MINISTERE DE L'EQUIPEMENT DES TRANSPORTS ET DU LOGEMENT - INSPECTION GENERALE DE L'AVIATION CIVILE ET DE LA METEOROLOGIE - FRANCE

BEA

Accident on 7 November 1996 near Donzeil (23), at « La Naute » to the Cessna 421 C registered HB-LRX

REPORT

h-rx961107a

F O R E W O R D

This report presents the conclusions reached by the BEA on the circumstances and causes of this accident.

In accordance with Annex 13 of the Convention on International Civil Aviation, with Directive 94/56/EC and with Law N° 99-243 of 30 March 1999, the investigation is intended neither to apportion blame, nor to assess individual or collective liability. Its sole objective is to draw lessons from the occurrence which may help to prevent future accidents.

Consequently, the use of this report for any purpose other than for the prevention of future accidents could lead to erroneous interpretations.

SPECIAL FOREWORD TO ENGLISH EDITION

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

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Glossary

AAIB	Air Accidents Investigation Branch (United Kingdom)
AD	Airworthiness Directive
AFIS	Aerodrome Flight Information Service
CCS	Rescue Co-ordination Center
CRNA	Air Regional Traffic Control Center
DGAC	General Directorate for Civil Aviation
DME	Distance Measurement Equipment
DNA	Deoxyribonucleic Acid
FAA	Federal Aviation Administration (USA)
FL	Flight Level
ft	Feet
GPS	Ground Positioning System
GSAC	Civil Aviation Safety Group
HPa	Hectopascal
IAS	Indicated Airspeed
IFCS	Integrated Flight Control System
IFR	Instrument Flight Rules
ILS	Instrument Landing System
ISA	International Standard Atmosphere
JAA	Joint Aviation Authorities
JAR	Joint Airworthiness Requirements
kt	Knots
MAC	Mean Aerodynamic Chord
METAR	Meteorological report
MHz	Megahertz
NM	Nautical Mile
NTSB	National Transportation Safety Board (USA)
OFAC	Federal Civil Aviation Office (Switzerland)
QFU	Runway magnetic heading
QNH	Altimeter setting required to read the aerodrome’s altitude on the ground
RN	French main road
SB	Service Bulletin
TAF	Terminal Aerodrome Forecast
TCM	Teledyne Continental Motors
VAR	Vacuum Arc Remelt
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
VMCA	Minimum Control speed in the Air
VOR	Visual Omni-Range equipment

S Y N O P S I S

Date and time
Thursday 7 November 1996 at 9 h 29[1].

Site of accident
Field at « La Naute » north-east of the village of Donzeil (23).

Type of flight
Private flight under IFR flight plan.

Aircraft
CESSNA 421 C Golden Eagle registered HB-LRX.

Owners
Jetcom S.A. and Garchel S.A. Geneva (Switzerland).

Operator
Jetcom S.A.

Persons on board
1 pilot,
7 passengers.

Summary

The aircraft took off from Geneva Cointrin Airport bound for Bordeaux Mérignac at 7 h 42 and reached cruise level 200 at 8 h 24. At9 h 03, as he had just started the descent, the pilot reported an engine failure. He decided to continue on track to the destination. He later informed Air Traffic Control that he could not feather a propeller. The aircraft continued to descend. At 9 h 29,the aircraft crashed into a field and caught fire.

Consequences

	Persons			A/C	Third parties
	Killed	Injured	Uninjured		
Crew	1			Destroyed	-
Passengers	7	-	-		

[1] The times shown in this report are expressed in Universal Time Co-ordinated (UTC). One hour should be added to obtain the time applicable in metropolitan France on the day of the event.

1- FACTUAL INFORMATION

1.1. History of the Flight

On Thursday 7 November 1996, at 7 h 42, the Cessna 421 C registered HB-LRX took off from Geneva Cointrin Airport bound for Bordeaux Mérignac with one pilot and seven passengers on board. The flight plan, transmitted the previous day by the pilot, indicated that this was a general aviation flight under IFR and that seven persons were on board the aircraft. He planned a Geneva – Chambéry – Lyon – Clermont-Ferrand – Limoges – Bordeaux route.

After take-off, the aircraft was authorized successively and without interruption to climb to flight level 150 towards Chambéry, then to 190 and finally to 200, the cruise level provided for in the flight plan. The aircraft started its cruise at 8 h 24 heading towards Clermont-Ferrand.

At 9 h 00, while the aircraft was west of Clermont-Ferrand, the pilot asked the South-West Regional Air Traffic Control Center to start the descent. Three minutes later, he announced an engine failure[2] and said that he absolutely had to descend. He added that he was going to try to restart the failed engine at a lower flight level.

Initially, he continued his flight towards Bordeaux. After several fruitless attempts to restart the engine and a continuous loss of altitude, he asked the en-route controller for his distance from Limoges Aerodrome in order to divert there. He was then transferred to Limoges Approach.

At 9 h 23, he informed the Limoges Approach controller that he was « *forced to continue descending a little as the propeller is blocked... it can no longer be feathered* ». He asked for the Limoges ILS frequency and the NOL beacon (initial approach identification). Shortly afterwards, he indicated that he was having trouble maintaining the safety altitude of 4,000 feet, then 3,500 feet.

From 9 h 25, witnesses, in the small village of Saint-Sulpice des Champs, saw the aircraft fly low along a south-north route with one propeller stopped.

At 9 h 26, the pilot informed the controller that had seen the ground but thought he « *can't get through there* » and asked if there was still radar contact. The controller answered in the negative. The last radar altitude recorded at 9 h 25 min 57 s was at 2,900 feet.

At 9 h 27 during the last radio contact, the pilot announced that he was on heading 350, above the high ground and the cloud cover and that he was just about managing to maintain 2,500 feet QNH. He added that he was trying to get to Limoges thirty-six nautical miles away.

[2] The investigation established that it was the RH engine.

A witness one kilometer from the site of the accident saw the aircraft turn to the east and bank 30 degrees to the right.

At 9 h 29, the aircraft crashed in a field near the village of le Donzeil, at «La Naute ». It caught fire immediately after impact with the ground. The eight people on board were killed.

From 9 h 30, several inhabitants of the hamlet of la Roche alerted the local rescue services, particularly the Ahun fire brigade.

The wreckage was found at a topographic altitude of 515 meters (1,690 feet) at thirty-five nautical miles (65 km) and a bearing of twenty degrees from Limoges Aerodrome.

1.2. Injuries to Persons

Injuries	Crew members	Passengers	Other persons
Fatal	1	7	-
Serious	-	-	-
Slight/None	-	-	-

1.3. Damage to Aircraft

The aircraft was destroyed by the accident and the subsequent fire.

1.4. Other Damage

No other damage was observed.

1.5. Personnel Information

<u>The pilot</u>

- Man, aged 45 of Swiss nationality.
- Director of the Swiss company Jetcom S.A..
- Holder of airline pilot's license No. 18128 issued in Switzerland and valid until 20 December 1996.
- Last medical inspection (audiometric test) performed on 22 May 1996 by a doctor certified by the Swiss Federal Aviation Office (OFAC). Declared to be fit for instrument flight without restrictions.
- Last IFR inspection flight as Captain on 15 November 1995 on a Falcon 20.
- Private aircraft flying instructor, instrument flight, airline pilot and instrument flight check pilot for OFAC.

- Holder of type rating on Falcon 20, 50, 90 and Cessna 500, 501, 550, 551 and 600. The pilot was not a holder of a Cessna 421 type rating as such, but the M57 rating he possessed enabled him to fly any multi-engine and single-pilot aircraft with a maximum takeoff weight under 5,700 kg.

The pilot's logbook was destroyed in the accident. However, his activity on the Cessna 421 HB-LRX was recorded in the registers of Jetcom S.A.. In particular, it has been established that he used the aircraft as an instructor for IFR flights. Between 8 August 1992 and 5 November 1996, he flew 113 hours 4 minutes on HB-LRX, including 57 hours 30 minutes as instructor.

During the three months prior to the accident, the pilot flew 7 hours 40 minutes on HB-LRX including 6 h 10 as instructor, mainly between Geneva and Grenoble.

In addition, his total known experience was 7,047 flying hours as of 20 June 1996, including about two hundred over the previous six months on all types of aircraft.

Passengers

The passengers had no known flying skills.

1.6. Aircraft Information

1.6.1. Airframe and Engines

The Cessna 421 C Golden Eagle is a twin-engine low wing aircraft with retractable tricycle landing gear. It is equipped with two turbo-compressed piston engines and has a pressurized cabin.

The aircraft trip logbook was destroyed in the accident. The airframe, engine and propeller logs provide the following information:

- the aircraft was imported from the United States in 1992 with export Airworthiness Certificate No. E260298 issued by the American Federal Aviation Administration (FAA);

- it arrived in Switzerland on 30 July 1992. On that date, the aircraft had accumulated 2,127 flying hours. It was then equipped with two Teledyne Continental Motors (TCM) GTSIO-520, the left engine with serial number 227872 R (rebuilt) of 520-L type and the right engine with serial number 606887 of 520-MCL type;
- the aircraft was purchased by Jetcom S.A. in 1995.

Airframe

- Manufacturer: CESSNA AIRCRAFT COMPANY.
- Type: CE 421C2.
- Serial No.: 421C02172.
- Year of manufacture: 1976.
- Airworthiness Certificates No. 1 issued by OFAC on 6 October 1995.
- Field of use in non-commercial operation: daytime VFR for private flights, night VFR for private flights, IFR Cat.I for private flights.
- Entry into service in Switzerland: 6 October 1995.
- Overall flight time: the last known figure dates from 4 November 1996 at 2,488.55 hours.
- Overall flight time on the date of the last periodic inspection on 4 August 1996: 2,476.45 hours.

