain confirms the inbound heading and converts (correctly) the descent slope shown on the chart

(5.5%) into a descent angle (3.3°). It has not been possible to determine whether the new MDH was set on the PERF APP page. There was no mention of it at this stage of the flight.

At 18h15mn31s, the aircraft is steady on heading 230° and begins its outbound leg. Its speed is 223kts. The crew switch on the air-intake anti-icing and wing de-icing. They complain about the lack of an ice warning system and the CVR conversation on this subject tends to suggest that they checked for icing with the aid of a torch. An increase in the N1 command followed by an increase in speed to 230kts indicates a very probable increase in selected speed.

At 18h16mn22s, the captain again stresses that a VOR DME 05 direct approach is not possible given the inbound configuration at the ANDLO: " What a mess! When you're not prepared, you're hardly on top the ANDLO at five thousand feet and hot...huh...it's not on...And...at ...what..ten nautical miles from finals?

21.57 - <u>Inbound turn and commencement of descent</u>

At 18h17mn49s the controller instructs them to turn left on to a heading of 090°. Four seconds later they begin the turn. The investigation into the vertical flight mode reported at § 117.5 shows that the auto-pilot was almost certainly in HDG-VS mode, and would remain so until the moment the accident occurred. The Air Inter standard approach procedure (synopsis 129.15.01 of the Air Inter operating manual) requires TRK-FPA mode to be selected before making the procedure turn. It is possible that, in order to make it easier to execute the controller's heading instructions, the captain decided to defer the change from HDG-VS to TRK-FPA.

Two seconds after starting the turn, ND1 switches from ARC NAV/20nm to ROSE/VOR (QAR time 2903). A new speed selection results in a reduction in the N1 command and stabilisation of speed at 180kts. Twenty-four seconds after the start of the turn, the captain requests flaps 1, and fifteen seconds later the co-pilot confirms flaps 1 selected.

At 18h18mn37s, with the aircraft heading 043°, that is more or less perpendicular to the final approach heading, the controller tells them to turn left to establish themselves on a bearing of 051° from STR, and gives their present position : "four nautical miles from the ANDLO....and to the left" The reconstructed flight path indicates that at that moment they were 3.8nm from the ANDLO, which coincides exactly with this information. The co-pilot acknowledges. The investigation into the vertical flight mode reported at § 1.17.5 indicates that the selected heading was then probably 051°.

At 18h17mn51s (QAR time 2959), the captain selects ARC NAV mode (20nm scale) for about ten seconds, probably in order to get a better idea of the geometry for intercepting the final inbound radial.

At this moment, the VOR STR is on a bearing of 060° and their heading is already 110°. The turn is too tight and the flight path is not going to bring the aircraft on to the final approach heading for the ANDLO. At 18h19mn01s, the co-pilot says: " We're going..(you're turning inside) look!" Two seconds later, the captain switches back to the ROSE VOR display on his ND (QAR time 2971). Air Inter procedures recommend this display for the pilot in control if the FMGS navigation is known to be LOW ACCURACY or when the raw data does not correspond to the geometry showing on the ND. This choice, which gives a presentation very similar to conventional instruments, may also have been the result of the captains particular preference at that particular moment.

At 18h19mn15s, the co-pilot repeats his earlier comment: "....you're (inside), look! You should have rolled out on 070". The captain replies " yeah, yeah" and selects a new heading of 066° (see § 117.5). The co-pilot immediately adds "at least". The aircraft steadies on heading 052° and then straightaway starts turning again towards a heading of 066°.

At 18h19mn23s, the controller clears the aircraft on to the final approach and advises that they are passing to the right of the ANDLO. This ambiguity - seen from the aircraft, it is left - is not picked up by the crew.

At 18h19mn30s (QAR time 2998), the captain asks for flaps 2 and, as the co-pilot is making the selection, changes (at 18h19mn32s) the heading selection to 071°. The QAR records flaps extending to position 2 at 18h19mn33s.

21.58 - <u>The descent</u>

The aircraft continues turning on to heading 071°.

At 18h19mn39s (QAR time 3006), at 11.2nm bearing 060° from STR, ALT mode is deselected. Auto-thrust is still set to SPEED mode, indicating that the descent mode is either VS, or FPA. Investigation (see § 1.17.5) has revealed that the descent mode was almost certainly VS.

Since the analysis at § 21.4 above has not enabled a positive identification of a single scenario responsible for the onset of this descent, the preferred hypotheses are repeated here:

1 - the captain selects the value "3.3" in the FCU window having forgotten to change mode from HDG-VS to TRK-FPA (or having forgotten that HDG and VS modes are coupled), or he goes to make the selection but presses the wrong button and presses the identical altitude units changeover button, thinking he has changed modes;

2 - the captain means to stay in VS mode, but mechanically sets "3.3" in the FCU window, that is to say the value calculated during his approach briefing;

3 - the captain makes the correct mode change, but the FCU reads it wrongly as a result either of a malfunctioning button or because the correct selected value is corrupted before being fed to the FMGC. (The commission considered this last hypothesis to be very improbable).

At the moment of commencement of descent, the aircraft is bearing 060° from STR (bearing measured in relation to the so-called "reconstructed" flight path). Its flight path is therefore staggered by approximately 9° in relation to the nominal axis of approach, which value coincides with the difference registered at that moment by the aircraft's instruments funtioning normally.

In each case, the FMA mode changes (deselection of ALT mode) are not mentioned. The descent is commenced with a mean load factor of 0.86 to 0.88g (that is a variation of load factor between -0.12 and -0.14g),

corresponding to an increased auto-pilot authority brought about as a result of the fact that the vertical speed had exceeded +500ft/min when the flaps were dropped after the descent had already been initiated.

At 18h19mn42s, that is to say fifteen seconds after deselection of ALT mode, the vertical speed indicator is showing a vertical speed of -1000ft/min and increasing. At 18h19mn56s, the undercarriage locks down and the co-pilot, who has just been speaking to the controller, calls "GEAR DOWN LOCKED" and probably consults the TAP chart. The WHEEL page appears on the ECAM. On the PFD, the VSI analogue indicator registers full deflection (-2000ft/min) and shows amber, as well as the numerical vertical speed, and remains like this until the accident occurs. The vertical speed stabilizes on -3300ft/min at approximately 18h20mn.

The indicated airspeed starts to increase because of the high vertical speed, although SPEED mode is selected. In fact, the engines are already at idle corresponding to the aircraft configuration, and the vertical speed safety-limit activation thresholds (reversion to OPEN DESCENT or OPEN CLIMB modes depending upon the altitude selected on the FCU) in the flaps 2 configuration have not been exceeded (VFE = 200kts; reversion at a speed greater than or equal to VFE + 4kts).

The aircraft descends below the nominal descent slope (3°3) at 18h20mn05s. At this time, the angle of pitch is 7° in a steep descent, the aircraft is accelerating and the excessive speed indicator needle enters the VFE zone for a flaps 2 configuration. At

18h20mn09s, the captain notices the high indicated airspeed (192kts) and gradually extends the airbrakes to counter the aircraft's acceleration and reduce speed so as to be able to extend the flaps further. There are no indications that the crew have noticed anything really unusual about the increase in speed.

At 18h20mn10s, the co-pilot calls out the passing height for overhead the STR beacon: " we should (pass over it) at 800 ft". This is the standard call in accordance with company procedures for monitoring the descent slope. However, the minimum heights for 9nm and 7nm from STR are not called out. At this time, the aircraft is 9.4nm from STR and about 150ft below the descent profile.

At 18h20mn19s (QAR time 3047), the aircraft is at 9nm from STR and about 550ft below the minimum specified altitude at this range. There is no indication at this time that the crew has taken any altitude/range control action.

At 18h20mn21s, the captain says: " we'll have to watch it doesn't descend". If this is a comment about the aircraft, it indicates that he is now worried about the vertical plane situation. The height error is now 500ft, but the captain is unaware of the rate of descent, because otherwise there can be no explanation for his not reacting immediately. The interruption of the co-pilot calling "on the inbound radial" probably renews the priority for his attention in the lateral plane.

At 18h20mn22s, the captain begins progressively to retract the airbrakes. The co-pilot continues to watch the inbound radial interception: " We're coming up to the inbound radial....half a point off the inbound radial. There you are, it was sixty, you see." The aircraft is now at 8.7nm from STR on a bearing of 056°. It begins a left-hand turn on to 051° from STR. This remark by the co-pilot and the captain's selection of a new heading attests to the fact that both pilots are closely monitoring the horizontal flight path.

At 18h20mn36s, the radiosonde announces "TWO HUNDRED".

A second later, banking 12° to the left in an attempt to intercept the final inbound radial, the aircraft hits Mont La Bloss at a speed of 190kts and a descent-path angle of approximately 11°. It is in configuration 2 (slats 22° and flaps 15°), undercarriage down, spoilers retracted. The thrust control levers are still in CLIMB. From those parts of the QAR that were capable of analysis, it seems that the pilot's and co-pilot's control columns remained in the neutral position. Finally, the auto-pilot was still engaged, at least until the second preceding impact, as evidenced by the absence of a drop-out warning on the CVR.

There had therefore been no attempt to break off the descent, nor to regain manual control on the part of the crew.

CHAPTER 2.2 - ANALYSIS OF FACTORS CONTRIBUTING DIRECTLY TO THE ACCIDENT

The main aim of this chapter is to conduct an analysis of the technical systems as well the behaviour of those persons directly involved in the flight of F-GGED (that is the pilots and the controller), in order to identify those elements which might have affected flight safety. The purpose of the analysis is to attempt to understand the underlying implications.

Note: as far as human behaviour is concerned, the analysis draws on knowledge or modelling from the various disciplines of psychology. The works of the following authors have been particularly useful:

René Amalberti, CERMA, Brétigny, France;
Lisane Bainbridge,University College, London, England;
Robert Helmreich, NASA/UT, Austin University, Texas, USA;
Erik Hollnagel, Computer Resources International, Denmark;
Véronique de Kaiser, University of Liège, Belgium;
Jacques Leplat, Ecole Pratique des Hautes Etudes, France;
Jens Rasmussen, RISO National Laboratory, Denmark;
James Reason, University of Manchester, England;
David Woods, Westinghouse Research & Development Center, USA;

22.1 - Technical malfunctions

The enquiry has shown (see chapter 2.1) that the only technical malfunctions that might have occurred and which could have contributed to the accident were in the auto-pilot system and the VOR radio-navigation system.

22.11 - <u>Analysis of a malfunctioning auto-pilot system</u>

The following have been established:

- The commands for the commencement of descent and descent parameters were fed to the FMGC1 computer (auto-pilot) as a result of crew switch selections on the buttons of the FCU fascia.

- The hypothesis for a corruption of one of the auto-pilot control parameters somewhere within the flight controls channel (see ATA 27) has been refuted (see § 117.23).

- It it has not been possible to refute the hypothesis for a corruption of a descent parameter between the FCU and the FMGC1. During the course of the enquiry, it was confirmed that there had been three occurrences of a fault of this nature in one particular aircraft and one specific installation. Investigation

of this malfunction revealed that it was caused by a faulty RAM memory in the FCU which resulted in a corruption of the descent parameter selected by the pilot.

The frequency of occurrence in operational service is 10 to the minus six per flying hour for this FCU defect, which has been identified as a corruption of the command descent value selected on the FCU, not detected by the system, and producing a stabilization in the vertical speed at a value different from that requested by the pilot.

Although the frequency of occurrence is low and the commission considered furthermore that a fault of this kind was a very improbable cause of the F-GGED accident, it believed that it was justified in using it as the starting point for a review of auto-pilot certification. (cf § 23.31)

In fact, the three hypothetical scenarios preferred by the commission have one element in common: the crew failed to detect the major anomaly in the vertical flight path following the commencement of the descent. Of these three, the one in which the crew made the correct mode and value selections, but were presented with an abnormal aircraft response in the vertical plane is, in the commission's opinion, the one where detection of the anomaly would have been the most difficult.

22.12 - <u>Hypothesis for a malfunction of the VOR</u>

22.121 Fault in the on-board systems

The commission examined the hypothesis for a malfunction of the on-board VOR system during the time the aircraft was attempting to intercept the inbound radial.

The BITE non-volatile memory of one of the twin VORs was read and analysed by the manufacturer Collins. The BITE had recorded a defect during the previous flight but, as has been shown at paragraph 117.3, this could not have given rise to incorrect VOR data.

However, in view of the circumstances in which the the aircraft lined up on the VOR inbound radial, the "VOR indicator fluctuation" phenomenon reported on the A320 since it entered service has been taken into account.

The temporary amendment (TR No.124) to the flight manual dated July 1991 requires that VOR procedures be carried out with NAV mode selected on the navigation display and that VOR primary navigation data be selected solely for monitoring purposes. This amendment also stipulates that, if a VOR approach is impossible using NAV mode on the navigation display, then an approach using VOR data alone may be made provided that fluctuations of the indicator do not exceed +/- half a point (ie. 2.5°). If the amplitude of fluctuations is greater than this when flying on instruments, the procedure calls for an immediate break off of the approach.

At the time of the accident, the Air Inter operating manual contained the following instructions under the heading " standard procedures, standard approach": " when a VOR or VOR/DME approach is the selected mode, the raw data should not be relied upon if fluctuations exceed half a point. If there is no adequate visual reference with the ground, a break off procedure must be initiated."

22.122 - Faulty ground installation

During the course of this particular flight, the interception problems arose principally as a result of the selection of headings at the start of the capture phase (heading of 051° selected on the FCU while the aircraft was on a heading of 143). The commission considered whether this selection could have been because of incorrect VOR information.

The commission noted (see § 21.211.1):

- that the CVR gives no indication that the crew had noticed any fluctuations;

- that the available VOR data were of sufficient quality that the co-pilot had no difficulty noticing the problem with the capture of the radial and pointing out the appropriate corrections;

- that, on the other hand, in the final thirty seconds or so of the flight, the co-pilot's references to the angular discrepancy between the true flight path and the VOR radial do suggest there were fluctuations of the VOR information.

22.123 - Conclusion

As regards the possible contribution to the accident of faulty VOR indications, the commission finally concluded that it was very unlikely that fluctuations were caused by the on-board system, and quite probable that they were caused by oscillations produced by a noisy ground signal between 9nm and 8nm

from STR, especially when the aircraft was flying an unusually low flight path. Furthermore, whatever the cause of the oscillations or fluctuations, the commission was of the view that they could not have contributed directly to the abnormal rate of descent. It was concluded however that these factors might have contributed by increasing the crew workload during the capture of the inbound radial. The commission noted the technical modification applicable to the on-board problem and did not consider it necessary to pursue the matter any further.

22.2 - Professional competence of the crew

22.21 - Aircraft captain

The aircraft captain's career dossier revealed that he was a rather average pilot and had qualified as an airline pilot only after a longer than average period of training. Training conditions during the early part of his career did not help him to acquire a sound professional grounding. He had some difficulty in the initial phase of his airline pilots' course. Later, he made progress and during the final part of training he showed signs that he had subtantially improved and reached a good overall standard of professional maturity. On his captaincy course, he reached the standard required for a captain with Air Inter.

With 8800 flying hours, he was an experienced pilot and one of the more senior in the company. He was perfectly familiar with all the routes in the network. In the preceding three months, he had flown 112 hours and 38 during the previous month. During the preceding 24 hours he had flown 3 hours 30 minutes.

During 1990 and 1991, he had undergone the regulation periodic training and flight checks, during which he was given favorable professional assessments.

His conversion course on to the A320 and subsequent route conversion were carried out in accordance with the approved syllabuses and gave rise to no problems worth mentioning.

22.22 - Co-pilot

22,221 - The co-pilot's professional dossier revealed no aptitude problems. The only negative

comment concerned a certain slowness of execution noted during his professional pilot 1 (PP1) course. This disappeared around the age of thirty, after which a long structured training course and the gaining of a progressive amount of practical experience as an airline co-pilot eliminated the weaknesses apparent during his initial training. His overall level of professional competence was assessed as average.

He had flown a total of 3600 hours and was therefore a pilot of average experience. During the preceding three months he had flown 61 hours, 40 of them in the previous month. During the preceding 24 hours he had flown for 1 hour.

In 1990 and 1991 he had undergone the regulation periodic training and flight checks during which he had received favorable professional assessments.

His conversion course on to the A320 and subsequent route conversion were carried out in accordance with the approved syllabuses and gave rise to a few critical comments concerning his behaviour as a crew member and his punctiliousness with regard to procedures.

22.222 - Possible effects of alcoholemia

The post-mortem toxicological analysis revealed an alcohol concentration of between 0 and 0.30 grams per litre (that is between 0 and 0.03%) in the co-pilot's blood at the time of the accident.

The commission consulted available expertise on the effects of alcohol on behaviour and cognitive performance, and in particular the following articles published by Aviation, Space and Environmental Medecine in 1991 and 1992:

-" Pilot Performance with Blood Alcohol Concentrations Below 0.04%" by Ross, Yeaze & Chau;

-" Effects of Alcohol on Pilot Performance in Simulated Flight" by Billings, Demosthene, White & O'Hara;

-" Effects of Acute Aspartame and Acute Alcohol Ingestion upon the Cognitive Performance of Pilots" by Stokes, Belger, Banich & Taylor.

This expertise led the commission to conclude that, even given the higher reading (0.30 g/l at the time of the accident), an alcoholemia at this level would not have had a significant effect on the co-pilot's cognitive performance, bearing in mind his probable habitual level of consumption of alchohol.

This conclusion is also borne out by what took place during the flight itself. All the comments made by the co-pilot are pertinent and valid in the circumstances: he sensibly suggests a VOR/DME approach, corrects an error on the part of the captain concerning the QFE setting, picks up the problem of lining up on the final inbound radial and makes the right recommendations for correction.

At § 22.4 the commission also reported on a study of the possible effects of alcoholemia on the co-pilot from the point of view of crew cooperation.

22.23 - <u>The constituted crew</u>

22.231 - The crew comprised of two qualified pilots whose level of professional experience equalled or was superior to the minimum required by the regulations and the company in order for them to perform their task.

The commission noted, however, the inexperience of both pilots on the A320.

The captain had approximately 160 flying hours on the A320. Although this equates to some 160 route stages on the Air Inter network, this is a low level of experience and means that the pilot was still in a period where he was adapting to the new type of aircraft. The co-pilot was even more inexperienced on the A320 with about 60 flying hours.

22.232 - For both pilots, the A320 was a novelty from three points of view:

- the classic novelty associated with any conversion on to a new type of aircraft;

- the novelty associated with the discovery of a new generation of flight deck and sophisticated automatic systems; the captain had flown Caravelle 12s and the co-pilot Mercures- sixties-technology aircraft. Neither had had previous experience of cathode-ray instrument displays, or FMS.

- the familiarisation with the most innovative aircraft of the current generation: power flying controls, mini-sidestick, fixed auto-throttle, FPA mode, overall digitalisation, ECAM.

22.233 - Any learning process is characterized by a regression of the cognitive modes employed by human operators: from the superior modes, the most costly in terms of the consumption of cognitive resources, and inevitable at the start, they pass progressively to

inferior modes ,the more automatic ones. The learning process gradually permits a freeing of resources, an improvement in the performance and reliability of the operator. The time required to develop totally automatic cognitive modes is of the order of 500 hours for situations involving complex processes.

Furthermore, a recent study (Amalberti 93) has estimated that it requires some 800 flying hours for pilots to form a clear idea of the extent and limitations of their knowledge of a new-generation aircraft. During this period, a pilot gradually "adapts" to the aircraft by building up a personal databank of acquired knowledge based upon his own experience and which is a determining element in his organisation of action strategies (management of time, priorities, risks).

This experience, corresponding on average to a year and a half of practice, is roughly equivalent to the maturation and adaptation phase for a pilot on a new type of aircraft. Before the end of this period, performance is more vulnerable to internal errors and external disturbances, and this happens irrespective of the type of aircraft. The ICAO ADREP databank shows that the graph of the number of accidents plotted against pilot experience on type varies substantially in relation to the spread of experience, and peaks between 100 and 700 flying hours with a noticeable maximum value at 250 hours.

22.234 - Because of the effect they have on the development of operating methods by pilots accustomed to flying more conventional aircraft types, new-generation aircraft tend to accentuate problems of maturation and the adaptation phase is longer. This is particularly noticeable in the following:

- the time required to form a clear operational concept of the system increases in proportion to the system complexity (extended functionalities, multiplication of sub-system interactions, complex logics);

- the time required to implant the cognitive processes for the execution and monitoring of automatic (routine) procedures increases in proportion to the level of automation of the system, the number of functionalities, and the reduction in sensorial feedback;

In view of the fact that their past experience was restricted to more conventional types of aircraft, and was limited on the A320, both these pilots were very much in the early stages of the maturation phase. Their performance was more vulnerable to various external disturbances (changes of approach procedure, mismatch of radar-controlled flight path) and internal ones (inter-crew relationships). And this was all the more true for rarely used procedures such as "standard" approaches and associated aircraft handling (FPA mode).

22.3 - Crew-Aircraft Interface

22.31 - <u>Introduction</u>

22.311 - Two of the three hypotheses preferred by the commission (see § 21.4) involve incorrect crew perception of the active descent mode selected or of the true significance of the value of the selected parameter.

More importantly, all three hypotheses have in common a failure on the part of the crew to detect a major abnormality in the vertical flight path.

The commission took note that a large number of errors of this type occurs during training on the A320, and that the number of residual errors in operational service seems to be sufficiently high to be of significance, despite the low level of feedback in this area. A few reported cases have given rise to dangerous situations (see § 117.6).

The commission consequently took the view that an analysis limiting itself solely to the nature of the errors identified within the posssible accident scenarios and which were attributable solely to the characteristics of this particular crew and flight would be incomplete. It therefore sought explanations for the identified errors in relation to any crew and any A320 aircraft by examining the following aspects:

- the general relationship of pilot confidence or lack of confidence in the aircraft;

- the ergonomics of the control selections of the vertical modes;

- the ergonomics of the presentation of control parameters in the vertical flight path;

- other warning factors;

22.312 - In this regard, the commission was totally unable to demonstrate a cause and effect relationship, direct and biunique, between the ergonomic layout of the components examined and the accident.

The study was not able to establish whether the layout alone could have been responsible for the crew error on this particular flight, or could have prevented them from being aware that an error had been made. Neither could the study establish whether the presumed behaviour of the crew during this flight, with respect to the controls and instruments concerned, in itself reveals the existence of design faults.

The commission relied upon the example furnished by the different hypotheses for the accident scenario, as well as on corroborative feedback, to analyse possible interaction between certain aircraft design characteristics, crew behaviour and finally flight safety, in an effort to deduce ways of improving safety, whether or not they have anything to do with the A320.

22.313 - Within this context, the commission adopted a general viewpoint with regard to the relationship between the ergonomics of the flight deck and safety which postulated the following:

- safety is served by reducing the probability of occurrence of certain errors;

- the ergonomic design of the controls and their instrumentation is one of the parameters of this probability;

- the probability of detection of an error after a given lapse of time also depends on the ergonomics of the instrument display of the consequences of the action performed.

In order to carry out its analysis the commission made particular use of certain simple physiological and psychological concepts and notions, often recent, and of which brief details are given in the introductory note to chapter 2.2. The conclusions in respect of the ergonomic criteria which arise from this analysis do not necessarily attract a consensus within the scientific community nor do they have a systematic aeronautical application. What is more, there has been no systematic comparative study of their application to types of aircraft other than the

A320, and in particular those equipped with cathode-ray instrumentation and computer-controlled flying controls.

22.32 - <u>General crew-aircraft confidence relationship</u>

22.321 - General points

22.321.1 - Nobody can pilot a system in real time without a minimum level of confidence in that system.

By definition, that confidence is what permits an operator to postulate that, in the interval between two checks, the behaviour of the system will have conformed to the operational models he has constructed for it. Without that confidence, the sampling frequency for checking each dynamic process would have to be infinite, which is obviously impossible.

22.321.2 - That confidence therefore determines the strategies for delegation of tasks and the actual level of monitoring that the operator will adopt in relation to the system, and in particular to automatic systems. If there is a high level of confidence, he will delegate quite a lot and/or monitor very little. In this case he runs the risk of failing to perceive the true situation. If the confidence level is low, he will delegate very little and /or monitor frequently, thereby running the risk of cognitive saturation. In both cases, there is a falling off in performance, and notably in regard to safety.

22.321.3 - A human operator is permanently compromising between these two risks. The compromise adopted is neither universal (it depends on the individual, their personality, previous experience, cultural background), nor global (there may a high level of confidence in some aircraft systems and a low level in others), nor constant (changing circumstances may lead to a redefinition of confidence as new priorities change perceptions).

22.321.4 - An essential determinant of confidence that operators bring to a system they have to fly is their awareness of what they know about that system, of their own overall knowledge and their personal limitations. The errors that they make are constituent elements of this perception of their limitations and, contrary to a cognitive pathology, they therefore constitute a fundamental feedback component of the learning process and, more generally, of human intelligence.

22.322 - It has been seen (cf § 22.2) that, in view of the inexperience of both pilots on the aircraft (162hrs for the captain and 61hrs for the co-pilot), this particular crew was still in the maturation and adaptation phase on type.

22.323 - There is a noticeable reticence in the overall attitude of the captain towards the aircraft. He delayed for as long as possible his transition on to the A320. Not long before the accident, he had an experience which had had a significant effect on him and probably served to reinforce his doubts about his abilities on the aircraft (see § 15.11). Learning that a fellow Air Inter A320 captain was on board during the Orly-Lyon flight, he invited him on to the flight deck to discuss his preoccupation with this earlier experience.

During the flight when the accident occurred, there are signs that he was unsure of his own ability that are consistent with his personality. He resisted as long as possible the change suggested to him by the co-pilot and later the controller's instructions, and obviously preferred the ILS approach with which he was most familiar on the aircraft. He made his turn inbound on to the ANDLO radial mostly using the ROSE VOR mode on his navigation display. This selection was the one with which he had been most familiar on previous aircraft types.

These overall signs of caution with regard to his own ability do not however rule out more specific areas of total confidence in certain automatic aircraft functions, and in particular the "standard" auto-pilot modes (selected as opposed to programmed modes) which were more easily translatable to his experience on other aircraft.

22.324 - The co-pilot on the other hand showed overall signs of being much more sure of himself and the aircraft. He was not slow to suggest amendments to certain strategies and commented on the way the captain was handling the aircraft: "let it settle at 340 knots". In most cases he did not announce that he was carrying out the checks of the automatic systems, in accordance with company procedures (FMA indicator changes).

22.325 - An examination of the CVR and QAR recordings revealed that the crew almost completely abandoned its checks of the vertical flight profile once the descent had been initiated.

This deduction is made principally from the absence of any comment about control changes in the vertical flight path as well as any reference to the rate of descent or descent slope; all communication between the pilots being concentrated on the lateral flight path and the aircraft configuration.

The conclusion is further strengthened by the fact that 28 seconds before the accident, the captain used the airbrakes. This indicates in fact that he at least had become aware that the speed was beginning to get too high (needle deflection in the VFE zone), but took corrective action without questioning the cause. But the increase in speed in itself constituted a sufficiently serious abnormality at that stage in the flight that it should have been questioned. The fact that it was not (because he was watching the speed indicator on the PFD without looking at the associated abnormalities: VSI, trim) perhaps is an indication of saturation, and much more probably of almost total

confidence in the fact that the auto-pilot would do what was asked of it - or what he thought it had been asked to do.

22.33 - <u>Ergonomics of the vertical control modes</u>

22.331 - General points

The A320 is the first aircraft to be fitted with an automatic vertical flight path angle (FPA) mode (and consequently mode selector). In this case, therefore, there is no possibility of transferring previously- acquired expertise, and it is necessary to start at the bottom of the learning curve. After a certain amount of practical experience, a routine procedure (and associated actions)is developed.

It is very unlikely that the experience of F-GGED's pilots would have been sufficient for them to have reached the stage where the procedure was routine. In fact, the selection of this command mode is not a frequent one; it is essentially used for "standard" approaches (which are rarely used on the Air Inter network).

In such circumstances, they would have been even less familiar with the procedure and very prone to distraction by outside factors: interruptions, focussing of attention, time pressure, stress. They would also have been prone to errors induced by possible ergonomic shortcomings (a difference between what the designer intended and assumed and what the operators actually do in reality).

22.232 - Design principles

The design philosophy behind the lateral and vertical control modes is based on the principle of lateral/vertical pairing. This pairing presents the pilot with the choice between two "coherent" references for flight path control: the conventional heading/vertical speed method of control, and direct control of the instantaneous flight-path vector. According to the designer, this philosophy seemed to indicate that the flight path selector/change-over switch should be located in the middle of the FCU, symbolizing the intersection of the vertical and horizontal planes. A liquid-crystal display positioned just above the change-over switch shows which mode is selected: HDG-VS or TRK/FPA.

The controls for selecting values as well as the associated windows in which those values are displayed are located either side of the mode selector switch; the lateral parameters to the left and the vertical parameters to the right (see annex 15). The control knob and parameter display window for rate of descent are common to both modes (VS and FPA) and are located to the right of the FCU at quite a distance from the

mode change-over switch. In the display window, a scale beneath the selected value indicates the type of parameter selected (VS of FPA). The value selected can then be changed simply by turning the selector knob. The mode selection can quite easily be made well before the point at which descent is commenced.

22.333 - Operating procedure

The operating procedure for commencing a descent normally consists of selecting the required mode (in the centre of the FCU), then setting the value by turning the "rotatary" selector switch and pulling this same switch out (on the right of the FCU). This separation of location of the two selector switches increases the probability of an interruption of two actions normally procedurally linked. Thus the probability of a lapse of memory occurring upstream or downstream of the interruption increases in proportion to the probability of interruption. Furthermore, there is a push-button identical to the mode-selector button (for showing altitude in metres on the EW/D display) located just next to the rotary selector switch for setting FPA or VS values. This gives rise to possible confusion between the two buttons which is made worse by the fact that there is no explicit indication as to the purpose of either.

22.334 - Reliability of the operating procedure

When under time pressure or stress, human operators automatically adapt their operating procedures by economising on actions perceived as less important, or less effective. They discard certain checks in favour of action, seek to employ ready-made responses (routines) to the detriment of reasoned responses, and more generally abandon thought in favour of action. In extreme cases, they will only carry out those checks seen as essential to a given course of action. This is a means of regulating the workload and is an internal determinism unavoidable in every human being.

For the crew of F-GGED, the aim was to make the aircraft descend. The essential element of the procedure which would bring this about was comprised only of final actions; that is to say, selecting (even approximately) a given rate of descent followed by the activation of the descent mode. However, in contrast to the sequence selection of descent mode/setting of desired value, there is a strong ergonomic correlation between these two actions: they can both be made using the same rotary selector switch and can also be carried out in one continuous movement. The layout of the controls therefore serves to facilitate the tendency of an operator under pressure to forget the preliminary phase of the procedure: the mode selection.

22.335 - Criticality of the operating procedure

The association between the selected descent mode and the selected value is a critical condition of flight safety. In fact, a standard setting in one mode (for example a descent angle of 3°3) can lead to a critical situation if it is registered by the autopilot as a target value in the other mode (3300 ft/min in this particular example).

This criticality arises as a result of the design of the selector control knob and the window displaying the selected value. Even though liquid crystal displays indicate what modes are actually selected, the rotary selector switch and the associated numeric display window are common to both reference modes. The format for displaying the selected numeric values is also much more legible (three times as large) than that used for displaying the mode selected. The selector switch is more than three times more sensitive in VS mode than in FPA mode: one click = 0.1° in FPA and 100ft/min in VS, that is to say, more than 0.3° at normal approach speed. The numerical formatting is very similar. The double-numeral format for vertical speed makes it impossible to descriminate reliably (from the format) between the two alternative values. On the contrary, the use of a two-figure coding (eg. 33) to represent a three- or four-digit number (eg.3300) increases the probability of a human operator becoming confused between the VS and FPA values. The probability of such confusion between the number 33 and 3.3 is high. Once it has occurred, this type of error is almost undetectable merely by looking at the displayed value. (The other means of detection available to the crew are discussed at § 22.34).

22.336 - Conclusion

In conclusion, the design of the rotary selector switch and the window displaying the vertical flight path control parameters means that the relationship between the selection of vertical mode and the parametric value is critical. Also, the probability of confusion in this area seems to be considerable, particularly for a crew new to the aircraft. The spatial separation between the mode selector switch and the value selector switch tends to accentuate the natural weakness in the human operator's cognitive process.

22.34 - <u>Ergonomics of presentation of the vertical flight path control parameters</u>

22.341 - Introduction

It follows from the foregoing that the a posteriori detection of a flight path abnormality brought about

by crew error is a critical element of flight safety. Moreover, the only element common to all the hypothetical scenarios preferred by the commission is the absence of detection of the anomaly by the crew.

The commission consequently examined the means at the crew's disposal for detecting an incorrect mode selection and subsequently the abnormal flight path. These included the auto-pilot mode-selection and selected value displays, the Flight Director (FD) symbology, the VSI, longitudinal trim, increase in speed, the rate of decrease in the altimeter reading and the discrepancy between the passing heights and the minimum height/range criteria laid down for the VOR -DME procedure.

In carrying out its analysis, the commission took account of the following known phenomena concerning the perception processes of a human operator; for example, the fact that they permanently read and filter external stimuli and adapt instantaneously the cognitive thresholds of perception in order to operate a highly selective process. The filtering is controlled by the mental image that the operator has of reality, and by present and future actions on the environment. This control is exercised via attention, which is the active interface of this mental image with the real world. When a stimulus occurs within the attention span and accords with the mental image, the perception threshold is low. When it does not, the threshold is very high.

In the terminology used by the commission in the following paragraphs, the " warning potential" of a particular piece of information is its capacity to override cognitive thresholds outside the attention span and/or despite an inadequate mental image of the situation. The fact that these thresholds can be very high (and in particular the fact that mental images are very stable and sometimes spectacularly resistant to discordant signals), does not mean they cannot be overriden. From this point of view, the commission did not believe that all methods of presenting information were equally effective, quite the contrary. The intensity of a particular physical signal (size, loudness, brightness, colour, mobility..)in relation to the enviroment seemed to be an evident parameter of the warning potential. The method of coding, the degree of analogy with the actual phenomenon represented, the novelty and degree of abstraction of the symbology in determining the complexity of the cognitive processes which are needed for decoding purposes also seemed to the commission to play an important role in this regard.

With this in mind and taking these criteria into account, the commission reached a certain number of critical conclusions concerning the instrumentation of various parameters. Because the cognitive processes develop rapidly during the learning and appropriation phase, it has made a distinction between the conventional configurations and more modern ones.

As has already been indicated, the commission acknowledges the subjective nature of its conclusions.

Finally, whilst directing this critical analysis at certain aspects of the ergonomic design of information feedback on the flight-deck, the commission remained conscious of the complementary nature of any initiative in this area with the application by the crew of resource management techniques and appropriate monitoring procedures, such as those taught on CRM (Crew Resource Management) training courses.

22.342 - Display of auto-pilot modes

The FCU comprises a display of selected modes. This information is shown in two places: in the display window of the selected flight path mode (HDG-VS or TRK-FPA), and in the upper part of the window displaying the selected value. The letters are considerably smaller in size than the numerals and can only be read from a position immediately in front of the window. Nevertheless, this display is not the main reference indicator. In fact, the basic design philosophy for detection of abnormalities follows the principle that any selection made on the FCU must be checked on the FMA. In particular, mode changes are highlighted by the appearance for ten seconds of a "box" around the mode selection display that has just been changed.

In the case of F-GGED, the problem posed differs according to the scenario hypothesis under consideration. In the case of forgetting to change modes, it is a question of detecting that the mode selected after disengaging ALT mode and highlighted by the apppearance of a white box is indeed the mode required. When the problem is one of a manipulation error or a malfunctioning of the push-button, then it is a question of detecting the absence of the expected change notwithstanding what is actually displayed. The reliability of "negative" detection of this kind is linked to the "positive" detection of the changes of mode.

The legibility of the mode changes on the FMA is adequate when the pilot is anticipating a particular piece of information and is either watching the FMA or is close enough to it to read the confirmation of the

expected mode change. (in accordance with standard operating procedures and the regulations taught). In fact, the angle of offset from which the ten-second highlight box can be seen, for a mean position of the eye, is about 2°. This corresponds to the size of the central zone of vision within which the alphanumeric display is readable. Outside of this zone, visual acuity rapidly becomes insufficent to permit direct reading of the mode selected, but vision remains sensitive to transitory phenomena. The appearance and ten seconds later the disappearance of the highlight box remains for example perceptible with the minimum of attention if the attention is focused on the centre of the PFD. However, to read the mode, a significant redirection of the focus of attention towards the FMA is called for.

On the other hand, the highlight box is not always sufficiently effective in "forcing" the information on a pilot who is not expecting a mode change (detection of an inadvertent change), or who is not in fact dedicating part of his attention to checking the mode activated (crew not complying with standard operating procedures and regulations taught). It is enough, for example, for the attention to be focused on the centre of the navigation display and concentrating on a navigation problem in order for a mode-change indication not to be noticed.

22.343 - Display of selected values

The philosophy put forward in the foregoing paragraphs holds good for selected values: any selection on the FCU should be checked on the PFD. However, a check of the vertical flight-path selected values (VS or FPA), and in fact those fed to the auto-pilot, is impossible on the PFD because they are not displayed, unlike those for heading, track, altitude, speed and mach number. On this point, therefore, there is a conflict between the design of the interface, the general philosophy put forward by the manufacturer, and the principles that are taught regarding its use.

In the absence of a presentation of selected vertical values, and because the vertical VS and FPA modes are always paired with the associated lateral modes (HDG and TRK), the ability to discriminate the symbology in respect of the active mode depends on the symbology for displaying the lateral selections of heading or track. But this is practically identical in both cases: whilst the instantaneous heading and magnetic track indicators are very distinctive (yellow vertical pointer and green diamond), the selected value is represented, both on the PFD heading scale and on the navigation display, by the same symbol (a cyan-coloured triangle) in both modes (or by a numeric value if the selected value is outside scale limits).

The only differences in presentation between the two reference modes from the point of view of the method of displaying values concern, in fact, on the one hand the brightness and length of the yellow heading indicator, which are not as great in TRK-FPA mode, and on the other the appearance of the navigation display horizontal marker in TRK mode for the selected magnetic track. However, there is also a vertical indicator (cyan-coloured) similar to the one used everywhere else as a heading indicator.

To recap, the selected values displayed on the PFD do not include the vertical flight-path parameters. The crew is therefore not able to check the value of the vertical parameter being fed to the FMGC. In addition, the display symbology for lateral flight-path selected values does not make it obvious which flight-path reference mode is in use.

22.344 - Variable Speed Indicator

22.344.1 - An essential instrument for detecting abnormalities in the vertical flight path is the variable speed indicator. The VSI display in the A320 is similar to that used in the majority of modern aircraft fitted with cathode-ray displays. There is no evidence to suggest that a linear analogue deflection display is intrinsically less efficient or less capable of attracting attention than the conventional circular type of instrument. It is different however, and consequently experience needs to be built up (empiric accumulation of perception) in order for warning thresholds for the immediate detection of abnormalities to be established and which the crew of F-GGED had not yet had time to acquire (see § 22.233, role of experience on type). It is even possible that these pilots had never had the opportunity, including during their training, to see what the amber warning of abnormal vertical approach speeds looked like.

22.344.2 - If the A320 VSI is compared with those fitted on other flight-decks using cathode-ray displays, it can be seen that in the case of the A320 the maximum deflection of the analogue display is limited to +/- 2000ft/min. Values higher than this are indicated by the full-scale deflection of the needle and the appearance at the end of the scale of two numerals (vertical speed expressed in hundreds of feet per minute). This being the case, the display would not attract sufficient attention if an abnormal vertical speed exceeded 2000ft/min. In fact, it requires a totally different interpretation (decoding), that is to say a cognitive process of a higher level than that required to interpret an analogue signal.

Such a process, which calls for a specific focussing of the attention, is too costly in terms of mental resources for an operator to be able to keep it up for long.

This process should be triggered externally using more elementary attention-getting signals. To achieve the same result, the designer chose an amber colour-code for ranges of descent rate regarded as abnormal: more than 6000ft/min, or more than 2000ft/min below a RAH (radio-altimetre height)of 2500ft, or more than 1200ft/min below a RAH of 1000ft.

22.344.3 - In the case of the accident, the warning potential was insufficient to make the crew aware of the gravity of the situation. The vertical speed had passed 1000ft/min (which can be considered to be a value on the limits for a standard intermediate/final approach) at 18h19mn53s, that is 15 seconds after descent mode was engaged and 44 seconds before the accident occurred. Following the logic of the preceding paragraphs, the vertical speed indicator should have shown amber when the two conditions, RAH less than 2500ft/min and vertical speed in excess of 2000ft/min were met, some 20 seconds after descent was initiated or 40 seconds before the acccident took place. The indicator must have continued to show amber up until impact, since the conditions continued to be met.

At 18h20mn9s, or 28 seconds before the accident, the captain extends the airbrakes: this indicates that he had looked at the PFD and had received the correct warning about the speed. Despite this, he was not alerted either by the amber colour on the VSI scale or by the vertical speed reading displayed on the PFD. This can be interpreted in two ways: firstly, from the point of view that the captain had a particular reason for verifying the speed because he was required to check the next VFE limit before selecting flaps 3 (VFE next); and secondly, from the point of view that the indicated airspeed at that moment was 192kts, that the excess speed indicator was entering the VFE zone, and because the yellow pointer indicating speed variations is more attractive and effective than the oblique bar which indicates altitude variations.

22.344.4 - The warning thresholds which apply in the case of this accident concern vertical speed values between 1000ft/min and 2000ft/min. These values are still shown by the analogue linear deflection of the indicator needle on the A320 VSI. Outside these values, the colour-coding system for indicating that the limit has been exceeded calls for a more complex interpretation than "reading" an abnormal needle position on a circular indicator. However, the association of abnormality with the colour amber is ingrained in every pilot.

The failure of this principle in the case of F-GGED suggests that one should question whether the colour amber is indeed consistent with the potential urgency associated with exceeding threshold limits such as those laid down during an approach. In particular, perhaps thought should be given to making it the same as the red zones which indicate VFE and VLE limits etc. It might also be standardized with the symbolic syntax laid down by law for warning lights (JAR.1322) or for instrument markings (JAR 1549 and the corresponding ACJ). The associations of the colours red and amber are in fact defined as follows:

- red: alarm; indicating danger requiring immediate action;

- amber: warning; indicating a need for future action to be taken;

Finally, the commission questions whether the multiplicity of colours used on small surface areas in cathode-ray symbology does not reduce the significance of those colours which are specifically intended to serve as warnings.

23.344.5 - The commission is of the overall view that as far as the VSI is concerned, the absence of awareness that warning thresholds had been exceeded in the case of this accident was the result less of the VSI display itself than its novelty for the crew of F-GGED. In fact, they had probably not acquired sufficient experience for them to have noticed the abnormal situation immediately. The commission nevertheless believes that the time required to obtain the necessary level of experience could be sharply reduced by improving the vertical speed presentation, and in particular by improving the methods of drawing the attention to abnormal values.

22.345 - Altimetre

The altimetre is also an essential instrument for detecting abnormalities in the vertical flight-path when carrying out a VOR/DME approach. In association with the DME, it enables aircraft passing heights to be compared to the minima laid down in the TAP charts for given ranges. But the CVR shows no sign that the check at 9nm from STR was carried out (this point is dealt with in more detail in paragraphs 22.523 and 22.53). Only an announcement at QAR time 3049 (" we'll have to watch it doesn't descend) perhaps indicates crew concern about height, without it being possible to determine what it was that led the captain to make the remark - maybe it was something other than the aircraft - or to tell what action he took subsequently.

In any event, the warning potential of an altimetre, whatever the type of display, is almost nil, because the mental process (reading numeric values, algebraic comparison) which would enable the height discrepancy to be detected calls for a focussing of attention and therefore a conscious check. The only factor that has the potential capacity to arouse alarm is the abnormally rapid decrease in the height indication which would then be funtioning as a VSI. With this in mind, the commission examined the effectiveness of the altitude instrumentation and reached similar conclusions to those relating to the VSI. The determining element is the novelty of the instrument for the crew, who had not had sufficient practical experience to have developed alarm thresholds capable of the immediate detection of an abnormal situation.

22.346 - Presentation of longitudinal trim information

The development of negative trim, which can be considered as abnormal for a 3° angle of approach, occurred some 45 seconds before impact and was in excess of -5° (obviously abnormal) about 40 seconds prior to impact. The absence of any reaction by the pilot at the controls strongly suggests that he had not noticed the abnormality. The presentation of trim on the A320 is of the conventional type, thus there was no question in this case of a learning curve.

However, it should be noted that there is some interaction between the trim presentation and the Flight Director symbology (see paragraph 22.346), as evidenced by the confusion that occurs between trim and angle of climb during an overshoot in FPA mode. If there had been an error in mode selection, the possibility cannot be ruled out that the expectation of a point of reference (that of the FPA) below the horizon might make it less likely the negative trim anomaly would be noticed.

Nevertheless, it may be concluded from the failure to detect an indication of an important abnormality on a perfectly conventional type of display, that the crew had stopped monitoring the trim during this phase in favour of either the lateral flight path, or of other more complex sources of information (eg. Flight Director).

22.347 - The Flight Director (FD)

The commission examined the warning potential provided by the flight director in the circumstances of the accident, both from the point of view of a possible error in mode selection and an abnormal flight path.

As far as the error in mode selection is concerned, the flight director presentation symbology on the PFD changes according to whether HDG-VS mode is selected or TRK-FPA (see annex 15). In HDG-VS mode, the symbology makes use of conventional crossed-bars. In TRK-FPA, a symbol of the aircraft seen from behind is displayed (Flight Path Vectorial or "bard") to represent the instantaneous speed vector, and a specific reference bar (Flight Path Director) for guidance. These two symbologies are therefore intrinsically completely different.

However, the correlation between the two symbologies and the modes is abstract, and their automatic association within the mental process assumes a reasonably high level of experience which the crew did not possess.

As regards the abnormal flight path, the flight director possesses practically no warning potential. In fact, in the event, the raw data presented to the pilots of F-GGED by their FDs in VS mode was: "crossed- bars centred", which immediately translates as "configuration correct". In this case therefore, the information being displayed is confirming a normal situation rather than the contrary.

22.348 - General balance of vertical- and horizontal-plane information

There is a tendency on the part of operators to concentrate their attention on sources of information which combine the highest number of inputs and consequently are the most operationally efficient. In the case of conventional types of instrumentation this is the Flight Director. For aircraft equipped with cathode-rays displays and FMS, the information display combining the greatest number of data inputs (strategic level) relating to the aircraft flight path is the navigation display. However, this shows only the lateral flight-path profile.

In a sense therefore, there is a marked dissymetry in the aircraft/crew interface between the lateral dimensions and the vertical dimension. The different nature of the information presented in plan and vertical profile and their synthesis is one of the basic difficulties encountered by a pilot during training in IFR conditions. The development of analogue displays of navigation data in the lateral plane has been more rapid than for data in the vertical dimension. This dissymetry, already accentuated by the advent of track guidance systems, has been further aggravated by the appearance of EFIS with very detailed plan-view navigation charts, but with no vertical profile information, or topographical and minimum safety altitude displayed data.

Although a number of aircraft types now use systems of this kind quite successfully, there exists within them an obvious cause of disequilibrium in the manner in which they concentrate the attention of the flight crew.

22.349 - Conclusion

Generally speaking, the failure to detect the abnormalities in vertical speed, the rapid descent of the altimeter and the aircraft passing heights occurred because the crew substantially discarded monitoring of the vertical profile and paid too much attention to the lateral configuration of the aircraft. There is no evidence that there was any major intrinsic failure in the presentation of the control parameters of the vertical flight path.

However, the commission is of the opinion that the presentation of information pertaining to the

handling and control of the aircraft in the vertical plane, whilst meeting the needs of a crew fully aware of the flight path it is following, is not capable of providing adequate and effective warning to a crew with an erroneous perception in this regard, and especially when certain conventional sources of sensorial feedback
are absent on this type of aircraft.

22.35 - <u>Other potential warning factors</u>

22.351 - The rule governing the trim setting in auto-pilot (limited to 0.05g of the differential load factor) played no part in the case of F-GGED because, since the rate of climb was 600ft/min at the time descent was initiated, the differential was 0.12g (the auto-pilot exercises increased control in this case). Despite this, the crew was not alerted as a result of the abnormally long period of acceleration (some forty seconds instead of a dozen or so to settle at 800ft/min). This is compatible with a standard physiological response, which mainly senses changes in acceleration.

22.352 - Head-up Display (HUD)

A decription of this equipment is at annex 15.

In view of what has been said in § 117.21, the HUD must have been switched on but the display visor had not been deployed. This action by the pilot (non-standard procedure. The operating manual states that " The HUD visor should only be moved with the control switch in the "OFF" position) does not mean that the captain did not deploy the HUD visor subsequently. But there is nothing to indicate that the pilot used the HUD to control the aircraft flight path. On the contrary, although the pilot is not forbidden to use it

at the commencement of descent, current standard approach practice is to use the HUD as soon as visual contact with the runway is made. Furthermore, in IMC conditions, the only reason the captain might have had for using the HUD was in order to try to bring the aircraft's actual descent path on to the selected path. But in this case, the absence of a selected descent-path reference would have been evident.

It is most probable, therefore, that the captain did not use the HUD.

22.353 - Throttle-lever lay-out

22.353.1 - The throttle-levers on the A320 are designed to be "fixed" in auto-thrust mode(A/THR). That means they are not subject to the movements generated by computer throttle adjustments to the engines and normally remain in a fixed and manually-gated position. The mechanically-set throttle position determines the maximum thrust that can be selected in auto-thrust. Thus, except for take-off, throughout the entire flight, and including the descent with engines at idling, the throttles are in the "CLIMB" gate.
All power settings less than or equal to "CLIMB" are therefore available in auto-thrust.

22.353.2 - In the case of the accident, given the descent slope and aircraft configuration, the engine speeds (N1) stabilized at 35%. Once the aircraft was established on a 3°3 descent path and final approach speed was set, all other things being equal, the N1 should have been in the region of 53%. If the throttles had been of the moving type, instead of remaining in the "CLIMB" gate, they would have moved to a position corresponding to N1. The difference between the two throttle positions in both these situations would have been approximately 1/5 of the power-setting range.

22.253.3 - The A320 throttles are small and it is unlikely that the crew would have noticed a difference of this order, particularly since they were inexperienced on type. With a more conventional design, the warning potential would have been intrinsically higher, especially via kinesthetic perception of the changes in the position of the pilot's hands resting on the throttles. The sense of touch in fact serves to provide a complementary channel of information, very instinctive, and one which does not call into use superior cognitive functions. However, the commission took the view that in the circumstances of the accident, bearing in mind the movement of the throttles in the expected direction and not far from their final position, a complementary channel of this sort would nevertheless have played only a very marginal role in detecting the abnormal flight path.

22.354 - Absence of Auto Call-Out at 400ft

On the A320, the automatic audio warning (auto call-out) of radio-altimetre height and decision height is provided by the FWC (Flight Warning Computer). Auto-call radio-altimetre heights are independently programmable. At the time of the accident, the possible programmable calls were: 400ft (the voice synthesizer speaks the words "FOUR HUNDRED"), 300, 200, 100, 50, 40, 30, 20, 10 and 5 feet.

Air Inter had chosen to activate calls at heights equal to or less than 200ft.

Given the flight path profile of F-GGED in relation to the ground relief, if the call "four hundred" had been programmed on this aircraft it would have sounded 3 to 4 seconds prior to impact. This would clearly not have given sufficient time to avoid hitting Mont La Bloss.

In addition, it is worth noting that the GPWS synthetic voice warnings take priority over the radio-altimetre calls. Consequently, if the aircraft had been equipped with a GPWS, this alarm (see § 117.9) would have taken priority over the "FOUR HUNDRED" call.

22.36 - Lack of a GPWS

22.361 - A computer simulation of the alarm sequence that would have been activated had F-GGED been fitted with a GPWS is reported in § 117.9. This reveals that the first "useful" alarm would have sounded some 18 seconds before impact.

The same paragraph also discusses the simulated behaviour of the aircraft during the final approach. This demonstrated that it takes 7 seconds to arrest the vertical speed when break-off is initiated in auto-pilot (load factor approximately 1.25g). This is reduced to about 5 seconds if the break-off is initiated in manual mode and the control column is pulled fully back (load factor is then limited to 2g). In both cases, reaction to the alarm would have enabled the aircraft to avoid hitting Mont La Bloss.

According to the manufacturer, flight tests would have shown that the average reaction time needed for the crew to take avoiding action is 5 to 6 seconds after the alarm sounds for the Mark II and III, and with pilots trained to use the GPWS in the simulator.

22.362 - A simple arithmetical calculation (6+7=13 is less than 18) therefore seems to confirm that a GPWS would have saved the aircraft, even for a flight path where the break-off was in auto-pilot. In fact, such confirmation, based on an order of magnitude whose significance is purely statistical (average reaction time), would be totally simplistic if it were to be applied to a particular event, because crew reaction time to a given alarm signal is not a deterministic process.

A few accidents where the aircraft "flew into the ground" have involved types equipped with a GPWS system which emitted warnings in sufficient time, that is for the ground to have been avoided following an immediate reaction. The crews simply had not reacted fast enough, being convinced that it was merely a false or invalid alarm because it was so much at variance with their own mental image of their position at that moment. This happens in particular when the system loses credibility as a result of the activation of too many false alarms (technical problems, trigger thresholds, or inappropriate flight procedures). Other similar accidents have occurred when the GPWS had deliberately not been switched on or was unserviceable.

Recent flight statistics for a major air line, which for several years has had a very liberal policy with regard to the use of the GPWS, show that of some 300 GPWS alarms reported world-wide, 60% did not result in a break-off of the approach, and 20% of those that were genuine also did not require break-off action to be taken. Moreover, in no case was break-off initiated in order to execute maximum-avoidance action: only normal climb out.

Finally, it should be remembered that in the two cases reported in 117.62, which were similar to the pivotal event in this accident, it was the GPWS which alerted the crew to the fact that the active descent mode was not what they thought it was.

22.363 - When examining a particular case, it is therefore necessary to take account of numerous factors, of which the majority have some influence on the reaction of the crew to an alarm. Their analysis has a subjective aspect within which sensitivity to context, both in terms of specific events and more generally (company policy) is important, and where the power of prediction of the available models is very low for a single isolated case.

In the case of F-GGED, the crew had fixed its attention on the lateral flight path and the change of configuration and had a mental image of a situation in which the vertical dimension, left to the auto-pilot, was perceived as being completely under control and standard. Accident records show that in such situations this mental image is spectacularly resistant to discordant inputs from outside which intially register themselves as fitting in with the crew's image: " It's normal, because.....".

In a more general context, the hypothesis " F-GGED was fitted with a GPWS" must be accompanied by peripheral hypotheses concerning company policy, its procedures and instructions with regard to the system. And obviously in this case it is a question of pure speculation.

It should be borne in mind that, when Air Inter took the decision not to equip its A320s with a GPWS, the Mark V was not yet on the market. Furthermore, at the time of the accident, the Mark V was available but had not yet received certification for use on the A320. For this reason, for the remainder of this investigation the commission will only consider the Mark III, which was the only model available when Air Inter made its decision. Nevertheless, it should also be noted that, compared with the Mark III, the advantage of the Mark V concerns mainly the number of operational limitations imposed in order to avoid activating false alarms. For example, on the flight-path followed by F-GGED into Strasbourg, the Mark III activates two inadvertent alarms at the aircraft speed of 230kts, whereas the Mark V does not. At a speed below 200kts, the Mark III and Mark V both behave the same and initiate no inadvertent alarms.

Two hypotheses have been taken, by way of example, from a whole range of possibilities.

22.364 - First hypothesis:

The aircraft is equipped with a GPWS Mark III. The Air Inter crews use Air France Group charts which mention potential inadvertent alarms on the Strasbourg VOR DME 05 procedure (helicoids). The crew therefore "knows" that it should pay no attention to the alarm in this case when it has clearly identified the origin. It has had no specific simulator training, nor has there been any special attempt to increase awareness of the need to react in all cases to GPWS alarms. There has been no special procedure laid down for the approach in question, and F-GGED executes an identical procedure to that flown at the time the accident occurred, at the same speeds.

At the end of the outbound leg, when the crew know they are level at a safe height, the alarm sounds. After making a few simple checks, they disregard it.

The alarm continues to sound for two minutes, which is particularly long and annoying. Half way through the turn, the conditions that set off the inadvertent alarm appear again. Finally, a final alarm, this time a genuine one, sounds 18 seconds prior to the accident, still in the zone in which possible inadvertent alarms are known to occur.

In such a context, it is extremely unlikely the crew would have reacted positively to the final alarm.

22.365 - Second hypothesis

The aircraft is fitted with a GPWS MkIII, the company as well as the aviation authorities have a specific policy with regard to the GPWS. There is no mention of inadvertent alarms on the charts, nor in the procedures. The approach and radar control procedures avoid areas in which inadvertent alarms occur. Approach speeds have also been adjusted to eliminate inadvertent alarms. Crews are regularly trained to execute a reflex break-off and avoidance action in response to all GPWS alarms activated below the safety altitude.

Under these conditions, there is no GPWS alarm until F-GGED commences its final descent and 18 seconds before hitting the ground.

In this case, it is highly likely the crew would have reacted positively to the alarm.

22.366 - Conclusion

In fact, the only conclusion to be reached with regard to the GPWS is a statistical one. From this point of view, the results are clear: equipping aircraft with GPWS and evolving appropriate policies for using it significantly reduces the number of flights into the ground.

22.4 - Crew Cooperation

As part of its systematic investigation of all the factors that may have had a role to play in this accident, the commission considered that it was necessary to ascertain whether or not there might have been problems in relations between members of the crew. Problems of this sort could have had a significant impact on overall crew performance. The commission is well aware that, in so doing, its deliberations fall within the bounds of a discipline, that of human sciences as applied to the profession of airline pilot, in which there is still much to be learnt and where

truths are only relative. The commission made its deliberations on three successive levels: a summary of reports on the personalities of the pilots, an analysis of their behaviour throughout the flight during which the accident occurred, and an analysis of their behaviour as a member of a crew.

22.41 - Personality and affinity reports

The captain appears to be a reserved, calm and careful man, reluctant to commit himself before he has fully undertood the situation, and proceeding rather slowly. He prefers to anticipate and does not like improvisation. The co-pilot seems to possess a more enterprising personality, rather sure of himself, and slightly condescending towards those he considers to be slower on the uptake than him. He is at ease with himself and has adapted well to his new professional environment. Brought together within a crew, these two personalities could give rise to a certain erosion of the normal relationship of authority between the captain and his co-pilot. However, there is really no evidence for such an erosion, and still less for a reversal of the authority relationship, in the various elements which the enquiry used to reconstruct the flight.

The two men had never flown together before the day of the accident and had never even met. It does appear, however, that when they first came into contact in Orly, before the first flight of the day, they showed no particular liking for each other. Two concordant testimonies in fact mention a particular atmosphere between the two crew members which might best be described as reflecting an attitude of being "lumbered". Another captain had in fact flown on the Paris-Lyons flight on the flight-deck and found the crew taciturn, reducing their communications to obligatory exchanges, each absorbed in his own personal task. A traffic policeman at the Lyon-Satolas also noticed this same "atmosphere of indifference" between the two men during the stop-over in Lyon.

The commission is therefore of the opinion that the initial contact between the two men may have been one of reciprocal lack of affinity. The physical and psychic differences between them may perhaps be the sole explanatory factor.

The commission nevertheless looked into the possibility that the particular atmosphere reported by the witnesses might have been provoked by an incident involving the two men when they first came on duty and when perhaps the captain had noticed that the co-pilot might be suffering from the effects of alcohol. In fact, the toxicological analysis following the accident revealed an alcohol concentration in the co-pilot's blood of between 0 an 0.30 grams per litre at 18.30 hours. However, the

the laws relating to the decay of alcohol levels as a function of time do not permit, after the lapse of time involved, to speculate on the possible level at the time the crew met in Orly. Furthermore, the enquiry was not able to produce evidence to indicate that the co-pilot might have consumed alcohol between leaving Orly and the time of the accident. In these circumstances, the commission does not regard this as a possible explanation for the cool atmosphere noted on the flight-deck.

22.42 - <u>Analysis of the individual behaviour of the pilots during the flight when the accident occurred</u>

The captain had prepared a plan of arrival at Strasbourg at the very beginning of the flight and tried to stick to it for as long as possible (ILS approach on runway 23, then ILS approach on 23 followed by an indirect approach on 05). He was therefore not in favour of the co-pilot's suggestion for a VOR/DME on 05, who probably had a straight-in approach in mind. Later, to avoid having to hold overhead the SE beacon, the captain agrees to the VOR/DME procedure on 05, along with the suggestion of radar guidance by the Strasbourg controller. Having discarded his pre-planned strategy, from this point on he seems to lag slightly behind events as they occur during the remainder of the flight.

Although the captain had had to remind him about two small mistakes (he forgot to call Reims Centre, and set the MDH in the wrong window on the MCDU: QAR 1923), the co-pilot seems to have adapted easily to the development of events and stays ahead of what is happening throughout the flight, being ready to take certain initiatives without telling the captain (selecting a VOR 05 approach on the FMGS after receiving the instruction from the ATIS). Similarly, he picks up and corrects the captain's wrong QFE setting. Finally, during the turn on to the final approach radial, he notices that they are turning inside and makes suggestions as to what the captain should do to correct this. It is possible that the co-pilot resented having to monitor the situation more closely because of the way the captain was handling the aircraft while trying to intercept the final approach radial. This may partly explain why he focuses his attention on the lateral flight path and abandons his checks in the vertical plane.

The commission is of the view that the individual behaviour of the members of the crew was consistent with the personality profiles that it was possible to construct for each of them on the basis of their professional dossiers.

22.43 - **Analysis of crew behaviour**

The commission was able to establish that there was a serious lack of communication between the captain and co-pilot, which initially was reflected in the parallel execution of two different approach strategies up until the commencement of descent and then, in the final phase of the flight, by the omission of the majority of the standard check calls.

The respective strategies of the captain and co-pilot regarding the approach were at first different, and indeed these reflected their different personalities and general attitudes towards the aircraft. At 17.15 hrs, as the co-pilot has just copied Strasbourg ATIS, which is giving 05 as the active runway, he seems to opt for a VOR/DME straight-in approach. In contrast to this, the captain tries to stick to his overall initial plan by adapting it to the changed circumstances. He opts for the planned ILS approach on runway 23 followed by an indirect approach on 05.

If there had been good crew co-operation, this would have required adequate and explicit communication between the captain and co-pilot concerning their respective intentions and actions, as well as their reservations about and reasons for decisions taken. There are numerous examples demonstrating that this was not the case. The co-pilot changes the arrival data on the FLIGHT PATH page and replaces ILS 23 with VOR 05 without telling the captain beforehand. On the other hand, the co-pilot's questioning of the captain's reasons for still wanting to make an ILS approach (" I still don't know why you don't want to try a VOR DME on 05") are not understood by the captain as a suggestion for a straight-in VOR/DME. In fact his reply stresses the fact that a full VOR/DME procedure takes too long. The co-pilot does not press the point, and things develop during this phase of the flight as if there was no common agreement on the approach procedure but rather an evolution of two parallel and different intentions with each pilot being unclear of what they other had in mind.

The commission was able to confirm that from commencement of descent, and especially in the final phase of the flight, there was no announcement of many of the actions, in accordance with company procedures, nor were any alternative courses of action mentioned. Thus, during this part of the flight, the co-pilot not once announced that he was changing FMA mode (when there were six occasions when he should have done so). Similarly, there is not a single check call referring to the aircraft's vertical flight-path that can be cross-checked by either the captain or co-pilot. The co-pilot's remark " We must on top at eight hundred feet" immediately after the Strasbourg controller replies " Call the VOR finals" shows that the co-pilot

is expressing his preoccupation with a height check that is coming up, whereas none of the relevant earlier height checks had been made.

This comment is followed by a remark by the captain who says: " We'll have to watch it doesn't descend", perhaps referring to the aircraft and thereby expressing his more immediate concern about control in the vertical plane (but it is difficult to understand why in that case he had not reacted when the aircraft had been descending at a rate of 3300ft/min for the past 20 seconds). But this remark, passed in undertones, seems to have been missed by the co-pilot who most probably was preoccupied with lateral flight-path control. The commission noted once again a major lack of communication between the crew during the final phase, who only seemed to have achieved any significant degree of coordination in the control of the lateral flight path.

Finally, the focusing of both crew-member's attention on lateral control of the flight path which, according to the evidence, played a major role in the accident, was analysed by the commission of enquiry from the point of view of crew co-operation. The first heading selected by the captain (most probably 051°), following the instruction from the Strasbourg controller to "Continue turning left to establish yourself on 051.." is short of the correct value because of the position of the aircraft.

Fifteen seconds later, the co-pilot notices this and twice mentions to the captain his views concerning the pick up of the inbound radial, adding the second time a suggestion for a heading correction. The captain only reacts the second time by making two changes of heading within the space of 16 seconds. From the time the radial capture phase starts, and bearing in mind the way the captain was handling it, the co-pilot devotes all his attention, other than for aircraft configuration purposes, on lateral flight-path control (apart from the brief comment " We must on top it at eight hundred feet"), and his subsequent comments only serve to rivet the captain's attention in like manner practically uninterruptedly until impact.

The commission is of the view that this double focusing of attention on the lateral flight path arose partly because of the personalities of the two pilots and the internal crew relations. During the capture phase of the inbound radial, the captain had difficulty flying the correct flight path and making the appropriate corrections speedily. The co-pilot however had a good awareness of the position in the lateral plane, but nevertheless did not call out the initial pick up heading selected by the captain and only passed comment when he saw the effect it was having on the aircraft's flight-path.

The captain's slowness to react to the co-pilot's suggestion can be explained either by the fact that he had not heard the first remark, or that it had taken him some moments to grasp its significance, or because of some reserve on his part. The manner in which the proposed correction was subsequently carried out suggests that it was on account of his reserve. The captain's attitude could stem from the difference in their personalities, or their dislike of one other. Above all, psychologically the captain seems to have grown progressively more sensitive, and this is brought on by the fact that he is reluctant to accept a VOR/DME procedure, and yet is eventually obliged to agree to the procedure initially suggested by his co-pilot, also by the fact that his failure to pick up the radial is noticed by the co-pilot, and finally by the fact that the descent was initiated some 10° offset from the final approach radial.

As for the co-pilot, his attention is focused on the lateral flight-path because of the way the captain is handling the pick up of the inbound radial, and perhaps also to gain the upper hand in the conflict of personalities by exercising particularly tight control over a weak point.

22.44 - <u>Conclusion with regard to crew cooperation</u>

The commission is of the view that the two crew members had rather different personalities. It also notes that their behaviour had been described as "cool" by several witnesses. Finally, the commission notes a major lack of communication and check calls between the crew members throughout the flight. In conclusion, it was observed that two parallel courses of action were frequently being followed during the flight which finally converged in a focusing of attention on the control of the lateral flight path.

22.5 - Crew-Procedure relationships

22.52 - <u>Cross-monitoring and Check Calls</u>

22.511 - An essential principle of flight safety with a crew comprising a minimum of two pilots is the practice of cross-monitoring. Effective cross-monitoring calls for a finely-balanced compromise between the independence of each pilot from the other's instantaneous plans of action (it is only possible to monitor by being uninvolved), and their inter-communication (it is only possible to monitor that which is known and understood). Conventionally, these conditions are satisfied by applying two principles: task sharing and the use of check calls.

22.512 - A sharing of pre-defined tasks laid down by company procedures not only saves time and improves efficiency but, by varying the respective aspects, priorities and constraints of the two pilots, by desynchronizing their preoccupations, it also disjoints the cognitive processes and reduces the probability of error in any one mode.

The check calls of key events (critical values, decision points, changes of configuration, of mode, intention) are communication vectors between plans of action, and equally represent points of resynchronization and mutual clarification of mental images. However, airline operators have very different philosophies with regard to check calls during flight.

Some insist on a systematic check call by each crew member, or by one or other of them, at each change of mode or command value on the auto-pilot. Others only insist on calls being made in the case of abnormality.

22.513 - The task-sharing laid down in the Air Inter Operating Manual (Operating Manual Pt 1) specifies that the pilot designated as the PF (Pilot Flying or 1st Pilot) is at the controls and exercises control over the aircraft's flight path and navigation. The other pilot (Pilot Not Flying (PNF) or 2nd Pilot) is responsible for the aircraft's configuration, systems' management and radio communications.

The manual states that all changes of mode on the FMA, as well as selected heading and altitude changes or target heights read off the PFD, must be the subject of audible check calls made by the pilot not in control. There is no reference to mandatory calls for VS or FPA values selected on the FCU.

22.514 - As has already been noted, numerous check calls specified by company procedures were not made during the part of the flight recorded on the CVR.

Particularly noteworthy is the absence of check calls for the following events and parameters:

- the selected flight level (FL 70) at commencement of descent from the cruising level (the check call for the change from "IDLE" to "OPEN DESCENT" is made);

- the successive target speeds selected (eg: 260kts at 18.12.27hrs);

- the FMA mode changes as the target height of 5000ft is reached;

- the selection of ALT mode at 18.13.46hrs and the heading selected for the left-hand turn;

- the new heading at the end of the outbound leg and the new speed of 180kts;

- the de-selection of ALT mode and the selection of VS mode at 18.19.38hrs;

- the new headings selected to pick up the inbound radial;

- the undercarriage down and locked (but check calls are made for all flap settings)

22.515 - A substantial number of the check calls required by company procedures were therefore not made. What is more, the range/height check call at 9nm STR/4300ft was also not made. In view of the safety implications involved, the fact that there was such a marked difference between what the crew should have done (and had been trained to do) and what they actually did in practice gives rise to the need to examine in more detail the possible reasons why this happened. In the foregoing paragraphs it has been possible to establish the following:

22.515.1 - Bearing in mind their inexperience and professional record, and especially in the captain's case his personality and reticence with regard to the aircraft, it is almost certain that neither of the pilots had acquired a very high level of confidence on the A320.

22.515.2 - There was a lack of communication between the crew members. Dialogue was strictly limited to professional aspects of the flight. The co-pilot's repeated inability to have his suggestions taken into account suggest that he did not inspire confidence in the captain. No doubt his efforts to cooperate might have met with more success had he observed company rules with regard to check calls.

22.515.3 - As far as can be ascertained, the workload does not appear to have been high, except during the line-up and final descent. During this phase, and particularly after the commencement of descent, the commission noted an abrupt increase (§ 22.524 below). The workload at this point, and notably that of the co-pilot, may partly explain the absence of check calls. In fact, Air Inter policy at the time of the accident was for the PNF to make a check call every time he observed a change. This presupposes however sufficient time available to make the necessary observations. This is not the case when, for example, at 18.19.38hrs, the captain initiates the descent. In fact, at this time, the co-pilot is busy selecting and monitoring the extension of flaps to position 2, having just been requested to do so by the captain. Nevertheless, check calls were not made, even when the workload was obviously low.

22.516 - Because no satisfactory explanation for this phenomenon was forthcoming from the data gathered relating to this specific flight and crew, the commission widened the scope of its deliberations to include more general factors such as the routine of high-frequency short-haul flights and poor understanding of the need for and methodology of cross-checking. This initiative appears to have been justified by indications that various other airline operators are also experiencing problems in this area during retraining. Irrespective of the policy in force (checks by the PF, PNF or both, check calls for all major changes or just for abnormalities), it seems in fact that at present there is no solution entirely without disadvantages or weak points.

The commission also noted that the ambient noise level on the flight deck was high(between 82 and 83dB), and conceded that this might have accounted for some reduction in the number of vocal exchanges, including check calls, and therefore the preference for hand signals. However, it did not consider that this factor of itself provided sufficient explanation.

22.52 - <u>Execution of the VOR DME approach procedure</u>

22.521 - General remarks

The obvious reluctance of the captain to make a VOR/DME approach may be interpreted, but only partially since this did not apply to the co-pilot, as a sign that he was much less confident about this type of approach than the ILS approach.

"Standard" approaches are rarely made on the Air Inter route network (about three per pilot per year), and pilots receive much less training in these procedures than for ILS approaches. On this aircraft, the requirement to qualify on type is three VOR approaches and one NDB approach per crew. A VOR approach is part of the final handling check. Finally, the Air Inter route-conversion instruction manual recommends to instructors that a VOR/NDB approach or an

an ILS approach without glide path is practised at each airport, traffic permitting. Statistics of some twenty-five students show that each student practised only five or six VOR or NDB approaches before entering airline service.

The number of hours flown by both the pilots of F-GGED since entering airline service on type does not suggest that they would have significantly improved upon this level of experience. In fact, the investigation showed that neither of them had ever previously made a VOR DME approach at Strasbourg on the A320.

22.522 - The Air Inter Standard Operating Procedure

The standard operating procedure laid down in the Air Inter operating manual (Vol 1. Standard Operating Procedures - Standard Approach and associated instrument displays) for a VOR DME approach specifies the following:

- the main radio-navigation aid used for the procedure is to be selected manually by the PNF;

- the HDG-VS/TRK-FPA mode selector must be switched to TRK-FPA before beginning the outbound leg from overhead the beacon;

- "high accuracy" state must be checked;

- the PF must select ROSE NAV or ARC NAV mode on his navigation display, and the PNF must select primary information (ROSE VOR);

- if in "low accuracy" state, or primary data (needles) do not accord with what is showing on the navigation display, the PF must also select

ROSE VOR;

- "green dot" speed reference: slats/flaps to position 1 before the end of the outbound leg;

- Speed reference S: slats/flaps to position 2 during the second part of the procedure turn and undercarriage down;

- Speed reference F: slats/flaps to position 3 at 1nm from the final descent point;

- at 0.5nm from the final descent point, slats/flaps to FULL position (speed dropping towards Vapp). If break-off is necessary flaps 3 is automatic. Select required descent path on the FCU;

- the synoptic diagram displays a 1nm-long straight line along the flight path prior to the final descent point.