Previous history: on 4 January 1993 at Cannes, the aircraft ran into a marker when taxiing and the left propeller touched the ground. The engine and the propeller were removed and replaced.

Engines

- Manufacturer: TELEDYNE CONTINENTAL MOTORS.
- Type: GTSIO-520.
- Maximum power: 375 CV at a propeller speed of 2,235 rpm and an intake pressure of 39 inches mercury.
- LH
  - Serial number: 241178.
  - Overall flight time on 14 August 1996: 1,951.25 hours.
  - Flight time as from 14 August 1996 since complete overhaul: 325.25 hours.

This engine was imported from the United States with export airworthiness certificate No. E283074 dated 25 March 1993 after complete overhaul at Mid-States Aircraft Engines. It was installed on the aircraft by France Aviation at Cannes on 19 April 1993 with 1,625.80 hours since new.

- RH
  - Serial number: 606887.
  - Overall flight time on 14 August 1996: 2,490.05 hours.
  - Flight time since complete overhaul on 14 August 1996: 912.45 hours.

This engine, manufactured in February 1981, was delivered to Cessna on 27 February 1981 and installed on the aircraft after complete overhaul at Mid-States Aircraft Engines in 1986.

Propellers

- Manufacturer: MAC CAULEY.
- Type: metallic three-blade propellers with variable pitch and feathering mechanism.
- LH
  - Serial number: 800351.
  - Model: 3FF 32 C501-A.
  - Overall flight time on 14 August 1996: 2,476.45 hours.
  - Overall flight hours since last complete overhaul on 14 August 1996: 349.25 hours.

After the incident on 4 January 1993, the LH propeller with serial number 766002 was removed and replaced by that numbered 800351. The propeller change was noted in the aircraft log. However, the propeller log associated with the aircraft remained that for propeller 766002. In addition, as from 15 July 1994, the operating time shown was that for the right engine propeller.

- RH
  - Serial number: 766621.
  - Model: 3FF 32 C501-A.
  - Overall flight time on 24 May 1996: 2,452.40 hours.
  - Overall flight time since complete overhaul on 24 May 1996: 325.20 hours.

The propeller was overhauled at Hoffmann in Germany in June 1992. It had been installed on HB-LRX on 15 July 1994.

1.6.2. Equipment and Cabin Fittings

The aircraft had an eight seat capacity and was equipped for instrument flight. It had a BENDIX FCS-810 automatic pilot and a GPS. This Trimble TNL 200A type GPS, coupled with the automatic pilot, had been installed in November 1992 when there was a modification of the instruments and on-board avionics.

The aircraft was not equipped with a propeller unfeathering accumulator (optional).

It should be noted that the aircraft was provided with two wing tanks with a total capacity of 213.4 US gallons and an additional tank located in the rear cargo compartment behind the left engine with a 28.4 gallon capacity. The total quantity of usable fuel was 234 gallons (886 liters).

1.6.3. Maintenance

Maintenance had been performed since August 1995 by Jetcom S.A. France, based at the Annecy Meythet airport and a Jetcom S.A., subsidiary according to the maintenance programmed approved by OFAC. The Jetcom S.A. France Company is holder of JAR 145 certification No. F-226 issued by the GSAC and recognized by the United States. The last maintenance work took place from 21 June to 4 August 1996. It included the 100 hours and 200 hours inspections and the annual overhaul.

1.6.4. Weight and Balance

Weight calculation

The empty weight of the equipped aircraft is calculated to be 2,450 kg (5,402 lb). This differs slightly from the weight given at 2,452 kg (5,406 lb) in the HB-LRX aircraft weighing record dated 8 July 1992 due to modifications made to instruments and to the on-board avionics in November 1992 leading to the replacement of certain items of equipment.

The data in the Cessna 421 C Golden Eagle Operating manual indicates that the maximum takeoff weight is 3,379 kg (7,450 lb) and the maximum weight on landing is 3,265 kg (7,200 lb).

The calculated loading takes into account the determination of the weight of the eight occupants – i.e. 665 kg from the information provided by the coroners who proceeded to examine the bodies. The weight of the luggage, a priori located in the forward compartment provided for that purpose, was arbitrarily set at 45 kg (100 lb) due to the number of occupants of the aircraft and the duration planned for the trip (three days).

The quantity of fuel on board the aircraft is not known with any certainty. The total fuel tank capacity was 241.8 gallons (915.2 liters or 659 kg calculated with a density of 0.72). It has been established that 240 liters of fuel was added before departure on the day of the accident. This quantity of fuel would not be enough to make the Geneva - Bordeaux flight (see calculation below).

It is therefore necessary to make assumptions as to the flight time and take into account fixed data (on the ground) as provided in the Cessna Operating Manual to estimate the quantities of fuel consumed during the following phases:

❶ start-up, taxiing and takeoff: fixed data 46 lb
❷ climb to flight level 200: 21 minutes, i.e. 105 lb
❸ cruise (at 1,900 rpm propeller speed and at an intake pressure of 29 inches): 1 hour 5 minutes, i.e. 250 lb
❹ descent: 18 minutes, i.e. 50 lb
❺ route reserve taken as equal to 5% of the consumption for the stage: 20 lb
❻ rerouting to the Bergerac alternative aerodrome: 30 minutes, i.e. 125 lb
❼ waiting: 45 minutes at 45% power, i.e. 125 lb
wind - 30 kt average on climb: 7 minutes, i.e. 35 lb
wind - 60 kt average on cruise: 27 minutes, i.e. 102 lb
wind - 30 kt average on descent: 3.5 minutes, i.e. 10 lb
❽ final reserve: 0 lb

The above calculation leads to a minimum quantity of fuel of 868 lb and at 225 minutes (3 hours 45) of flight. The latter value is compatible with autonomy of three hours forty minutes relative to the flight plan signed by the pilot.

In total, by adding the empty weight of the equipped aircraft, the weight of fuel and that of the aircraft occupants and their luggage, the weight of the aircraft on takeoff was 3,550 kg (7,819 lb). It exceeded the maximum authorized weight on takeoff by 171 kg (369 lb), i.e. a relative excess weight of 5%.

At the time the pilot indicated engine failure, the aircraft had performed start-up, taxiing, takeoff, climb for forty-two minutes and cruise at flight level 200 for forty minutes. The quantity of fuel used can be estimated at 186 kg (410 lb) .

The estimated weight thus calculated for the aircraft at the start of RH engine failure was 3,364 kg (7,409 lb), which is extremely close to the maximum takeoff weight.

Balance calculation

The center of gravity rear limit is set by the manufacturer at 158 inches (4.01 meters) behind the reference line located at the nose cap of the aircraft. The length of the Mean Aerodynamic Chord (MAC) is 63.64 inches (1.62 meters).

Two aircraft balance calculations on takeoff were drawn up due to the uncertainty of the position occupied by one of the passengers. In the first case (a), the passenger would have occupied seat No. 5, while in the second (b) it would have been seat No. 3. These calculations are summarized in the following table:

Position	**Weight in lb**		**Moment / 100 in lb in.**	
Empty weight of the equipped aircraft (calculation)	5,402		8,311 (calculation)	
Pilot and front passenger (No. 2)	360		493	
Passengers No. 3 and 4	(a) 330	(b) 375	(a) 587	(b) 667
Passengers No. 5 and 6	(a) 385	(b) 340	(a) 839	(b) 741
Passenger No. 7	190		475	
Passenger No. 8	180		470	
Luggage in forward compartment	100		71	
Fuel	868		1,406	
Total	7,815		12,652	12,634
Position of center of gravity expressed in inches	(a) 161.9 (b) 161.7			

In both cases, the position of the center of gravity on takeoff, the result of the division of the moment by the weight, exceeds the rear limit for balance set at 158 inches. The relative deviation represents between 5.8 and 6% of the MAC.

When the accident occurred, taking into account trip fuel, the position of the center of gravity remained at 161.8 inches, which represents a relative deviation of six por cent.

1.6.5. Calculation of Performance

The performances used in § 1.6.5.2. are taken from the Performance chapter of the Cessna 421 C Golden Eagle Operating manual (section 5). This Manual is approved by the FAA and constitutes the Flight Manual.

1.6.5.1. Performances during climb

According to a statement made by one of his trainees, the flying parameters usually used for climb by the pilot of HB-LRX were as follows: intake pressure 32 inches, propeller rotation speed 1,900 rpm. They allowed the aircraft to climb at an indicated (air) speed of 120 knots. In the temperature conditions on that day (ISA + 7 at FL 200), with the maximum weight on takeoff, the climb took twenty-one minutes.

1.6.5.2. Performance in the event of engine failure

Performance with propeller feathered

With the maximum weight of the aircraft, at a speed of 107 kt (IAS), the practical single-engine ceiling is 16,000 feet in the conditions prevailing on the day (ISA + 7 on FL 200).

With the maximum weight of the aircraft, at a speed of 104 kt (IAS), still in the prevailing conditions on the day, the rate of descent on single engine is 100 feet per minute at 20,000 feet.

Performance with windmilling propeller

The Operating Manual provides data to estimate the degradation in performance in the case of a windmilling propeller. For all flight levels, a fixed quantity of 400 feet per minute must be subtracted from the aircraft performance in single-engine conditions with the propeller feathered.