In addition, the A320 conversion training programme for VOR DME approaches stresses the importance of stabilizing speed, aircraft configuration and engine speed, and being steady on the inbound radial at 1nm before the descent point (however, if need be, FULL flaps may be selected at 0.5nm from the descent point when stabilization is scarcely possible before descent). The programme also stresses the basic rules: wind-adjustment of VSI, adjustment of descent timing on the basis of DME range-readouts, check calls for variations in speed, VSI readings, height, and MDH +200ft and +100ft.

22.523 - Procedure actually followed by the crew

22.523.1 - The procedure followed by the crew of F-GGED differs in two respects from the general guidelines on which the company had formulated its operational instructions: firstly, the intermediate approach was flown under radar control on a different initial flight path than the one in the published procedure, and secondly, certain aspects of this intermediate approach are at variance with the basic rules governing the drawing up of the procedure (see § 111.422).

22.523.2 - The VOR DME procedure laid down for the approach to Strasbourg includes a racetrack on the SE beacon, an outbound leg on the 251° radial from STR and a procedure turn to rejoin the inbound radial on 051°. The crew was not aware of this procedure because they accepted the controller's suggestion of radar guidance (see § 22.6). This led them into a different flight path than the published one.

From the point of view of flight management, the outbound leg on a heading of 230° (under radar guidance) can be equated to the published outbound leg. However, in this case the company instruction regarding the use of HDG or TRK mode no longer seems to be clear. A heading instruction from the ground controller can be followed in either mode: either by directly selecting it in HDG, or by selecting the corresponding track in TRK mode (current operational practice is to use HDG mode). The Air Inter instruction in this case only

applies at 18.18.37hrs, when F-GGED is released from radar guidance. It should also be noted that the radar guidance provided by the radar controller did not bring the aircraft over the ANDLO beacon, contrary to what the controller said he would do. (see § 22.6)

22.523.3 - From this point on the peculiarities of the approach procedure itself come under scrutiny. In fact it does not include a deceleration level before commencing the final approach. Consequently, three normally separate actions are grouped together: the line-up on the inbound radial, the configuration of the aircraft and the initiation of descent. This increases the workload on the crew. If there is a problem with any one them, checks of the other two will be skipped.

This same difficulty may lead to problems with interpreting the company procedure for configuring the aircraft. In fact, the procedure specifies configuration 3 at least 1nm before "final descent" and full at 0.5nm if break-off is possible in configuration 3 (which was the case for the flight when the accident occurred).

22.523.4 - If "final descent" is interpreted in the strict sense of the approach procedures (final approach segment), the FAF being located at 7nm from STR, the crew could have waited until they were at 8nm before taking this action, but then it would have been necessary during the descent.

If "final descent" is interpreted in the general sense of a final stabilized descent, then the FULL configuration would have to have been selected during the turn (which is not usual) before reaching 11nm from STR, unless the crew could have managed to fly straight and level for a short while before the descent point.

22.523.5 - It must be assumed the crew had opted for the first of these interpretations, since they had still not selected configuration 3 by the time of the accident, that is some 8.5nm from STR. Furthermore, in FPA mode it is easy to decelerate on a constant descent slope. In that case, the captain would only have been preoccupied by the need to control the increase in speed through the use of the airbrakes so that he could select the configuration in time.

22.523.6 - But it could equally well be assumed that the crew, or at least the captain, had opted for the second interpretation. In fact, in his briefing he refers to the commencement of descent saying "we start descending at 11 STR " and without mentioning the FAF, which furthermore is not shown on the approach chart which he had.

Seen from this point of view, the awareness of being late and of not having selected configuration 3 before final descent could have added to the captain's worries about intercepting the inbound radial.

22.523.7 - It has been shown in fact that the descent commenced while the aircraft was still 9° off the inbound radial. This offset was very probably quite correctly shown on the aircraft's VOR indicators. And it has also been demonstrated that in fact (cf § 21.231.1) there was nothing to suggest any fault in the indication at that moment of the flight. In all likelihood, the captain was therefore fully aware of the fact that he had started the descent offset from the inbound radial at an angle substantially greater than allowed for by the accepted rules or the air, and that he had looked upon that part of the descent as the intermediate or final descent. This could only have strengthened his concern about intercepting the inbound radial as quickly as possible.

The commission noted that the normal rules of the air referred to above are not to be found in any operational regulations. They are merely the standard rules taught during pilot training based upon the basic principles applicable when formulating safe approach procedures. In France, these are defined in instruction No. 20754 DNA, which essentially conform to ICAO recommended procedures (Doc 8168-OPS). The basic safety principles are clarified for operators in " Operators' Memorandum on standard practice for instrument approach and departure procedures." The commission also noted that the memorandum is the only existing document on the subject and has no power of enforcement.

The ICAO document 8168 states the following:

" Once a final approach fix is obtained, the intermediate approach leg commences as soon as the aircraft enters the standard turn and is closing with the inbound radial, (..)" and " (..) If a new descent is specified after the turn inbound is started, it is not to be intiated until the aircraft is established on the inbound radial (the aircraft is deemed to be "established" when, in the case of an ILS or VOR, the indicator needle deflection is less than half scale or when, for an NDB, the aircraft is +/- 10° maximum off the desired bearing.

In other words, the deflection tolerance for the VOR indicator providing a procedural safety margin is about 5° for a descent on the inbound radial. Any greater offset does not in theory guarantee that the aircraft flight path will be able to remain within the safe break-off limits for the procedure, given all the other safety tolerances to be taken into account. But that does not mean that in practice, a flight path 10° offset from the inbound radial is not within the safe limit zone. In fact, it has been confirmed that F-GGED was indeed within this zone throughout its descent. In other words, the accident happened as a result of being outside safe limits in the vertical plane, not the lateral.

22.524 - Workload

The commission analysed the workload imposed on the crew during this procedure. Despite the decision taken close to the STR beacon to change to a VOR DME approach, there was no indication that the workload was high during the first part of the procedure, flown under radar guidance. On the other hand, from the time the controller cleared the aircraft on to the final approach (18.19.23hrs), the commission noted an abrupt increase in the rate of crew activity. Seven seconds after receiving final approach clearance, which also amounted to reassuming responsibility for the lateral flight path (capturing the inbound radial), the captain asks for flaps 2. While the co-pilot is complying, the captain selects a change of heading on to 071°. Six seconds after that, he disengages ALT mode to begin descending, and four seconds later, he asks for the undercarriage to be dropped, and the co-pilot complies. Two seconds after that, he steadies on a heading of 070°. After a further four seconds, the vertical speed goes negative, the controller requests they call passing the VOR on finals, and the co-pilots answers, probably consulting the terminal approach chart. Before the co-pilot completes his message, the undercarriage is down and locked. After another thirteen seconds, the captain becomes aware of the high indicated airspeed and gradually extends the airbrakes.

In conclusion, the commission established that there was an abrupt increase in workload after final approach clearance was given. The analysis showed that this increase was largely brought on by a combination of circumstances. This was the result of the specific procedural aspects discussed earlier, calling for simultaneous actions to pick up the inbound radial and prepare for the approach and descent, but most of all of the manner in which the crew carried out those actions. In this regard, the commission noted a manifest lack of anticipation for which several of the factors studied in chapter 22 provide an explanation:

experience of the crew on the aircraft and of the type of approach, interface with the aircraft, inter-crew cooperation, and the interchange with the ground contoller and the way in which the radar guidance was carried out.

22.53 - <u>Charts available during flight</u>

22.531 - Introduction

As far as the charts available to the crew on board F-GGED are concerned, and in view of the circumstances of the accident, the commission limited its investigation to those documents most likely to have been consulted for the arrival and the approach.

The procedural flip-charts appear in annex and are described in § 111.43.

In accordance with the Air Inter operating manual for the A320, the crew of F-GGED had a single copy of the charts published by Air France. It is permissible for an airline operator to use aeronautical documentation other than that officially published by the Aeronautical Information Service (AIS). It should be noted that Air France produces charts specially adapted to its own operating needs, and they therefore differ in certain regards from the official publications.

22.532 - Differences noted compared to the official chart publications

A comparative study of the standard arrivals chart for Strasbourg (STAR: Standard Arrival, in force on 20 January 1992) published by the AIS, and the " Arrivals-Strasbourg Regions" chart (dated 22 August 1991 available to the crew of F-GGED), shows in particular that the Air France document combines the arrival approaches for runways 23 and 05 on one chart and they are difficult to differentiate clearly. Considering what is known about the arrival at Strasbourg, it is not at all certain whether the crew made use of this chart. For example, when the captain is told by Eastern Regional Air Traffic Control Centre to route via the ANDLO beacon, he does not change his planned approach, although an examination of the chart might have caused him to.

A comparative study of the "L-VORTAC Rwy 05" approach chart (dated 3 May 1990, in force on 20 January 1992) published by the AIS, and the "VOR DME 05" chart (dated January 1991) available to the crew, also showed differences.

Consideration will only be given in the following paragraphs to those differences thought by the commission to be sufficiently significant in terms of

their likely influence on the crew's understanding of the procedure (see charts attached in annex). For example, on the chart available to them:

- the procedure turn is only partially shown and therefore only a part of the terrain overflown during the procedure appears on it;

- the intermediate approach fix (IF, located on the inbound radial at 11nm from the STR TACAN), and the final approach fix (FAF, located on the inbound radial at 7nm from the STR TACAN) are not marked as such;

- it is possible to interpret the passing height over the STR beacon as not being a minimum passing height;

- the arrivals via the ANDLO beacon on 074° and 107° are not shown.

22.533 - Review of the facts relating to the crew's use of the approach chart.

In order to evaluate whether this lack of sufficient detail in the information supplied may have had some influence on the course of the flight, the following should be borne in mind:

- before departing Orly, in accordance with Air Inter practice for crew handovers, the crew of F-GGED received a single copy of the Strasbourg approach procedure charts. Generally placed on top of the instrumental panel during flight, these are within easy reach of both crew members.

- having accepted the controller's suggestion to join under radar guidance for a VOR DME 05 procedure, the captain tells the co-pilot " I'll put 05 on again for you". It is therefore probable that he made the selection for an arrival on runway 05 himself.

- the captain then used the "VOR DME 05" approach chart (see CVR transcription from time 2708, during the turn outbound) in order to give a new approach briefing.

- he makes no comment about the incomplete coverage of the procedure turn on the chart.

- he specifies that after the procedure turn "We on top the ANDLO beacon again on the inbound radial and start descending at 11nm from STR". He mentions passing heights at 9nm STR and 7nm STR but says nothing about the passing height overhead the STR beacon.

- the captain chooses the correct final descent slope having converted the chart percentage value (5.5%) into a sexagesimal value (3.3°) which can be selected directly on the FCU as a descent angle.

- at no time does the crew refer specifically to the status of the ANDLO and 7STR marker beacons.

- final reference to the chart was made without any apparent haste before completion of the outbound turn, two and a half minutes before the instruction to turn back inbound.

- when the controller tells F-GGED to turn left on to a heading of 090, neither the captain nor the co-pilot mention that this flight path would not allow them to overfly the ANDLO beacon lined up on the inbound radial.

- at QAR time 3047, the aircraft is 9nm from STR and 500ft below the minimum published altitude for overflight. The crew does not mention the passing height.

- at CVR time 3038, twenty-seven seconds before the accident, the co-pilot mentions the passing height for overhead the STR beacon (this had not been mentioned by the captain).

22.534 - Could the absence of certain information on the charts have influenced the flight?

The commission was at pains to determine whether the information identified as missing from the Air France chart could have affected the aircraft handling during the final turn and approach.

Particular reference has been made to the fact that starting the turn back inbound at the moment the controller told them to turn left on to a heading of 090 prevented them from overflying the intermediate approach marker (ANDLO) lined up on the inbound radial.

The absence of any comment on the part of the crew indicates that it is very unlikely the fact that the procedure is not complete on the chart would have caused the pilot to opt to curtail the turn rather than overfly terrrain not marked on the chart.

Furthermore, the fact that the status of the ANDLO and 7STR marker beacons is not mentioned on the Air France chart was not sufficient to have prompted the crew to curtail the procedure, especially when the procedure profile shows commencement of descent overhead the ANDLO.

In summary, it is very unlikely the differences noted between the charts available to the crew and the official ones would have exercised a negative influence on the conduct of the final turn and descent.

22.535 - The VOR DME approach "Step Down" profile

The charts available to the crew, in common with the official charts, show the vertical descent profile from overhead the ANDLO beacon and the final descent as a straight line, which suggests a continuous angle of descent.

Other approach procedure charts, in cases where there is no radio reference for the glide path (so-called "standard" approach), use the "step-down" which is a series of steps representing the successive safe heights.

The commission examined the possible effects of the vertical plane information available to the crew. The important factor in making a safe approach of this kind is awareness that there is a succession of safe heights related to specific ranges, as well as familiarity with when to check the various height/range pairs.

The step-down procedure facilitates realisation that there are successive minimum descent heights, but is not immune to mis-reading, thereby leading for example to a displacement of the safe height steps, as happened in another recent accident. In the case of F-GGED, the captain's briefing around 18.15hrs makes correct reference to the heights associated with the ranges 9nm and 7nm, but makes no explicit mention that these are minimum safe heights. However, in conducting its analysis, the commission did not consider that possible crew ignorance of the fact that these were minimum values was a plausible explanation for commencing the abnormal descent. Consequently, the commission does not think that the final descent vertical profile shown on the aircraft charts could have played a significant part.

22.536 - Could the fact that there was only one copy of the approach chart available have influenced the conduct of the flight?

The fact that only one copy of the appropriate chart was given to the crew should logically oblige the pilots to communicate. The pilot flying reads aloud and makes use of the charts; the pilot not flying actively monitors. Also, in the specific case of the Air Inter

route network, experience gained by their crews practically allows them to do without the help of charts after the briefing.

One possible disadvantage would be that it would be impossible for the pilot not flying to read the charts at the same time as the pilot flying. However, the outbound leg was of sufficient duration (about two and a half minutes) for him to have used the sole available flip chart if he had wanted to. The same thing goes for the arrivals flip chart. Furthermore, although the captain does not mention the published overflight height for the STR beacon, the co-pilot does, which shows that he did use the chart.

As a result,the fact that the crew of F-GGED only had one single copy of the chart document available was thought unlikely to have influenced the nature of the arrival and approach.

22.537 - Conclusion

The information available in the procedural flip chart available to the crew was sufficient to have permitted them to make the approach.

Consequently, the commission considers it very unlikely that the manner in which the turn back inbound,the line up and the commencement of descent were flown could have been caused by any of the documentation shortcomings.

22.6 - Crew - Ground Control Cooperation

22.61 - Introduction

This analysis covers the phase of the flight between the time the crew contacts the Reims Air Traffic Control Centre (en route control, CNRA) and the final instruction passed by the Strasbourg approach controller (APP). It relies upon the CVR transcript, the transcript of radio-telephone communications, the transcript of telephone communications between the CNRA and the APP, and the flight path plot of F-GGED.

The aids employed by the Strasbourg APP are described in chapters 15, 19, 110 and 111.

Relevant official references for phraseology are: Departmental Instruction dated 7 September 1984 and decision No. 20285/DNA/2/6 dated 10 September 1984 entitled "Phraseology", Fourth edition, June 1991.

22.62 - Phase of the flight controlled by the Eastern CRNA

At 17h53m47s F-GGED established contact with the Eastern CRNA, which authorised it to "proceed Luxeuil and standard arrival for Strasbourg".

It was not necessary for the Eastern CRNA Controller to specify the runway in service at Strasbourg, as this airport has an ATIS. On this subject it may be noted that when the crew consulted this ATIS, at 17h56m, it received the November information, registered at 16:00h. This information was thus more than one hour old, which did not comply with the regulations in force. However the information received was globally valid, and this delay in updating did not influence the progress of the flight. Regarding the arrival envisaged by Control, the term "standard" is not explicit (although in current use by pilots and Controllers). From LUL VOR, several arrival flight paths are possible. Whichever runway was in service at Strasbourg, all aircraft at arrival and routing via VOR LUL (Luxeuil) must follow the Magnetic Route (MR) 041 as far as the OBORN point if runway 23 is in service, or as far as the point situated at 21 NM from STR on radial 041 from LUL if runway 05 is in service (which was the case on the arrival of F-GGED). After that, to make the VOR DME 05 approach, the alternatives are as follows: either carry out the whole of the procedure via ANDLO then SE, or make a direct approach via

ANDLO. This shows us that in the case of F-GGED the term "standard" did not in fact convey any precise information to the crew concerning the route to be followed after LUL. The Captain was able to interpret this instruction as signifying the absence of restriction in the choice of approach (ILS 23 followed by a visual manoeuvre for landing on runway 05, or a VOR DME 05 approach).

It is appropriate to note that at the time of the accident, the flight paths for arrival at Strasbourg were not named. In these conditions, to specify the route which F-GGED was to follow, the Controller had no other option but to enumerate the waypoints to be flown over, which was not done. According to him, the crew did not ask for more clarification: they simply copied the instruction "Luxeuil and standard for Strasbourg".

At 18h06m13s, the crew informed the Eastern CRNA that it wished to "descend in one minute". The Eastern CRNA authorised the descent towards Flight Level 130.

Previously, at 18h01m34s, the Eastern CRNA had called the Strasbourg APP to inform them of the arrival of F-GGED. The APP had then noted that the flight path

of Air France Flight 1870, at the departure from Strasbourg, was interfering with that of F-GGED. Consequently it had been agreed between the two control organisations that the Eastern CRNA would ensure the safe crossing of the two aircraft and would direct F-GGED towards ANDLO, in descent towards Level 70.

According to the testimony of the Approach Controller, this solution had been chosen with the aim of reducing the flight time of F-GGED by allowing it to make a direct VOR DME 05 approach.

This co-ordination was made in conformity with the letter of agreement existing between the two control organisations (1 July 1990) which specifies that "the APP may ask the Eastern CRNA to take the arrivals from LUL or EPL directly overhead ANDLO, with a view to an approach towards runway 05".

The Eastern CRNA ensured the crossing of the two aircraft, then transfered F-GGED to the APP in descent towards Level 70 and ANDLO, without having specified the route to be followed after ANDLO. It is appropriate to note here the Captain's comment: "ANDLO, oh there, they are damaging my feet with their stuff there..." (see CVR, time 2223). This reaction is probably explained by the fact that the ANDLO point does not appear on the flight plan for an ILS 23 approach. ANDLO was not therefore displayed on the navigation screen. The instruction received imposed an action by the Captain described in § 117.723. This criticism by the Captain is not followed by a questioning of his approach strategy, nor by interrogating the Controller about the route to be followed after ANDLO. The crew probably did not establish a connection between this instruction and the fact that the Strasbourg Controller had envisaged that they would make a direct approach, and therefore that they would pass by ANDLO.

22.63 - <u>Phase of the flight controlled by the Strasbourg APP</u>

22.631 - The arrival over ANDLO

Direct contact between F-GGED and the APP was established for the first time during this flight at 18h09m01s.

It is noted that the crew did not acknowledge reception of the information (Oscar) broadcast by the Strasbourg ATIS. This did not comply with the regulation phraseology. Equally, the reply from the APP did not comply with the regulation phraseology. In fact

the Controller should have ensured that the crew was indeed in possession of the ATIS information, or, better still, given the crew directly all the details which it was able to receive on the ATIS.

On initial contact, the APP authorised the A320 to proceed overhead the ANDLO point, asking it for its distance: "... proceed ANDLO; your distance?". There again, the route instruction was incomplete. It should in fact have indicated either a reporting point after ANDLO or a procedure proposal to be engaged from this point in view of the landing. Moreover, the Controller asked for a distance without specifying in relation to which point or means of radio navigation the crew was to give its position. The crew replies: "We are at twenty two nautical DME STR". The Controller asked this question to confirm that the aircraft was at a distance close to "21 NM STR" from which the aircraft could fly at 5000 feet QNH (see the approach chart: the safety altitude is 4800 feet from 21 NM STR in a defined sector which contained the route of F-GGED). Taking account of the pressure altitude information displayed on the radar screen, the Controller anticipated and authorised the descent towards the altitude of 5000 feet "Received, continue the descent towards five thousand feet at QNH one thousand twenty-three". The Captain checked that following this instruction was compatible with the Safety Altitude (see CVR, time 2398 and 2400).

The Controller added: "re-call ANDLO, five thousand feet".

This instruction can be interpreted in different ways. At all events, it did not indicate explicitly what (in the Controller's intent and again in his testimony) corresponded to an authorisation given to F-GGED to press on to the overhead of ANDLO stabalised at 5000 feet, to enable a direct VOR DME 05 approach.

At 18h11m51s, when F-GGED had just signalled its vertical passage over ANDLO, the Controller replied: "You are number one for the VOR DME zero five, call overhead the VOR on final". The crew was then aware of the Controller's strategy.

Between this instruction and the acceptance by the Captain of radar guidance to return to ANDLO, about one and a half minutes elapsed, a period during which events built up:

— taking account of the position of the aircraft and its configuration, the direct approach could be carried out (see § 21.35).

— for the first time the crew advised the Controller of their intention to " (..) proceed Sierra Echo, make an ILS with an indirect for the zero five after that."

— Control then informed the crew that the choice of effecting the ILS 23 procedure would probably entail a Hold because three take-offs were envisaged on runway 05 (see CVR, time 2596).

— obviously to avoid the execution of the approach being delayed, the Captain then decided to make a complete VOR DME 05 procedure (see CVR, time 2608). He then remarked to the co-pilot that Control ought to have warned them in advance of these traffic constraints, since they influence the choice of procedure best adapted to the circumstances. This remark can be interpreted as a criticism in respect of the Approach Controller, who would not have taken into account the need for adequate warning (notably in order to reduce the speed of the aircraft).

— when F-GGED arrived at the overhead of STR, the Controller proposed radar guidance to rejoin ANDLO (see CVR, time 2636). This allowed the procedure to be shortened.

— this solution satisfied the Captain. He accepted it immediately.

22.632 - The missed approach

The instruction to change the Transponder code follows immediately, accompanied by the instruction to turn left towards the outbound track 230 deg.

The Controller commented on the adopted solution: "There you are, that will save you some time" and the Captain clearly expressed his approval (see CVR, time 2654).

(During the radar guidance and the final approach of F-GGED, the APP Controller directed three IFR departures).

In the course of the turn, the Controller gave the following position information on his own initiative: "... six nautical, radial two hundred ninety from Strasbourg". It was given in relation to the position of the radar antenna and was not directly usable by the crew, since the position of the radar is not mentioned either on the Arrivals screen, nor on the approach chart, nor on the navigation screen (see § 21.3). The CVR transcription shows that, immediately after the

co-pilot's acknowledgment of reception, the Captain, who was in the process of describing the VOR DME procedure in a loud voice, immediately resumed this task and calculated the descent slope. Neither he nor the co-pilot commented on the position information provided by the Controller.

The rejoin on track 230 lasted about two and a half minutes, a period during which the crew undertook certain actions detailed in § 21.3. In the course of this rejoin, the Captain once again refered to the need for sufficient anticipation to prepare for an approach. It is probable that he had never envisaged the possibility of making a direct VOR DME 05 approach and that for him the choice was limited to the ILS 23 and the VOR DME flying over the SE beacon, while showing a clear preference for the ILS procedure for reasons of orderliness of the operation.

22.633 - The rejoin procedure turn

When the Controller gave the instruction to turn left to track 90, the Captain immediately executed the inbound turn. He changed the display mode of his navigation screen (it changed from NAV ARC mode to VOR Rose mode). The crew made no comment about the validity of the route instruction which had just been given to them. Whereas examination of the flight path analysis shows that the choice of track 90 would not have permitted overflying ANDLO.

Let us remember that it is very probable that the display of the VOR DME 05 approach track and that of the waypoints ANDLO and/or STR D7.0 were available on the navigation screens from the time that the MCDU was selected for the VOR DME 05 procedure (see QAR recording and § 117.7). The simulation described in § 117.7 has not made it possible to establish if the ANDLO point was or was not displayed on the navigation screen. On the other hand, it has been shown that in all possible cases of display, the STR D7.0 waypoint was shown on the screen.

Forty seconds later the crew received from the Controller a new route instruction, this time together with position information in relation to the ANDLO point: "Air Inter Delta Alpha follow the left turn to set yourself on the zero fifty one, you are at four nautical from ANDLO ... abeam left ANDLO". At this moment, it is clear that the radar guidance will not permit flying over ANDLO. The flight path ground radius of the aircraft (cf Appendix 12) clearly became narrower, under the double effect of the reduction of speed and the rotation of heading relative to the wind, which resulted in a large reduction in the ground speed, while the bank angle was maintained constant by the Autopilot.

It may be that the Controller's instruction ("continue the left turn to set yourself on the 051...") was interpreted by the pilot at the controls as: "maintain your setup, and that will lead you onto the 051". In the rest of the procedure, other indications are also noted of this pilot's tendency to let himself be led by the Controller.

The CVR transcription shows at all events that this instruction received no comment from the crew, notably about the impossibility of flying over ANDLO. The Captain selected display of the ARC mode within a few seconds, temporarily replacing the VOR Rose mode. If ANDLO was shown on the screen, he could have made sure that the position calculated by the FMS agreed with the position indicated by the Controller. The lack of reaction may also be interpreted by the fact that the display of the map would have allowed him to establish that the flight path followed would allow interception of the radial before the 7.0 STR waypoint, and that ascertaining this was "enough" for him.

Nothing indicates that the Captain had used the approach chart during this phase of the flight.

The route instruction provided in the course of the radar guidance did not allow the pilot to align the aircraft at ANDLO. Owing to this fact, the crew did not have available the whole of the designed Intermediate Approach segment to prepare for the Final Approach (reduction of speed and setting up the landing configuration of the aircraft). This inconvenience came in addition to the fact that the approach segment is in descent, which constitutes a derogatory aspect, examined in § 111.42. In these conditions, the crew was constrained to carry out, virtually simultaneously, the actions which the procedure envisages to be performed sequentially (leaving the turn, alignment, reduction in speed and aircraft preparation).

The Air Regulation Circular in force at the time of the accident (ARC 3-10-07 dated 22 February 1965) contains no specification relating to possible criteria to be respected in the case of radar guidance for interception of the Final Approach track.

On the other hand, the ARC 3-121 dated 16 March 1992 and applicable from 2 April 1992 specifies that:

"When the aircraft must execute the Final Approach with the aid of a means other than the radar, the last course provided on the radar guidance must allow the aircraft to rejoin the final track within a maximum angle of 45 deg. The guidance provided must allow the aircraft to effect level flight on the track for at least 30 seconds before intercepting the nominal descent slope.

An aircraft which proposes to use a Final Approach aid whose data are interpreted by the pilot must receive as instructions to call back when it is indeed established on the Final Approach track. The guidance comes to an end at that moment."

The Commission notes on the one hand that the guidance provided to F-GGED did not allow the arranging of level flight of at least 30 seconds on the approach track before intercepting the nominal descent slope, and on the other hand that the guidance came to an end before the aircraft was established on the Final Approach segment.

While remembering that these regulatory points did not exist at the time of the accident, the Commission notes that the application of these instructions would probably have avoided all haste at the time of preparation of the aircraft and the setting up of the descent.

Concerning the position information "abeam left ANDLO",it is noted that this does not comply with the regulation phraseology. It is ambiguous, because the notion of right or left may refer to either the flight path of the aircraft ("You have ANDLO on your left beam), or to the orientation on the radar map "I can see you abeam left of ANDLO on my screen". According to his testimony, the Controller wanted to indicate to the crew: "You have the ANDLO point on your left beam". It should have been formulated like this: "... position four nautical north-west ANDLO".

The aircraft is approximately in proximity to the 330 deg from ANDLO when the Controller authorises the crew to make the Final Approach (see CVR, time QAR 2991). This authorisation signifies that the radar guidance has ended. It is matched by position information which uses the expression "abeam (right)" again. This position information is given in application of Air Regulation Circular ARC-3-10-05 § 3.3.3, concerning radar guidance: "When the aircraft at the end of radar guidance has rejoined (or is on the point of rejoining) a common radio-beaconed flight path, the position of the aircraft shall be specified to the pilot."

On the previous logic, in giving the position information "abeam right ANDLO", the Controller wanted to indicate to the crew: "You have the ANDLO point on your right beam" As has already been noted, this does not comply with the regulation phraseology and is ambiguous. However the crew made no comment.

22.634 - The setting up for descent

Without it being possible to establish formally a direct cause and effect relationship, it is noted that, immediately after the acknowledgment of reception of the approach authorisation, the Captain asks the co-pilot to put the aircraft into configuration 2 ("flaps towards two") then begins the descent to 11 NM from STR. At that moment, the aircraft is not aligned on the approach track. It is approximately on the radial 060 or still about 10 deg from the track.

It may also be noted that the initiatives for the two changes in configuration carried out seem to depend more on the messages from Control than on a clear perception anticipating the segments of the procedure. Configuration 1 ought to have been established before the end of the rejoin: It is noted that the crew maintained a high speed (230 Kt) and that this change of configuration follows within about twenty seconds the start of the left turn requested by the Control. It is noted equally that the changing to configuration 2 is ordered 7 seconds after the authorisation "Air Inter Delta Alpha, abeam right ANDLO, authorised for the Final Approach".

It is evident from this that the Captain has probably relied entirely on the Controller from the moment that the Controller offered him radar guidance to return to ANDLO. It is the co-pilot who draws his attention to the need to relax the turn. On finishing the procedural turn, the crew probably focuses its attention on the lateral navigation. The Final Approach authorisation appears to be the event which sets off the decision to set the aircraft up in landing configuration and commence the descent. It could have had the effect of an authorisation to descend, even though the decision to commence descent was the sole responsibility of the crew.

A few seconds later (see CVR, time 3019), the Controller asks the crew to call overhead the VOR on Final. This is the last exchange between the Control and the crew.

Although the radar guidance had come to an end (see § 111.32), the Commission has attempted to evaluate whether, allowing for the precision of the radar track, the position of the plot and the pressure altitude indication of F-GGED could have alerted the Controller.

The image displayed on the Strasbourg Approach Controller's screen is not recorded. The testimony of the Controller (cf § 120.5) indicates that he had

selected the scale of 50 NM. Measurements made on an image set at this scale show that an aircraft situated at 10 NM from Strasbourg airport is represented by a trace of about 3 mm in size, or about 1 NM to scale; at 20 NM the trace has a size of about 5 mm, or about 1.5 NM to scale (the diameter of the screen is about

35 cm). Taking account of the flight path analyses obtained from the recorded radar tracks, the centre of the plot was therefore probably slightly to the north of the approach axis on the screen, without that being able to be considered by the Controller as significantly abnormal. Furthermore, at that moment, the aircraft was still approximately on the nominal descent slope. The information coming from the altitude encoder and displayed on the screen did not, therefore, indicate, a priori, any flight path anomaly. All the more so because, for an aircraft descending at 3000 ft/min, the level read by the Controller is about 500 ft higher than the actual level of the aircraft. Consequently, it is only at best in the last twenty seconds of the flight that an abnormal situation could probably have been detected.

22.64 - Conclusion

The Approach Control had envisaged that F-GGED would make a direct VOR DME 05 approach. However, neither the arrival segment at Strasbourg nor the type of approach had been clearly indicated to the crew. The misunderstanding concerning the approach procedure would have been avoided by a precise formulation of the route envisaged by the Control for this flight.

Contrary to what had been proposed by the Controller, the radar guidance did not allow the interception of the approach track at ANDLO. In these conditions, the Intermediate Approach phase was truncated.

On several occasions, the phraseology used did not comply with the regulation in force. However, it is not established that the divergences noted had influenced the progress of the flight.

The Captain had not envisaged the possibility of a direct VOR DME 05 approach. The radar guidance offered allowed him to shorten the procedure. He accepted it immediately and seems to have been satisfied, as far as the rest of the horizontal navigation is concerned, to carry out the instructions given by the Controller until the end of the radar guidance.

22.7 - Crew - environment reports

22.71 - Introduction

The known circumstances of this accident have led the investigators to examine the possible influence of the meteorological conditions on the conduct of the flight.

22.72 - The meteorological conditions

The Investigation has established that the descent from the cruising level towards the altitude of 5000 feet began first of all in a sky practically free of clouds (a few residual banks of altocumulus could be encountered at a neighbouring altitude of 10000 feet), then it was continued from about 6000 feet in a layer of strato-cumulus.

It was dark, but the illumination conditions were probably such that the crew clearly perceived the entry into the layer of clouds, as it resulted in the loss of external visibility.

It was very probably this realisation that prompted the crew to put into operation the anti-icing systems of the engine nacelles.

The meteorological observations and the testimonies received are consistent and indicate that the flight was conducted in the layer of clouds until the impact with the ground. The crew therefore had no external visual reference.

Concerning the icing, it is appropriate to note that the testimonies received from crews who had made the approach shortly before or shortly after F-GGED note moderate icing conditions consistent with the advantage of the available meteorological parameters. Examination of the recordings of engine parameters and the engines themselves has allowed total refutation of the hypothesis of a reduction in their performance.

The intensity of the wind encountered between 5000 feet and the altitude of the accident has been evaluated at about twenty knots (or about 35 km/h) and no significant turbulence phenomena have been reported.

22.73 - Conclusion

The meteorological conditions encountered, without being ideal due to the lack of visibility, do not in themselves represent a dangerous feature.

CHAPTER 2.3 - ANALYSIS OF THE REGULATORY, ORGANISATIONAL AND STRUCTURAL CONTEXT

After having established as far as possible the factual scenario of the accident (Chapter 21), then having analysed the underlying mechanisms which directly or indirectly contributed to producing, at the time of the scenario, the anomalies noted (Chapter 22), the Commission has examined the elements of a regulatory, organisational, socio-economic or cultural nature, contributory to the background of the operation of F-GGED and capable of having induced, favoured or allowed the action of the mechanisms in question. The Commission has notably taken into consideration the Air Inter company, the DGAC services responsible for its technical guardianship, the certification of the aircraft, and the results of experience.

23.1 - The context connected with the Air Inter company

23.11 - Characteristics of the network and the operation

23.111 - The particular characteristics of the Air Inter network and operation have been reviewed in Chapter 17. The Commission has noted in particular the strong culture of respect for schedules and reduction of flight times which characterises the company, notably as a result of customer expectations and competition from surface transport. Taking account of these constraints has resulted, at the levels of maintenance and handling of staging flights, in putting into operation a particularly efficient system, adapted to rapid solutions. At the level of aircraft utilisation procedures, it has resulted in a general practice of rapid descents and approaches.

23.112 - In its analysis of the scenario and the mechanisms of the accident, the Commission has not found elements capable of pertinent comparison with the above. The F-GGED crew was not late (it was, rather, one or two minutes ahead of its schedule). The CVR does not contain any indication that preoccupation with saving time could have played a significant role in the choice of strategies carried out during the flight and in the difficulties encountered. The only allusions to the flight time are the following:

— at 18h04m, the Captain justifies to the co-pilot his refusal to make a VOR DME 05 approach in terms of the loss of ten minutes of flight in relation to an ILS 23 approach. In fact that would not have been true where the complete procedure had been carried out.

A systematic concern to gain on the flight time would, on the contrary, have encouraged the Captain to wonder about the possibilities of a direct approach on runway 05.

— at 18h13m44s, the Controller comments on his offer of radar guidance towards ANDLO, which has just been accepted by the crew, by saying: "There you are, that will save you some time". In fact, radar guidance normally leads to a greater comfort in the conduct of the approach.

23.113 - The Commission has in turn compared the negative conclusions which were drawn by Cir Inter with regard to the compatibility of the GPWS with its daily operation, and the details of that operation recalled above. It has noted that the negative decision had been taken at the end of an in-depth practical experiment conducted by the company in the years 1976 and 1977 on the GPWS, in particular because of an excessive rate of alarms not related to dangerous flight path anomalies. The reduction of this rate would have probably imposed, in addition to technical development, a major revision of the approach procedures used in aircraft, and even of certain published approach procedures. Consequently the Commission considers that this company culture is an important element in understanding the negative position taken by this company with regard to the GPWS.

23.114 - Among the other operational characteristics of Air Inter capable of being highlighted as pertinent context elements, the Commission has identified the high frequency of flights and the significant repetitiveness of actions by the crew which results from this, as well as the considerable proportion of ILS approaches compared with non-precision approaches. The repetitiveness of the flights inevitably induces a strong routine effect, particularly negative in relation to the perennial announcements. The relative rarity of VOR/DME and other "standard" approaches has certainly encouraged the company training system to place the accent above all on automatic precision approaches. Perhaps this may contribute to explaining the reticence noted by the Captain on board towards the prospect of making such an approach for runway 05.

<u>23.12 - The indirect effects of the social</u>

climate

23.121 - The Commission has noted that at Air Inter, the introduction of the aircraft to service was undertaken in a strained social climate, due to the fact of the rejection by some of the pilots of an

aircraft designed for a crew of two. In this context, prior to the development of the A320, positions taken concerning this aircraft became radical. The safety argument, strongly advanced to justify a crew of three, together with the numerous difficulties encountered in the technical adjustments to the aircraft in the first year of operation, and the accident occurring at Habsheim in June 1988, encouraged an atmosphere of suspicion about the aircraft and its safety. Rumours developed about odd behaviour of the automatic devices, which amplified certain individual reservations about the major innovation in the company which this type of aircraft represented.

23.122 - The Commission has taken note in its deliberations that this particular climate carried weight or could carry weight in the following decisions, positions or attitudes adopted by the individuals in charge of the Air Inter company:

— the decision to treat the A320 as an aircraft in a class of its own, fully utilising the principle, traditional in the company, of a specific structure for taking technical and operational responsibility for it, and putting in place a high level crew training system (cf § 23.131 below) so as to minimise the risks of setbacks;

— the traditional recourse to voluntary service, possible until January 1991, for the designation of pilots called to move on to the A320 led to a selection of the most motivated pilots, or those considering themselves to be the most capable, for the first period of training. From mid 1991, the arrival in training of other pilots, mainly from the abolished Caravelle 122 sector, led to some difficulties, which were compensated for by lengthening adjustment to the line from five to seven flights;

— the decision not to choose the GPWS option, despite its low cost owing to serial precabling. This decision was defended by a concern to maintain the homogeneousness of the fleet. Taking account of the specific structure put in place for this aircraft, including in the area of maintenance, it could well be a case here of a concern more psychological than technical: not treating the A320 differently from the other aircraft in the fleet so as not to offer a supporting point for the controversy about the level of safety of the apparatus with a crew of two;

— a policy of restrictive dissemination of information concerning the technical and operational difficulties encountered in the implementation and operation of the aircraft, and an emphasis on the

positive technical results obtained in operation (in 1989 and 1990 Air Inter received from Airbus Industrie the award for the best technical operation of the A320).

23.123 - In addition, this climate could have carried weight with each airman in the company, often obliging him to take part. In this context, possible difficulties in the course of conversion to the A320 were capable of being interpreted as taking a stand.

23.13 - Elements concerning training

23.131 - The Commission has sought to evaluate the quality of the training given to the F-GGED pilots in the course of their qualification for the A320 type at Air Inter. Its general impression is that this training programme seems to be globally positioned at the peak of what is done in this field internationally.

23.132 - Its strong points are essentially the joint utilisation of Computer Assisted Teaching (EAO) and classroom courses by the technical instructors for theoretical training, the total number of course hours (55 hours for the study of the systems) and simulator hours (44 hours of FBS and 32 hours of FFS), and the supplementary technical module after one month of line experience. Its weak points are summarised in a certain imbalance of effort invested in knowledge of the systems (which obviously remains a normal objective of all types of qualification) and the emergency/aid and Precision Approach procedures, to the detriment of the "normal" use of the aircraft. Whereas in practice serious problems, and particularly accidents, encountered on this generation of aircraft seem to result more from bad use of systems, incidentally functioning normally, than as consequences of serious technical failures.

23.133 - The training in standard approaches is based on the assumption that the know-how already possessed by the pilots in this field will be transferred with no particular problems to the A320. A total of four approaches is envisaged in the programme for this adaptation of competence. Now the VOR DME approach on the A320 presents two specific features: There is no lateral coupled Autopilot mode on the VOR, but there is on the other hand a coupled Autopilot or Flight Director mode on a selectable descent slope (FPA).

The use of this new function carries, as with all functions, its own specific difficulties and risks of error. Certain companies have proscribed its use

rather than teaching the way to use it. Further, the standard approaches are approaches rarely carried out in the fleet, which leads to a chronic under-training of the crews in this area. The Commission therefore considers that there was a need for reinforcement in the training of standard approaches during the type ratings on new-generation aircraft, in relation to the Air Inter company programme.

23.134 - The Commission has noted the existence at Air Inter of a preparatory stage in the type rating proper (the STAN stage). This stage was designed globally as an academic technical training module on electronics, automation, automatic devices and modern avionics. It is intended for company pilots and technicians and it meant to be a tool to demystify the aircraft for pilots who are discovering these new-generation techniques. However, it is not excluded that this attempt at demystification could prove, as it were, too efficient for some pilots. In particular, it may be asked whether some pilots of the second period, those who had a less motivated and perhaps also a less than rational attitude to the aircraft, did not progress on this occasion from a systematic distrust to a systematic confidence in certain particularly practical automatic devices.

The Commission has, in return, clearly recognised (cf especially § 22.23) the extent of the transition represented by the conversion to an aircraft of the A320 type for a pilot who only has experience of classical aircraft of the old design and of piloting with a crew of three. Consequently it supports the principle of an adaptation module for pilots making their first transition to a new-generation aircraft. It considers, however, that its objectives should be different from those pursued by the STAN stage and should be centred on a functional presentation of the design and the philosophy of using the high level automatic devices, as well as on the modifications and problems which they give rise to in the crew workload:

control of anomalies of functioning, problems of supervision, overconfidence, awareness of the real situation and communication between pilots, and the critical nature of mutual control.

23.2 - The exercise of the guardianship of the DGAC on Air Inter

23.21 - <u>DGAC control on the operation of the A320 at Air Inter</u>

23.211 - The Commission has shown in different parts of its analysis a certain number of anomalies in the performance of the crew. It has in particular identified the absence of calls of the command values, on the change of mode of Autopilot, and on the control of the vertical flight path in the final phase of the flight. It has also identified in this phase the setting up of the aircraft in descent when it was still at about ten degrees from the approach axis envisaged by the procedure.

The French regulations and those of the major aeronautical countries provide that the professional level of the crews is determined and checked by the Operator itself (at the issuing of the phases of type ratings and line familiarisation, and at the regulation annual inspections). Moreover, in principle the effectiveness of this inspection is supervised by the DGAC in the course of exercising its technical guardianship.

23.212 - The Commission has therefore sought to assemble the judgement formed of the F-GGED pilots by the system of training, maintenance and control of competence of the company itself, then it has sought external evaluation references for the global effectiveness of this system.

Consequently the Commission has examined the methods of control exercised by the DGAC on the operation of the A320 at Air Inter. The description of these methods appears in paragraph 17.3 of the present report. Taking account of the scarcity of inspection or in-flight inspection documents in existence concerning this company, the Commission has not been able to determine whether the below standard performance of this crew was purely circumstantial or on the contrary connected to a drift within the company. More generally, it has pointed out a certain number of indications of inadequacies or difficulties in the exercise of the guardianship of the DGAC on the company.

23.213 - Concerning the role occupied by the SFACT, it has noted in particular:

— that the approval of the instructors charged with the monitoring competence provided for by the regulations, was percieved by the Air Inter officials concerned as purely an administrative formality without any real safety function. This led to the fact that no instructor had been appointed for these controls by the SFACT between 1988 and February 1992, whereas at the same time, in accordance with the company agreement, their nomination was decided by length of service with Air Inter;

— that the operational inspections, carried out by the engineering personnel and intended to check the application and adequacy of the procedures laid down by the company, were perceived by the aircrew personnel of Air Inter (and of other French companies) as being inspections within their own competence, and as such were refused on the grounds of the incompetence of the monitoring personnel;

— that the information from Air Inter to SFACT concerning the difficulties encountered in the operation of the A320 had remained minimal, in particular in the course of the operation report required by the regulation at the end of the first year of operation of a two pilot aircraft of more than forty tonnes;

23.214 - Concerning the OCV, whose central function is concerned with the professional level of the crews, the Commission has no knowledge of acceptance difficulties comparable with those described above. It has, however, noted two factors capable of
limiting the effectiveness of the supervision and the controls exercised by the OCV over a company like Air Inter.

The first concerns the status itself of the pilots on duty to the OCV. Their double allegiance - to the OCV and to an airline company -guarantees their competence but makes it more difficult to exercise formalised, strong, independent supervision with regard to their own company.

The second factor which limits the possibilities of effective supervision of the OCV concerns its means, and in particular its manpower, which does not allow it to proceed with in-flight tests on the professional level of the crews of all the operators with appropriate frequency.

In fact, the OCV did not practise any formal line control on A320 at Air Inter between the end of 1988 and the accident. At the end of the introduction phase, the only direct evaluation which the OCV had available on the professional level of the Air Inter crews flying on the A320 came from the daily practice of the operation of the A320 by an OCV pilot-inspector who was also an A320 leading Captain at Air Inter.

The Commission has the feeling that this control system was not in a position to detect a possible drift in the daily operating practices concerning the call-outs mcde by the crews.

23.215 - Globally, the Commission retains the impression that the potential and the reality of the operational supervision exercised by the DGAC on a company of the size of Air Inter are very limited. This company has never been the subject of a global SFACT/OCV inspection and the last sectoral inspection giving rise to a report appears to date back to 1984. In this regard it seems that the officers and aircrew personnel of this company perceive the role of the SFACT as being limited to the production of regulatory texts, and show some reluctance when this service exercises its functions of controlling the application of the regulations. Furthermore, the in-flight inspections exercised by the OCV seems in practice mainly orientated towards the small companies and to lack formality in relation to the large ones. Thus the Commission of Investigation has had no knowledge of recent written reports which would allow it to know the opinion formed by the OCV on the line performance of Air Inter crews which might have been monitored.

23.216 - Although it has not been able to make a comparison with other countries, the Commission has the impression that the weakness of the external control authority can be prejudicial to the safety of functioning of a system as complex as a large airline company, whatever the quality of its personnel and however tight its organisation might otherwise be.

The Commission also considers that a rigorous formalisation of the inspections carried out is indispensable to enable the directors of the company to ensure that corrective measures have been taken, where applicable.

23.22 - <u>The regulations concerning the GPWS</u>

23.221 - The Commission has enquired into the reasons which could have led the DGAC not to incorporate into their French operational rules the norm adopted in 1978 by the ICAO in its Appendix 6 concerning the obligation of carrying a Ground Proximity Warning System (GPWS) for certain types of aircraft. Among the factors capable of having initially influenced this decision, the Commission has noted:

— the operational limits of the system shown by the experiments conducted by the CEV from 1975: high

rate of false alarms or alarms not justified by a real risk, absence of anticipation in the flight path track leading in certain cases to alarms delayed too long, problems of compatibility of the evasive manoeuvres arising from the alarms with the Air Traffic Control;

— the reserved position expressed by the French aeronautical community consulted by the SFACT in 1976 on a regulation project, a position which was confirmed by Air Inter following in-depth practical tests carried out in 1976 and 1977 on the Mercure and on the A300 on the company network;

— the reticence on principle of the DGAC to promote an obligation to carry equipment protected by the filing of an industrial patent;

23.222 - The development of European operational regulations (JAR OPS) providing for the obligation of carrying the GPWS created, from 1990, the context for a review of this national position. However, the DGAC did not consider it necessary to proceed with a specific amendment of the French regulations on this point before proceeding with the whole revision imposed by the alignment with the common European text. Following the handling of an incident and intervention by the OCV, the SFACT merely informed Air Inter in December 1991 of its surprise at the fact that, despite the requirements provided for by the future European norms, its fleet was still not equipped with GPWS.

23.223 - The Commission points out that the excessive influence of the position expressed by such and such a participant in the process of elaboration of regulations could lead to insufficient regulation. For those in charge of operations in the companies, this inadequacy could result in a lack of formal decision elements necessary to implement a safety policy, taking account of the existing constraints.

23.3 - The certification of the aircraft

23.31 - <u>Certification of the automatic pilot system</u>

In its exploration of the possible accident scenarios, the Commission has not been able to exclude

totally (see § 21.24, hypothesis no.3) the possibility of a failure of the Autopilot system, either at the level of the push-button flight path reference selector, or at the level of the transmission of the command value to the FMGC. It has considered this hypothesis as being of very slight probability,
but nevertheless has undertaken, beyond the case of the accident, a more general consideration of the certification of Autopilots, taking account of the importance of the subject.

23.311 - The principles of certification

23.311.1 - The document JAC 25-1309 (Joint Advisory Circular) provides the necessary elements of interpretation and indicates an acceptable means of demonstrating conformity with the requirements set out by the corresponding article of JAR 25 of the European certification regulations for automatic piloting systems in transport aircraft. The central concept of this interpretation is the association between the consequence of a failure and the maximum acceptable probability of occurrence.

Thus, this document defines the concepts of catastrophic, critical, major and minor consequence, and associates with them the brackets of probability of occurrence, defined by the limit values calculated and designated respectively: extremely improbable, extremely rare, rare, and probable. Thus, failures of major consequence must have a probability of occurrence of less than 10^{-5} per flight hour, failures of critical consequence a probability of less than 10^{-7} per flight hour, and failures of catastrophic consequence 10^{-9} per flight hour. The words "catastrophic", "critical", "probable" or "improbable" have a different and more precise meaning here than in the rest of the report.

23.311.2 - In their present design, the automatic pilot systems which equip transport aircraft do not detect certain types of failure such as a possible corruption of a command value selected by the pilot.

The certification document System Safety Assessment (SSA) of the FMGS on the A320 envisages in particular "failures with limited effect not detected by the system". The concept of limited effect concerns the resulting load factor and the lateral trim of the aircraft and relates to the only analysis of the direct effects of the failure of aircraft systems.

In fact, the more long-term consequences of these failures obviously depend on the capacity of the crew to detect and remedy their effects within a useful time, a capacity which depends on the supervision exercised by the crew. The study of acceptability of such failures by the certifier thus takes into account notably the possibility of correction of their effects by the crew, particularly in terms of the flight phase. This is verified during in-flight tests as part of a global evaluation of the aircraft/crew/procedures systems which considers: the fact that the failure was detectable or not, the time of its detection, the (outright) delay in crew reaction, and the effects of the corrective procedure carried out (correctly) by the crew.

At the end of this test, the failure is judged to be detectable or non-detectable. If it is judged to be detectable, its consequences are evaluated, taking account of the possibilities of action by the crew and the procedures laid down. If it is judged to be non-detectable, its consequences are evaluated without crew reaction.

23.311.3 - By way of example, in the course of processing certification of the A320, the principles reviewed above were applied to the evaluation of the FCU failure "corruption of the command value VS or FPA". The effects of such a failure are limited, in the sense defined above.

At the stage of in-flight evaluation, this failure was judged to be:

1) easily detectable
2) easily correctable.

It was therefore assumed that it would be taken in hand by the crew, and it was then shown that this type of failure could be classed as having "minor" consequences down to a failure occurrence height of 400 feet, and that it should be classed as having "major" consequences below 400 feet.

The estimated probability of these failures, such as is deduced from the analysis of the reliability of the systems (10^{-5} per flight hour) was thus compatible with the safety objective above 400 feet ("minor" classification). Below 400 feet, this probability is not compatible with the classification of consequences ("major"). The certifier then takes into account the fact that the time of exposure to the failure below 400 feet (about one minute in approach) reduces the real risk by an order of magnitude in relation to it which corresponds to the normal reference period (one hour), which makes the probability of failure acceptable in the case of "major" effects.

23.312 - Analysis of the experience in service

Concerning the identified cases of FCU malfunction which could be categorised under the heading "corruption of the descent command value selected on the FCU, not detected by the system and producing a stabilisation of the vertical speed to a value different from that desired by the pilot", the experience in service known at the end of the present investigation leads to a frequency of the order of 10^{-6} per flight hour (one case of defective FCU identified with certainty, having given rise to three instances of corruption, for about one million four hundred thousand flight hours).

This frequency noted does not call into question the formal demonstration of conformity. In fact the latter takes into account a non-detected FCU failure probability (which includes less than about ten other failure modes) of 10^{-5} per flight hour.

23.313 - Analysis of the certification principles

The Commission has enquired into the validity of the foundational reasoning, that is to say, the justification for the classification of the consequences of the failure of a vertical mode of the Autopilot of an aircraft of any kind in certain phases of flight, most particularly in intermediate and final phases of an approach procedure known as "standard".

It has been seen that the in-flight evaluation leads to judging the failure to be detectable or non-detectable. However, in all strictness, the detection of a failure by a crew after a given time is a probabilistic notion of the same kind as the occurrence of the failure itself. Converting it into a binary variable (detectable/undetectable) amounts to neglecting, in the evaluation of the consequences, those which are associated with the choice complementary to the one which has been retained. For example, to decide the FCU failure is "easily detectable" in Final Approach amounts to neglecting, in the estimation of its consequences, all those which are associated with its non-detection. In the same way, once the failure is recognised, its proper correction by the crew is likewise a probabilistic notion.

Now the consequence of a failure which remains unknown, or which is badly handled, is the probable loss of the aircraft. It would be appropriate, therefore, to make sure, in the course of certification, that the global risk corresponding to the occurrence of a failure that is not recognised, or that is recognised and badly handled, is acceptable, in the sense used today in the principles of certification, having regard to the consequences of these events.

The Commission is aware of the fact that, at the current state of knowledge, it could not be a case of dealing with a true quantification, comparable with that which allows the evaluation of the probabilities of technical failure (albeit with approximations and empiricism).

Nevertheless, the Commission considers it necessary for future aircraft to complete the current certification procedure for Autopilots. This is in effect reduced today to a subjective in-flight evaluation, carried out by test crews, in very specific conditions. The Commission has noted for example that if the principle lays down that these crews would not be warned of the failure, the practice of a test flight programme leads to a notably different reality.

The Commission thinks that this procedure should be completed by a more analytical consideration using the available knowledge (which, moreover, it is certainly necessary to develop) concerning the behaviour of the human operators. In this case, the certifier would be led to consider the supervision procedures defined for the crew, as well as the design of the aircraft/crew interface with respect to the means provided to the crew for recognising failure.

Finally, the Commission notes that, being concerned hypothetically with failures which are not the object of automatic surveillance, and thus not provided with associated alarms, the observations which it has formulated in paragraph 23.32 with respect to the certification of certain ergonomic aspects of the flight decks, and concerning the alerting ability of certain information, are equally applicable to the certification of Autopilots. In effect, the means which the crew has available for recognising an Autopilot failure without an alarm are the same as those which it has available for recognising its own command errors on the system.

23.32 – Certification of flight deck ergonomics

23.321 – Lessons learned from the accident and from in-service experience

23.321.1 – Having analyzed the way the accident happened with regard to the interaction between the crew and the aircraft (see especially § 22.3), the Commission came to the following conclusions:

(1) The concept of the plan of command and control of the Autopilot's modes and data for the vertical plane trajectory is such that:

- on the one hand the probability of confusion in the selected mode is greater in certain situations;

- on the other hand, the consistency between the selected mode and the selected target value's display unit is a vital safety element;

(2) The way the control and flight path data are presented in the vertical plane will give convenient information to a crew who are suitably aware of their flight path, but it does not have much chance of warning a crew whose performance was in error in this regard.

23.321.2 – Having examined possible lessons from hindsight, the Commission found that the preceding conclusions agree with the following factors:

- the existence of a greater margin of error in selecting Autopilot vertical modes during the initial instruction phase;

- the definite likelihood of a significant residual margin of error in service;

- the fact that there are cases in service where modes have been confused and where the crew has not detected this until a GPWS alarm was triggered or outside visual reference was made.

23.321.3 – With reference to the above, the Commission has been able to reconcile the various assessments that it has made of the aspects of the interaction between aircraft and crew, and the paragraphs referring to certification regulations (see § 118.12).

In particular, these paragraphs require:

— that the commands should be presented in such a way as to reduce crew errors to a minimum: it appears to the Commission that in the light of its analysis and the lessons of operational experience currently available, that the design of this command did not fully conform to the intent of these Articles;

— that flight and navigation information should be presented clearly and without ambiguity, and that the medium connected with observing the Autopilot should be designed so as to reduce crew errors to the minimum where such errors could create additional dangers: it appears to the Commission that from this vantage point, the way the data for controlling the vertical plane trajectory was presented did fulfil the objective of certification for normal situations, but probably did not in a situation where the crew's performance was in error.

23.322 — Principles and Method of Certification

23.322.1 — Paragraph 118.1 cites the principles of certification that apply to designing a flight deck, in particular regarding Autopilot commands for the flight path and regarding the instruments controlling this flight path. This paragraph also cites the manner in which the A320 was evaluated in the process of certification to see that the aircraft conformed to regulation requirements.

23.322.2 — On examining the extracts that apply to certification regulations, the Commission found that it was basically a question of regulating by objectives. Having analyzed the interpretative JAC documents, the Commission found that only a very small number of ergonomic aspects — such as the form of commands for the landing gear and flaps, or the way the commands were placed, were standardised. On examining the accepted methods for showing conformity, the Commission did not find any indication of any particular method of evaluation. The method of demonstration is dealt with and accepted within the confines of each certification.

23.322.3 – The Commission examined the way in which the certification process applied to the A320 put the above-mentioned regulation requirements into practice.

The Commission found that a particular effort was made to evaluate the quality of the interaction of aircraft and crew for flights intended to demonstrate minimal crew. In particular, a systematic summary of errors made and an analysis of these errors, a posteriori, have been carried out in this framework.

However, the Commission noted that the main thrust of this effort to justify a minimal crew of two pilots in the context of the tense social climate already referred to, was marked in the evaluation as having implications of unaccustomed tasks and managing
unaccustomed situations. Thus the Commission considers that even though evaluation methods were employed that on the whole more than complied with existing international practice, the process of certification for the A320 did not allow for the detection of peculiarities of design which only came to light during use, and which were indeed doubtful with regard to certain regulation objectives (for example, avoiding confusion).

The Commission also found that at the stage of specifying the ergonomics of the A320, and taking

into account the especially innovative nature of this machine in this area, the evaluations should have been carried out in conjunction with future base users, eg at the time of preliminary specification studies carried out in flight simulation. These evaluations should then have been available with sufficient warning to allow for more realistic choices of what conditions would be acceptable, within the programme's industrial timetable. This is much more difficult at the certification stage.

Finally, the Commission found that the methods employed at the certification stage give preference to evaluations of a subjective nature carried out by a limited group of pilots serving with the manufacturer or having official functions.

23.322.4 – The Commission therefore queries the ability of the regulations, principles and current certification procedures to provide the necessary guarantees in this area, especially in cases of particularly innovative designs.

As a result of this reflection, the Commission has listed certain aspects of the principles and of the current certification process which appear to be weaknesses in this regard:

— errors on the part of the crew are considered from the point of view of very general objectives (cf the regulation clauses quoted above), without differentiating between these errors according to how likely they are to occur, nor their consequences; the evaluations of the associated methods of observation, which are often the same as those used to observe correctly functioning piloting devices, are based on the theory that standard practice is used and that the specified procedures are being strictly enforced. It appears to the Commission that these theories do not necessarily correspond to the reality of service on the line;

— the evaluation of ergonomics conducted in the process of certification are almost totally the first impressions of test pilots and official pilots. In the opinion of the Commission, new-generation cockpits considerably reduce the predicting ability of this method, even when carried out by pilots designated by the launching companies, especially in the case of aircraft that are very innovative in all respects. Actually, the new interfacing produces new kinds of errors, especially of the kind that develop while pilots are learning and adapting. The pilots used certainly do not have individual experience of the new type of aircraft beyond the level of the initial

stages. Moreover, they have more thorough knowledge of the aircraft, and the purpose of their work is different to that of future every-day users. The methods of observation that they use and the types of errors that they are likely to commit are therefore different to some extent from those of service pilots in a routine situation.

— The administrative act of certification takes place long after the design process, at a time when major industrial choices have already been made. It is then extremely difficult for the certifying body to raise such issues. However, even if the certifying body's opinion is asked for at the beginning of the design stage, ergonomic aspects would not be reason enough for making changes at that stage. The weaknesses noted above concerning the predicting ability of current methods are actually made worse in this case, since the framework for prediction is less tangible, and only models and partial simulations are available. The subjective nature of individual first impressions makes them even more fragile as criteria for rejection, no matter how well qualified they may be.

Consequently, the Commission has come to the conclusion that an effort should be made to agree to re-adapt the methods used in the certification process to fit their purpose as regards ergonomics, more clearly redefining the regulation objectives and the related protocol for evaluation.

23.33 – <u>Approval of the on-board DME system</u>

23.331 – Analysis of in-service experience and conclusions

Having analyzed the possible involvement of F-GGED's DME system in the way the accident happened, the Commission came to the conclusion that if the system malfunctioned, this would neither have caused nor contributed to the accident.

However, using examination techniques in the analysis to detect possible malfunctioning of the Collins-700 DME, the Commission did ascertain the existence of multiple fault modes in this equipment.

When experts were used by the Commission to investigate whether a "sleeping mode" fault could have affected F-GGED's DME, inconsistencies and malfunctions came to light in the data recorded in non-volatile memory by the BITE software. These faults involved distortions of tables of values, which disturbed the functioning of the equipment,s operational software (see § 117.325).

Consequently, the Commission questions both whether the Collins-700 DME conforms to the technical reference regulations, and the process of approving this equipment.

23.332 – Approval of the Collins-700 DME

23.332.1 – Technical requirements in force

The points examined for the approval of radio equipment such as the DME cover fulfilling requirements of applicable technical conditions, environment, and finally software. The requirements for software are set out in the Radio Technical Commission for Aeronautics document RTCA DO 178 A and its European counterpart, the document EUROCAE ED 12 A.

This regulation allows for software to conform to different levels of quality depending on its greater or lesser importance. The lowest level allowed for is the "non-essential" level, whereby the main requirement is that should not interfere with the functioning of other software.

The technical findings reported in the preceding paragraph indicate that the lowest level for non-essential software of the RTCA DO 178 A document was not met by the Collins-700 DME BITE software.

These standards were not formally in force when the Collins-700 DME was approved. However, the new standards were developed specifically on the basis of this new equipment and its numeric technique. These standards were sufficiently developed at the time to be taken into consideration in the development and approval of the software for the Collins-700 DME, and there were no other standards for software.

Software checks as described in the document RTCA DO 178 A consisting mainly of the execution of integration and validation processes, would probably have detected the anomaly behind the sleeping mode before the equipment was put into service.

23.332.2 — The applicable approval process

Since the equipment was made in the USA, the main approving body was the FAA. In France, approval was granted by the STNA (Service Technique de la Navigation Aérienne — Air Navigation Technical Service).

The STNA checked for conformity as regards CTAs and the environment, but did not go on to check for conformity to software standards. For this, the DGAC therefore granted approval in 1982 on the basis of work done by the FAA.

The Collins-700 DME underwent one modification before being fitted to the A320 and other aircraft of the same generation. It was basically a case of adding the interface protocols of the A320's

CFDS system and replacing the MFM (Maintenance Fault Memory) with a BITE. This modification, recorded as 20558, was classified as "minor" and was approved in 1988.

Since the Collins-700 DME was familiar equipment already approved by a Technical Standard Order (TSO) when it was integrated into the A320, it was not given a specific safety analysis to see whether it worked properly. On the contrary, since this equipment was one of the FMGC's peripheral captors, its failure modes, the likelihood of their occurrence and the means of detecting them were included in the FMGC's safety analysis.

23.4 – The Function of the System from Hindsight

23.41 – Particularly in view of the difficulty of establishing the scenario of the accident, extensive and intensive investigations have been made in this Investigation to find any incidents that may have taken place in similar circumstances, either having led to or being likely to lead to an abnormally high rate of descent instigated by the crew. These investigations have led the Commission to consult enquiry bodies or collections of documented incidents from the countries that are the principle users of the A320, and to examine the testimony of several French pilots of this aircraft.

The results of these investigations are largely given in paragraph 1.17.6. During the investigations, the following came to light:

– at least two incidents have happened in the past that are very similar to one of the possible scenarios of the accident (confusion of the VS FPA mode). These happened in different countries, and neither the certification authorities nor the manufacturers nor other operators knew of them;

– such occurrences were often known to some or other information-gathering system, but their potential seriousness was not perceived, and more often than not the information available was not precise enough to provide an in-depth analysis or lead to any action being taken;

– incidents of an analogue nature happened in service on various types of aircraft where the crew did not think it necessary to give a report to their company or to the civil aviation authorities;

23.42 – Consequently it appears that scattered information did exist among A320 users about the frequency of confusion in managing the Autopilot's vertical modes, and the risks involved. At least one Operator had taken the preventative measure of forbidding crews to use the FPA mode, because the Operator did not wish to invest in the extra training that it felt was necessary. However, this information has never been expressed or centralised at the right level to tabulate the difficulties that have been encountered and to launch corrective measures.

23.43 – Of all the information sources used by the Commission (national and international databases supplied by systems of compulsory reports, confidential collections of voluntarily given reports, databases belonging to manufacturers or equipment suppliers), only one is judged capable of reliably supplying sufficiently detailed, complete and accurate information to allow in-depth analysis of incidents of this kind: a systematic analysis system for Flight Data Recorders used by one company, a system whereby any significant irregularity detected by the automatic system is sent for an in-depth operational analysis of the incident, if necessary obtaining information from the crew involved. However, concerns about safeguarding the extremely sensitive consensus of opinion arrived at by the management of this company led to the information that was collected not being spread outside the company. So far, then, the considerable safety potential of such measures has not been fully exploited.

23.44 – The general organisation and the nature of the French system as regards the benefit of hindsight (cf § 118.6) are a definite handicap to efficient functioning. The Commission lists the following aspects in particular:

– the regulations consist of reams of very unequal legislation that has not been revised as a whole since the Fifties, resulting in a mixed collection of rules that are almost incomprehensible to the parties concerned;

– the regulations do not lay down any explicit obligation, either on the pilot in command or on the Operator, to inform the SFACT, the service responsible for technical supervision of the Operators,
of any incidents occurring during operation.

Notification of any incidents is supposed to be given to the Accident Enquiry Bureau, regardless of the nature or the seriousness of the incident, and that does not reflect the reality of how the available information is handled;

— the position of references concerning incidents in the general layout of the texts suggests that their primary objective is not that of organizing the benefit of hindsight for the purpose of safety analyses, but rather for establishing the obligation of reporting abnormal occurrences for the purpose of investigations and salvage on the one hand, and on the other hand, disciplinary proceedings. This confusion between disciplinary action and the benefit of hindsight struck the Commission as especially likely to put a considerable damper on any initiative on the part of the crew to submit a voluntary report of incidents such as serious errors that were corrected before the consequences became perceptable from the outside;

— on the contrary, the plan of action contained no provision for guaranteeing confidentiality to anyone giving a voluntary report of an incident that would otherwise go undetected — no assurance that such a person would not be disciplined or dismissed as a result of his initiative;

23.45 — For the past few years, the French authorities have wanted to emphasise promoting organised gathering systems, on the one hand for industry from clients, and on the other hand within each user-company. Thus in its amendment regarding conditions for authorizing an Operator to use an aircraft of more than 40 tonnes with a crew with no Flight Engineer, the Order of 5 November 1987 (Chapter 12) made it obligatory to have systematic analysis of the recorded flight data. However, this obligation does not include the obligation to keep the DGAC informed of incidents that have been detected, except during the first year of service, and only as a one-off occurrence. Neither does it imply any obligation to carry out in-depth operational investigations into the circumstances and the mechanics of the more significant incidents.

23.46 —In summary, the Commission of Investigation finds that aeronautics is one of the few areas of activity that has a feed-back system for learning from hindsight. This provides searching results as regards dealing with technical problems. On the other hand, the Commission has become aware of the obvious limits of this system in operational terms. In this area, information is not often forthcoming, and even when it is, it is only seldom analyzed with all parties concerned participating. Moreover, the results of these analyses are generally not passed on to the manufacturer or administration.

CHAPTER 2.4 - SURVIVAL, SEARCH AND RESCUE

24.1 - Survival of the impact and the accident

24.11 - In this section, the Commission of Investigation analyses the conditions of preparation of the cabin before the landing, the causes of death of the accident victims and the state of the seats after the impact.

The characteristics of this accident, and especially the force of impact, do not correspond with a situation where survivors would normally be expected. More specifically, the decelerations sustained by the airframe of the aircraft and its level of fragmentation are such that the factors of individual survival are not accessible to any known modelling technique. Consequently, the lessons which may be drawn from such an accident concerning passive security are quite limited. The Commission has, however, undertaken consideration of this subject, while remaining strongly aware of the limits of the exercise.

24.12 - The instructions for cabin preparation before landing were applied and all the passengers were probably fastened in. However, one member of the company cabin crew personnel was not seated at the moment of impact. The security area for that crew member was located at the rear of the aircraft in the part where there were some survivors. The Commission has analyzed the sequence of operations to be carried out by the company cabin crew before the landing with respect to the moment when the operations should have been commenced in order for the PNC to be seated and strapped in under all circumstances in the final phase of the flight. The circumstances of this accident do not allow any conclusions to be drawn on this point, but a re-examination of these procedures could be useful so as to ensure that the chronology of these operations is indeed such that this condition can be satisfied.

24.13 - The Commission of Investigation notes that, despite the violence of the frontal shock which the aircraft sustained, nine people survived this accident. The examination of some seats has not allowed precise evaluation of the load factors to which they were subjected and has not yielded any significant additional details to explain the number and distribution of the survivors.

All of the victims suffered multiple traumas, very extensively in some cases. Certain types of injury however present with a particularly high frequency, and it appeared to be of interest to note them in order to discuss their possible relationship with certain characteristics of the seats or their arrangement in the cabin. These are injuries at head level, injuries at the pelvic girdle level and injuries of the extremities of the lower members.

The frequency and nature of certain injuries suffered by the victims has led the Commission of Investigation to examine the tests and inspections carried out by the manufacturer or the administration to ensure the compliance of this aircraft, in the configuration chosen by Air Inter, with the regulatory requirements concerning seats and safety belts.

The certification requirements concerning the passenger seats and the seat belts are laid down by the paragraphs JAR 25-785(a), JAR 25-785(c) and JAR 25-785(i) of the European Joint Certification Regulation. In the case of type certification, the passenger seats and the corresponding seat belts are not identified individually, as the equipment is, generally, chosen by the operating company. However, the requirements which are applicable to them are contained in a document, approved by the certification authorities, entitled "passenger seats: outline specification". For the individual certification of each aircraft, the airframe manufacturer submits a dossier for approval to the competent authorities in which conformity with the requirements for the type certification of the specific equipment on the aircraft is demonstrated.

The dossier submitted by Airbus Industrie for approval of the passenger cabin of the aircraft F-GGED (File ref MBBTLQ 21/135/03/88 Edition 4) refers, for the passenger seats, to the specification approved at the time of type certification (Ref 00D2520004/C01). The conformity of the aircraft to the certification requirements was confirmed by the inspection reports TLQ 21-562/12/88 and 10D021K4590S12. As far as the safety belts are concerned, they were recognised as conforming to TSO C22F issued by the FAA.

The Commission of Investigation has noted that the regulatory requirements were satisfied, but it has pointed out that the certification regulation

applicable in the case of the A320 (JAR 25 Revision 10) contains only statistical tests in relation to the seats. Since then, new technical conditions for passenger seats have been imposed in Europe and the United States, to reinforce the protection of passengers in the case of an emergency landing (JAR 25 Revision 13 published on 05/10/89). The statisical load factors have been increased and a requirement for dynamic testing of the seats has been introduced.

However, the Commission has been informed in the course of the investigation that the type of seat which was fitted on F-GGED had been submitted to the HIC (Head Injury Criteria) tests at a date subsequent to that of the accident, and had successfully passed these tests.

24.2 - Organisation of the search

Note: The Commission of Investigation has worked on this point starting from the reports established by the Centre d'Opérations de la Zone Nord-Est (Operations Centre of the North-East Zone) (global operations report SAR) and the Lower Rhine Prefecture (report of the meeting dated 14 February 1992).

24.21 - The Commission of Investigation has noted that more than four hours were required to find the wreckage from the moment when the alarm had been triggered. This fact clearly calls into question the ideas commonly accepted about searching for a heavy transport aircraft in a metropolitan area. It is explained in part by the characteristics of the accident site (snowy mountainous forest), by the conditions of its occurrence (winter night) and by the difficulties encountered during the search operations (weather conditions and the absence of signals from the radio distress beacon).

24.22 - Taking account of the environmental conditions (night, overhanging ridges, icing in the cloud layer, and the difficulty of using special vision equipment), it was necessary essentially to rely on the human resources available to locate the site with the emphasis on combing operations. The Commission of

Investigation therefore analyzed the way in which these ground search operations were conducted and the respective roles played by the Drachenbronn Rescue Co-ordination Centre (RCC) and the SATER Plan of Action directed by the Lower Rhine Prefect in the outline of the regulatory provisions laid down (see § 116.21).

24.23 - In the case of air accidents, the RCC handles the general conduct of the search. It has available adequate means to do this and qualified personnel capable of exploiting the information which reaches them. For this accident, the first information was transmitted to the RCC by the Strasbourg Approach Control Centre at 18h31 with the triggering of the alarm. The Approach Controller having indicated that the loss of radar contact had taken place between 8 and 9 NM in the 230 deg radial over the terrain of Strasbourg, the RCC, with the Prefecture, immediately (18h34) initiate the SATER 2 measur in the region of Mont Sainte-Odile.