To obtain the flight level beyond which level flight is possible, the highest flight level to which the aircraft is capable of climbing at 400 feet per minute witha propeller feathered must be considered. At this flight level, if the fixed value of 400 feet, corresponding to the windmilling propeller, is subtracted, the maximum level for level flight windmilling can be obtained.

The calculation shows that level flight was not possible under the weight and temperature conditions on the day. It can therefore be deduced that the aircraft was incapable of maintaining level flight with a windmilling propeller.

Performance with propeller stopped

Performance levels with a propeller stopped are not available. However, it is possible to estimate that the drag of a stopped propeller is less than that of a windmilling propeller.

1.6.5.3. Stall and minimum speeds for control in the air

The Operating Manual indicates that with a weight of 7,450 lb, the speed for symmetrical stalling is 86 kt indicated in the landing gear and flaps retracted configuration. The minimum air control speed (V_{mca}) is 80 knots. This speed is obtained with the maximum weight on takeoff, at sea level and in standard temperature conditions. It is indicated by a red arc on the anemometer.

1.7. Meteorological Conditions

1.7.1. General Conditions

The general situation on Thursday 7 November was characterized by the presence of an active warm sector located ahead of a cold front on the Niort - Nevers - Nancy axis and moving south-east, passing through the area of the accident towards midday.

1.7.2. Meteorological Conditions Observed at Neighboring Aerodromes

The applicable TAF forecast messages were:

- Clermont-Ferrand

LFLC 0700800Z 070918 22015G25KT 9999 SCT025 BKN050 TEMPO 0913 22020G30KT BECMG 1215 8000 -RA SCT015 BKN030 BKN100 BECMG 1518 27010KT 9999 SCT020 BKN 030 =

- Montluçon Guéret

LFBK 070600Z 070715 22015G25KT 9999-DZ BKN010 BKN050 TEMPO 0913 240020G30KT 4000 RADZ BR BKN005 BKN015 BECMG 1315 25012KT 9999 BKN020 BKN 050

- Limoges

LFBL 0615 22015G25KT 5000 RADZ BKN003 OVC010 TEMPO 0612 22020G35KT 1100 RADZ BR BKN001 OVC003 BECMG 1315 26014KT 9999 BKN013 BKN 040 TEMPO 1315-SHRA=

LFBL 0918 22015G25KT 1200 BR DZ OVC003 TEMPO 0910 0700 FG DZ BECMG 1012 5000 RABKN010 OVC030 BECMG 1214 30010KT 9999 NSW BKN020 TEMPO 1215 SHRA

- Bordeaux Mérignac

LFBD 070500Z 070615 22012KT 9999 SCT016 BKN040 BECMG 0609 22015G25KT 6000 -DZRA SCT006 BKN015 OVC040 TEMPO 0913 240020G35KT 4000 RA BKN005 OVC013 OVC080 BECMG 1315 27012KT 9999 NSW SCT020 SCT040=

1.7.3. Information Collected by the Pilot before the Flight

According to information from Switzerland, the pilot did not use the facilities to collect information available at Geneva aerodrome in order to find out the meteorological conditions forecast on the route. Nevertheless, he may have consulted meteorological services using a telephone-based information system installed at his home.

1.7.4. Meteorological Information Received in Flight

During the descent, the controller of the SL/NL sector of Bordeaux Control provided the following meteorological information to the pilot:

- Observation from Bordeaux at 9 h 00: « wind 220° 12 kt, visibility greater than 10, with FEW at 3,000 feet, BROKEN at 9,000. Temperatures 17 ° and 13 ° dewpoint. QNH is 1021 and NOSIG ».
- Conditions at Limoges: « ..., there is 7 km visibility, runway 22, wind 230 °/11 kt with gusts at 16 kt and broken at 300 feet, 1019 QNH ».

1.7.5. Conditions Encountered during the Flight

The wind conditions encountered at altitude on the path between Clermont-Ferrand and Limoges estimated by Météo France were as follows: at FL 200, mean wind was west sector at a speed of 65 kt, at flight level 100, wind was oriented 270°/280° at 35 knots. The outside temperature was -18°C (ISA + 7) at FL 200.

Radar images timed 8 h 30 and 9 h 00 show levels of reflectivity associated with near zero precipitation on the aircraft's route. Satellite images timed at 8 h 30 and 9 h 00 show that the temperature « at the peak of the clouds » was equal to + 4 °C over the entire route between Geneva and Limoges. Thus the aircraft did not encounter icing conditions and that above the lower cloud cover, it was in clear skies.

1.7.6. Conditions Estimated at the Site of the Accident

The closest source of information was the station of Lépaud situated at the Montluçon-Guéret aerodrome. This station is located at forty kilometers from the scene of the accident at an altitude of 1,362 feet (410 meters). On the aerodrome, the sky was covered with stratus whose base varied between 200 and 300 feet from the ground (observations at 8 h 00, 9 h 00 and 10 h 00) and whose peak was at 1,500 feet. From a base situated at 2,000 feet, broken strato-cumulus rose up to 5,000 feet. Slight drizzle was observed. Visibility on the ground varied between three and four kilometers away from precipitation and diminished to between one and three kilometers in drizzle. The surface wind was oriented to the south-west sector between 200 and 240°. Its intensity varied between 15 and 20 kt with gusts reaching 35 knots. The surface temperature was 12 °C.

1.8. Aids to Navigation

On route UG22 between Clermont-Ferrand and Limoges, the pilot had VOR-DME CMF to the aft for fifteen nautical miles when engine power loss was announced and VOR LMG was ahead. It is not known whether the pilot had already selected the latter.

1.9 Telecommunications

1.9.1 Radio communications

From Geneva to the last contact with an air traffic service, the pilot communicated successively on the following frequencies:

- Geneva Ground, Geneva Tower, Geneva Departure.
- Marseille Control on 126.700 and 133.420 MHz.
- Bordeaux Control on 133.100 MHz and 127.670 MHz.
- Limoges Approach on 119.200 MHz.

The transcript of radio communications is in Appendix 1.

The points of interest are as follows:

At 9 h 00, the pilot asked the controller of sector F1 of the Bordeaux Regional Control Center to start descent.

At 9 h 03, when the controller asked him to climb back up to flight level 200, the pilot announced: « *HRX we have an engine failure; I have to go down; we absolutely must go down* ». The controller asked him to display the transponder 7700 code. The pilot added that he «*recover at 100 if possible to restart ».*

At 9 h 05, the pilot asked the controller of sector SL/NL permission to continue as far as Bordeaux. The controller suggested he «*take a route to Limoges initial and (…) land at Limoges »*. The pilot answered: « I*'d be happier if I could go as far as Bordeaux (…) we're taking heading 270 and we're descending 500 feet per minute, we're going through 160* ».

At 9 h 07, the pilot answered the controller, who was asking him if he could maintain level flight with one engine and if so at what level, « *we can hold level flight at 8,000 feet on one engine* ».

At 9 h 08, the controller told him for information there was a ground speed of 70 kt as read on radar. The pilot confirmed the presence of a GPS on board.

At 9 h 11, the controller asked him if he had « *tried to re-start the engine* » and the pilot answered: « *yes, I made a try; but it didn't work »* and added that he « *was looking into it* ».

Two minutes later, he accepted a direct route proposal to Bordeaux then information on meteorological conditions at Limoges.

At 9 h 15, he asked: « *can you give me the safety level?* » The controller gave him level 70 without restriction. Shortly after this, the pilot indicated that he was going « *into a small layer of cloud there* ».

At 9 h 17, the controller told him: « *check your speed all the same, I have pretty low speeds (...), between 70 and 100 kt »* and he answered: « *that's right, on GPS that gives us 75 knots* ».

Shortly after this, he specified: « *it's a bit jammed there, I can't re-start for the moment* » and at 9 h 18 he stated: « *I can't hold level flight* (Note: FL 75)*, I'll have to go down all the same. Can you tell me for Limoges, how far for Limoges?* » The controller answered « *Limoges, that's at 38 to 40 NM with a bearing of 270 (…), I think you'd be better heading for Ussel which is close by, it's a slightly smaller aerodrome but I think there'll be no problem with a Cessna 421 ».* The pilot answered « *no, we'll try to get to Limoges* » and he received the four-letter identification code for Limoges LFBL.

At 9 h 23, after having been transferred to Limoges Approach frequency, he reported that he was « *... forced to continue descending a little as the propeller was blocked..., We can no longer feather it* ». He asked for and obtained the Limoges ISL frequency and the NOL beacon (initial approach identification).

At 9 h 24, he indicated: « *I'm having difficulty keeping to 4,000 feet, can you give me another altitude, please? ».* The controller answered: « *RX can you hold up to 3,500 feet QNH? »* The pilot answered: « *RX negative, for the moment I can't hold 3,500 feet ».*

At 9 h 26, the pilot said: « *RX view of the ground but I don't think I can go through that way... have you still got radar contact on us? ».* The controller answered no.