It is from these initial elements that the RCC initiated, at 19h09, the SATER 3 measure in defining an initial search sector between Mont Sainte-Odile and Andlau, which it later extended at

19h30 to an area boundered by Mont Sainte-Odile/Barr/Andlau/Le Hohwald. The Commission of Investigation considers that the definition of this initial search zone was in keeping with the initial details known by the RCC (aircraft position north of the approach track at the termination of guidance, limits of radar precision, trace of the ground track axis, and reference scale of the procedure). The Commission notes, however, that it represented a large area (21 km^2) which necessitated the deployment of a large amount of manpower on the ground.

The Commission notes, moreover, that it needed 1h30 and 3h30 respectively for the radar recordings from Drachenbronn and Reims to be communicated to the RCC and for the RCC to be able to narrow the ground search area for the regular CP. This time seems to be excessive, taking account of the means of information processing available in the Centres (radar pursuit of flights, recording of flight data, playback programmes). Finally, certain foreign Centres could equally have been asked for this purpose (e.g. Karlsruhe).

The Commission also points out that for the first search area, the position given proved to be appropriate, (between Mont Sainte-Odile and Andlo), and was very quickly extended to a larger area before being progressively recentred on the first positin given. It has therefore enquired into the causes of this dilution phenomenon without being able to arrive at any precise answer. The concern for identification of the search area by the geographical reference marks easily identifiable by ground resources may represent part of the answer to this question.

The Commission notes finally that, despite the deployment by the Strasbourg airbase of an airforce officer to the regular CP of the Prefecture, the exchange of information between the RCC and the regular CP envisaged in the SATER Transport-Interior-Defence protocol paragraph 5.1.3 dated 08 September 1987 appears not to have functioned well, notably in the direction regular CP to RCC (the RCC was in fact only informed of two of the statements which had been received from the ground). This may arise from difficulties encountered at the regular CP for making a synthesis of the information received. The Commission has noted in this connection that the problems of co-ordination and reassembling of the information coming from the units engaged on the ground, notably to the regular CP and the SAR organisations had already appeared frequently in the SATER operations.

In terms of the information which it had available, it seems that the role of the RCC in specifying the ground search pattern was limited to some indications transmitted to the regular CP: Confirmation at 20h15 of the first pattern and request to send ground resources between the Landsberg Chateau and hill 826 (La

Bloss), and communication at 22h04 of the last known position by the Reims Centre and indication of La Bloss as the possible place of the accident.

24.24 - The conduct of the ground search operations was thus essentially ensured by the representatives of the Lower Rhine Prefect. A regular CP was immediately activated at the Prefecture. The operational CP was installed at Barr (20h45). The assembling of the SAMU firemen as means of assistance took place starting at 19h20 at the Obernai assistance

centre designated as the point of initial destination. The search there was directed by the commander of the police group of the Département together with the Deputy Prefect of Sélestat. The Commission of Investigation has not analyzed in detail all the entirety of the search operations which were undertaken and is not therefore in a position to give an adequately based global assessment in this regard. However, two points appear to it as needing to be noted.

First of all the extent of the ground searches to be launched, notably because of the fact of the large size of the initial search area (21 km^2) and the limitations imposed on the aerial resources, immediately exceeded all the resources of the police force of the Département. Reinforcements were requested starting from 19h30 from the mobile police force and the land army. Taking account of the calling and route delays, they were available in the area at 21h30 and 22h respectively. It was only after the arrival of these reinforcements that intensive combing operations were able to commence. It may therefore be asked whether it would not have been preferable, in the circumstances of this accident, to alert and mobilise large amounts of manpower starting from the initiation of the SATER/2 measure, so as to allow a more rapid and more complete implementation of the SATER/3 measure from its initiation.

On the other hand, if a large number of search operations had been launched during the first two hours by those in charge of operations, in terms of the elements available or diverse information, the search plan directed from the regular CP of the Prefecture appears only to have reached full effectiveness after the installation of the operational CP at Barr about 20h45 and from its assembly by those in charge of the different services. It is therefore possible that, at first, the decisions did not integrate all the information available at the time. This shows the importance of the speed of implementing the operational CP and manning it with all those concerned in charge, and also the importance of the choice of its implementation and the means of liaison with which it is equipped to communicate with the crews on the ground and with the other organisations.

24.25 - In summary, the Commission of Investigation notes that the emergency phases were initiated within the prescribed delays and the search operations were conducted in conformity with the texts in force. It has, however, noted the large delay in restoring the radar flight path of the aircraft, the delay in putting into effect the land strategy in relation to the large size of the search area and the difficulties encountered in exchanging information between the RCC and the Prefecture, notably in the direction regular CP to RCC.

23.3 - Analysis of the non-functioning of the radio distress beacon (RBDA)

24.31 - The radio distress beacon, destroyed in the impact, did not work. The type of beacon installed in F-GGED corresponded with the norms and recommendations of the ICAO and with the French regulations in force on the day of the accident. However, the operational test carried out on 9 April 1992 does not permit confirmation that, if the beacon had worked, the site would have been found much more quickly (see § 118.33).

24.32 - The Commission of Investigation notes, however, that the French and international regulations concerning the RBDA (described in § 118.3) were essentially orientated towards searching for light aircraft. In these types of accidents, the organisations responsible note in fact that these searches were extremely long and expensive. On the contrary, with the exception of ditching at sea or certain landings in desert areas, it was commonly admitted that in the case of a large transport aircraft accident, its site was found very quickly, taking account of the precision with which the flight paths of these aircraft are followed by the control services. These are considerations which explain why the norms for approval of this equipment were strongly influenced by an objective of price accessibility for general aviation. This also explains why, in the course of a generalised installation requirement, the French administration considered it possible to leave it up to the large-scale carriers to decide the conditions of installation and functioning of the RBDAs mounted on board their aircraft.

24.33 - The duration of the search operations for F-GGED seriously calls unto question this idea accepted by the carriers as well as by the Administration. This is the reason why the Commission of Investigation has considered it necessary, starting with its preliminary report, to recommend that the regulatory conditions for approval and installation on board aircraft of radio distress beacons with automatic triggering (RBDA) should be reviewed in order to ensure a higher probability of proper functioning after an accident. This recommendation adopted by the Minister has led to a modification of the order dated 5 November 1987 relating to the conditions of use of aircraft operated by an air transport company (order dated 12 January 1993). This modification introduces approval norms and installation conditions appropriate for diminishing the risks of damage and non-functioning in case of accident. However, the Commission points out that it would be appropriate also to set and to control the application of norms for the radius of these installations (notably emitted power).

24.4 – Organizing the Rescue

24.41 – In accordance with international practice as regards aviation accident inquiries (Appendix 13 of the International Civil Aviation Organisation), the Commission has only briefly analyzed rescue operations. It has done so using analytic reports carried out locally under the auspices of the Prefect, the Strasbourg Legal Medical Institute's report and various testimonies. The Commission felt it was useful to submit some thoughts on the way the rescue was organised on the one hand, and on the other, on the way the multiple trauma sufferers were treated.

24.42 – The choice of Obernai as the place to install the medical CP and one of the waiting rescue teams was based for the most part on weather conditions and the distance to cover from the town of Obernai to the different parts of the massif where the search was taking place, and was in any case limited. For the same reasons it was judged preferable to prioritise concentrating the rescue party without splitting it up. On the twisting and icy roads leading to Mount Sainte-Odile, it was actually very difficult to turn around, and it would have been very difficult for any advance party to be recalled immediately.

At first it appeared to the Commission that this choice might have held back the arrival on site of vital rescue resources, baring in mind the problem caused by congestion on main roads and by the condition of the roads (snow and black ice). Additionally, in the prevailing conditions, this could have made it more difficult to coordinate the various participants (rescue and police units at Barr and medical unit at Obernai).

On the other hand, regarding the choice of not sending an advance party until the search zone had been located, the Commission noted that the teams that were best trained for operating in serious multi-trauma cases arrived too late to be able to operate on-site and stayed on the main road to receive the injured. It seems that on-site operations were performed only by two military doctors of the 153e Regiment from Mutzig and one military doctor from the 124 Strasbourg-Entzheim air base, all three being independent of the medical and rescue Plan of Action. It seemed that at least two civilian doctors, one of them unidentified, also operated on-site. These are the doctors who were present on-site and who examined and authorised transport for one group of injured people in accordance with their disposition, the available resources and weather conditions.

24.43 — Finally, the Commission note that two victims who later died were still alive when the rescuers arrived. According to the Legal Medical Institute's report, they died, one from a state of shock aggravated by breathing difficulties, and the other from multiple injuries to the skull, abdomen and lower limbs. The autopsy failed to make it clear whether one of the deceased victims could have survived, neither was it easy to distinguish between the different factors leading to death. Finally, one of the injured survivors was evacuated in circumstances that would have greatly reduced his chances of survival if he had had serious internal injuries.

However, the Commission notes that rescue and salvage operations were carried out in accordance with the rules of rescue, the only reservation being that available axiological facts (emergency and disaster medicine) state that resuscitation, treatment for shock and making the patient comfortable on the spot, whatever the surrounding circumstances, is the best strategy for caring for victims of an accident.

24.44 — The Commission therefore considers it advisable to take this new knowledge into consideration and include it in the instructions given to personnel called to assist in this type of accident. Particular care needs to taken in instructing these people because waiting on-site with someone seriously injured is particularly painful for the rescue worker, whose natural instinct is to operate and evacuate the injured to get them out of surroundings that are considered unfavourable.

24.5 — Organizing Communication

Many of those involved in rescue and first aid operations complained of traffic problems that they were faced with on the access roads to Mont Sainte-Odile due to the presence of a lot of vehicles and because of weather conditions.

The movement of traffic was caused by media announcements of the disaster, and by appeals made by those organizing the search to town councils and associations, perhaps also by people overhearing communications among the parties in the search and rescue plan. The Commission of Investigation notes that some thought is probably needed with regard to communications and the mobilisation of the public, to provide for procedures and ways of using useful authorities and for informing the public, all the time strictly controlling access to the site of the accident.

CHAPTER 2.5 – RECORDING DEVICES

25.1 – Regulation on-board recorders (DFDR and CVR)

25.11 – Accident resistance

25.111 – The regulation DFDR and CVR recorders were damaged in the fire. The CVR tape was usable, but the DFDR tape had been completely destroyed.

These on-board recorders are the only ones intended for investigations. These should resist fire under conditions defined in the certification process.

It would therefore appear necessary to attempt the answer the following questions:

- did the model of DFDR on F-GGED conform to certification standard?

- where the temperatures to which the DFDR was subjected higher than in the standards?

- should the certification standards be revised?

25.112 Regarding the first question, the Fairchild F800 was given offical certification in several countries. The NTSB indicates that it resists worse fires (satisfying the most recent ED 55 standards) than those defined in the TSO C51a standard for the kind of recorders likely to be used of F-GGED (this standard dates from 1966).

Extract from TSO C51a:

"The recording medium should remain intact so that information be analysed after the recorder has been exposed to flames at 1100 degrees C enveloping at least 50% of the outside surface of the box for the following periods of time: Type I – 30 minutes – Type II – 15 minutes – Type III – 1.5 minutes."

Extract from ED 55

"Fire:

a. The recorder should be subjected to fire producing minimum thermal flux of 158 kW/m^2. The whole of the

outside surface of the recorder should be exposed to fire for a continuous period of at least 30 minutes. An absorption constant may be applied. (...). No screens are permitted.

NOTE: Manufacturers of the equipment are strongly urged to give the greatest possible protection against fire, for more than the period of 30 minutes provided for in this MOPS.

b. The temperature of the flame should be 1100 degrees C (nominal), measured at a distance of 25mm (one inch) from the surface of the recorder. The configuration of burning should give a thermal flux as defined in a.

c. Before being tested by fire, the recorder should have been prepared at a stable internal temperature corresponding to the temperature it would reach when functioning in an atmospheric temperature of 25 degrees C, plus or minus 5 degrees. The electronic components outside the memory module that is protected from the crash should be disengaged.

d. The recorder should be allowed to cool naturally after the test by fire.

e. The protection of the recording medium may depend in whole or in part on a thermal barrier which does not work efficiently below a critical temperature as long as it takes care of the maximum temperature at which the recording medium can survive. The survival of this medium should therefore also be demonstrated at a minimum efficient temperature for the thermal barrier during a certain period. This period should be at least 30 minutes increased by a factor proportional to the relationship between the minimum efficient temperature of the thermal barrier and the maximum survival temperature of the recording medium.

f. If the efficiency of the anti-fire protection material diminishes while the recorder is in normal use and/or while it is stocked, the material should be taken to its minimum acceptable protection level by means of prolonged cycles of applying pressures and temperatures, for example."

25.113 – Regarding the second question, experts have been able to show that the DFDR's box had been

subjected to fifteen minutes of high-intensity fire (temperature above or equal to 700 degrees C), then five to six hours of a lower-intensity fire (average temperature estimated at 260 degrees C). It should be added that the examinations to which the parts of the recording system were subjected showed that the inside of the box must have been subjected to a temperature of 430 degrees C for around forty-five minutes (see § 112.151). These values for temperature and duration are higher than the values specified in the certification standard. The constraints to which this recorder was subjected were therefore out of the ordinary, from this point of view.

25.114 – Regarding the third question, the Commission has observed that the incident in question is not an isolated incident. Checks of the recorders from other accidents, instruments that also satisfy the most recent standards, show that these standards ought to be reconsidered, particularly as regards resistance to fires of long duration.

NB: The QAR and the non-volatile memories of certain on-board computers have provided recorded data that were used in this Investigation, but unlike the regulation recorders (DFDR and CVR), they were not subject to any standards of protection for accident conditions.

25.12 – Recorded information

25.121 – Flight data recordings

The data recorded by the DFDR were also recorded by the QAR (the same data and the same recording samples). This is the reason why the thoughts that have come up as part of this Investigation regarding the quantity and quality of the information available on the QAR recording have a direct bearing on the choice of frame for recording data.

At the time of the accident, the applicable standard for aircraft such as the A320 was set at a minimum recording frame of twenty-five parameters. Actually, the DFDRs on the A320s record more than two hundred parameters.

In spite of that, reconstructing the circumstances of the accident was made more difficult by the fact that certain data mainly relating to the management of the flight (FCU command) and flight surveillance (the display of flight information on CRT screens) were not recorded. Resorting to simulation methods (eg comparing the recorded values of certain flight data of F-GGED with simulated behaviour as a result of different hypotheses of command) and to using the contents of certain non-volatile memories made it possible to piece together most of what was missing, without, however, casting light on all the important information. By way of example, it was not possible to find out which displays the co-pilot had selected on his navigation screen.

It is noted that the new specifications in this regard (ED 55) cover these concerns (see § 118.42). Nevertheless, aircraft built before these standards were included in national regulations, unless some action is taken, remain at the previous standard.

25.122 – Recordings of conversations and alarms sounding

The difficulties encountered in deciphering the words of the two pilots as recorded on the CVR (see § 112.134) have been mentioned. This problem is often encountered in investigations. At present, in the absence of other technical solutions, one solution would be to use hot mikes, and the most recent international work (ED 56) confirms that they are efficient in making the words of the pilots comprehensible.

25.123 – Recording visual information in the flight deck

At present there is no means whatsoever of making known with any degree of certainty the information that was displayed on the FCU and the flight and navigation screens prior to an accident. Neither is there any record of the actions and any non-verbal communication by the pilots.

Bearing in mind the importance of this information for finding out about and understanding the circumstances of an accident, it would be appropriate to study the idea of visual recordings on protected media.

25.2 – Ground recorders

<u>25.21 – Radar Information</u>

The radar picture provided of the approach to Strasbourg was not recorded. The lack of local radar recording at Strasbourg meant that images of the tracks supplied by this station to the Approach Controller were not available.

In France, nine Approach Control Centres are equipped with a system for recording their local radar: Bâle-Mulhouse, Bordeaux, Marseille, Nice, Orly, Pointe à Pitre, Roissy, Satolas and Toulouse. Having this kind of system would probably have made it"possible to fine-tune the understanding and analysis of the conditions under which the radar guidance was given.

It would therefore be appropriate to equip all Approach Control Centres that have a local radar, with a radar recording system.

25.22 – Radio Communications

The Radio-communications that are established between air traffic organisations and the aircraft they are dealing with, are recorded. In the case of F-GGED, no technical difficulty was experienced in making use of these recordings.

25.3 - Co-ordinating Administrative and Judicial Procedures

The outline for co-ordinating administrative and judicial investigations is described in § 118.5. The Commission of Investigation has found that even though there was a preoccupation on the part of the judicial authorities with following the strict letter of some documents (particularly as regards recording devices), the technical investigators were generally able to take the necessary measures on the ground, and it would seem that no significant data were lost as a result of these procedures.

However, the Commission of Investigation has found that this outcome was more the result of chance and of the calibre of contacts established and maintained on

the ground between the administrative and judicial authorities, than the result of institutional collaboration set up by the inter-departmental order of 3 January 1953 which does not apply to the judge. In his procedures, a judge does in fact tend to give preference to rigorousness in seizing instruments. This could sometimes be disastrous to their preservation unless certain safeguards are seen to immediately.

It would therefore be appropriate for those responsible for administrative and judicial investigations to make full use of the lessons of real-life experience from this accident and to set up a judicial framework allowing technical investigators access for the purposes of researching and preserving vital instruments before they are impounded with the best possible assurances of being preserved, within a judicial procedure which nonetheless cannot be contested.

SECTION 3

C O N C L U S I O N S

CHAPTER 3.1 - FACTS ESTABLISHED BY THE INVESTIGATION

F-GGED held an separate and valid Certificate of Airworthiness.

It was maintained in compliance with the regulations in force.

During the entirety of the flight which led to the accident it was within the limits of mass and load distribution.

It was in an airworthy condition with no known failures.

On this type of aircraft anomalies relative to the processing of VOR data by on-board systems had been notified. They had formed the subject of an Notice to Airmen (NOTAM) and of an operational procedure. The Investigation did not find evidence of any malfunction within the processing system for VOR data, nor any sign that the crew had noticed flutter in the VOR indication resulting from such malfunction, in the course of the alignment phase to the approach path before descent towards the runway.

Faults likely to affect the operation of DME systems of the type installed on F-GGED had been identified. They had formed the subject of a Notice to Airmen and of an operational procedure. Modifications specified by the equipment manufacturers had not yet been made to the DME equipment of F-GGED. However, on the basis of technical data available, the Investigation was able to refute the theory that a failure associated with "deaf mode", "sleeping mode" or "jumping mode" had occurred around the moment the decision was taken to place the aircarft in descent mode towards the runway.

Anomalies in the FCU on the A320 were notified some months after the accident. The Investigation did not find evidence of any malfunction of the FCU installed on F-GGED. Nevertheless, it was not possible to rule out the hypothesis of a failure in the push-button which controls the change of mode, or of a corruption in the target value displayed by the pilot on the FCU before it was captured by the Autopilot computer.

F-GGED was not equipped with a Ground Proximity Warning System (GPWS).

The STR VOR ground station was functioning normally. The flight inspection showed that the characteristics of the signal transmitted were within the tolerances sanctioned by the ICAO. However, irregularities due to the recombining of the direct signal and signals reflected by areas of high ground were discovered in the approach path sector, between 9 and 8 NM from the STR station. These irregularities were of such a kind as to give rise to fluctuations in on-board indications after the aircraft was put into descent mode, on the segment corresponding to the trajectory, especially as F-GGED's flight path was abnormally low over the scan horizon of the ground station.

The VOR-TAC 05 approach procedure to Strasbourg is derogatory in three areas, owing to the constraints imposed by the Strasbourg air traffic environment and the surrounding mountains. In particular, the Intermediate Approach segment does not contain a level section.

The crew possessed the statutory certificates, licences and Type Ratings necessary to complete the flight. On Airbus A320s, the Captain had 162 hours experience, the Co-pilot 61 hours.

Toxicological analyses showed the Captain's blood alcohol level to be nil, while the Co-pilot had a level of under 0.30 g/l.

The Captain was the pilot at the controls.

The crew had planned to carry out an ILS 23 approach followed by a visual manoeuvre for runway 05 which was in use. The Controller, for his part, was expecting them to carry out a direct VOR-TAC 05 approach.

During the arrival phase, after the aircraft had passed ANDLO and the crew had signalled their intention to carry out an ILS 23 approach followed by a visual manoeuvre for runway 05, the Controller informed the crew that this would not be possible until a delay had elapsed due to three IFR departures on runway 05.

Up to this moment, the crew and the Controller were not aware of the differences in their respective plans.

The crew changed its strategy and chose to carry out a VOR-TAC 05 procedure in order to avoid the announced delay.

To shorten the VOR-TAC 05 procedure, the Controller suggested the crew be given radar guidance to take them to the ANDLO point. The crew accepted this proposition.

Radar guidance did not enable the crew to align the aircraft on the approach track to ANDLO.

Once authorised for Final Approach, the crew began the descent, even though the aircraft was still approximately ten degrees to the left of the approach track.

The descent commenced at 11 NM from STR TACAN, i.e. at the nominal published distance.

The aircraft's vertical speed stabilised at 3,300 ft/mn, instead of the figure of approximately 800 ft/mn corresponding to the glide path complying with the published procedure for the nominal approach speed.

The flight mode utilised for the final turn and the descent was a "selected" Autopilot mode. The flight path reference was not modified between the final turn and the exact moment of the accident and it was almost certainly an HDG-VS reference.

The auto-thrust was in SPEED mode.

At the exact moment of the accident the aircraft was in configuration 2, with the gear down.

It was night time and the aircraft was flying in conditions of zero visibility.

The aircraft crashed into La Bloss mountain, which has a height of 826 m (2,710 ft). The point of impact is located at an altitude of 799 m (2,620 ft), approximately 0.8 NM to the left of the runway approach track, 10.5 NM from the threshold of runway 05, and 8.2 NM from the STR VOR and TACAN ground stations.

Cabin preparation procedures for landing had been carried out and all the occupants of the aircraft were seated with their seat belts fastened, apart from one member of the cabin crew.

Nine people survived the accident.

The Emergency Locator Transmitter was destroyed on impact.

Search operations culminated in the discovery of the aircraft a little more than four hours after the accident.

CHAPTER 3.2 - DIRECT CAUSES OF THE ACCIDENT

In analysing the direct causes of the accident, the Commission reached the following conclusions:

32.1 - Due to ambiguities in communication between the crew and Control, the crew were late in modifying their approach strategy. They then let themselves be guided by the Controller, relaxing their attention particularly with regard to the way in which they plotted the aircraft's position. Also, they did not adequately anticipate preparation of the aircraft's configuration for landing.

32.2 - In this context, and due to the fact that radar guidance carried out by the Controller did not bring the aircraft to a position which allowed the acting pilot to align the aircraft on the approach track before ANDLO, the crew was faced with a sudden intensive workload to enable them to make the necessary lateral adjustments, prepare the aircraft's configuration and put it into descent.

32.3 - The pivotal event in the sequence leading to the accident was therefore putting the aircraft into descent mode at the correct distance specified by the procedure, but at an abnormally high rate of 3,300 ft/mn instead of approximately 800 ft/mn, and the fact that this abnormal rate was not corrected by the crew.

32.4 - The reason for the occurrence of this unusually high rate of descent could not be established by the Investigation with any degree of certainty. Among all the hypotheses it explored, the Commission retained the following, as they appeared to be the ones which called more particularly for wider consideration and preventive measures:

32.41 - the (quite probable) hypotheses of a misunderstanding involving vertical mode (resulting either from an omission to change the trajectory reference, or from poor execution of the command to change it) or of an error in displaying the consigned value (mechanical digital display of the numeric value given out during the briefing).

32.42 - the (very improbable) hypothesis of a malfunction of the FCU (fault in the push-button used for changing mode or corruption of the consigned value displayed by the pilot on the FCU before it is captured by the Autopilot computer).

32.5 - In all of these hypotheses retained by the Commission, the accident was made possible by the crew's lack of perception of the resulting discrepancy in the vertical trajectory, as evidenced primarily by a particularly obvious rate of vertical speed which was four times higher than the reference value, an abnormal pitch-down attitude, and an increase in speed over the flight path.

32.6 - The Commission attributes this lack of perception by the crew to the following factors, which are arranged in no particular order of importance:

32.61 - below average crew interaction, characterised by a distinct lack of mutual checks and monitoring of the results of actions delegated to automatic equipment. This lack manifested itself especially in terms of disregard for a large proportion of the call-outs specified by the Operations Manual and the absence of height/distance checks laid down for the execution of a VOR DME approach;

32.62 - an atmosphere among the crew characterised by minimum levels of communication;

32.63 - the ergonomics of presenting control parameters for the vertical flight path, appropriate for normal situations, but not possessing a warning capability sufficient for a crew in a situation where there is a display error;

32.64 - belated modification of the approach strategy, induced by ambiguities in communication between the crew and Control;

32.65 - slackening of the crew's attention during the radar guidance phase, followed by a sudden intensive workload which led them to pay disproportionate attention to horizontal navigation and the setting of the aircraft's configuration, and to hand over vertical navigation completely to the automatic equipment of the aircraft;

32.66 - the fact that during the alignment phase on to the approach track, the two crew members focussed their attention on horizontal navigation and failed to monitor the vertical flight path being flown in automatic mode;

32.67 - the absence of a GPWS together with an appropriate usage protocol, which deprived the crew of one final warning opportunity concerning the serious irregularity of the situation.

32.68 - in other respects, and notwithstanding the hypothesis of FCU malfunction, the Commission considers that the ergonomic design of Autopilot command sequencing in the vertical plane could have had a part to play in the origin of the accident scenario. In fact, this design appeared to the Commission, particularly in cases involving sudden and significant workload, to be axiomatic in increasing the probability of certain utilisation errors.

CHAPTER 3.3 - OPERATING CONTEXT

In assessing the operating context of F-GGED, the Commission noted:

33.1 - the deficiencies in the national and international system for applying the lessons learned from experience, essentially in the area of operational utilisation of aircraft. An essential safety element, this system relies on the active collaboration of pilots, companies, manufacturers and the authorities. Here certainly, the gathering and distribution of information are manifestly inadequate;

33.2 - the absence of a national regulation making it mandatory for aircraft to carry a Ground Proximity Warning System;

33.3 - the limited amount of experience acquired by both pilots on this type of aircraft, and the absence of regulations or national/international guidelines on this subject;

33.4 - the inadequacy of technical control exercised over Air Inter by the authorities, which are poorly equipped to detect possible drifts in operation (for example, with regard to checklist call-outs);

33.5 - indications that over the passage of time the practice of call-outs taught during Type Rating courses becomes more lax;

33.6 - the low number of "conventional" approaches in Type

Rating and line familiarisation programmes, together with the limited practice of these types of approach in normal operation;

33.7 - the lack of uniformity in current interpretations of the certification regulations and of the accepted means of demonstrating compliance associated with them, with respect to ergonomic problems affecting the aircraft-crew interface raised by the latest generation of flight decks.

CHAPTER 3.4 - SEARCH AND EMERGENCY OPERATIONS

With regard to search and emergency operations, the Commission noted:

34.1 - that several people survived despite the extreme violence of the impact;

34.2 - the destruction on impact of the Emergency Locator Transmitter. This device was thus unable to play any role in the search operations;

34.3 - the poor weather conditions which hampered search operations;

34.4 - the length and difficulty of search operations which invalidates accepted ideas concerning the ease of finding the wreckage of a large transport aircraft;

34.5 - the difficulties of co-ordinating search resources and the time required for ground search personnel and equipment to get up to the accident site in sufficient numbers;

34.6 - difficulties encountered in the organisation and conduct of emergency operations, leading in particular to the non-intervention on the site of medical teams specialising in the treatment of serious multiple traumatisms;

34.7 - the hindrance caused to emergency operations by congestion on access routes to Mont Sainte-Odile.

Section 4

STEPS TAKEN AND ADDITIONAL RECOMMENDATIONS

Foreword:

The following recommendations convey the information that the Commission believes can be drawn from its analysis of the accident, in order to improve aviation safety. They have been formulated with reference to in-depth investigations, and are thus based on knowledge and understanding which may be considerably different from the knowledge and understanding the various parties had access to prior to the accident. On the other hand, in these measures, the Commission has chosen to err on the side of safety. For this reason it has not restricted the scope of its recommendations solely to the points connected with the accident relative to direct or demonstrable causes, neither has it chosen its main line of thought based on the only hierarchy of probability that it has been able to link from other sources to the various theories of the scenario.

CHAPTER 4.1 – RECOMMENDATIONS CONCERNING THE CREW

41.1 – Information from the crews regarding the conduct of the flight at the time the descent began

On 20 February 1992 the Commission approved "the first provisions taken immediately by the DGAC to inform the Operators of the risk of confusing the Vertical Speed and Flight Path Angle modes, and asking them to check the protection afforded by their working procedures as a crew, their documentation, and the crews' knowledge."

To explain the descent at an unusually high rate, the Commission has retained several theories, including the theory of an unintentional command by the crew, as a result of an incorrect knowledge of the Autopilot vertical mode. This theory encompasses several variations, mainly concerning the choice of vertical guidance mode, its command, and its control by the crew.

It would therefore appear to be necessary to ensure that adequate procedures for the conduct of the flight are taught to the crews.

Accordingly, the Commission of Investigation confirms the preliminary recommendation of 20 February 1992 quoted above.

41.2 – Matching crews

The Investigation has shown the lack of relevant experience of the two pilots of F-GGED (162 hours and 61 hours for the captain and co-pilot respectively). From other sources it has established a probable link between this lack of experience and the fact that the pilots were unaware of the serious error of their vertical situation. More generally, accident statistics and ergonomic studies alike indicate that about one year's relevant, active experience is necessary to acquire a fully mature understanding and knowledge of new-generation aircraft. Thus, forming a crew using two inexperienced pilots constitutes an increased risk factor.

When a company brings in a new aircraft type, all its pilots are inexperienced. Later, however, it is possible to see to it that the total experience of the crew is above a certain threshold. Current French regulations do not include a clause encouraging or obliging Operators holding a public transport licence to ascertain how much relevant experience on type pilots have, when matching up crews.

Consequently, the Commission recommends:

– that Operators should study and apply methods of managing air crew personnel to prevent, as far as possible, selecting two pilots both of whom lack experience with the particular type of aircraft;

– that the DGAC, in conjunction with the competent authorities in Europe and the relevant international bodies, should apply appropriate measures to encourage this and, if necessary, further develop regulations in this regard.

Note 1: Since April 1992, Air Inter has enforced a regulation regarding the composition of crews, forbidding the selection of crews consisting of two "novice" pilots on the A320. A pilot with fewer than 300 flying hours on the A320 is considered a "novice", and this minimum is increased to 500 hours if the pilot has less than 1000 flying hours in total, either as captain or co-pilot before entering the A320 sector.

Note 2: As one notable result of an NTSB recommendation of 3 November 1988, the FAA published an NPRM (Notice of Proposed Rule Making) on 23 March 1993 regarding minimum experience required for pilots of flights covered by the regulation FAR 121.

41.3 – Teaching the So-called "Standard" Approaches

It emerged from the Investigation that there was a certain reticence on the part of the captain as regards a VOR-DME approach, as well as some evident deficiencies in the execution of this approach on the part of the crew. It also emerged that the training received by the two pilots when they qualified for this aircraft type was more geared towards automatic approaches and failures, than towards "standard" approaches. On the one hand, the execution of these approaches can be just as challenging on the latest generation of aircraft, and on the other hand, the infrequence of their occurrence in service tends to lead to a resultant lack of training.

However, the present criteria for approving courses giving qualifications for an aircraft type, do not include specific requirements in the area of the "standard" approach.

Consequently, the Commission recommends:

– that the DGAC should encourage the relevant bodies to emphasize so-called "standard" approach training both

quantitatively and qualitatively, by defining regulated minimum levels appropriate to the qualification for the aircraft type and to the refresher courses, and a desirable minimum for the in-service cross-training programme.

41.4 – Simulator Practice for Anomalies Linked to On-board Software and in EFIS.

Analyses carried out while attempting reconstruct the scene of the accident have led to speculation concerning errors on the part of the on-board software or the EFIS (faults concerning VOR or DME information, the navigation map, the FCU, etc). Some of these errors are acknowledged on the certificate together with the related criteria on the understanding that the crew will recognise these and handle them appropriately. This assumes that courses leading to a qualification for the aircraft type and refresher courses cover these aspects appropriately.

However, the directory of failures currently available on flight simulators does not allow for simulating some of the anomalies mentioned above.

Consequently, the Commission recommends:

– that training courses and tests should be revised to include scenes of faults in specific situations using on-board software and EFIS, based on experience;

– that the relevant authorities approving simulators should undertake to revise the proposed directories of failures to take into account specific faults connected with on-board software and EFIS.

41.5 – Transition from Classic Aircraft to New-Generation Aircraft

The two pilots of F-GGED had no experience whatsoever of new-generation aircraft before beginning their training on the A320. Moreover, their previous experience was of aircraft piloted by a crew of three. In the opinion of the Commission, this amounts to a major new experience, hardly comparable to coming onto a new type of aircraft of the same generation. In this regard the Commission has noted the existence of a

preparatory module in Air Inter's training course (known as STAN), before actual qualification for the aircraft type. The Commission agrees with the principle, however with a few provisos (cf paragraph 23.134) concerning its heavily technical, theoretical content and presentation.

Consequently, the Commission recommends:

– that when an Operator introduces an aircraft or equipment involving a major fundamental change in operational techniques, the Operator should ensure preparatory training is given covering at least:

1) the principles of the concept, architecture and philosophy behind using the new systems;

2) the effects of the new innovation on how the crew work together, new division of tasks, communication between the crew on the aircraft and the ground crew;

– that this training should be based around a practical, operational presentation of the new functions;

– that the relevant bodies approving courses leading to a qualification for the aircraft type and the methods of crew training ensure that these principles are put into effect.

Note: With effect from September 1993, Air Inter has decided to amend the contents of its cross-training course for new aircraft (STAN) to present it as less academic and more geared towards operating new-generation aircraft.

41.6 – Training in Human Factors

Analysing the behaviour of the crew of F-GGED has shown considerable deficiencies in the areas of communication, division of tasks, cross-checking and observing the automatic functions. In fact, in the Commission's view, the crew's teamwork was one of the main factors in the accident.

French regulations do not at present legislate on training crews in the area of human factors, in particular the management of the resources available in the cockpit.

Consequently, the Commission of Investigation recommends:

– that theoretical and practical training in human factors should be introduced into the initial training a transport pilot receives, for example as specified in Appendix 1 of the ICAO;

– that Operators holding a public transport licence

should quickly introduce "CRM"-type (Cockpit Resource Management) complementary training courses for all their pilots, if possible right from the stage of qualifying for the aircraft type;

– that the relevant bodies make appropriate arrangements for incentives and regulations to bring this about;

– that tests of competence carried out by the Operators and in-flight testing carried out by the authorities should include how well the crew works together, as main testing criteria.

41.7 – General Comments on On-Board Announcements

The Investigation showed that during the flight that ended in the accident, there were significant deviations from the procedures for announcements required by the company. It emerged in the analysis that a lack of announcements could have contributed to the lack of manual checks and therefore the knowledge each pilot had of the actual situation.

More generally, it appears that in the airline's every-day practice, the average reproduction quality of announcements could be lower than intended, although the extent of the phenomenon and reasons for it are well known. Manual checks are by nature vitally important to safety, especially on the latest generation of aircraft.

Consequently, the Commission recommends:

– that a study of the everyday practice of announcements should be undertaken, together with analysis of the reasons for violations by novices in this area, and a study of sufficiently stable methods and procedures within the time for monitoring automatic functions at high altitudes, as well as for cross-checking within the crew.

CHAPTER 4.2 – RECOMMENDATIONS REGARDING GROUND PROXIMITY ALERT DEVICES

42.1 – Points on the Regulations Regarding the Carrying of a GPWS

As early as 20 February 1992 the Commission recommended that "French regulations should be amended as soon as possible to make it obligatory for air transport aircraft to carry a Ground Proximity Warning System (GPWS) under the same technical conditions as those laid out in paragraph 6.15 of Appendix 6 of the Chicago Convention."

Taking into account the decision made by the Minister on 24 February 1992 following this recommendation, in 1992 Air Inter has equipped its entire fleet with GPWS.

In addition, the order of 5 November 1987 relating to the conditions of using aircraft operated by an air transport company was modified by the order of 12 January 1993. The paragraph quoted below has been inserted:

"Any aircraft fitted with turbine engines, for 31 or more passengers, or having a certified maximum take-off weight greater than 15000 kg, must be equipped with a Ground Proximity Warning System. This device must be capable of generating alarms, warning of excessive proximity to the ground, an abnormally high rate of decent, a loss of altitude after take-off or Go-Around, and an abnormal deviation below a glidepath descent beam (glideslope).

The analysis carried out for paragraph 22.36 does not conclude that the presence of a GPWS on board would have made it possible to avoid the accident. However, it does show that statistically, carrying this equipment is beneficial, and that with modified procedures, it is very likely that the crew would have responded positively to the alarm.

The Commission of Investigation thus confirms its preliminary recommendation of 20 February 1992 quoted above.

42.2 – Training of crews; Concept of Air Traffic Procedures

Simulations carried out for the Investigation into the accident involving F-GGED showed that the aircraft's rate of advance is a decisive factor as regards the risk of untimely triggering of alarms, which can greatly reduce the crew's confidence in the system.

Certain controlled flights over the same landscape have led to accidents even though a GPWS was operating on board and it had given an early enough warning. Other incidents happened in which the GPWS had been taken out of service, either deliberately or because of a maintenance problem. This could be for various reasons: lack of interest in the system, distrust of false alarms, or the crew did not react immediately to an alarm because it went against the crew's understanding of the situation at a given time.

In addition to fitting the equipment, a series of measures should also be taken to define more clearly the instructions for operating the aircraft, to ensure that crews are trained as regards what action to take in the event of a false alarm, and to modify air traffic procedures by way of eliminating possible instances of false alarms.

Consequently, the Commission recommends:

– that airlines develop procedures for operating the aircraft and practical training tailored to Ground Proximity Warning Systems;

– that in developing their procedures, air traffic organizations should take into account criteria for triggering alarms of on-board Ground Proximity Warning Systems, and that Instruction No. 20754/DNA should be amended accordingly.

42.3 – Ground-based alarm system for excessive proximity to the terrain

A ground-based system born out of the MSAW (Minimum Safe Altitude Warning) concept and already in operation in some countries, is currently being studied in France. The purpose of this system is to permit the controlling body to inform the crew of an aircraft as early as possible if it is flying too low in relation to the terrain.

Putting such a system into effect should reduce the occurrence of "Controlled flights into the ground", since there would be more than one means of detecting dangerously low altitude relative to the terrain.

Consequently, the Commission of Investigation recommends:

– that a real effort should be made to conclude as soon as possible both the study and the implementation by air traffic services of a Below Minimum Altitude for Terrain ground-based detection system, wherever this is technically possible.

<u>CHAPTER 4.3 – RECOMMENDATIONS CONCERNING INSTRUMENTS</u>

43.1 – Durability Standards for Regulation Flight Recorders

Use of the DFDR Flight Data Recorder on F-GGED was rendered impossible when the magnetic recording medium was destroyed in the fire.

Examinations carried out on the DFDR have established that it complied with applicable standards, which are criteria for resisting fires of medium or low intensity but continuing for a long time, as covered by the standards of protection (including the most recent ones, ED 55). These standards have proved to be insufficient. Fires such as these could occur especially when it may take several hours to locate the accident and transport fire-fighting equipment to the scene, as was the case with F-GGED.

This instance of the tape being destroyed by a fire of low intensity but of long duration is not unique. Similar cases have been mentioned in the remarks and recommendations supplied by the NTSB in this regard, to the FAA in May 1992.

Consequently, the Commission recommends:

– that the relevant body should undertake a study, liaising with industry and international regulatory bodies, to ensure greater protection for regulation flight recorders against fires of low intensity and long duration.

43.2 – Standards for Recorded Flight Data

Some flight data were missing in the analysis of the accident, so it was not possible to base the scenario on specific factors from the data.

The new standards (ED 55) provide for recordings as being of vital importance, but these standards were not enforced by the Order of 12 January 1993 amending the Order of 5 November 1987, except for aircraft whose first flight takes place after 31 December 1994. Consequently, unless additional legislation is made, a large number of aircraft fitted with a DFDR satisfying the previous standards (TSO-C51) are in danger of retaining this equipment, which has been demonstrated to be inadequate.

Consequently, the Commission recommends:

– that the DGAC, together with the international regulatory bodies, should study

ways of extending this new legislation to aircraft that are subject to having this equipment on a compulsory basis and that make their first flight prior to 1 January 1995.

43.3 – Standards for CVR Sound Quality

It required extensive study to make out F-GGED's CVR because the crew's conversations were scarcely intelligible, recorded as they were by an omni-directional microphone.

One solution to this problem would be to have the crews use hot mikes, particularly for take-off and landing.

Thus the Commission re-states recommendations already made on this matter by other Commissions of Investigation and by the Accident Investigation Bureau in recommending:

– that insofar as aircraft have hot mikes fitted, their use should be obligatory during take-off and landing;

– that studies into improving omni-directional recordings in the flight deck should be pursued, in particular to ensure greater intelligibility of crew members' conversations during flight.

43.4 – Recordings of Visual Information

At present, no visual information is recorded, neither the information displayed on the flight instrument screens giving navigation information and observing the aircraft's performance, nor the body language and non-verbal communication between crew members. The absence of any recordings of visual information has made it impossible to establish the scenario of the F-GGED accident with any certainty.

Aspects linked to the analysis of visual information supplied to the crew, as well as aspects linked to cockpit ergonomics and teamwork are becoming increasingly vital to Inquiries.

Consequently, the Commission recommends:

– that studies should be carried out into recording pictures, on protected media, of instrument panels and the flight deck. These pictures would then be synchronized with the other regulation recordings.

43.5 – Recording Approach Radar Information

The approach radar information at Strasbourg was not recorded. The absence of recordings from this radar has prevented the use of the picture of the tracks supplied by this station to the Approach Controller at Strasbourg.

In France, nine approach control centres have a recording system for their local radar. Having such a system provides better knowledge and analysis of the conditions under which different air traffic functions are carried out, and also permits better research if this should be necessary.

Consequently, the Commission recommends:

—that all Approach Control Centres should use a type of local radar that is fitted with a recording system that is also able to rapidly reconstruct information supplied by that radar.

43.6 — Coordinating Administrative and Judicial Procedures

In its analysis of the coordination of the administrative and judicial procedures, especially as regards recording devices, the Commission notes that in the case of this accident, the vital instruments were recovered and utilized. However, the Commission does find fault with the institutional confines set out by the inter-departmental communique of 3 January 1953.

The present confines and the way the practice has developed of giving greatest importance to the exactness of legal documents can, in the opinion of the Commission, have disastrous consequences as regards preserving certain vital instruments such as flight recorders. Both from the point of view of analysing the causes of an accident, and from the point of view of investigating where the responsibility lies, it would be useless, simply for the sake of fulfilling formalities, to seize instruments; moreover their preservation is not guaranteed.

Consequently, the Commission of Investigation recommends that:

— a study should be carried out of the legal framework and the clauses which should then have written into them permission for the work of the technical investigator, allowing him to safeguard instruments immediately, by prerogative of administrative and judicial enquiries.

CHAPTER 4.4 - RECOMMENDATIONS RELATING TO THE ERGONOMICS OF THE AIRCRAFT-CREW INTERFACE

and

RECOMMENDATIONS RELATING TO THE CERTIFICATION OF THE AUTOMATIC PILOTING SYSTEMS

44.1 - Modification of the flight deck ergonomics of the A320

The Investigation has shown that the most probable accident scenarios imply an error in the command of the descent effected by the pilot by means of the FCU. In particular, confusion between the VS and FPA modes appeared probable to the Commission. All the other scenarios imply that the crew did not recognise the very great anomaly of the resultant vertical flight path.

The Commission is fully aware of the part played in the cause of this situation by the shortcomings it has noted in the performance of the crew, notably in the areas of cross-checking and monitoring of automatic devices. At the end of its deliberations, however, the Commission considers that it cannot by any means exclude the possibility of the recurrence of disruptive factors which could reduce the rigorousness of cross-checking among the crew to more or less the same extent, whatever the level of training may be.

Moreover, the Commission's deliberations have led it to consider that the ergonomic conception of the relevant Autopilot control could have contributed to the cause of the accident situation: This concept seems by its very navure to favour some mix-ups which could have catastrophic results if they are not detected, while the PFD symbols do not offer the best chances of detecting such confusion.

The Commission of Investigation therefore confirms and clarifies its preliminary recommendation of 20 February 1992 concerning the conception of the aircraft-crew interface relative to the vertical modes of the Autopilot on the A320.

Consequently, the Commission of Investigation recommends for the A320:

- that the target value of VS or FPA should be displayed on the PFD in order to clarify their coherence with the fundamental utilization philosophy, as taught (order effected with the FCU, control of the order and its result on the PFD);

— that the display of the FCU corresponding to the

target values of vertical speed or flight path angle should be changed to a non-ambiguous expression in the current units;

It also recommends that, as far as possible:

— the difference between the respective symbols associated with the HDG-VS and TRK-FPA references and the legibility and alerting ability of the vertical speed information should be reinforced on the PFD.

44.2 Representation of the Autopilot modes of new-generation aircraft

In the process of its analysis of this accident, the Commission has been led to note inadequacies in the effectiveness of the presentation to the crew of the various active modes, the references used, the actions in progress and the targets pursued, with regard to the Autopilot devices, notably in the vertical plane. Most particularly, in the opinion of the Commission, the total information presented is inadequate in terms of its likelihood of alerting a crew, who at a glance, then absorb a wrong mental picture of the state of the automatic devices.

In practice, a good number of the observations made by the Commission apply to one degree or another"to all new-generation aircraft, which all use (if only for reasons of standardisation) the same techniques for displaying information, the same distribution of information, the same ergonomic principles (e.g. indicating the modes using a small-sized alphanumeric display, which has to be read in central vision and requires high-level cognitive decoding). Finally, the Commission has the impression that a scarcely distinguishable series of symbols are associated with functions whose actions and interactions are complex.

Consequently the Commission recommends that for all new-generation aircraft:

— consideration should be given by the competent authorities and organisations with a view to improving, in a standardised manner on an international basis, the presentation and the symbols of the displays and information relating to the different active modes of the Autopilot, notably in the vertical plane.

44.3 - Balancing the horizontal and vertical information

The analysis has led the Commission of Investigation to note the crew's strong focus on lateral navigation during the intermediate approach phase, to the detriment of monitoring the vertical flight path. The Commission has analysed the economic factors which might have been the reason for this focus. It has also retained the idea that the very presentation of position information on the cathode ray screens was of such a nature as to encourage or prolong such a focus.

The Commission notes in fact that the abundance and the level of synthesis of the information presented in the horizontal plane on the navigation screen (direct analogue positioning relative to a suitable map of the world) does not have an equivalent in the vertical plane (no representation of the profile of the vertical plane nor of the safety constraints: safety altitude, determining objects, high ground). This phenomenon seems to be characteristic of all aircraft fitted with Cathode Ray Tube (CRT) instrumentation and notably an FMS without vertical profile.

Consequently the Commission recommends:

– that a study should be carried out into how new-generation aircraft can be provided with a better balance in the presentation of the horizontal and vertical position information, reinforcing the latter (e.g. representation of the vertical plane profile, topographical representation, safety altitudes representation), and developing the associated methods allowing the crew members to be more aware with respect to the vertical situation (e.g. automatic significant height clearance announcements in descent before the final approach phase).

44.4 - Certification of flight deck ergonomics

In studying the certification process of the A320 relating to the ergonomic aspects of the aircraft-crew interface, the Commission has noted that the certification authorities concerned had established a basis for certification, comprising several special conditions and acceptable means of additional conformity to regulations JAR 25 and ACJ 25. It has also noted that particular effort had been devoted to the corresponding evaluations during in-flight or simulated operations carried out for the purposes of certification.

In spite of that, in the course of its analysis of the F-GGED accident, the Commission has come to consider that certain aspects of the ergonomic concept of the FCU and the aircraft's instruments did represent a contributory factor in the accident, and that this could happen again.

Consequently the Commission of Investigation recommends:

– that a study should be carried out into the methods by which manufacturers should, as far as is possible in the industrial process, obtain the best information on the probable behaviour of the user when considering new ideas in aircraft ergonomics that could have major consequences;

– that the certification authorities undertake a revision of the transport aircraft certification regulations in order to clarify the objectives and certification criteria concerning flight deck ergonomics (in particular the interaction of the crew and the high-level automatic devices) and its impact on the safety of flight, taking into account the associated likelihood of human error;

– that the acceptable means of demonstrating compliance associated with this recommend experimental protocols, taking into account the latest ergonomic experience

44.5 Recommendations concerning the Autopilot systems

In September 1992, a malfunction of an FCU was identified. It displayed a corrupt instruction value on the FCU when transferring to the Autopilot computer (FMGC). The French certification authorities have informed the French A320 Operators, as well as the supervising authorities of the foreign Operators, asking them to warn their crews against the risk of such malfunctions, and to define an adaptable operational procedure. From the technical point of view, measures have also been taken to make reception tests on suspect electronic components more stringent, and to define a new version of FCU manufactured with more resistant components.

The Commission has analysed this case of corruption of target value displayed on the FCU and has considered that such a scenario was very unlikely in the case of the accident.

However, in arriving at this kind of theory of the circumstances of the accident, and more generally of

the context of a "standard" approach, in the framework of the applicable certification criteria, the Commission did query the probability of the crew overlooking faults that would not have been observed by the Autopilot on approach.

Consequently, the Commission of Investigation recommends for the certification criteria of Autopilots that, in the operational environment of so-called "standard" approaches,

– the probabilities of failure of an Autopilot verticle mode, not detected by the system, as well as their probabilities and delays of detection and correction by the crew, notably in dynamic situations, should be re-evaluated;

– the repercussions of such undetected failures or failures not corrected by the crew in the final approach phase should be re-evaluated, and that their combined effects thus estimated should be verified with the risk level taken into account in the certification process.

44.6 – Quality control of the Collins-700-020 DME Software

In the course of the Investigation relating to the F-GGED accident, the Commission proceeded to examine the non-volatile memories of both pieces of Collins-700-020 Distance Measuring Equipment (DME) of the aircraft. The hypothesis of the occurrence of one of the currently recognized malfunction modes can be refuted by considering the available technical factors.

However, this examination has brought to light some anomalies that could have been avoided by applying software verification and test procedures such as those described as standards RTCA DO 178 A and EUROCAE ED 12 A.

From the results obtained from the software in question, the Accident Investigation Bureau recommended that "whatever means are judged necessary should be put in place to eliminate the bugs of the Collins-700-020 DME". The French and American certification authorities have carried out a quality control procedure. The first conclusions of this test have confirmed the software's inadequacies and the need to overcome them. They have been communicated to the equipment manufacturer, who is committed to pinpointing the necessary corrections before the end of 1993.

Parallel to that, the French certification authority has made it obligatory for all aircraft on the French register to make specific changes to correct the faults that have been identified in this equipment. For its part, the American certification authority has introduced an identical process.

The Commission notes the measures taken and does not have any recommendations to add.

CHAPTER 4.5 – RECOMMENDATIONS ON SURVIVAL

45.1 – Certification and use of safety belts

The Commission established that the injuries sustained by the victims in a large number of cases had been caused by the impact against the seat in front of each passenger, or by the passenger's safety belt.

The regulations for certification ensure that under specific conditions of deceleration (as in a minor crash), the seats and safety belts should not cause severe injury to their occupants.

The Commission is aware that the constraints suffered at the time of the impact were generally greater than the constraints envisaged in the regulations for certification. However, the presence of survivors suggests that some lessons can at least be learnt from this accident. In particular, the nature of the injuries sustained by the victims led the Commission to contemplate the matter of safety harnesses.

The Commission noted that new regulatory demands had been introduced since the A320 received certification. These give the passengers added protection in case of an emergency landing. However, they do not provide for the mandatory use of safety harnesses.

Consequently, the Commission recommends:

– that studies should be carried out to improve on the regulatory demands in the area of protecting passengers in the case of an emergency landing. In particular, the matter of compulsory use of safety harnesses should be studied.

45.2 – Conditions for installation of the ELBA

The Investigation showed that the ELBA had been destroyed on impact and that as a result, this equipment was of no use in locating the wreck, a task which proved long and difficult, contrary to popular belief in the case of an accident involving a large transport aeroplane.

The Investigation also demonstrated that the conditions of approval and installation of this equipment in force on the day of the accident did not reflect normal requirements for public transport and should have been more stringent. For this reason the Commission presented a preliminary recommendation on this point to the Minister on 20 February 1992.

The Commission has established that this recommendation has been followed up, and that conditions for approval and installation of this equipment were modified in the Order of 12 January 1993. However, the Commission notes that the methods used for verifying that installations conform to this modified legislation have not yet been updated in the relevant documents SFACT and STNA, and that significantly, the conditions for verifying the range potential are not specified.

Consequently, the Commission recommends:

– that methods of verifying that ELBA installations comply with the new regulation should be updated in the relevant documents SFACT and STNA, and that the demands and conditions for measuring the range potential should be added.

Furthermore, improving the Emergency Location Beacon's performance in terms of crash-resistance and range would be pointless unless the search teams are equipped with the necessary means of using them. In this regard it is important to use to the full the available means of pinpointing at their disposal: Terrestrial radio (amateur radio), location by satellite, but equally, aerial radiogoniometry.

Consequently, the Commission recommends:

– that there should be a re-appraisal and stock should be taken of the aerial media that can be used by RCCs, so that within half an hour of a DETRESFA phase being triggered, these organizations can despatch an aerial platform equipped with a radio-electrical detector that can function day or night.

45.3 – Organising Searches

In the analysis, a certain number of imperfections came to light regarding pre-established search devices, which the Commission thinks should be remedied.

Consequently, the Commission recommends:

– that systems and procedures should be studied and implemented to quickly reconstruct the radar trajectories and the radio-communications recorded by civil and military controlling bodies, so that these elements can be communicated to the competent RCC within half an hour of a distress signal being triggered;

— that directives should be set up to undertake a re-appraisal of all the current SATER plans, taking into consideration lessons learnt from this accident, especially the following points:

. methods of installing and powering up the operational Command Post

. methods of employing personnel on the ground;

. sending back information about the terrain to the on-site CP and the RCC.

45.4 – Organizing Aid

The Commission has established that the specially equipped medical units (SAMU) did not in fact operate at the scene. Medical operations were in fact carried out partly by military teams, accustomed to operating in the terrain, and partly by civilian doctors. Neither group was working within an organized framework. The Commission is also in doubt about conditions of evacuating some of the seriowsly injured, particularly considering their primary treatment at the scene, before being evacuated. The Commission has not been able to reach any conclusion on this point, but it appears that ways of improving the plan of action for giving first aid should have been studied.

Consequently, the Commission recommends:

— that appropriate directives should be set up, leading to a revision of the Red Plans, taking into consideration the lessons learned from this accident and especially the following points:

. a specialized, elite medical team should be made up immediately and despatched swiftly in the search zone, arriving at the scene of the accident well able to treat cases of multiple traumas;

. coordination between the leaders of the search party, first aid and medics should be improved;

— that training programmes and operational orders given to medics and first aid workers should be checked and if necessary updated regarding conditions for providing care and evacuation for the seriously injured at the scene of an accident.

45.5 – Organizing Communications and Controlling Access to the

Site of the Accident

The Commission has found that traffic problems on the access roads to Mont Saint-Odile, if not a hindrance to the search operation, were definitely a nuisance to the rescue operations. The Commission notes that these problems could be the result of methods of managing communications on the accident, and of conditions set down for controlling access to the site. On the other hand, the participation of the media and the public could sometimes be desirable during the search stage. It is a difficult subject and is not specifically addressed in the pre-established plans.

Consequently, the Commission recommends:

– that communications professionals should be brought into consultations on the question of handling communications in the event of an accident;

– that the principles of putting into effect measures for controlling access to the site of an accident or a search zone should be studied by the competent services, and that if necessary, they should be included in the appropriate plans.

4.6 – RECOMMENDATIONS REGARDING AIR TRAFFIC PROCEDURES

46.1 – Exceptional Approach Procedures

The 05 VOR DME procedure in force at Strasbourg at the time of the accident contains three characteristics that are exceptions to the terms of Instruction No. 20754/DNA of 12 October 1982 regarding the establishment of procedures for departing, holding and approaching using instruments.

The investigation of the conditions surrounding the approach showed that the aircraft exited the turn in the procedure below the intermediate approach track, and as a result, this segment allowed for the reduction of the speed of the aircraft and for configuration for final approach, before it was curtailed.

Strictly speaking, since the aircraft had not assumed the whole of the intermediate approach segment, the exceptions of this segment were not re-examined.

However, the speed with which the necessary actions were executed to prepare the aircraft for the final turn in the procedure would probably have been compensated for by flying level after coming out of the turn.

This suggests that the existence of a segment of level flight in the intermediate approach is, in terms of safety, a significant factor in defining a VOR DME approach procedure.

Consequently, the Commission recommends:

– that air traffic services re-appraise all the exceptions agreed when the approach procedure was set up, particularly if there is no level flight on the intermediate approach stretch;

– that if there is no possible solution other than an exception, the air traffic services are to inform users of the existence of an exceptional procedure and give details of the agreed exception;

– that in their respective areas, Operators and air traffic services are to inform crews and Air Traffic Controllers of the existence and the details of such exceptions.

46.2 – Crew Information Regarding Flight When Descending On Approach

An examination of the circumstances surrounding the command to begin the descent shows that at the time, the aircraft was at about 10 deg. to the approach track. The Commission did not consider this fact to be a cause of F-GGED crashing into the relief, but it does wish to emphasize the importance of this in terms of safety of the flight path.

Actually, bearing in mind the protection principle in a VOR DME approach, the ICAO's document 8168 advocates that the descent on the approach flight path should not begin until the deviation of the VOR indicator needle is greater than half of the scale, which corresponds to a deviation of 5 deg.

There are no regulations stipulating precisely what piloting orders apply when carrying out an approach procedure using instruments. In France, the texts concerning the establishment and use of approach procedures using instruments are Instruction No. 20754/DNA and the "User Manual for utilization of approach and departure procedures using instruments". The main purpose of the second document is to introduce the user to the basic principles and theories upon which the procedures have been constructed, by way of extracting certain rules for execution of the manoeuvres. In particular it highlights margins for flying which if abided by, will guarantee that the flight path of the aircraft is maintained in the region of protection of the approach.

Consequently, the Commission recommends:

– that training organisations and Operators make sure that the methods of piloting they use are in line with the thresholds of flight tolerances recognised in Instruction No. 20754/DNA regarding the establishment of procedures for departing, holding and approaching using instruments.

46.3 – Radar Guidance Training and Related Phraseology

The Strasbourg Approach Control provided the crew of F-GGED with radar guidance for part of the VOR DME approach. An examination of this guidance and the phraseology employed by the Controller showed that on the one hand the guidance did not allow the crew to go to the overhead of the intermediate approach fix (IF) and on the other hand, in several instances, the position information was not formulated according to regulation phraseology; this could have made it difficult to interpret.

The analysis carried out in connection with § 22.6 shows that the routing instructions given to the crew by way of radar guidance did contribute to cutting short the intermediate approach segment provided for in the definition of the approach procedure to prepare the aircraft for the final approach. They could also have contributed to the difficulties experienced in achieving the inbound track of the approach. This could have influenced the behaviour of the crew and encouraged them, at least for a moment, to instigate the execution of the commands necessary for preparing the aircraft for a descent.

The Commission notes that the development of regulations regarding radar approach guidance deals with this aspect and guarantees, a priori, the execution of level flight before the descent for final approach begins. RCA 3-121, dated 16 March 1992 and in effect from 2 April 1992 stipulates among other criteria that "guidance provided must permit the aircraft to execute level flight on the inbound track for at least 30 seconds before intercepting the glideslope".

Regarding the phraseology employed to inform crews of their radar position, the Order of 7 September 1984 specifies what formulation should be used. Although the analysis of § 22.6 did not show an erroneous interpretation on the part of the crew, the Commission believes that a particularly rigorous effort needs to be made concerning the phraseology employed.

Consequently, the Commission recommends:

– that air traffic services make a special effort in training their Air Traffic Controllers, and in training them about procedures and the phraseology to employ when giving

radar guidance;

– that these services should regularly check that phraseology connected with radar guidance of an aircraft heading towards the final approach track is on the one hand in accordance with the established principles of the new regulations, and on the other hand is free from any ambiguity, especially for the crew;

– that the use of terms such as "through right" and "through left", used to give a crew its position relative to a fix are eliminated in practice.

46.4 – Content and Update of ATIS Messages

To prepare for their arrival at Strasbourg, the crew of F-GGED used information given by the ATIS at Strasbourg (ATIS: Automatic Terminal Information Service).

At the time of the accident, operating instructions for the ATIS appeared in Instruction No. 10140/DNA of 28 February 1984.

An examination of the contents of the messages received by the crew and the times at which the messages were sent show that on the one hand, the message November recorded at 16.00 hours was still being sent out at 17.56 hours, and on the other hand that the approach procedure to be expected was not mentioned.

Regarding the first point, the instruction in force at the time of the accident stipulated that "in all cases, an update of the ATIS message is essential at least once an hour in order to guarantee the credibility of the information. In all cases, any message more than an hour old should be considered invalid and should no longer be transmitted". Thus the ATIS had not been renewed as per the requirements of the regulation in force at the time.

Concerning the second point mentioned, the regulation that was applicable at the time of the accident did not require that the approach procedure should be prepared for. The analysis carried out for § 22.62 shows that informing the crew of the type of

procedure to prepare for, would probably have clarified the situation. The Commission of Investigation notes that the development of regulations provides a solution to this problem by integrating which type of approach to expect, into the list of elements contained in the ATIS message (see Instruction No. 10120/DNA, and RCA 3.76 of 16 March 1992).

Consequently, the Commission recommends:

– that air traffic services should make a special effort to ensure that the ATIS is used in conformity with regulations.

46.5 – Identifying Arrival Procedures

The analysis carried out for § 22.62 shows that in the absence of precise information concerning which arrival route to follow, the crew of F-GGED could have envisaged several possibilities. Actually, the phrase "standard arrival at Strasbourg" used by the Controller of the Regional Air Navigation Centre did not convey the information that probably would have helped to clarify the situation.

At the time of the accident, the only way to inform the crew precisely, would have been to list all the bearings of the course to follow.

An examination of the procedure charts for arrival at Strasbourg shows that the arrival routes have been named since 25 June 1992. This amounts to a solution to the stated problem.

Consequently, the Commission recommends:

– that air traffic services should make sure that all departure and arrival routes in the Terminal Control Area are designated and published according to the ICAO's recommendations, and that these designations should be used when clearance is being given.

CHAPTER 4.7 – RECOMMENDATIONS REGARDING STATE SUPERVISION

In its analysis of the context F-GGED was operating in, the Commission has come to see the lack of control exercised by the relevant services of the DGAC as regards applying operational regulations and

concerning the professional level of crews at Air Inter. This fact, which would probably extend to other large companies, is as much a result of structure as of lack of means. This is worrying, because the possible negative results can be clearly seen.

Consequently, the Commission of Investigation recommends:

— that methods and times should be defined for inspection, operational control and in-flight monitoring of the major airline companies;

— that a re-evaluation should begin of the funds set aside for the DGAC for this purpose, that procedures for using these funds should be set up, so that all the relevant services would be in a position to perform the necessary checks at agreed intervals.

CHAPTER 4.8 – RECOMMENDATIONS FROM HINDSIGHT

48.1 – Reorganizing French Legislative Plan of Action for Handling Incidents

In the course of investigations into possible incidents related to the scenarios the Investigation explored, the Commission realised the obvious limits of the present system of the benefit of hindsight, both nationally and internationally. Especially when investigating the French legislative Plan of Action for handling incidents, the Commission holds that present organization and funds do not allow efficient operation.

Consequently, the Commission recommends:

– that the French legislative Plan of Action and procedures for handling incidents should be re-vamped in orfer to allow more efficignt use of the benefit of hindsight for aviation safety needs, especially for incidents of an operational nature.

48.2 – System for systematic analysis of Flight Data Recordings

In the course of its investigations into possible incidents related to the scenarios that the Investigation explored, the Commission realized that only systematic analysis systems for recorded flight data would be able to detect any anomalies in the progress of the flight that were not apparent to the crew, and be able to provide those involved in an investigation with sufficiently precise and in-depth information that would make possible a full understanding of the incident. The Commission did however note that this result would only be possible with two provisos, that any significant anomaly would be the object of an operational analysis, and that the system would not be closed to all but the company concerned.

Consequently, the Commission recommends:

– that with regard to Operators of public air transport at both the national and the international level, the Civil Aviation Authorities should employ a plan of action to:

. expand the practice of having the Operators use systematic analysis for recorded flight data;

. systematise a more thorough analysis of any significant anomalies thus detected, especially on the operational level, using a specialist department of the

Operator;

. communicate the results of these analyses to the supervising authorities, the manufacturers and other Operators, while giving particular respect to the constraints of confidentiality of information and of anonymity.

APPROVAL OF THE REPORT

This report was unanimously approved by the members of the Commission of Investigation on 26 November 1993.

Chairman	Vice-Chairman
Alain Monnier	Paul Arslanian
Jean Paries	Jean-Louis Chatelain
Pierre Bernard	Henri Marotte
Frédéric Rico	Michel Guillaume
Philippe Gourguechon	Dominique Marbouty
Alain Tert	Guy Lagrange

LIST OF APPENDICES

APPENDIX 0 : Glossary

APPENDIX 1 : Exact location of accident site

APPENDIX 2 : Topographical plan of accident site

APPENDIX 3 : Sketch showing distribution of wreckage

APPENDIX 4 : Sketch showing distribution of sources of fire

APPENDIX 5 : Drawing showing distribution of survivors on board

APPENDIX 6 : Arrival and approach procedure charts:
1) issued by the SIA
2) used by the crew

APPENDIX 7 : Illustrations of Quick Access Recorder (QAR) parameters

APPENDIX 8 : Extracts from Cockpit Voice Recorder (CVR) transcription

APPENDIX 9 : Transcription of Air Traffic Control (ATC) radio communications

APPENDIX 10: Transcription of the telephonic communication between the Eastern Regional Centre for Air Navigation (CRNA/Est) and Strasbourg Approach

APPENDIX 11: Radar flight path analysis and associated technical note

APPENDIX 12: Flight Management Guidance Computer 1 (FMGC1) and synthesised flight path analysis

APPENDIX 13: Meteorological records

APPENDIX 14: Tree of potential causes of the accident

APPENDIX 15: Description of aircraft control and navigation systems on the A320

APPENDIX 16: Photographs of the wreckage

APPENDIX 0

- GLOSSARY -

ACARS : Aircraft Communication Addressing and Reporting System
System allowing the exchange of information in digital form between the aircraft and the ground.

ADIRS : Air Data Inertial Reference System

AFS : Auto Flight System

ALT : Altitude

AP : Auto-pilot

APU : Auxilliary Power Unit

ARPT : Airport

ATA : Nomenclature

ATIS : Automatic Terminal Information Service

ATC : Air Traffic Control

A/THR : Auto-thrust

AWY : Airway

BITE : Built-in Test Equipment

CFDIU : Centralized Fault Data Interface Unit

CLA : Local Airport Control

CMD : Control (N1 CMD: N1 Controlled)

CORTE : Company Route

COST INDEX : The cost index is the ratio between the cost of one flying hour and the cost of fuel. For the FMGS it is the essential parameter in calculating the speed that will be adopted by the aircraft in managed mode. A higher cost index leads to a higher managed speed. The cost index figure is unique to each company and each route. It is contained in the database with the CO-ROUTE, and can be modified in flight

CPU : Cabin Pressure Controller Unit

CRNA/Est :Eastern Regional Centre for Air Navigation, based in Reims

CRS : Course

CRT : Cathode Ray Tube

CVR : Cockpit Voice Recorder

DDRMI : Digital Distance and Radio Magnetic Indicator

DFDR : Digital Flight Data Recorder

DIR TO : Direct To

DMC : Display Management Computer

DME : Distance Measuring Equipment

ECAM : Electronic Centralized Aircraft Monitoring (on the Airbus aircraft)

EFIS : Electronic Flight Instrument System

ELAC : Elevator Aileron Computer

ENAC : National Civil Aviation School, based in Toulouse

E/WD : Engine/Warning Display

FAF : Final Approach Fix

FCU : Flight Control Unit

FD : Flight Director

FL : Flight Level

FMA : Flight Mode Annunciator

FMGC : Flight Management Guidance Computer

FMGS : Flight Management Guidance System

F/PLN : Flight Plan

FPV : Flight Path Vector

FWC : Flight Warning Computer

GA : Go-Around

GPWS : Ground Proximity Warning System

HDG : Heading

hPa : Hectopascal (unit of measurement of atmospheric pressure)

HUD : Head Up Display

IAF : Initial Approach Fix

IAS : Indicated Airspeed

IDLE : Idle

IFR : Instrument Flight Rules

ILS : Instrument Landing System

INIT : Initialisation

IRS : Inertial Reference System

KT : Knot

MCDU : Multifunction Control and Display Unit

MDA : Minimum Descent Altitude

MDH : Minimum Descent Height

METAR : Regular Meteorological Observation Report for Aviation

MSA : Minimum Safe Altitude

NAV : Navigation

NAVAID : Navigation Aid (VOR/DME)

ND : Navigation Display

NM : Nautical Mile

N1 : For the CFM 56, this parameter represents engine thrust during each flight phase

PA : Public Address

P/B : Push-Button

PFD : Primary Flight Display

PHR : Horizontal Adjustable Stabilizer

QAR : Quick Access Recorder
Recorder of parameters for maintenance purposes

QFE : Atmospheric pressure at aerodrome elevation

QFU : Magnetic orientation of runway

QNH : Altimeter Setting to obtain aerodrome elevation when on the ground

RA : Radio Altitude

RBDA : Emergency Locator Transmitter with automatic release
ELBA: Emergency Location Beacon for Aircraft

RTE : Route

RWY : Runway

SC : Single Chime

SD : System Display

SEC : Spoiler Elevator Secondary Computer

SID : Standard Instrument Departure

SLT : Slat

SPAR : Slight Precision Approach Radar

SPD : Speed

SPLR : Spoiler

STAR : Standard Terminal Arrival Route

SYS : System

TACAN : Tactical Air Navigation Aid
Tactical navigation system (includes a "distance measurement" component utilised by Civil Aviation

TAF : Landing Weather Forecast

TAS : True Air Speed

TAT : Total Air Temperature

THR : Thrust

THS : Trimmable Horizontal Stabilizer

TLA : Thrust Lever Angle

TO : Take-off

TOGA : Take-off Go-around

TRK : Track Route

UTC : Universal Time Coordinated

VBV : Variable Bleed Valve
Variable Bleed Valve in low pressure compressor (on CFM 56 engines)

VFE : Maximum Velocity Flaps Extended

VHF : Very High Frequency

VOR : VHF Omnidirectional Range

VORTAC : Combination of **VOR** and **TACAN**

VREF : Landing Reference Speed

V/S : Vertical Speed

VSV : Variable Stator Vane
Variable Stator Vane (on CFM 56 engines)

APPENDIX 1

(1): SITE OF THE ACCIDENT

APPENDIX 2

(1)
Topographical plan of the A320 crash zone
Date of plan: 22.01.1992

(2)
Title of plan: Plan - Profiles

(3)
AIR BASES SUBDIVISION, STRASBOURG-ENTZHEIM AIRPORT,
67960 ENTZHEIM

(4)
LONGITUDINAL PROFILE OF THE TERRAIN

(5)
EXT. FUSELAGE DEBRIS

(6)
EXT. AUXILIARY GROUP

(7)
BASE ALTITUDE
IMPACT ALTITUDE

(8)
BASE ALTITUDE
IMPACT ALTITUDE

(9)
BROKEN TREE
BASE ALTITUDE
TOP ALTITUDE

(10)
BROKEN TREE
BASE ALTITUDE
TOP ALTITUDE

(11)
IMPACT ALTITUDE

(12)
PROFILE OF THE IMPACTS AND BREAKAGES, LEFT SIDE OF THE
FLIGHT PATH

(13)
BROKEN TREE
BASE ALTITUDE
TOP ALTITUDE

(14)
BROKEN TREE
BASE ALTITUDE
TOP ALTITUDE

(15)
PROFILE OF THE IMPACTS AND BREAKAGES, RIGHT SIDE OF THE FLIGHT PATH

(16)
ALTITUDE ESTIMATED BY PROJECTION

(17)
BROKEN TREE
BASE ALTITUDE
TOP ALTITUDE

(18)
PATH AXIS

(19)
PLAN VIEW OF THE TERRAIN

(20)
PLAN AXIS

(21)
SUPPOSED COURSE OF THE A320

(22)
UNDAMAGED TREES

(23)
BOUNDARY OF UNDAMAGED TREES

(24)
UNDAMAGED TREE
BASE ALTITUDE
IMPACT ALTITUDE

(25)

BASE ALTITUDE
IMPACT ALTITUDE

(26)
BROKEN TREE
BASE ALTITUDE
TOP ALTITUDE
(27)
BROKEN TREE
BASE ALTITUDE
TOP ALTITUDE

(28)
BOUNDARY OF BROKEN OR IMPACTED TREES

(29)
BROKEN TREE
BASE ALTITUDE
TOP ALTITUDE

(30)
BROKEN TREE
BASE ALTITUDE
TOP ALTITUDE

(31)
BROKEN TREE
BASE ALTITUDE
TOP ALTITUDE

(32)
BROKEN TREE
BASE ALTITUDE
TOP ALTITUDE

(33)
BROKEN TREE
BASE ALTITUDE
TOP ALTITUDE

(34)
BROKEN TREE
BASE ALTITUDE
TOP ALTITUDE

(35)
PATH AXIS
(approx. 195.00 NGF)

(36)
LANDMARK ALTITUDE
NOTIONAL SPOT HEIGHT
(ROCK SUMMIT)

(37)
BROKEN TREE
BASE ALTITUDE
TOP ALTITUDE

(38)
BROKEN TREE
BASE ALTITUDE
TOP ALTITUDE

(39)
BROKEN TREE
BASE ALTITUDE
TOP ALTITUDE

(40)
BROKEN TREE
BASE ALTITUDE
TOP ALTITUDE

(41)
BROKEN TREE
BASE ALTITUDE
TOP ALTITUDE

(42)
BROKEN TREE
BASE ALTITUDE
TOP ALTITUDE

(43)
BROKEN TREE
BASE ALTITUDE
TOP ALTITUDE

(44)
BROKEN TREE
BASE ALTITUDE
TOP ALTITUDE

(45)

BOUNDARY OF BROKEN OR IMPACTED TREES

(46)
BASE ALTITUDE
IMPACT ALTITUDE

(47)
CROSS SECTION AT THE LEVEL OF THE FIRST IMPACT

(48)
BOUNDARY OF UNDAMAGED TREES

(49)
SECTION 1

(50)
TERRAIND ALTITUDE

(51)
IMPACT ALTITUDE

(52)
IMPACT ALTITUDE
IMPACT ALTITUDE

(53)
SECTION 2

(54)
TERRAIN ALTITUDE

(55)
SECTION 3

(56)
TERRAIN ALTITUDE

(57)
EXT. FUSELAGE DEBRIS

(58)
EXT. PLANE

(59)
EXT. AUXILIARY GROUP

APPENDIX 3

F-GGED

(1) Sketch NOT TO SCALE

(2) Area of projection of the front cabin interior
Area with majority of the victims

(3) Numerous computers

(4) T.P. wheel

(5) Right engine and pylon

(6) Burnt area

(7) Nose landing gear

(8) T.P. wheel

(9) Piece of right wing and spoiler

(10) Left engine body

(11) Right T.P. structure

(12) C.D.B. sliding window

(13) Left T.P.