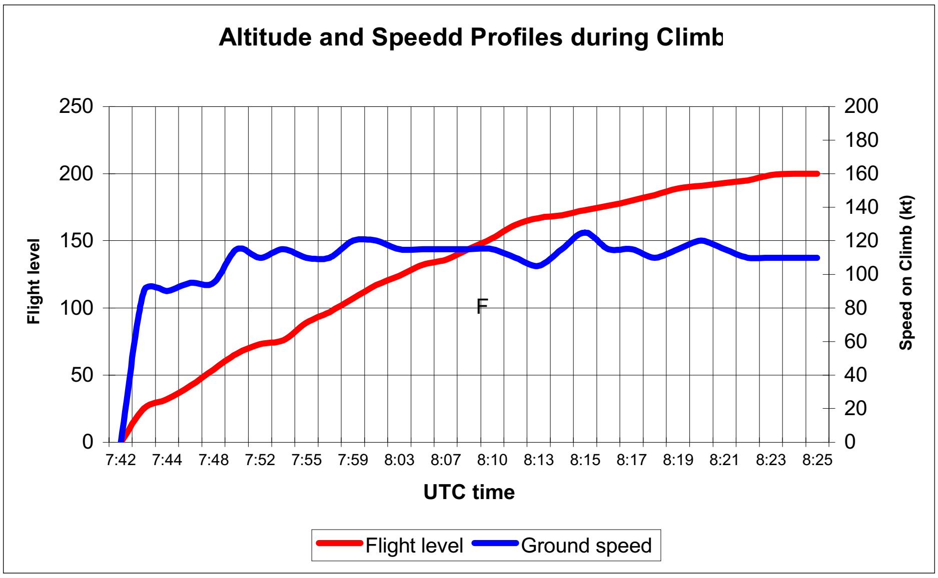
At 9 h 27, the pilot announced during the penultimate radio contact: « *I'm on heading 350 to switch to... I'm below the high ground. Right now, I can just hold 2,500 feet... and have you got a distance for Limoges? I've got 36 nautical for the moment, I'll try to get there but I'll keep you informed... I'm below the cloud layer* ».

The controller told him: « *I had a last radar contact at about 28 nautical en route for Limoges and so now I'm checking VFR charts for obstacles situated in your region at 2,700 feet on QNH... max. obstacles, that I can see north of the Lac de Vassivière* ».

The pilot read back. That was the last radio contact.

1.9.2. Radar Recordings

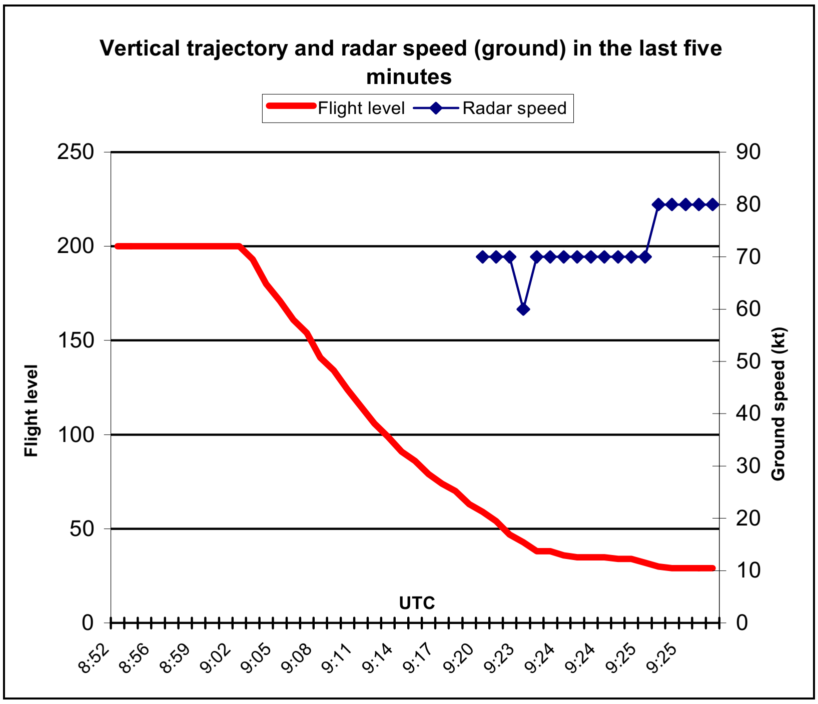
The data relating to takeoff and climb to cruise level 200 was transmitted by the Swiss Aviation Accident Investigation Bureau. This gave us the ground speed of the aircraft and its real rate of climb.



For descent, by using the radar recording equipment, we can follow the aircraft from 8 h 10, before the first radio contact with the first sector of South-East CRNA, up to disappearance of the marker at 9 h 25 min 57 s.

The information collected enabled the following to be reconstituted:

- its vertical trajectory thanks to the altitude reporting device and its ground speed profile,



- its horizontal trajectory, on which an alteration in heading to the north in the last minutes of flight can be seen.

1.10. Aerodrome Information

Not applicable.

1.11. Flight Recorders

Swiss regulations do not require flght recorders to be fitted on aircraft of this type. HB-LRX was not so equipped.

1.12. Information on Aircraft Wreckage and Impact

1.12.1 Environment around the Site of the Accident

The wreckage of the aircraft was found in a field at «La Naute » located north-east of the village of Donzeil. There are fields surrounded by hills culminating at an altitude of 580 meters and whose mean altitude is 500 meters. The altitude of the wreckage was 515 meters (1,690 feet).

The wreckage was oriented south-west / north-east and was surrounded to the west, the east and the south by rows of trees. No tree showed traces of contact with the aircraft.

Three craters were visible in the loose earth and peat:

- the first contained a part of the right wing, the RH engine and propeller. It was 1.90 m long, 1.50 m wide and 0.75 m deep,
- the second was one meter deep and contained the nose of the aircraft and part of the cabin,
- the third was from 0.70 to 0.80 m deep and contained the LH engine and propeller.

1.12.2. Examination of the Wreckage

The entire airframe and engines were confined in an area comparable to that of the aircraft itself.

The airframe was dislocated: the cabin was resting on the left side after having pivoted 90 degrees, the door situated to the rear left of the fuselage was closed and blocked against the ground. The vertical stabilizer, the horizontal stabilizers and the elevator were separated from the rest of the airframe and had pivoted to the left through 90 degrees in relation to the cabin.

Cockpit and fuselage

The airframe had burnt completely up to the horizontal and vertical stabilizers. The cockpit, the controls and on-board documents were destroyed by the fire. The on-board clock had stopped at 9 h 50 and the directional gyroscope indicated a value of 220°.

Moving aircraft components

All moving components of the aircraft were found. There was no rupture in the control cables. It was impossible to determine the position of the flaps. The landing gear was retracted.

Observation of the position of the elevators after the impact gave the following results:

- the right elevator and the trim were respectively in nose-up and nose-down positions,
- the left elevator and trim were in a nose-up position,
- the rudder was deflected to the right,
- the rudder trim was deflected to the left stop.

Due to the opposite deflections of the elevator and the rudder trim, the latter was subjected to an additional inspection to determine the direction of deflection before impact. Both cables of the trim mechanical actuator drive control line were broken in static traction. The attachment link of the right strand was at stop on the toothed pinion. The trim line was unwound on the side of the left cable. The toothed pinion bore marks between the linking teeth resulting from stresses greater than those encountered in service.

These observations are helpful in understanding the rupture sequence. On rotation of the aircraft's tail to the left, the trim cables were pulled. The right cable broke first, pulled to the left by the overall movement. The line was blocked against the pinion when the right cable attachment came into contact on the pinion. The stress created by traction of the cable broke the line. When the latter broke, the trim positioned itself mechanically on the left stop. This deflection thus resulted from the impact.

Wings

Both wings were complete.

To the right, the wing tip, the aileron and the trim were present. Both spars were broken; the wing broke at the engine wing nacelle. The latter was found shifted to the right by 1.15 m. The wing burnt up to the RH engine nacelle. It was again broken near the wing tip. The latter raised a piece of loose earth. It was found detached from the rest of the wing by about 1.50 m.

To the left, the wing was attached to the airframe. It had burnt more than the RH wing. Beyond the wing, the burnt grass spread over about eight meters.

Engines, accessories and propellers

The RH engine and its nacelle were heavily damaged by fire.

The LH engine was driven into the earth. It was not damaged by fire. It was subject to a major head-on impact.

Inspection of the fuel tank selector valves showed that the left valve was set to « off » and that on the right between « off » and « right main ».