(14) Cockpit debris area

(15) Burnt area

(16) Left pylon

(17) Left fan

(18) Piece of wing

(19) Piece of fuselage lower part only

(20) Area with engine and cockpit debris

(21) Left wing undersurface

(22) Wing box

(23) Galley

(24) Recorders

(25) Artificial Horizon

(26) Burnt area

(27) Left adjustable tailplane

(28) Adjustable tailplane screwjack

(29) Burnt fin and steering

(30) Left wing tip

(31) Area of distribution of pieces of wing and tail empennage

APPENDIX 4

Distribution of the three main sources of the fire

(1) Front area

(2) Airframe

(3) Right jet engine

(4) Central area

(5) Floor panels

(6) Rear area

APPENDIX 5

Distribution of the survivors on board

(1) Door (left)

(2) Door 1 (right)

(3) Positions of survivors

(4) Overwing exits

(5) Overwing exits

(6) Door 2 (left)

(7) Door 2 (right)

APPENDIX 6

6.1

(1) SPECIAL RULES AIRSPACE OF STRASBOURG Entzheim
Arrival procedures RWY 05

(2) Approach

(3) Tower

(4) On special APP authorization

(5) All vertical distances expressed in feet

(6) When holding is necessary, it is effected:

Overhead SE to a MAX SPEED of 220 KT, turn right (RM 230/050) with a leg time of 1 MIN

COM FAILURE
Apply the procedure defined in the National Regulations; display mode A3 code 7600 climb straight ahead, then turn right 1 NM after STR to intercept the STR RDL 349. At 3500 AMSL turn right to rejoin SE at 3500 AMSL. After rejoining the hold, descend towards 2500 AMSL and make a new approach.

MISSED APPROACH PROCEDURE CONTROLLED AIRSPACE
Climb straight ahead to STR, intercept and follow the STR RDL 260 (RM 260) towards EPL, leave controlled airspace at FL 070 and look for VMC conditions.

6.2

(1) SPECIAL RULES AIRSPACE OF STRASBOURG Entzheim
Arrival procedures RWY 23

(2) Approach

(3) Tower

(4) On special APP authorization

(5) All vertical distances expressed in feet

(6) Holding - see IAC map

(7) When holding is necessary, it is effected:

Overhead SE to a MAX SPEED of 220 KT, turn right (RM 230/050) with a leg time of 1 MIN

COM FAILURE
Apply the procedure defined in the National Regulations; display mode A3 code 7600 climb straight ahead, then turn right 1 NM after STR to intercept the STR RDL 349. At 3500 AMSL turn right to rejoin SE at 3500 AMSL. After rejoining the hold, descend towards 2500 AMSL and make a new approach.

MISSED APPROACH PROCEDURE CONTROLLED AIRSPACE
Climb straight ahead to STR, intercept and follow the STR RDL 260 (RM 260) towards EPL, leave controlled airspace at FL070 and look for VMC conditions.

6.3

(1) SPECIAL RULES AIRSPACE OF STRASBOURG Entzheim
Terminal radar guidance zone

(2) Approach

(3) Tower

(4) Outside operating schedule LF R 45

(5) All vertical distances expressed in feet

(6) COM FAILURE

Apply the procedure defined in the National Regulations; display mode A3 code 7600 climb straight ahead, then turn right 1 NM after STR to intercept the STR RDL 349. At 3500 AMSL turn right to rejoin SE at 3500 AMSL. After rejoining the hold, descend towards 2500 AMSL and make a new approach.

MISSED APPROACH PROCEDURE CONTROLLED AIRSPACE

Climb straight ahead to STR, intercept and follow the STR RDL 260 (RM 260) towards EPL, leave controlled airspace at FL070 and look for VMC conditions.

6.4

(1) APPROACH WITH INSTRUMENTS
Cat. A B C D

Apt. Ele. 502 (18 hPa), Threshold: 502

(2) Approach

(3) Tower

(4) On instructions

(5) Max Speed

(6) Cathedral

(7) Steeple

(8) Tower

(9):
In the absence of distance information: Minm Alt
25 NM : 5400

(10):
Alt and height in ft

(11) RIGHT

(12):
API - Climb on STR Rdl 051 deg (RM 051 deg). At 12 NM STR, turn left to rejoin the hold at 2500 (1998), unless instructed by Ctl.
Climb to i 300 (798) prior to level acceleration.

(13):
Minimum standard: vertical distances in feet, VH in metres.

(14):
Notes: (2) 2500 ensures Obstacle Clearance in the holding pattern.

6.5

(1) APPROACH WITH INSTRUMENTS
Cat. A B C D

(2) Approach

(3) Tower

(4) On instructions

(5) Tower

(6) Alt and height in ft

(7) Minimum standard: vertical distances in feet, VH in metres

6.6

(1) APPROACH WITH INSTRUMENTS
Cat. A B C D

(2) Approach

(3) Tower

(4) On instructions

(5) Alt and height in ft

(6) Pylon

(7) Pylon

(8) Cathedral

(9) HOLDING> 3500 - T = 1min
RACETRACK at 2500

(10) max distance 12 NM TACAN

(11) Tower

(12):
In the absence of distance information: Minm alt.
25 NM : 5400

(13):
API: Climb straight ahead. At 1 NM STR, turn right to intercept STR Rdl 350 deg. At 3500 (3011) turn right to rejoin the hold at 3500 (3011) unless instructed by Ctl. Climb to 2400 (1911) prior to level acceleration.

(14) RIGHT

(15) Minimum standard: vertical distances in feet, VH in metres

(16) Note: Attention to VASIS 2.5 deg slope (different slope and GP point of origin)

6.7

(1) ARRIVALS

(2) STRASBOURG Region

(3) 22 August 91

(4) Level 80 max

(5) Level 90 min

(6) Controlled zones

(7) Outside operating schedule FL 45

6.8

(1) INDIRECT APPROACH

(2) Visual movements prohibited north of the runway

(3) OFFICIAL "AIR FRANCE" PROCEDURE

(4) Parachuting zone
to level 120

(5) Max speed 220 kts

(6)
MISSED APPROACH
Climb straight ahead, then turn right 1 NM after VOR "STR" to intercept R349. At 3500 (3011) turn right to return to the holding pattern unless CTL instructs. Climb to 2400 (1911) prior to acceleration.
HARG : 1900

MAPt ILS without glide : MM
VOR-DME : 4 "STR"
VOR and L : 3 NM "SE"

(7)
SCALE

(8)
TIME (min. sec.) / RATE (Ft. minute)

(9)
Ground speed (Kts)

QFE threshold 23
on request

6.9

(1) Visual movements prohibited north of the runway

(2)
MISSSED APPROACH
Climb straight ahead (Rm 050). At 12 after STR turn left to rejoin the holding pattern at 2500 unless CTL instructs

6.10

(1) AERODROME PLAN AND INFORMATION

(2) Civilian parking

(3) Civilian parking

(4) Terminal

(5) Tower

(6) Military parking

(7) Parking area

(8) Trees

(9) Terminal

(10) Freight

APPENDIX 7

7.1

(1) F-GGED Accident

(2) Mont Ste-Odile 20 January 1992

(3) We are going to put the anti-ice ... engine

(4) And... the same total... the wings.

(5) Engines de-icing

(6) Wings de-icing

(7) Engine Parameters

(8) Flow 1 (Kg/h)

(9) Flow 2 (Kg/h)

(10) Time generated (sec)

(11) 7 July 1992

7.2

(1) F-GGED Accident

(2) Mont Ste-Odile 20 January 1992

(3) Pressure altitude (feet)

(4) Flight parameters

(5) Area of special analysis of the data

(6) Vertical speed (Ft/min)

(7) Radio-altitude (Ft)

(8) Course (degrees)

(9) Conv. Speed (Kt)

(10) Roll (Degrees)

(11) Order: Gear down

(12) Gear locked down

(13) Air brakes deployed

(14) Time generated (sec)

(15) 8 July 1992

7.3

(1) F-GGED Accident

(2) Mont Ste-Odile 20 January 1992

(3) right

(4) left

(5) Air brakes

(6) right

(7) Area of special analysis of the data

(8) left

(9) Conv. speed (Kt)

(10) Time generated (sec)

(11) BEA Laboratory 8 July 1992

7.4

(1) Accident at Mont Ste-Odile

(2) Surveyed 20 January 1992

(3) Long. trim (degrees)

(4) Longitudinal parameters

(5) Incidence (degrees)

(6) Time generated (sec)

(7) BEA Laboratory 21 September 1992

APPENDIX 8

APPENDIX: TRANSCRIPTION OF CVR - version 3.2 dated 8 July 1992

NOTE

The following represents the transcription of the elements which could be understood, at the date of issue of the present report, by making use of the voice recorder (CVR). This transcription consists of the conversations between the two pilots, or between the pilots and the cabin crew, the radiotelephone messages exchanged between the crew and the air traffic control services, and the various sounds corresponding, for example, with the movements of the selectors or the alarms.

Those parts of the recording which were not understood or which remain uncertain are indicated by the symbol (*), with a note, if need be, of the corresponding number of words. Those exchanges not related to the conduct of the flight are marked as such and have not been transcribed.

The words or groups of words noted in brackets demand specific study in order to be understood and are possibly only identifiable after listening a large number of times.

The attention of the reader is drawn to the fact that the transcription of a CVR recording constitutes only a partial reflection of the sound record of events and of the atmosphere in a cockpit. This record is itself distorted by the non-appearance of all non-verbal communication. Consequently the interpretation of such a document requires the utmost prudence.

Communications concerning third-party aircraft which were registered on the CVR have not been transcribed.

The ATC times mentioned are based those recorded by the controls at Reims and Geneva. These clocks have an automatic synchronisation system (FRANGIN). On the other hand, as the time of the local control at Strasbourg is manually regulated, a recalculation conforming to Reims and Geneva has been undertaken.

*** GLOSSARY ***

CAM	: Cockpit Area Microphone
PF	: Pilot on duty (Flight commander for t his flight)
PNF	: Pilot not on duty (Copilot for this flight)
PUBLIC ADDRESS	: Cabin messages
VHF1	: Radio assigned to PF, here used by the PNF
VHF2	: Radio assigned to PNF, here used for receiving ATIS frequencies and morse signals of the radio beacons
(*)	: Word uncertain or not understood
(...)	: Words requiring specific listening and study
(@)	: Various sounds and alarms

Page 1

(A) CHANNEL 3 (CAM)

(B) CHANNEL 1 (PUBLIC ADDRESS)

(C) CHANNEL 2 (VHF1)

(D) CHANNEL 4 (VHF2)

(E) Version 3.2/08 July 1992

(1)
It is a little... it is a little before Luxeuil. If you want we only have to take it like that before Luxeuil too

(2)
It's twenty nautical.. eighteen nautical before Luxeuil.

(3) You have (*) (2 words)

(4)
Yes yes... I am going to take it like that

(5) (*) (4 words)

(6) It's strange that he's not making us climb... It seemed to me that we were climbing before.

(7)
Yes!
Before we were climbing at one hundred and ninety yes!

(8)
Let him take his three hundred forty knots after all!

(9)
Are you lifting your FPA track?

(10)
We will descend to thirty nautical before STR

(1)
Ctl: Air Inter one four eight Delta Alpha Contact Reims one two four niner five, goodbye.

(2)
Thirty before!

(3)
It's not for us that one two four niner five?

(4)
You are calling for Delta Alpha?

(5)
Ctl: Affirm Delta Alpha, one four eight contact Reims one two four decimal niner five

(6)
With Reims one two four decimal niner five, thank you. Bye!

(7)
Ctl: Goodbye!

(8)
Reims Air Inter Delta Alpha one four eight, good evening

(9)
Ctl: Air Inter Delta Alpha one four eight good evening. Proceed Luxeuil and standard arrival for Strasbourg

(10)
Luxeuil and standard on Strasbourg

(1)
Do you want something?

(2)
No no... it's... If you don't ask the met, they don't know there...
we are going to take five minutes there...
We are going to see what they give...

(3)
Ah!..

(4)
Have we made thirty five minutes of flight just now?

(5)
Er ... I don't know what else to tell you

(6)
Steward: Do you want something to eat or drink?

(7)
No thank you

(8)
Forty one minutes

(9)
Forty one minutes

(10)
Steward: Do you want something to eat or drink?

(11)
I like my tray, to eat a little bit...

(12)
It's zero five in service

(13)
Zero five?
What sort of wind are they giving us?
(*)

(14)
(words not related to the conduct of the flight)

(15)
Will you pass me our met? What kind of ceiling are they passing there?

(16)
Eight eighths at three thousand!
I need to take it again

(17)
(words not related to the conduct of the flight)

(18)
/..wind of zero four zero for eighteen knots, visibility (*) kilometres, five eighths at eight hundred feet, eight eighths at three thousand feet, temperature two degrees, dew point one, QNH one thousand and twenty one, Fox Echo one thousand three. Inform Strasbourg on initial contact that you have received the information November...

Strasbourg good evening, information November recorded at one six zero zero. Runway in use zero five, transition level five zero, wind zero four zero, one eight knots, visibility ten kilometres, five octa at height ...er... hundred feet, eight octa at three thousand feet, temperature two degrees, dew point one, QNH one zero two one, Fox Echo one zero zero three. Inform Strasbourg on initial contact that you have received information November...

Strasbourg good day, information November registered at sixteen hundred hours. Runway in service zero five, transition level five zero, wind zero four zero for eighteen knots, visibility ten kilometres, five eighths at eight hundred feet, eight eighths at three thousand feet.../

(1)
And a wind of zero five zero degrees for ten knots?

(2)
Eighteen knots.

(3)
Eighteen knots.. oh no chance

(4)
I'll listen to it again... because... I'll leave you the ATC eh.

(5)
Yes yes

(6)
Zero five one zero kilometres, three eighths at eleven hundred, eight eighths at two thousand, eight.... one thousand twenty three, one thousand five

(7)
Ten kilometres of vis

(8)
You can look at the minimas for zero five, what they're saying

(9)
I'm looking at that immediately... there it is, it's good.
(*)

(10)
Strasbourg VOR/DME zero five... four hundred ten feet... and one thousand eight hundred fifty metres

(11)
Is there a MVL above?

(12)
Night MVL.. eight hundred fifty feet... eight hundred fifty feet and two thousand eight hundred metres

(13)
/..wind zero forty, twenty knots gusting thirty, visibility ten kilometres, ceiling three eighths eleven hundred feet, six eighths two thousand six hundred feet, temp one, dew point zero, QNH one thousand twenty three. Fox Echo one thousand five, inform Strasbourg on initial contact that you have received the information Oscar...

Good evening Strasbourg information Oscar recorded at eighteen zulu time, (*) runway zero five, transition level five zero, wind zero four zero, (*) twenty gusting thirty, visibility ten kilometres, ceiling three octa one thousand one hundred feet, six octa two thousand six hundred feet, temp one, dew point zero, Quebec November Hotel one zero two three.../

(1)
We will attempt to position, from due traffic, make an ILS interception

(2)
With an opening to right propose a tailwind, a tailwind and a zero five final

(3)
Yes

(4)
If we use the zero five procedure.. oh well we... (whistle)

(5)
You have to take the minimas of the MVL

(6)
How much is that?

(7)
Eight hundred fifty feet

(8)
Eight hundred fifty...

(9)
MDH
MDH

(10)
Yes, yes, MDH

(11)
You see, I'm going to put the twenty three, otherwise personally I couldn't make the ILS interception. I'm putting back the twenty three eh?

(12)
You're taking the twenty three?

(13)
Yes! That's.. to make the ILS arrival

(1)
Agreed

(2)
Then the safety, from twenty five thousand feet until twenty one, five thousand two hundred feet.. and four thousand nine until eight and four thousand two after that...

(3)
Yes

(4)
For an ILS, then.. in twenty three, track two hundred thirty one, one hundred ten ten.

(5)
Procedure turn to two thousand feet floor, the Sierra Echo beacon, thirteen hundred feet

(6)
Yes

(7)
.. and in case of Missed Approach, if you can't see it, you climb again straight ahead, one nautical STR

(8)
One nautical after overhead the VOR, you turn right to intercept the three four niner radial to climb towards three thousand feet, turn right to rejoin the holding pattern and climb to nineteen hundred feet prior to accelerating...

(9)
..three thousand

(10)
HARG... nineteen hundred feet, minima and MVL eight hundred fifty feet and four hundred ten feet if we do a zero five...er...

(11)

since... the authorised ceiling as far as three thousand feet...

(12)
Agreed

(13)
I don't understand why you are not holding a zero five VOR DME even so

(1)
Because the zero five VOR DME, it has to arrive here, to depart... to go to one hundred thousand diables and come back

(2)
Then you would have also quickly done...

(3)
Oh yes, agreed

(4)
Otherwise, you need to extend to eleven STR, that makes eleven, that makes twenty two nautical.. It's departed for ten minutes of flight more there eh... that's what it's for...that

(5)
Yes, you need to do a...

(6)
(SE Morse signal)

(7)
Sierra Echo identified

(8)
I've taken from you the inbound leg on STR eh... zero fifty

(9)
Agreed

(10)
We will do the procedure before descent

(11)
Wait..

(12)
It's not serious

(13)
I'm ready

(14)
Check list before descent

(15)
ECAM Status verified
Speed Bugs

(1)
They are in order

(2)
Standby altimeter

(3)
One thousand twenty three

(4)
One thousand twenty three, altimeter (*) checked
Engine anti ice

(5)
Check OFF

(6)
FMGS parameters inserted and harnesses

(7)
Fastened

(8)
Checklist completed

(9)
We are descending in one minute
Is it good?

(10)
In one and a half minutes, two minutes, we have time

(11)
Air Inter one hundred forty eight Delta Alpha, we would like to descend in one minute

(12)
Ctl: Delta Alpha descend level one hundred thirty

(1)
Towards the one hundred thirty, we will descend Delta Alpha

(2)
Ctl: Delta Alpha the course towards ANDLO

(3)
The course towards ANDLO correct?

(4)
Ctl: Affirm

(5)
towards?

(6)
ANDLO

(7)
ANDLO, oh there, they are breaking my feet with their stuff...

(8)
Ctl: Air Inter Delta Alpha what course are you making towards ANDLO?

(9)
We have course zero fifty three towards ANDLO

(10)
Ctl: Delta Alpha, maintain course zero fifty three until further instruction!

(11)
We are maintaining until further instruction

(12)
Oh, I say, Reims, their control there...

(1)
All that because there was one going towards Epinal

(2)
Ctl: Air Inter Delta Alpha continue the descent towards level seventy

(3)
We are continuing the descent towards seventy, seven and zero Delta Alpha

(4)
There you are, it's gone
Idle Open

(5)
Idle Open descent

(6)
PNC announcement:
Ladies and Gentlemen, we are commencing our descent we ask you to please return to your seats. Thank you!

(7)
Ctl: Air Inter Delta Alpha the descent level?

(8)
We are crossing one hundred fifty in descent towards seventy Delta Alpha

(9)
Ctl: Delta Alpha received, no further course restriction, contact Strasbourg one hundred twenty point seven. Goodbye.

(10)
No further course restriction one hundred twenty seven, goodbye

(1)
Strasbourg Approach good da{, Air Inter one hundred forty eight Delta Alpha

(2)
Ctl: One hundred forty eight Delta Alpha good day proceed towards ANDLO
Your distance?

(3)
(*) (1 word)

(4)
Yes ANDLO, and we are at twenty two nautical DME from STR

(5)
Ctl: Received, continue the descent towards five thousand feet at QNH one thousand twenty three, re-call ANDLO five thousand feet

(6)
Five thousand feet, one thousand twenty three we re-call ANDLO five thousand

(7)
There, one thousand five..

(8)
And sixty for the moment

(9)
The safety.. twenty two... oh well that's all right.. five thousand two hundred feet.. twenty one.. OK that's good

(10)
Five thousand

(11)
One thousand five.. we will do the procedure at ten thousand... the initial approach at the same time

(12)

Eleven thousand two hundred feet

(13)
OK

(14)
TOP

(1)
No. Eleven thousand one hundred feet, one thousand five.. one thousand five not one thousand eight

(2)
PNC announcement:
Ladies and Gentlemen, we are continuing our descent, we ask you please to fasten your seat belts. Thank you. Ladies and gentlemen we are continue our descent would you please fasten your seat belt. Thank you.

(3)
Yes it's one thousand eight

(4)
One thousand twenty three, that makes one thousand five

(5)
One thousand five?

(6)
For Delta Alpha, confirm Fox Echo one thousand five, zero five correct?

(7)
Ctl: The Fox Echo is one thousand five, zero five and the QNH one thousand twenty three

(8)
Thank you Sir

(9)
One thousand five
Ten thousand four hundred..

(10)
Ten thousand four hundred feet, watch... TOP

(11)
It's correct.. It's good

(12)
Initial approach check list,

Baro ref altimeters compared - in order,
Seatbelts ON

(13)
It's in order

(14)
Engine anti ice OFF for the moment.
I'm going to put them after...
Marker ON, listen at right
Engine mode selector ON, normal Check list completed

(15)
No

(1)
We are passing ANDLO

(2)
We are passing ANDLO, Air Inter Delta Alpha, level... er sorry seven thousand five hundred feet in descent

(3)
Ctl: Received forty eight Delta Alpha, you are number one for the VOR DME zero five, call back passing the VOR on final

(4)
Number one for the VOR DME zero five

(5)
We could ask him to confirm the ceiling now how many nautical?

(6)
Ten nautical... That's not right
Tell him, we are going to do a..

(7)
Yes, max, max...

(8)
Confirm the ceiling Strasbourg?

(9)
Ctl: Er.. currently we have three eighths at one thousand one hundred feet and six eighths at two thousand six hundred feet

(10)
That's good

(1)
Yes, we would envisage proceeding Sierra Echo to do an ILS with an indirect for the zero five after that

(2)
(SINGLE CHIME)

(3)
Clear, clear!..

(4)
Ctl: Received Delta Alpha

(5)
How high the temperature?

(6)
The temperature...

(7)
Ctl: Delta Alpha, you will maintain initially five thousand at QNH one thousand twenty three and given that we are going to have three take-offs on zero five, you risk waiting in the stack at five thousand feet.

(8)
We will revert to the VOR DME procedure.. then..

(9)
We will revert to the VOR DME procedure at that moment

(10)
Ctl: OK

(11)
We are not going to mess about descending like that in India Mike if they have warned in advance, but there, we're arriving full pelt

(1)
Ctl: Delta Alpha er.. Strasbourg

(2)
I hear you

(3)
Ctl: If you want I can take you with the radar to lead you to ANDLO at five thousand

(4)
Oh yes, that's good!

(5)
Oh yes!

(6)
Ctl: OK! Then sixty one zero zero, turn left on course two hundred thirty

(7)
Sixty one zero zero and steer two hundred thirty left

(8)
Ctl: There you are, that will save you some time!

(9)
Yes, yes...

(10)
Thank you

(11)
I'm putting you back zero five

(1)
Ctl: Then you maintain five thousand until reaching ANDLO, the QNH is one thousand twenty three

(2)
QNH one thousand twenty three, we are maintaining five thousand

(3)
Then those distances..er.. oh yes there (*) vertical the two hundred fifty on the outbound as far as eleven STR, we pass by ANDLO again on the inbound and we break at eleven STR... four thousand five hundred feet, nine STR, three thousand eight, seven, three thousand, two; In case of Missed Approach we climb again straight ahead

(4)
Ctl: Delta Alpha, six nautical, radial two niner zero from Strasbourg

(5)
Received Delta Alpha

(6)
The break is made on zero fifty, it's a glide of three decimal five er five decimal five... that makes three degrees three.

(7)
We are going to put the anti-ice...
... engine

(8)
And... the total the same... the wings.

(1)
The (leading) edge of the aircraft has no icing detector...

(2)
Yes

(3)
Damn!

(4)
It is fine and modern but that it lacks

(5)
Yes, yes.. there is some ice above

(6)
It's shit eh, when you are not ready at arrival time at five thousand feet on ANDLO, full pelt ..er.. that's not on eh.. Further.. to... what... ten nautical from final

(7)
Ctl: Air Inter Delta Alpha turn left steer ninety zero nine zero

(8)
Steer left ninety, zero niner zero Delta Alpha

(9)
The Flaps line one

(10)
Flaps line one

(11)
Flaps one

(1)
Ctl: Air Inter Delta Alpha continue the left turn to set yourself on the zero fifty one, you are at four nautical from ANDLO...askew left of ANDLO

(2)
OK

(3)
Received, we call back established on the QDM zero fifty one

(4)
Ctl: Affirm Sir

(5)
We're going...(inside) there eh!

(6)
...you're (inside) there eh!
You should have needed to open at zero seven zero

(7)
Yes yes

(8)
At least

(9)
Ctl: Air Inter Delta Alpha cross right ANDLO, authorised... for the final approach VOR DME zero five

(10)
Delta Alpha

(11)
Flaps towards two

(12)
Flaps towards two

(13)
Flaps at two

(14)
Gear down

(15)
I'm preparing the landing lights without putting them eh

(16)
Ctl: Delta Alpha call overhead the V-O-R on final

(17)
OK

(18)
Call overhead the VOR on final

(19)
Cabin crew announcement:
Ladies and Gentlemen, we are going to land in a few minutes, for your safety please check that your seat belt is fastened and close the table at your seat. Thank you. Ladies and gentlemen, we shall be landing shortly, for your safety please make sure that your seat belt is fastened and your table is (*).

(20)
We're going (to pass it)
eight hundred feet

(21)
(needs to watch that it is not descending)

(22)
On the radial!

(23)
We're arriving on the radial!... a half point off the radial. There it is, it was at sixty it's good you see

here

(24)
Radio Altimeter: TWO HUNDRED

(25)
(IMPACT)

(26)
END OF THE RECORDING

APPENDIX 9

ATC TRANSCRIPTION - LYON

GROUND FREQUENCY 121.8 MHZ

(1) TIME UTC (2) FROM (3) COMMUNICATIONS (4) COMMENTS

DA Satolas, Air Inter one hundred and forty-eight Delta Alpha good evening

Ctl Delta Alpha good evening

DA Bravo twelve, we are going to be ready for the push and setting course for Strasbourg

Ctl Set course, you can push, Delta Alpha

DA Received

DA To taxi Air Inter Delta Alpha

Ctl Delta Alpha, for the eight Bravo, taxi runway thirty-six, your clearance

DA We are taxiing runway thirty-six, we are listening to you

Ctl A departure Luxeil one November, level eighty, transponder sixty seven zero three

DA Sixty seven zero three, in departure Luxeil unity November, level eighty, Air Inter Delta Alpha

Ctl Affirm

Ctl Air Inter, contact Satolas tower one hundred twenty zero; goodbye

DA One hundred twenty zero, goodbye

ATC TRANSCRIPTION - LYON

TOWER FREQUENCY 120.00 MHZ

(1) TIME UTC (2) FROM (3) COMMUNICATIONS (4) COMMENTS

DA	Satolas tower, good evening, Air Inter one hundred forty-eight Delta Alpha
Ctl	Good day Delta Alpha, you will hold, an aircraft is on CAT II final
DA	An aircraft on CAT II final, we will hold, Air Inter Delta Alpha
DA	We have visual on the final which has just passed in front of us, Air Inter Delta Alpha
Ctl	Air Inter Delta Alpha, line up and hold
DA	We are lining and holding, Delta Alpha
Ctl	Air Inter Delta Alpha authorised for take-off, the wind three hundred and forty, six knots
DA	Three hundred and forty, six knots, we are lining up and taking off Air Inter Delta Alpha
Ctl	Air Inter Delta Alpha, have you selected sixty seven zero three?
DA	Affirm, Madame
Ctl	Thank you, contact the Approach, one hundred twenty eight five. Goodbye
DA	One hundred twenty eight five, goodbye

ATC TRANSCRIPTION - LYON

APPROACH FREQUENCY 128.500 MHZ

(1) TIME UTC (2) FROM (3) COMMUNICATIONS (4) COMMENTS

DA	Satolas Approach, good evening, Air Inter one Delta Alpha one four eight
Ctl	Delta Alpha one four eight Delta Alpha, good evening, call bac
DA	Sixty towards forty eight
DA	Sixty towards forty eight, Air Inter Delta Alpha
Ctl	Delta Alpha, contact Marseille Control one hundred twenty six seven, good evening
DA	One hundred twenty six seven, good evening

ATC TRANSCRIPTION - MARSEILLE

FREQUENCY 126.70 MHZ

(1) TIME UTC (2) FROM (3) COMMUNICATIONS (4) COMMENTS

DA	Marseille, good evening, Air Inter Delta Alpha one four eight
Ctl	Good evening, one hundred forty eight Delta Alpha, contact radar, climb level one hundred eighty, unit eight zero
DA	Eight zero Delta Alpha
DA	Approach one hundred eighty Air Inter Delta Alpha
Ctl	Correct Delta Alpha, maintain one hundred eig
DA	Presently changing course to Luxeuil, we are maintaining one hundred eighty
Ctl	Air Inter Delta Alpha, contact Geneva one hundred twenty seven three, good evening
DA	Yes, Geneva twenty six three, goodbye
Ctl	One hundred twenty seven three

ATC TRANSCRIPTION - GENEVA

APPROACH FREQUENCY 127.3 MHZ

(1) TIME UTC (2) FROM (3) COMMUNICATIONS (4) COMMENTS

(5):

DA Geneva, Air Inter one four eight Delta Alpha good evening

ATC TRANSCRIPTION - REIMS

FREQUENCY 124.95 MHZ

(1) TIME UTC (2) FROM	(3) COMMUNICATIONS (4) COMMENTS
DA	Reims, Air Inter one hundred forty eight Delta Alpha good evening
Ctl	Air Inter one hundred forty eight Delta, good evening, proceed Luxeuil and standard arrival for Strasbourg
DA	Luxeuil and standard on Strasbourg
DA	Air Inter one hundred forty eight Delta Alpha, we would like to descend in one minute
Ctl	Delta Alpha descend level one hundred thirty
DA	Towards the one hundred thirty we will descend Delta Alpha
Ctl	Delta Alpha steer for ANDLO
DA	Steer for ANDLO correct?
Ctl	Affirm
Ctl	Air Inter Delta Alpha which course are you on for ANDLO?
DA	We have the course zero fifty three to ANDLO
Ctl	Delta Alpha maintain the course zero fifty three until further instruction
DA	We are maintaining until further instruction
Ctl	Air Inter Delta Alpha continue descent towards level seventy
DA	We are continuing the descent towards seventy, seven and zero Delta Alpha

Ctl Air Inter Delta Alpha the descent level?

DA We are crossing one hundred fifty in descent towards seventy Delta Alpha

Ctl Delta Alpha received, no further course restriction, contact Strasbourg one hundred twenty point seven. Goodbye

DA No further course restriction one hundred twenty seven, goodbye

ATC TRANSCRIPTION - STRASBOURG
APPROACH FREQUENCY 120.7 MHZ

(1) TIME UTC (2) FROM	(3) COMMUNICATIONS (4) COMMENTS
DA	Strasbourg Approach good day Air Inter one hundred forty eight
Ctl	One hundred forty eight Delta Alpha good day, proceed to ANDLO. Your distance?
DA	Yes, ANDLO, and we are at twenty two nautical DME from STR
Ctl	Received, continue descent towards five thousand feet at QNH one thousand twenty three, call back ANDLO five thousand feet
DA	Five thousand feet, one thousand twenty three we call back ANDLO five thousand
LGL854	Luxair 854, is passing 5000
Ctl	Roger 854 proceed to GTQ, climb FL 140, contact Reims
LGL854	Roger. GTQ, 140, to Reims 128.3. Bye bye
DA	For Delta Alpha, confirm Fox Echo one thousand five, zero five correct?
Ctl	The Fox Echo is one thousand five, zero five and the QNH one thousand twenty three
DA	Thank you,"Sir
DA	We are passing ANDLO, Air Inter Alpha, level... er sorry seven thousand five hundred feet in descent
Ctl	Received one hundred forty eight Delta Alpha you are number one for the VOR DME zero five, call back passing the VOR on final
DA	Number one for the VOR DME zero five
DA	Confirm the Strasbourg ceiling

Ctl	Er.. currently we have three eighths at one thousand one hundred feet and six eighths at two thousand six hundred feet.

DA	Yes, we would envisage proceeding Sierra Echo doing an ILS with an indirect for the zero five after that

Ctl	Received Delta Alpha

Ctl	Delta Alpha, you will maintain initially five thousand, one thousand twenty three and given that one will have three take-offs on zero five, you risk waiting in the stack at five thousand feet

DA	We will do a reciprocal turn with the VOR DME procedure at that moment

Ctl	OK!

ATC TRANSCRIPTION - STRASBOURG

(1) TIME UTC (2) FROM (3) COMMUNICATIONS (4) COMMENTS

Ctl	Delta Alpha er.. Strasbourg
DA	I hear you
Ctl	If you want I can take you on radar to lead you to ANDLO at five thousand
DA	Oh yes!
Ctl	OK, then sixty-one zero zero, turn left to steer two hundred thirty
DA	Sixty-one zero zero and steer two hundred thirty by the left
Ctl	There you are, that will save you some time
DA	Thank you!
Ctl	On reaching five thousand, then you maintain as far as ANDLO, the QNH is one thousand twenty three
DA	QNH one thousand twenty three, we are maintaining five thousand
IT EK	Strasbourg, good day Air Inter Echo Kilo, we are approaching the threshold zero five and we are ready
Ctl	Received Echo Kilo, line up and hold
IT EK	We are lining up and holding Echo Kilo
Ctl	Air Inter authorised for takeoff, wind 040/24 kts
IT EK	Echo Kilo, we are taking off
Ctl	Delta Alpha, six nautical, radial two hundred ninety of Strasbourg

DA   Received Delta Alpha

AF1204	AF 1204 is ready
Ctl	AF 1204 good evening, line up and hold
AF1204	AF 1204 is clear to line up and hold 05
Ctl	Air Inter Delta Alpha you turn left steer ninety zero nine zero
DA	Steer ninety, zero nine zero by the left Delta Alpha
Ctl	Echo Kilo authorised the turn towards Epinal to level one hundred forty

ATC TRANSCRIPTION - STRASBOURG

(1) TIME UTC (2) FROM	(3) COMMUNICATIONS (4) COMMENTS
EK	At left towards Epinal, to level one four zero, Echo Kilo
Ctl	Affirm, call back the seventy, break, Air Inter Echo Kilo
EK	Agreed
QZ	Good day Air Inter Quebec Zulu, we are approaching the stopping point zero five
Ctl	Received Quebec Zulu, hold, I will call you back
Ctl	Air Inter Delta Alpha, continue the turn to left to establish yourself on zero fifty-one, you are at four nautical from ANDLO...askew left of ANDLO
DA	Received, we call back established on the QDM zero fifty-one
Ctl	Affirm Sir
AF1204	AF 1204, take-off, clear take-off, wind 040-24 knots maintain runway heading after.
AF1204	AF 1204 is clear to take off and maintain runway heading
Ctl	Air Inter Quebec Zulu, after the take-off, line up and hold
QZ	After the take-off we will line up Quebec Zulu
Ctl	Air Inter Delta Alpha cross right to ANDLO, authorised...for the VOR DME final approach zero five
DA	Delta Alpha

EK We break seventy towards one hundred forty. Air Inter Echo Kilo en route for Epinal

Ctl Received Air Inter Echo Kilo. Contact Reims control one hundred twenty eight five. Good flight

EK One hundred twenty eight five. Thank you

Ctl Delta Alpha call overhead the VOR on final

DA Call the VOR on final

Ctl AF 1204 - Left turn inbound GTQ is approved

AF1204 Left turn to GTQ AF 1204

IT QZ Surface wind zero forty zero - twenty four kt take-off authorised, zero five

QZ We are taking off. Quebec Kilo

Ctl DA, your position?