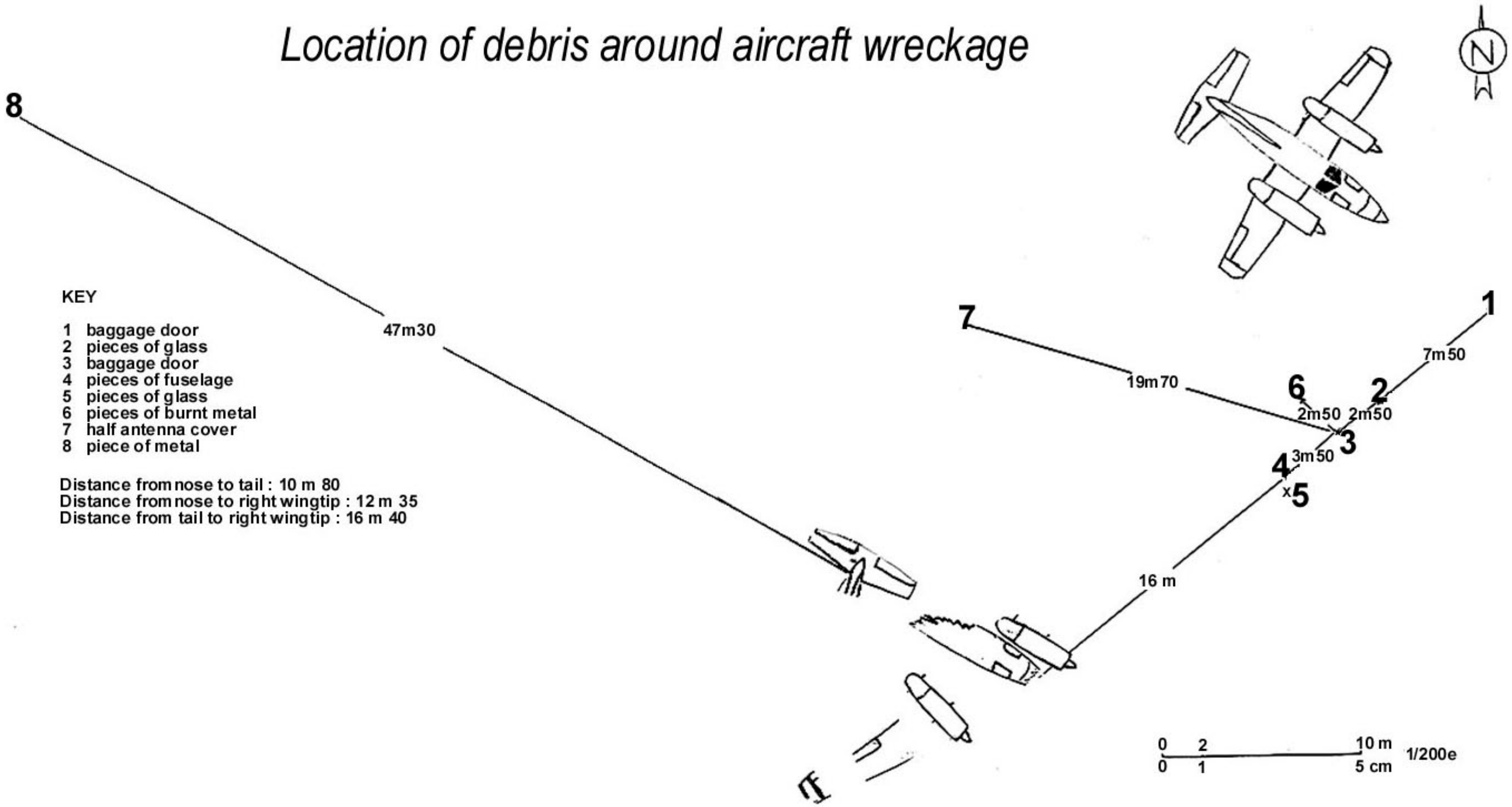
The RH propeller was not attached to the engine. It showed damage resulting from the impact with the ground. The three blades were no longer attached to the hub. They did not show scratches. Two of them were deformed towards the rear and the third towards the front.

The LH propeller was no longer attached to the engine. It showed damage resulting from impact with the ground. Two blades were still linked to the hub: one of them was deformed to the front and the other to the rear. The third blade, separated from the hub, showed scratch marks in the direction of the chord on the cambered surface.

1.12.3. Orientation of Marks on the Ground

The accompanying sketch represents the distances and the orientation of marks on the ground observed on the site (main magnetic orientation 130°). The nose of the aircraft was driven deeply into the ground. The traces left by the end of the RH wing and the relative position of the wing tip in relation to the rest of the wing indicate that the aircraft hit the ground with a slight tilt to the right.

Location of debris around aircraft wreckage



1.13. Medical and Pathological Information

The burnt bodies of the eight persons on board were autopsied. Identification took place two days after the accident. Because of the shocks sustained, samples of body tissue were taken to establish the DNA profiles for identification of the victims.

1.14. Fire

An extremely intense fire followed the accident and destroyed the entire cabin. It started in the LH wing around the fuel tank, then spread to the airframe.

1.15. Questions Relating to Survival of the Occupants

According to the pathologists, the death of the occupants of the aircraft resulted from deceleration when the aircraft hit the ground. X-rays showed that these eight people suffered major multiple traumatisms that were immediately fatal. Moreover, there was no trace of soot on their upper respiratory tracts.

1.16. Tests and Research

1.16.1. Examination of the Power Plants

1.16.1.1. RH Engine and Propeller

1.16.1.1.1. Observations

The engine and the turbocompressor, which were still attached to the frame, were heavily damaged. They showed traces of exposure to the heat resulting from the impact of the aircraft. The rear table accessories were torn off, together with most of the turbocompressor pipes and connections.

On disassembly, the propeller shaft could turn about a half rotation. This rotational movement was not transmitted to the crankshaft.

Removal of the cylinders showed complete rupture of the crankshaft on rod journal No. 5 and connecting rod No. 5.

1.16.1.1.2. Examination of the RH engine crankshaft

A detailed examination was made of the crankshaft: inspection on a laboratory bench, using a Scanning Electron Microscope, geometrical measurements and micro-hardness testing.

Rod journal No. 5 suffered a fatigue rupture. The rupture observed on rod journal No. 5 had an oblique plane going from the fillet and ending towards the middle of the cylindrical bearing surface. The orientation of the rupture lines, which were extremely pronounced, show that the area where this crack started was located in the rod journal fillet on arm M5/M6. On either side of the rupture, the area where the crack started was completely obliterated. Traces of friction show that jamming of the engine shaft was not immediate and thus that the engine was running after the rupture. It is, however, difficult to evaluate this operating time.

The front lines of the rupture surface that could still be used were the result of very high stresses.

Metallurgical inspection of the crankshaft showed no material defect.

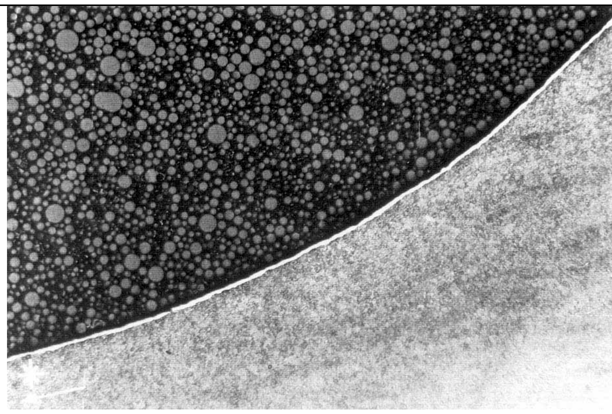
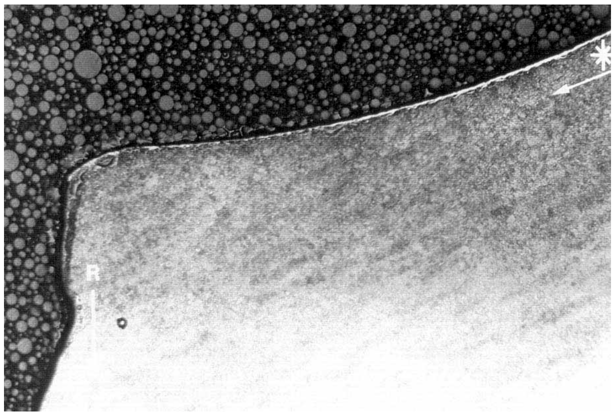
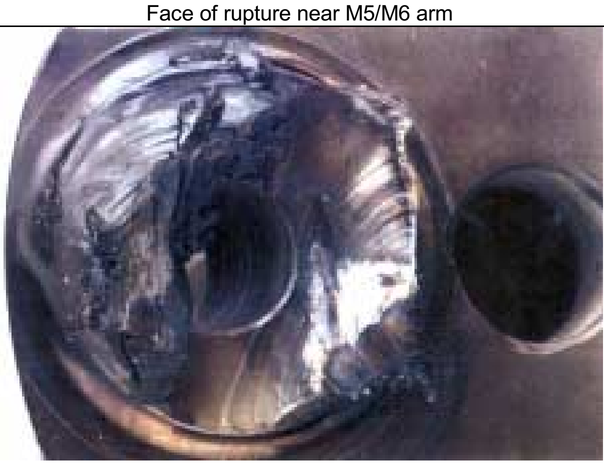
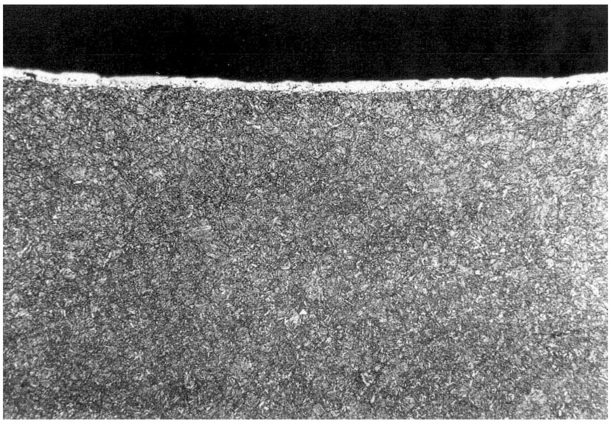
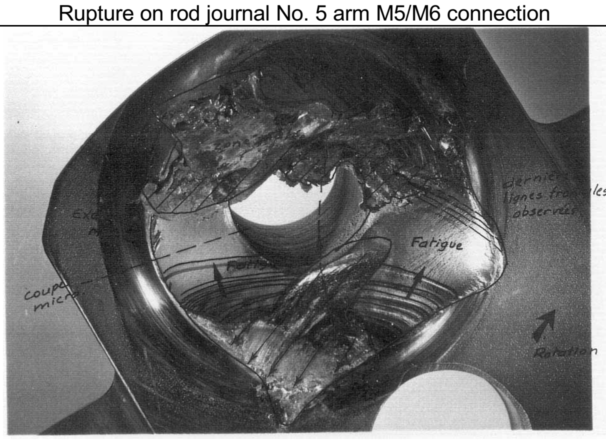
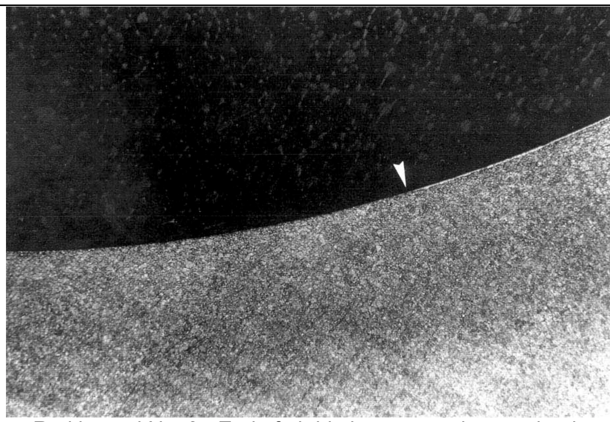
The rod journals dimensions show that they had all been repaired: they had been subject to surface grinding to a depth of less than 1/100 inch (M010). The diameters measured for all the rod journals, with the exception of rod journal No. 5, which was destroyed, were within the minimum and maximum dimensions the manufacturer specifies for such an operation.

Rod journal No. 5 was subjected to a micrographic cross-section. A reduced thickness of the protective layer was measured. This layer is intended to reinforce the hardness of the steel on the surface, the reinforcement being assured by nitriding, as shown by the white color in the photo. The thickness of the layer, which is 400 microns, diminishes the closer it is to the fillet. According to TCM, the thickness of the nitriding layer on a newly nitrided crankshaft should be between 500 microns and 1 millimeter.

By way of a comparison, rod journal No. 3 was also subjected to a micrographic cross-section and micro-hardness tests. Note the absence of marks on the nitride layer in the profile (cylindrical journal bearing) of the rod journal. This layer is visible in the radius of the fillet and its thickness complies with that specified by the manufacturer.

The results of micro-hardness measurements on rod journal No. 3 give hardness values lower than the values required in the cylindrical bearing, which indicates start of wear while those for the radii of the fillet were close to the specified values.

Examination of the counterweights and their attachment components showed no sign of wear. Weighing of the paired counterweights did not show any deviation higher than a gram.

METALLURGICAL EXAMINATION	MICROGRAPHIC CROSS-SECTION
 View of ruptured crankshaft	 Rod journal No. 5 : Nitride layer in middle of fillet
 Face of rupture near M5/M6 arm	 Rod journal No. 5 : Thin white layer near the rupture ®
 Rupture on rod journal No. 5 arm M5/M6 connection	 Rod journal No. 3 : Structure of the acid and nitride layer in the fillet
 Overall view of rupture	 Rod journal No. 3 : End of nitride layer towards arm cheek

Consequence of the rupture

Considering the angle and position of the rupture, both parts of the broken rod journal could stay aligned, held in place by the head of rod No. 5. Nevertheless, the oil leak through the crack led to a lack of lubrication of the rod journal, overheating, the destruction of the bushes of rod No. 5, the destruction of rod No. 5 and wear to the bushes of the other rods.

The front part of the crankshaft, to which rod No. 6 was no longer attached, was only centered by the front bearing. The rear part of the crankshaft was still held by three bearings. It is therefore likely that the front part of the crankshaft rapidly went off-center in relation to the rear part.

Origin of the rupture

It can be seen from the preceding that the zone where the rupture started was damaged to such an extent that it is difficult to accurately locate the origin of the rupture.

A micrographic cross-section made in the fillet of rod journal No. 5 showed that the thickness of the nitride layer, allowing the surface to be hardened, gradually diminished as it got closer to the rupture. Another cross-section made on rod journal No. 3, which was in good condition, also showed that the nitride layer only kept its original thickness on the two fillets. The nitride layer even disappears towards the arm cheek.

The thickness of the nitride layer may diminish through wear in service. However, compared with rod journal No. 3, the low thickness of the nitride layer on rod journal No. 5 could lead one to think it was inadequately coated during application. However, the application procedure for the nitride layer should not leave different thickness between the various rod journals.

Apart from engine restart with rod journal No. 5 broken, possible causes of in-service damage to the nitride layer on rod journal No. 5 have been notified by the FAA: incorrect tightening of the attachment bolts on an adjacent cylinder or a piston which is not quite perpendicular to the crankshaft rod journal. The lack of data relative to the crankshaft's life since the last rectification makes it impossible to draw any further conclusions as to the real cause of the rupture.

1.16.1.1.3. History of the RH engine

During manufacture, engine serial No. 606887 was of type GT 510-520-M2A. Subsequently, it was converted[3] to a GT 510-520-L, for which reason its plate bears the inscription MCL: M Converted to L. In August 1986, this engine was completely overhauled. At that time, the cylinders and a number of engine accessories were replaced by those that equipped engine serial number 606693

[3] Service Bulletin M 75-6 defines the appropriate conditions applicable for such a conversion.

previously installed on the Cessna in the RH position. The cylinders installed had accumulated 1,564.3 operating hours when it came to complete overhaul.

1.16.1.1.4. History of the right crankshaft

Research into the complex history of the crankshaft, as for the engines and propellers, was made difficult due to the lack of complete information from the manufacturer TCM or the Mid-States Aircraft Engines repair workshop, despite a considerable exchange of correspondence with the NTSB (the American National Transportation Safety Board) and TCM.

On delivery of the RH engine, the latter had a crankshaft with standard dimensions whose serial number was A020M1. The crankshaft examined after the accident, that was mounted inside the RH engine, was not the one that was originally installed on this engine. It bore serial number E012 (number engraved into a counterweight attachment cheek) and, on a short cheek of a bush, the indication VAR 562. The VAR identification means that the crankshaft was made using the Vacuum Arc Remelt technique when the part was cast. TCM started using this method in 1978 before completely replacing the former air remelt method with it in January 1981. TCM specified that renitriding was not indicated with the letters RN.

According to TCM, the crankshaft in the accident was manufactured between 1978 and 1979 then sold on 27 February 1981. Nothing is known from that date to its installation on engine 606887 in August 1986. It is not known, for example, whether it remained on the shelf or entered into service; and whether, in that case, it was inspected between 1981 and 1986.

1.16.1.1.5. Inspection of the rods

Rod No. 5 was broken in two places: the breaks resulted from rupture of the rod journal. The other rods show significant wear on the journal bushes.

1.16.1.1.6. Inspection of the RH propeller

The RH propeller was broken. Only the front part of the hub, held by its attachment to the cylinder and containing the pitch change mechanism, still formed an assembly. The three propeller blades whose driving pins were torn off, were slightly damaged.

Blade No. 1 was bent thirty degrees towards the upper surface and showed no marks on the leading edge. Blade No. 2 was bent ten degrees towards the lower surface from a distance of 55 cm from the base of the blade and was marked by traces of impact and scratches on both sides. Blade No. 3 was very slightly bent from the base in the direction of the lower surface. It only had a few superficial scratches.

One of the conical stops (arrow head) that immobilize the piston in low pitch was sheared along a direction parallel to the propeller axis. This static type rupture was the result of the accident. The position of the piston it highlighted does not, however, enable us to come to a conclusion as to the pitch of the propeller on the moment of impact. Indeed, it may correspond to a propeller set in low pitch but it may also have resulted from the impact that would have engaged the locking mechanism.

1.16.1.2. LH Engine and Propeller

1.16.1.2.1. Observations

The LH engine, turbo-compressor assembly and propeller were no longer attached to each other. These three assemblies showed notraces of exposure to heat.

Disassembly of the engine showed no internal damage. The oil pan was deformed on impact. It bore signs of rotation consecutive to interference with the drive pinion on the camshaft.

1.16.1.2.2. Inspection of the LH propeller

The propeller was no longer attached to the engine. Blade No. 1 was torn off, blade No. 2, which was still attached to the hub, was in feathered position and blade No. 3 was in low pitch position. The driving pins of blades Nos. 2 and 3 were torn off. The deformations observed on the three blades resulted from violent impact with the ground but do not allow us to come to a conclusion as to the real power provided by the engine.

One of the conical stops that immobilized the piston in low pitch was sheared. As for the RH propeller, this observation does not enable us to come to a conclusion as to the propeller pitch on the moment of impact.

1.16.1.2.3. Inspection of the LH engine crankshaft

The cylindrical journal bearing surfaces of the rod journals and the crankshaft bearings were in good condition. Magnaflux inspection of the crankshaft showed that the whole part, particularly the radius fillets, was in satisfactory condition. The pinion showed significant traces of wear in service.

1.16.2. Regulatory Provisions Relating to Crankshaft Inspections

1.16.2.1 Inspections scheduled in the complete overhaul manual

Inspections of crankshafts scheduled for the complete overhaul are described in section IX of the complete overhaul manual. This manual drawnup by TCM is approved by the FAA.

The inspections requested involve:

- a Magnaflux inspection of the crankshaft (Magnaflux inspection);
- a visual inspection;
- a dimension check (of the bushes, in particular).

The complete overhaul manual also specifies that all crankshafts whose rod journal have been rectified must be re-nitrided. After re-nitriding, they must be checked by a double dimension and Magnaflux check , as if they were new.

1.16.2.2. Airworthiness monitoring steps taken

Crankshafts on GT 510-520 engines were not subject to any specific regulatory measures following entry into service. However, various measures were applied to other types of TCM engines such as T 510-520 and LT 510-520.

- In February 1981, TCM published an ultrasonic inspection procedure in a Service Bulletin (reference M81-2).