ATC TRANSCRIPTION - STRASBOURG

(1) TIME UTC (2) FROM (3) COMMUNICATIONS (4) COMMENTS

Ctl	Air Inter Delta Alpha Strasbourg?
Ctl	Air Inter Delta Alpha Strasbourg?
Ctl	Quebec Zulu, your limit two thousand five hundred feet
QZ	Two thousand five hundred feet Quebec Zulu

APPENDIX 10

TRANSCRIPTION

Telephonic communication established between the Eastern Regional Centre for Air Navigation (CRNA/Est) and Strasbourg Approach

18h01min22sec APP -Yes Strasbourg

18h01min24sec CCR - Yes it is for an arrival, the Air

18h01min27sec APP - At what time?

18h01min28sec CCR - At thirteen

18h01min30sec APP - Delta Alpha at thirteen, you are

18h01min35sec CCR - What?

18h01min36sec APP - You are putting it on ANDLO, level seventy...

18h01min40sec CCR - Yes...

18h01min40sec APP - ...and you are crossing with the

18h01min45sec CRR - With the eighteen seventy

18h01min47sec APP - OK?

18h01min47sec CCR - Yes, OK

APPENDIX 11

EXPLANATORY NOTE ON RADAR FLIGHT PATH ANALYSES

Summary principle of secondary radar

The radars used in civil aviation for "en route" control purposes are "secondary" radars which necessitate the active participation of an electronic system installed on board the aircraft to reflect their measurements. They effectively "interrogate" the on-board "responders" located in their area of coverage in a regular pattern. The "responders", when the radar beam intercepts them, send a coded response onto which the measurement is made.

The Transponder transmits its identification code in response to a "mode A" type interrogation, and its "altitude pressure" in response to a "mode C" type interrogation. The reference "altitude zero" is the isobar 1013 hPa.

Each passing of the radar beam in front of the target gives rise to several interrogations in the two modes in order to confirm the responses by correlation. A measurement of position is effected on each response from the on-board "responders".

It consists of:

- the oblique radar/target distance subtracted from the time elapsing between the departure of the interrogation and the arrival of the response.

- the azimuth of the target, the angle formed by the zero degrees reference axis (North) of the radar antenna and that of the radar beam at the moment of the measurement.

An extraction and correlation algorithm synthesises the responses of each Transponder to form the radar "plot" of an aircraft.

The plots are sent by transmission of data on channel support to the radar processing system of the Regional Control Centres responsible for air traffic in the region.

The range of the radars is 180 nautical miles in open space. It is limited to the radio horizon at low altitudes by virtue of the curvature of the earth or when an obstacle or the relief interposes between the radar and the target (Ground Clutter). Furthermore, detection is voluntarily reduced along the radio horizon in order to suppress the harmful disturbances which are observed in its vicinity.

When the targets are detected in weak locations, the radio liaison balance varies greatly. Frequent breaks in liaison due to masking of antennae are noted when there are changes in trim changes of the aircraft.

The radar processing system

Its role is to reconstruct the tracks of the aircraft from the plots received in order to present, on the screens of the Regional Control Centre, the most pertinent information updated with the most recent multiradar measurements.

It therefore initially receives the plots of all the radar sources and verifies their coherence and the data. It converts the positions received in such a way as to place them in a common geographical reference point independent of the radars locations, after correcting them for system biases and for their diagonal relationship, given the altitude of the aircraft.

Various, very elaborate algorithms then enable it to re-attribute to each identified track which it maintains, the last radar return measurements corresponding to that aircraft. The radars being classified localny in descending order of performance, the system maintains, for each aircraft, the tracks of the three best radars. The one of the highest quality will finally be sent to the control screens. It should be noted that an aircraft flying at high altitude can be detected simultaneously by six or more radars.

Before transmission to the control screens, each track is again subject to a filtering of position and altitude, employing very high-performance techniques in order to eliminate radar aberrations and then determine the speed vector and the vertical trend.

When the radar processing identifies a new track, it establishes a dialogue with the flight plan processing system to produce a correlation between the track and its flight plan in order to attribute to it the aircraft identifier corresponding to its call sign (company line number or registration number of the aircraft).

This synthesised information is finally sent to the radar screens of the Controllers, the image being updated at a rate once every 10 seconds.

The average time which elapses between the radar measurement and the last updating of each track is approximately equal to the rate of updating of the image on the control screens.

The system also carries out internal measurements which enable it to estimate and then to correct the system biases of the radar positions, such as the convergence of the norths.

Radar imperfections and errors

Radar measurements are marred by random "noise" inherent in the imperfections in the ground/on-board/ground chain and the extraction principles employed. For example, the digitalisation of the video is done by dividing the airspace into azimuth/distance cells of predetermined steps (0.1 degrees and 1/8 NM). The azimuth of the plot is that of the cell containing the mediant echo among the echos received. In case of partial loss of the responses, the plot becomes eccentric and in fact split in two; if it changes a distance cell, the distance is modified by the length of the step.

The most serious errors, however, originate in the covering or overlapping of responses, a frequent occurrence in zones with high traffic density. This mixture induces random position and code errors which the new techniques employed for signal extraction and processing can still only partially resolve.

The intrinsic performance of a radar station is equally a function of its material characteristics and/or its regulation, which leads to a certain disparity between stations. The following factors may be mentioned:

the emission strength, the gain, the angle and rotational speed of the antenna, the period of interrogation, the characteristics of the receiver, the extraction techniques, etc...

Today the Air Navigation Directorate has developed software applications which make possible, periodic evaluation of the quality and precision of radar stations. These applications are based on the exploitation of ordinary traffic, i.e. they are confronted with real situations in the same way as an Air

Traffic Control officer would be.

Performance of radar stations:

This is expressed in terms of probability of detection and precision.

The probability of detection is the relationship, expressed as a percentage, of the total number of plots received from all the aircraft located within the radar coverage area in a specific period of time, and the number of plots which would normally have been received if there had been no loss.

The precision is the standard deviation of the divergences observed between the actual position of the plots and their theoretical position reconstructed a posteriori by means of modern flight path reconstruction techniques, knowing at each moment and for each track its present, its past and its future.

NOTE: This measurement is indicative as it does not take into account inevitable system radar biases, e.g. the bias in azimuth (a divergence of constant magnitude). The latter is revealed by carrying out absolute measurements on an aircraft whose strict position is known, or by means of mathematical error minimisation techniques employed in mulitradar processing,

However, the distribution of radar errors follows a convergent quasi-gaussian law, it may be said (not taking account of unknown biases) that 95% of the plots detected present a position error less than or equal to three standard deviations.

Measured values:

RADAR Points at the Standard Deviation (vicinity of STR)	CHAUMONT	LA DOLE	DRACHEN-BRONN
radial distance	0.05 NM	0.05 NM	0.06 NM
azimuth	0.08 deg	0.07 deg	0.12 deg
absolute distance	0.06 NM	0.12 NM	0.17 NM
Probability of detection (towards 5000 feet)	94.5%	0%	87.6%

NOTE: An arc of 0.1 at 60 NM is equal to 0.1 NM.

Observations on radar processing

Radar processing is applied at each moment to the most probable knowledge of the past in order to determine the future. Unlike radar which has a very limited view of a plot in time and space, it examines, in a largely open spatio-temporal window, the situation of each plot according to its antecedents and its environment with regard to the adjoining plots and tracks. It is therefore in a position to make the best choice on the pertinent criteria to re-attribute each plot to"the track to which it belongs. Efficient filtering enables it to correct certain aberrations, or to limit their effects.

In spite of that, this processing becomes faulty when the system is confronted with situations which current computer methods are unable to resolve by virtue of the limitation of calculating power. For this reason, the system in turn becomes a source of errors because it is led to make approximations which make the calculation of certain correction parameters, and in the end the calculated position of the tracks, less precise.

This results in practise in a slight discrepancy (in relation to one another) of the tracks which represent the same aircraft in the internal model, and on the control screen it results in a slight jump in position each time the track which is being displayed changes radar source.

Taking account of the security rules which the Controller must apply, these reasons have led the Air Navigation Directorate to stipulate in its Directive concerning the spacing norm, that the minimum radar spacing applicable for air traffic organisations using this means must be EIGHT nautical miles.

Flight path analyses

(1)
Representation of the dispersion corridor of the radar measurements in the racetrack from 18h12 to 18h22, from the radars of:

Drackenbraunn registered at Drackenbraunn
La Dôle registered by the Cautra_4 of Reims
Chaumont registered by the Cautra_4 of Reims
Drackenbraunn registered by the Cautra_4 of Reims
German radar of Pfalzerwald (reconstituted to scale)

Perception of the flight by the French radar processing system

Three CAUTRA tracks have been generated:

LA DOLE which was the master radar until FL 83, extends to 10 NM to the south-west of STR where the track ceased due to lack of definitive detection.

CHAUMONT on which the track commuted to FL 59 in descent towards FL 47. This track itself then ceased at the start of the turn, probably due to blocking of the antenna.

DRACHENBRONN then picked up the track in monoradar during the turn and at the start of the rectilinear section of the racetrack opposite STR where a swing was picked up again at CHAUMONT, its detection becoming correct again on leaving the turn.

CHAUMONT then maintained the track until total loss of detection took place at FL 44.

The position errors:

It is observed that the tracks show a slight curve in relation to one another on the whole of the course of the aircraft, with a maximum divergence for the CHAUMONT track of 1.2 NM at 8 NM north of LUL.

At the entrance to the racetrack the CHAUMONT track diverges by 0.3 NM in relation to the DRACHENBRONN track. The difference between the two tracks will be the cause of a series of alterations in the geometry of the track generated by the system by virtue of the successive fluctuation of one track upon another, which the radar 'best choice algorithm' will engage.

In fact, following the loss of LA DOLE, the track curves round towards the exterior because CHAUMONT was taken into account. On the switch to DRACHENBRONN at the start of the curve, the system slightly anticipates the turn, because the plot which it takes into account appears to employ a tight turn, allowing for the relative errors between the two tracks, while the following plot confirms this tendency. This jump in position by change of the master radar at the start of the turn induces the system into error and leads it to have recorded a tighter turn of the aircraft than the processed radar perceived. The maximum difference in the middle of the curve between radar plots and displayed track then reaches 0.5 NM. On exiting the curve the CHAUMONT track reappears but shows a difference from that of DRACHENBRONN of 0.7 NM. The 'best choice algorithm' radar return shows the track again on CHAUMONT, this time making it undergo an inflexion towards the interior of the racetrack, since the tracks have maintained their relative divergence.

Finally, the CHAUMONT and DRACHENBRONN tracks converge progressively towards each other until the DRACHENBRONN track disappears by loss of definitive radar.

Comparison of the French and German "racetracks"

If the two racetracks are superimposed, taking the position of STR in the two representations for reference on the one hand and superimposing the curves of the racetracks of the side of the Vosges on the other hand, there is noted to be:

A difference of the two tracks of 0.6 NM at the overhead of STR.

A turn taken by the French displayed track (and a fortiori by that of Drackenbraunn [sic] while this radar is the master radar) larger than that of the German radars (curvature radius of 2.4 NM in one case, 1.95 NM in the other)

A superimposition of the two tracks until common loss of them more or less at the same place.

In summary:

It can be considered that the most important radar error was of 1.2 NM on the LUL/STR section, the track which showed this distance (CHAUMONT) not however being the one which was displayed by the Controller.

In the racetrack the differences reach +/- 0.6 NM in relation to an imaginary average flight path because in the French system residual position biases remain.

Finally, CHAUMONT and the German radar had more or less the same vision of the final flight path.

It should be noted that the French system updated the information on the Controller's screen every 14 seconds or approximately every 1.5 NM on the en route flight section and every 1 NM in the racetrack.

APPENDIX 12

(1) FMCG1 flight path analysis

(2) Synthesised flight path analysis

(3):
We are passing ANDLO Air Inter Delta Alpha, level... er, sorry seven thousand five hundred feet in descent

Ten nautical... That won't do tell him, we're going to do a...

@ (Gong)

Delta Alpha, you will initially maintain five thousand at QNH one thousand and twenty three and given that there will be three take-offs at zero five,"you risk holding in the stack at five thousand feet.

If you want I can take you on the radar to lead you to ANDLO at five thousand

OK! then sixty-one zero zero, turn by the left to steer two hundred and thirty

ALT HOLD, 5000 FT QNH

Then you maintain five thousand until reaching ANDLO, the QNH is twenty three miles

Then the distances there...er...oh yes there (*) vertical two five zero, in distance as far as eleven STR, one passes by ANDLO again on the radial and breaks at eleven STR...four thousand five hundred feet, niner STR, three thousand eight, seven, three, seven, three thousand and two; In case of Go-Around one will climb again straight ahead

Delta Alpha, six nautical, radial two niner zero from Strasbourg

The intercept is made at zero five zero, it is a slope of three decimal five, er five decimal five...that makes three degrees three

(4):

2765: We are putting the anti-ice ... engine

2810: It's shit eh when you are not ready at arrival time at five thousand feet on ANDLO full pelt er... that won't do eh...More...to...what...ten nautical from final

2897: Air Inter Delta Alpha you turn left steer ninety, zero niner zero

2925: The flaps to one

2945: Air Inter Delta Alpha follow the left turn to set yourself on the zero five one, you are at four nautical from ANDLO...askew left from ANDLO

2983: ...you are (inside) there eh! You would have needed to open to zero seven zero

2991: Air Inter Delta Alpha through right of ANDLO, authorised... at the VOR DME final approach, zero five

2998: Flaps to two

3010: Gear down

3017: VZ NEGATIVE

3019: Delta Alpha call overhead the V-O-R on final

3038: We are going (to pass it) eight hundred feet

3049: On the radial

3054: One is arriving on the radial... a half point of the radial. There see it was at sixty, it's good you see here

3064: Radio Altimeter: TWO HUNDRED

APPENDIX 13

Map:

(1) 20 January 1992 - 1800 UTC]

[Map:

(1) Conical Lambert projection: Scale 1: 5,000,000]

FLIGHT FORECAST

(1):

Flight No IT 5148

Flight Path SXB

Communicated by the ITD Meteorological Centre
at 1530 UTC on 20 JAN 1992

by

The times used in this document are in UTC

(2) Aeronautical Meteorological Codes Used

(3) or

(4) NOTE: The elements or groups in brackets are omitted or included according to the conditions specified in the instructions relating to each group.

(5) NOTE: The maps making up the flight dossier may be maps reproduced at a different scale from the original document whose scale is shown in the legend.

8537

(1) Valid for

(2) Negative temperatures without sign

(3) Stereographic polar projection

(1) Reply:

(2) 20th January 92 at 15 hours 19 minutes 28 seconds

(1) STRASBOURG INFORMATION

(2) REGISTERED AT

(3) RUNWAY IN SERVICE

(4) STATE OF THE RUNWAY

(5) LEVEL OF TRANSITION

(6) VARIOUS:
Radio Aids
Bird Situation
Activation of Zones

(7) WIND

(8) VISIBILITY

(9) PRESENT WEATHER

(10) CLOUDS or
CEILING or
VERT. VISIBILITY

(11) TEMP./DEW POINT

(12) Q.N.H.

(13) Q.F.E.

APPENDIX 14

TREE OF CAUSES

(A): is expanded below

R1
abnormally high rate of descent

0
effectively controlled by the crew

1
not controlled by the crew

00
controlled voluntarily

01
rate of descent controlled involuntarily

10
failure of a means of control of the vertical flight path

11
other factors

000
following a positioning error induced by the data presented to the crew

001
other factors

100
loss of thrust

101
other factors

110
loss of aerodynamic control

111
other factors

000
positioning error induced by the data presented

0000
origin in ground systems

0001
origkn in on-board systems

00000
VOR

00001
TACAN

00010
anomaly of ND map

00011
raw data anomaly

000110
VOR

000111
DME

00 01100
intermittents

00 01110
"deaf mode"

00 01101
false QDM

00 01111
other factors

001
controlled voluntarily (other factors)

0010
acquisition of a visual reference mark

0011
bad understanding/execution of the procedure

00110
willing to descend rapidly to the MDH

00111
other factors

001110
error in calculation of the value to be displayed

011111
other factors

01
rate of descent controlled involuntarily

010
unaware of vertical mode

011
unaware of the value displayed

0100
neglected to change mode

0101
execution error in changing mode

0110
crude display and neglect of control

0111
other factors

01110
display 3 deg 3 as calculated before

01111
other factors

101
other factors

1010
upstream failure in taking instructions by the FMGC

1011
downstream failure in taking instructions by the FMGC

10100
vertical mode

10101
value of instructions

101000
faulty selection

101001
untimely activation of mode + other factors

101010
failure of the display

101011
instructions badly taken into acount + other factors

1010000
untimely change of mode

1010001
not taken into account + other factors

1010110
failure of rotary selector

1010111
corruption of the value transmitted + other factors

APPENDIX 15

APPENDIX 15 - Description of the piloting and navigation systems of the A320 Airbus

This section contains a brief description of the navigation and piloting systems of the A320 and the modes in which they are used.

The abbreviations used are those of the names of the systems in English.

Note: From the point of view of piloting and navigation, and taking account of the progress of the flight during the final minutes, the last turn and the descent can be broken down into two phases: a phase during which the pilot was directing his flight by integrating the flight and altitude commands given by the Controller at Strasbourg, followed by a phase where the pilot was ensuring full management of the approach.

1- Introduction

1.1 - The piloting modes of the A320

The A320 Airbus can be piloted according to three modes:

- manual mode
- "managed" automatic mode
- "selected" automatic mode

1.2 - The electronic display system (EFIS) of the A320.

The EFIS (Electronic Flight Instrument System) is made up of three Display Management Computers (DMCs) installed in the avionics bay and connected to the screens on the flight deck.

The DMCs collect the information from the other computers which are also located in the avionics bay and from various sensors. Functioning in parallel, the DMCs examine all the inputs in order to check their validity before transmission to the CRT screens (Display Units - DUs) in the flight deck. If the validity tests are not satisfied, the crew is warned.

Figure 1

Figure 2

Figure 3

Figure 4

The information presented is regrouped in a logical manner on the following screens:

- Primary Flight Display (PFD)
- Navigation Display (ND)
- Engine and Warning Display (E/WD)
- System Display (SD).

The PFD and ND screens are part of the EFIS, while the E/WD and the SD are part of the Electronic Centralized Aircraft Monitoring (ECAM).

Each pilot is provided with a PFD and an ND.

Data displayed on the PFD:

see Figures 1 and 2.

Data displayed on the ND:

The Navigation Display functions according to five different modes. Three of the five modes represent the traditional electromechanical Horizontal Situation Indicator - these are modes ILS Rose, VOR Rose and NAV Rose. The other two modes of the ND are ARC, which displays a sector of 90 degrees in front of the aircraft and PLAN, which is a map always orientated with north at the top of the screen. Unlike the other modes, in which the map moves behind a fixed aircraft symbol, in PLAN mode the aircraft symbol moves on the map.

Figure 3 shows a set of examples of the five different modes of the ND, and Figure 4 illustrates the ND in NAV Rose mode.

1.3 - The Head Up Display system

Description:

The A320s of the Air Inter company are equipped with a HUD installed on the glareshield, left side, which supplies the pilot in the left position flight information on a semi-transparent mirror. This information is focused at infinity and is then superimposed on the pilot's "normal" vision when he looks through the windscreen.

Figure 5

Figure 6

According to the phase of the flight and the systems used, the HUD can show five configurations: basic "in flight" configuration, ILS approach, view approach, rolling after automatic landing and rolling at take-off. The choice of configuration is effected automatically by the system according to the Autopilot or Flight Director modes. Within the context of a VOR-DME (or VOR-TACAN) approach, only two sorts of configuration are possible:

- the basic "in flight" configuration, if the aircraft is flying level, in IDLE OPEN DESCENT mode, or in Vs mode;

- or the "view approach" configuration in FPA mode. In this case where the FPA mode is engaged, the selected slope of the FCU (represented by horizontal lines), the speed vector (with the virtual slope arrows and the speed) and the radio-altimetric height appear.

By way of an example, Figure 5 shows the symbols of the HUD in the "view approach" configuration. The slope (FPA) selected on the FCU and the actual slope of the aircraft are equal and slightly less than -3 degrees, the radio altitude is 2630 ft and the speed indkcated is 156 kt.

Figure 6 shows, in basic configuration, a situation where the descent slope is between 10 and 11 degrees, the speed indicated is 185 kt and increasing, and the radio altitude is 2000 ft.

Use of the HUD in standard approach:

The HUD was not designed to display the radio navigation information necessary to conduct a standard approach (for example, VOR deviations and DME distances are not displayed on the HUD).

The presence of the flight speed vector, and possibly the selected slope, provides a piloting aid which can be used when the runway is in view, representing the termination point of the flight path.

2 - The manual piloting mode

In this mode, the piloting orders are transmitted to the flight controls by the pilot by moving the mini-handle (side-stick) and the rudder bar to control the flight path and the thrust levers to control the engines.

The pilot can use this mode in all phases of the flight and notably in a reflex action requiring great speed of execution. Instant disengagement of the Autopilot can be obtained in several ways, notably by moving a side-stick beyond a certain torque, or by means of a button located on each side-stick.

Note: Manual mode is the only mode authorised for take-off.

3 - The Automatic Flight Control System of the A320

3.1 - General

The automatic flight control system of the A320 is organised around two types of computers:

the Flight Management and Guidance Computers (FMGC) and the Flight Augmentation Computers (FAC),and two command systems:

the Flight Control Units (FCU) and the Multipurpose Control and Display Units (MCDU).

The FMGC and FAC computers are duplicated and are installed in the avionics bay.

The FMGCs perform the following functions:

- the automatic pilot (Auto Pilot - AP)
- the Flight Director (FD)
- the Flight Management (FM)
- the automatic management of the thrust of the engines (Auto Thrust - A/THR).

The FACs perform:

- the damping of yaw
- the direction trim
- limitation of deflection of control surface
- calculation of speeds and the flight envelope characteristics
- acquisition and execution of the AP commands in yaw

The FCU is located on the glareshield in the flight deck and the two MCUs are on the central console.

There are two operating modes for the automatic flight command system of the A320:

- the "managed" mode, where the commands executed (whether by the Autopilot or by the pilot following the indications given by the Flight Director, are deduced from the flight plan by the Flight Management Function of the FMGC.

- the "selected" mode, where the commands executed are deduced from a manual selection displayed by the pilot on the FCU.

3.2 - Parameters of the aircraft flight path

The Autopilot and Flight Director modes enable the lateral and longitudinal parameters of the aircraft flight path to be maintained. The references according to which these parameters are expressed then determine the type of flight path followed.

a) - Altitude reference

Standard barometric calibration: A standard calibrated altimeter indicates the altitude pressure of the place where it is located. This is the calibration used to define the flight levels.

QNH barometric calibration: An altimeter calibrated to indicate QNH, thereby indicating the altitude of that airport at its reference point.

QFE barometric calibration: An altimeter calibrated to indicate QFE, thereby indicating zero at the point of reference of the airport.

b) - Transmitted values

The magnetic course (Heading - HDG) is the angle between the aircraft and Magnetic North.

The magnetic route (Track - TRK) is the angle between the speed vector of the aircraft in relation to the ground (Ground Speed - G/S) and Magnetic North.

Vertical Speed (V/S): This speed is obtained by combining the information from the calculations of the ADC (Air Data Computer) for the slow dynamics and the Inertial Reference System (IRS) for the rapid dynamics. In a stabilised regime the vertical speed calculated by derivation of the altitude pressure and that calculated by integration of the inertial vertical acceleration have the same value.

The planned angle of descent or ascent (Flight Path Angle - FPA) is the angle between the speed vector of the aircraft in relation to the ground and the horizontal. By misuse of language, Flight Path Angle is sometimes translated [into French] as "slope" (for example, a Flight Path Angle on approach of 3.3 degrees corresponds to a descent slope of approximately 5.5%).

The TRK and FPA values are characteristics of the ground speed vector of the aircraft. Their subservience to the commands defines the aircraft flight path in relation to the ground.

Figure 7

(1) Levers

3.3 - Interface between the crew and the automatic piloting system

The automatic flight command system (Auto Flight System - AFS) of the A320 exchanges information with a large number of systems, and of course with the pilot, through the two command systems: the FCU and the MCDU.

3.31 - The MCDU

In "managed" mode,the MCDU (Multipurpose Control Display Unit) keyboard-screen is the interface system between the pilot and the FMGS. See Figure 7.

The MCDU allows:

- the introduction and modification of the flight plan;
- modification and display of the parameters connected with the management of the flight;
- and the execution of certain maintenance and communication tasks, but without the AFS aspect.

3.32 The FCU

In "selected" mode, the FCU (Flight Control Unit) panel is the interface system between the crew and the FMGS.

The FCU allows:

- engagement of the AFS,
- selection of modes and commands
- definition of the reference of altitude and flight path:

a) The engagement of the two Autopilots and the two Flight Directors (AP1, AP2, FD1, FD2) and the activation of the Auto Thrust (A/THR).

b) Selection of the commands for the AP/FD (altitude, speed or mach number, vertical speed, slope, course, route),

c) The selection of guidance modes,

d) The control of on-board instruments (without the AFS aspect).

Figure 8

Description of the FCU panel

See Figure 8.

The FCU is made up of the following elements in particular:

. Four selectors and display windows allow the pilot to define and display the commands which he inputs to the AFS:

- the speed or the mach number,
- the course or the route (HDG or TRK)
- the Flight Level, the altitude or the height.
- the vertical speed(V/S) or the slope (FPA).

The same window and the same selector are used for the course or the route, according to the reference selected. The selection of HDG (or TRK) mode allows the capture and maintenance of the course (or the route) selected by the pilot.

The same window and the same selector are used for the vertical speed or the slope of the trajectory. The selection of the V/S (or FPA) mode allows the acquisition and maintenance of the vertical speed (or the slope) which the pilot has selected on the FCU.

A luminous legend located above the mode reverser indicates the mode selected: HDG V/S or TRK FPA as the case may be. In the target values display window, a luminous legend located above the value in question indicates the nature of the activated parameter: V/S or FPA according to the mode selected.

Note: There are two other modes for changing level.
They are the OPEN and EXPEDITE modes.

. The signal buttons for engaging and disengaging the two Autopilots (AP1 and AP2). A single AP can be engaged at a time, except in LAND mode for automatic landing.

. The signal buttons for engaging and disengaging the two Flight Directors (FD1 and FD2).

. The signal buttons for activating Auto Thrust.

. The push button for switching the modes HDG-V/S and TRK-FPA. Switching from one mode to another changes the indications on the FCU, the mode announced on the FMA, and the symbols on the Flight Director, if it is engaged. In addition, the value selected in the new mode engaged synchronises with the aircraft value.

The philosophy of using the FCU is as follows:

- The action of pulling a selector engages the corresponding selected mode.

- The action of pressing the selectors for speed-Mach and HDG-TRK engages the corresponding managed modes. The action of pressing the V/S-FPA selector has no effect.

Following the action of pulling or pressing, the button is returned by a spring.

<u>Methods of using the FCU</u>

There are two possible procedures:

- Either the pilot begins by turning the rotary selector of the parameter which he wants to modify. This causes the display of the parameter in the corresponding window and allows selection of the desired value. Then, by pulling the selector, the pilot orders the transmission of the selected value to the FMGS.

- Or the pilot begins by pulling the selector. This action engages the mode and causes the current value of the parameter to be displayed. It is then possible to modify this value by turning the selector.

<u>Example of use of the FCU for horizontal guidance</u>

The pilot could adopt HDG mode when executing the radar guidance instructions given for a course and adopt TRK mode to follow a route.

Selection and display of HDG or TRK mode:

Selection of HDG mode (course) or TRK (route) is made by pressing the button [4].

The rotary selector [9] allows displa{ of the desired course (or route) value. When this button is pressed, the parameter is selected and processed immediately by the FMGS. The indication HDG or TRK appears on the FMA.

The target value (HDG or TRK) of the FMGS is written on the course/route scale of the Primary Flight Display (PFD) which is graduated in degrees, from 0 degrees to 359 degrees.

<u>Example of use of the FCU for vertical guidance</u>

When ordering a descent, the pilot has, among other possibilities, the option of selecting the vertical speed (V/S) or the planned angle of descent (FPA).

V/S and FPA modes:

These longitudinal guidance modes allow the acquisition and maintenance of the vertical speed or the slope selected on the FCU.

Selection and display of mode V/S or FPA: This choice is made by pressing the button [4].

Let us remember that the FPA and TRK magnitudes are characteristics of the speed vector in relation to the ground. V/S mode is associated with HDG mode, while FPA mode is associated with TRK mode. The combinations TRK-V/S and HDG/FPA are not possible.

The rotary selector [15] allows display of the desired vertical speed value (or the planned angle of descent).

When this button is pulled, the parameter is selected and processed immediately by the FMGS.

When the pilot selects a vertical speed or a planned angle of climb or descent, the target value is displayed in the window [7] of the FCU, in hundreds of feet per minute in the first case and in degrees and tenths of degrees (the two figures are separated by a point) in the second case. A + or - sign precedes this indication, according to whether a climb or a descent is involved.

It is possible to select the vertical speeds between -6000 ft/min and +6000 ft/min (display from -60 to +60) or slope angles between -9.9 degrees and +9.9 degrees (display from -9.9 to +9.9).
The indication V/S or FPA appears on the FMA. The target value (V/S or FPA) of the FMGS is not registered on the PFD.

3.4 - Symbology of Flight Director

The Flight Director is a function of the FMGC. Provided that it has been engaged by the pilot, the Flight Director indicates the action to be carried out on the side-stick in order to obtain the flight path corresponding to the selected modes and commands. If it is engaged, the Auto Pilot automatically carries out the control itself.

There are two different types of symbols of orders for the Flight Director:
- If the pilot selects the HDG-V/S guidance mode, the Flight Director is represented on the PFD by two bars known as "crossed bars" or "V bars". The pilot must operate the controls so that the bars remain centred on the PFD. See Figure 9.

Figure 9

Figure 10

Figure 11

- If the pilot selects the TRK-FPA mode, the symbols are of the FPV (vector speed) and Flight Path Director (FPD) type. The pilot must operate the controls to make the speed vector and the centre of the Flight Path Director symbol coincide. See Figure 10.

4 - Radio-navigation: Display of the methods, and calculation of the FM position

4.1 - Selection of the methods of radio-navigation

Selection of the radio-navigation beacons can be effected in three modes:

- Automatic (autotuning): The FMGC chooses the beacons to be displayed in terms of the flight plan and the DATABASE information;

- Manual: The pilot himself selects the beacons to be displayed and displays them by means of an MCDU;

- Emergency: In case of failure of the FMGC or the MCDUs, the pilot selects and displays the beacons to be displayed by means of the Radio Management Panels (RMP).

4.2 Display of VOR and DME information

The A320 is equipped with two VOR receivers (designated VOR 1 and VOR 2), and two DME interrogators. Selection of the DME frequencies is automatic and corresponds to the VOR (or ILS) frequency selected.

The VOR and DME information can be shown on the NDs and on the Digital Distance and Radio Magnetic Indicator (DDRMI) located on the central panel, to the left of the SD screen and the ECAM. See Figure 11.

4.3 - Calculation of the FM position

4.31 - Principle of calculating the position

The FM (Flight Management) position is calculated by a series of filters which use the inertial position, the radio position and the aircraft speed as input.

In order for the position calculated to be valid, it is necessary for the inertial position and the speed to be valid. A position bias is calculated by the position bias filter as being the difference between the radio position and the inertial position.

4.32 - Calculation of the inertial position and the speed

The inertial position is equal to the composed average of the positions calculated by the three Inertial Reference Systems (IRS): this is the mixed IRS position.

4.33 Calculation of the radio position

For its position calculations, each FMGC uses the "ownside" VOR and DME information (VOR 1 and DME 1 for FMGC 1, and VOR 2 and DME 2 for FMGC 2).

The radio aids used by the system come from a list of the 20 nearest DME or VOR/DME (or VOR/TACAN) stations. This list is updated during the flight from the DATABASE of navigation data (names of ground stations, frequencies, geographical positions, range, ...). Geometrical and operational criteria (in the case of stations specified in the approach procedure) allow the system to select the best pair of DME stations and the best VOR/DME station, to check their validity constantly and to select new stations whenever necessary.

Validity tests are carried out on the radio and inertial positions as well as on the inertial speed.

4.34 - Navigation modes

At each moment the system uses the navigation mode giving the smallest estimated position error (the error calculation is based on the inertial position combined with the best available radio position).

The possible navigation modes are:

- DME/DME/Inertial: The radio position is calculated by the intersection of the position arcs around each of the DME stations used, then the radio position and the inertial position are combined.

- DME/VOR/Inertial: The radio position is calculated from the position of the station and the azimuth and distance information. The radio position and the inertial position are combined.

- Pure Inertial: None of the radio positions is used. The aircraft position is established by the inertial position corrected with the last bias calculated before [text ends here - last words of sentence missing?]

Figure 12:

(1) AUTO-THRUST

(2) can be engaged

- Inertial/LOC: This navigation mode does not use the radio position. In a Localizer (LOC) or Instrument Landing System (ILS) type approach, when the guidance mode "LOC capture" or "LOC track" is engaged, the LOC distance information is used to recalulate the FM position perpendicular to the LOC axis.

4.35 Class of Navigation

The system determines (and presents to the pilot) the quality of the navigation according to a criterion of "High Accuracy" or "Low Accuracy", the thresholds of which are defined according to the values established by the certification authorities, in terms of the situation (cruising, terminal zone, approach) and the navigation mode used.

5 - Operation of the Auto-Thrust

See Figure 12.

The Auto-Thrust (A/THR) function allows:

- Maintenance of a speed or a mach number as the case may be, in managed or selected mode,

- Maintenance of thrust (idle or maximum authorised thrust according to the flight conditions and the position of the levers),

- Alpha-floor protection which ensures the demand for full thrust when a condition of excessive incidence is detected by the FAC computers.

The A/THR function is engaged by pressing the "A/THR" pushbutton located on the FCU. It is disengaged by pressing the FCU button again or by pressing one of the two buttons located on both sides of the levers, or by positioning the levers to the IDLE setting.

When engaged, the A/THR function has two operating modes. It can be armed or active. When the pilot puts the levers into the MCT-TOGA range (Max continuous, Take-Off/Go-Around), the A/THR function is armed: it is ready to ensure control of speed/mach or thrust. When the pilot puts the levers into the IDLE-MCT range, the function becomes active: it acts to maintain a thrust or a speed/mach.
There are two types of control: Speed/mach (SPEED) or thrust (THR). The type of control effected depends on the guidance mode adopted by the pilot:

- When the longitudinal control mode controls a longitudinal parameter such as the vertical speed (V/S mode) or the slope of the flight path (FPA mode), the A/THR is in speed/mach mode. The FMGS maintains the selected vertical speed (or the slope) by means of the elevators and the selected speed (or mach) by means of the A/THR.

- When the longitudinal mode controls a speed (e.g. in OPEN mode) the A/THR is in thrust mode.

6 - Choice of the piloting mode in terms of the flight phase

Each flight parameter can, at each moment, be managed or selected.

We have seen that the use of manual mode was obligatory to execute the take-off and that in a case of reflex action, it was preferred to the automatic modes.

The mode most often used in the other flight phases is managed mode.

The selected mode is used in executing radar guidance instructions. In particular, the selected mode allows punctual and temporary modifications to the flight plan data to be performed without disengaging the Autopilot, e.g. during approach at the time of a late change of runway, when the available time is not sufficient to reprogramme the automatic devices.

APPENDIX 16

(1) Ground view of the place of impact

(2) Adjustable tailplane screwjack

(3) Flight recorders (night of the accident)

(4) Firewall bulkhead of the A.P.U.

(5) Leg of left main landing gear

(6) Remaining seats

(7) Damaged distress beacon

(8) Right side of the centre fuselage

(9) Rear part of the torn fuselage

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