- In 1987, TCM published a Service Bulletin (reference M87-5 of February 1987 then M87-5 revision 1 of May 1987) drawing up an ultrasonic inspection procedure for the crankshafts installed on TSIO-520 engines. All versions were concerned as were all refitted or overhauled engines. This inspection was undertaken within the scope of a program to refit the crankshafts. Indeed, the crankshafts covered by the Service Bulletin were those whose casting process was by vacuum air remelt as opposed to those whose remelt was performed by vacuum arc remelt. This Service Bulletin indicated that « certain types of engines have shown fatigue cracks arising under the surface of the fillets of the intermediate gudgeon pin and whose origin, which was not superficial, remained unexplained ». TCM added that these cracks may « lead to crankshaft rupture » and that « the cracks could not be revealed using the normal Magnaflux inspection method ».

- In 1987, the FAA issued an airworthiness directive (reference AD 87-23-08) that took up Service Bulletin M87-5. For information, the DGAC took up the American AD in the form of CN 87-174-IMP(AB) dated 23 December 1987. Note: the French airworthiness directive recalls that ultrasonic inspection of the crankshafts does not dispense with Magnaflux or other inspections defined in the complete overhaul manuals.

- In June 1996, TCM issued a Critical Service Bulletin (reference Critical Service Bulletin CSB96-8). This Service Bulletin dealt with crankshafts whose casting code was not VAR. It called for the replacement of all crankshafts whose casting code used was not VAR or on which there were doubts. In August 1996, it was followed by a Mandatory Service Bulletin (reference MSB96-10) that replaced Service Bulletin M87-5 revision 1 and that called for ultrasonic inspection of any crankshaft (VAR or otherwise) installed on six-cylinder TCM engines on the next inspection or complete overhaul.

- In 1997, the FAA issued an airworthiness directive (reference AD 97-26-17) for crankshaft replacement, effective in March 1998, taking up Service Bulletins CSB96-8 and MSB96-10. This directive, which replaced that of 1987, specified that an ultrasonic inspection was to be conducted on VAR crankshafts on the first of the two due dates, complete overhaul or removal of the crankshaft. The directive came into effect on 23 January 1998. It was taken up by the Swiss OFAC in the form of an airworthiness directive dated 6 August 1998. The DGAC also took it up in the form of CN 98-077-IMP(A) dated 11 December 1998.

1.16.3. Research into other Cases of Crankshaft Rupture

Research conducted in the United States with the FAA enabled us to list cases of incidents having arisen between 1990 and 1997 due to failure or rupture of crankshafts installed on GTSIO-520 engines equipping Cessna aircraft. Seven cases were listed including two concerning crankshaft ruptures. In one instance, the crankshaft of the RH engine of a Cessna 404 was found to be broken in three places. Inspection of the crankshaft revealed fatigue cracks that had developed where each of the ruptures occurred.

Further, another search showed the case of a crankshaft rupture that occurred in flight on a Cessna T303 Crusader equipped with a TCM TSIO-520-AE engine in September 1997. This incident was covered by a British Air Accidents Investigation Branch (AAIB) investigation for which the report is featured in bulletin AAIB No. 3/99 with reference EW/C97/9/6. The circumstances mentioned in the report were as follows:

1. Whilst cruising at 2,000 feet, the pilot heard and felt a «bang » from the left engine. The aircraft rolled to the left and the pilot saw heavy smoke coming from the top and bottom of the left engine nacelle. He initiated the shutdown procedure for the left engine but then observed that the left propeller was stationary. He tried to feather the propeller without success and found that the propeller control lever would not move to the full feather position. However, the pilot then managed to continue his flight without any subsequent problems.
2. The last complete overhaul of the VAR type crankshaft (serial number 631349) took place in December 1996. The engine with this crankshaft had run 233 cycles since complete overhaul on the date of the incident. The engine had run 1,930.50 hours in all since its delivery to Cessna.

3. Inspection of the crankshaft showed a triple rupture, the first starting through fatigue on the rear of rod journal No. 6 and the second on the rear of rod journal No. 5. The rupture made an oblique angle with the axis of the crankshaft, which allowed the crankshaft to continue operating.
4. Three metallurgical inspections were conducted to estimate the time the crack took to propagate:
   - the first, conducted at the AAIB, concluded that the phenomenon propagated in 150 ± 20 cycles. The AAIB evaluated the duration during which the engine ran with the first rupture of the crankshaft at about five cycles or flights,
   - the second, conducted by the engine manufacturer, counted more than 100 cycles without giving any further details,
   - the last, performed in a third party laboratory, evaluated the duration for propagation at 225 ± 20 %. This means that it is impossible to know whether the crack occurred before or after the last complete overhaul.
5. The AAIB considered the detection of such a crack unlikely in a complete overhaul with the Magnaflux method then used, considering its length.

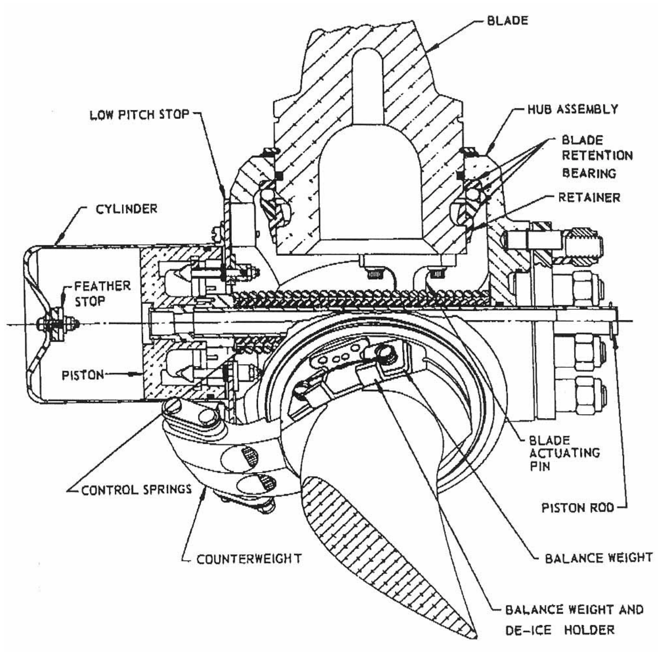
1.16.4. Operation of Propeller Governing System

1.16.4.1. General

When the governor detects a trend towards an increase in the number of revolutions, it increases the pitch of the propeller (which increases its drag). If the trend is towards a reduction in the number of revolutions, the governor reduces the pitch (which reduces drag). The pitch thus adapts automatically according to the power available on the shaft and the number of revolutions commanded by the propeller lever. There are two other functions added to this one: the feather function and a low pitch position conservation function during engine stop to facilitate start-up.

To reduce the pitch, the pilot pushes forward the propeller lever. A control slide (not shown on the accompanying diagram) increases oil pressure into the cylinder. The piston then moves back in the cylinder and compresses its control spring, making the blades spin.

To go towards high pitch, the pilot has to pull back the propeller lever. The control slide diminishes oil pressure. Centrifugal force acting on the latch weight, accompanied by the action of the spring, brings back the blades to high pitch and brings the piston back to the front.



1.16.4.2. Feathering the Propeller

The propeller feathering device means that in the event of engine failure block the blades can be blocked at high pitch. In practice, oil pressure on the piston falls. The piston then moves to the left due to control spring action. Centrifugal force acting on the latch weight allows the blades to be set into the wind. The propeller will slow down then stop.

Note: to feather the propeller, a minimum rotation speed is required for centrifugal force acting on the latch weight to be adequate. For the Cessna 421 propeller governing system, this value is about six hundred rpm.

1.16.4.3. Setting Blade Mechanism on the Ground

There are conical stops (small conical-headed rods) allowing the piston to be held to the rear when the propellers are turning on idle and the oil pressure drops, that is to say when the engine is shut down on the ground. This low pitch stop system means you can avoid the propeller switching to high pitch when the engine stops on the ground. This is intended to facilitate start-up.

1.16.5. Engine Failure Emergency Procedures from the Cessna 421 Manual

Section 3 of the Cessna 421 Operating Manual is devoted to emergency procedures. The sub-section relating to the case of in-flight engine failure above 80 kt indicated speed includes a framed section the pilot should learn by heart (see below). This concerns recognizing the failed engine, adjusting the working engine power and attempting to re-start the engine.

In the event of failure, the engine must be shut down using the throttle, cutting off the fuel supply and setting the propeller to feather. After this, the working engine's power must be adjusted, the aircraft balanced using the rudder trim, the electrical load reduced as much as possible, with a landing as soon as possible on an appropriate airfield.

In addition, the manual contains a sequence of actions devoted to isolating the failed engine. This sequence includes three items:

1.	Throttle -	CLOSE
2.	Mixture -	IDLE CUT-OFF
3.	Propeller -	FEATHER

ENGINE FAILURE DURING FLIGHT (Speed Above 80 KIAS)

1. Inoperative Engine - DETERMINE.
2. Operative Engine - ADJUST as required.

Before Securing Inoperative Engine:

3. Fuel Flow - CHECK. If deficient, position auxiliary fuel pump to ON.
4. Fuel Selectors - MAIN TANKS (Feel For Detent).
5. Fuel Quantity - CHECK.
6. Oil Pressure and Oil Temperature - CHECK.
7. Magneto Switches - CHECK ON.
8. Mixture - ADJUST. Lean until manifold pressure begins to increase then enrichen as power increases.

If Engine Does Not Start, Secure As Follows:

9. Inoperative Engine - SECURE.
   a. Throttle - CLOSE.
   b. Mixture - IDLE CUT-OFF.
   c. Propeller - FEATHER.
   d. Fuel Selector - OFF (Feel For Detent).
   e. Auxiliary Fuel Pump - OFF.
   f. Magneto Switches - OFF.
   g. Propeller Synchronizer - OFF (Optional System).
   h. Alternator - OFF.
10. Operative Engine - ADJUST.
    a. Power - AS REQUIRED.
    b. Mixture - ADJUST for power.
    c. Fuel Selector - MAIN TANK (Feel For Detent).
    d. Auxiliary Fuel Pump - ON.
11. Trim Tabs - ADJUST 5^{o} bank toward operative engine with approximately 1/2 ball slip indicated on the turn and bank indicator.
12. Electrical Load - DECREASE to minimum required.
13. As Soon As Practical - LAND.

The sub-section dedicated to single-engine go-arounds with an IAS above 111kt includes a warning. This indicates that level flight may not be possible under certain weight, temperature and altitude conditions, and that in any event, no go-around should be attempted with a failed engine after the flaps have been extended beyond 15 degrees.

WARNING

Level flight may not be possible for certain combinations of weight, temperature and altitude. In any event, do not attempt an engine inoperative go-around after wing flaps have been extended beyond 15^{o}.

Section 9 of the Operating Manual contains information related to optional equipment. In this section, there is an addition devoted to the Integrated Flight Control System (IFCS) and, in particular, to the automatic pilot. In section 9, emergency procedures are modified to take into account the presence of the automatic pilot. Here it is indicated that in the event of engine failure, the first action is to disconnect the pilot using a switch located in the center of the control column.

1.17. Information on Organization and Management

1.17.1. Information on the Operator

Jetcom S.A. which is co-owner of the Cessna 421 C HB-LRX, was also operating two Falcon 20s, for charter flights, when the accident occurred. According to information provided by OFAC, only these two aircraft were authorized to make commercial flights.

Having consulted the missions and trips made by the Jetcom S.A. pilots, it would appear that Swiss companies hired the Cessna 421 C HB-LRX and that transport of passengers was paid for.

Further, it should be noted that Jetcom S.A. had indicated in April 1995, on renewal of the insurance policy for the Cessna 421 C HB-LRX, that this aircraft could be used as a « commercial transport aircraft ».

Note: Issues 1995/1996 and 1996/1997 of the JP airline-fleets international review mentions HB-LRX in the fleet list of Jetcom S.A.. Although the information in this review is not official or contractual, it is likely that Jetcom S.A. declared to JP that HB-LRX was included among its aircraft used for commercial transport.

1.17.2. Conditions of Acceptance of the Cessna 421 for Commercial Operations

According to OFAC, permitting an aircraft like the Cessna 421 to undertake commercial operations was subject in 1996, that is before application of operational ruling JAR-OPS 1, to the following regulatory requirements:

- filing of an operating manual with the relevant services of OFAC,
- presence of an emergency kit and a fire extinguisher,
- automatic pilot in service on-board where a single pilot is flying.

Jetcom S.A. did not declare the Cessna 421 C HB-LRX as being likely to make paid flights and did not file an operating manual with OFAC.

Note: Of course, commercial operation of the Cessna 421 would have implied satisfying other more general criteria relating to the pilot's or crew's licenses, IFR flight, respect for rules relating to transporting passengers, maintaining crew skills, etc.

1.17.3. Context and Nature of the Flight

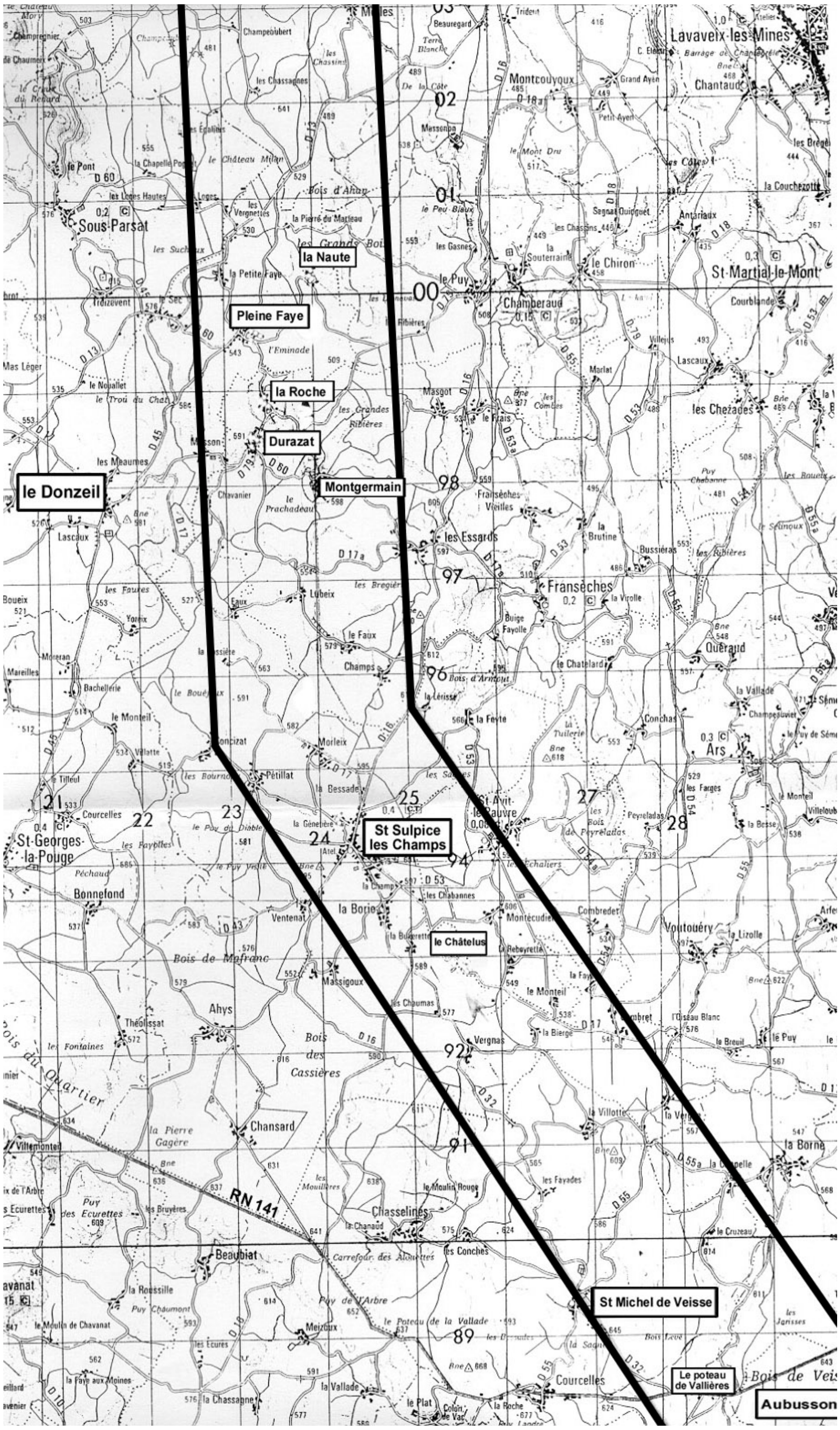
From statements taken in Switzerland, it appears that the accident flight between Geneva and Bordeaux was a leisure trip, made without paid services, bringing together a certain number of friends. The trip had, however, been prepared in the context of an Autumn seminar for a group of Swiss engineers. Those taking part in the seminar were the seven passengers and the pilot of HB-LRX. The seminar program started on 7 November with a meeting of the participants at Geneva Airport and was due to finish at the end of the afternoon of Saturday 9 November by return to Geneva.

Nothing in the investigation showed that the accident flight led to Jetcom S.A. drawing up an invoice to cover the expenses for transport of the passengers or the issue of flight tickets.

1.18. Additional Information

1.18.1. Accounts from Persons close to the Scene of the Accident

Various witnesses heard or saw the aircraft during the five last minutes of flight. The list of witness accounts given below has been drawn up according to the geographical situation of the witnesses and the chronological indications they could provide.



The first account comes from a person who was on the RN 141 main road at the place called Poteau-de-Vallières (Note: this person was in fact almost vertically under the radar plot timed at 9 h 25 min 10 s). This person heard an aircraft flying at low altitude and following a south-north route. The flyover was noted at 9 h 25.

Shortly afterwards, a second witness saw the aircraft heading north (St-Sulpice des Champs) at an « *altitude of 200 m at most* » with both propellers moving.

A third witness, who was managing a team of four roofers on the roof of a house at Saint-Sulpice, saw the aircraft flying very low, « *slightly tilted* *to the left* ». He added that « *the propeller of the RH engine was stopped* ». One of the roofers stated that « *the aircraft was approaching in fog and fine rain* » and at a « *height of between 250 and 300 meters* » and « *seen from behind, the aircraft continued to flutter ».*

A fourth witness living in the village of Saint-Sulpice saw « *the aircraft pitch* » and noted that « *the RH engine was not running* ».

The following witnesses situated to the east of the village of Saint-Sulpice heard and saw the aircraft flying at such a low altitude and at such a low speed so that some could see the aircraft registration number under the wings or count the number of windows.

One witness, living in the village of la Roche situated one kilometer from the scene of the accident, stated that they had « *seen the aircraft tilt to the right, fly to the north and move off to the east* », tilt by « *30° to the right* » then disappear behind a hill.

The last but one witness followed an aircraft, coming from the village of la Roche, that was flying just above the trees of the Eminade Forest heading towards la Naute.

The last witness, who lived at la Naute, heard the aircraft coming from the Eminade Forest, « *heard a loud noise, like something that had fell in one go* », then saw « *an instant after* » fire start. He added that the « *flames spread from the valley to the thicket of trees, from* (his) *left to right* ». He went up to the site of the accident and then left to call the fire brigade.

1.18.1.2. Accounts of Engine Failure Simulations made on HB-LRX

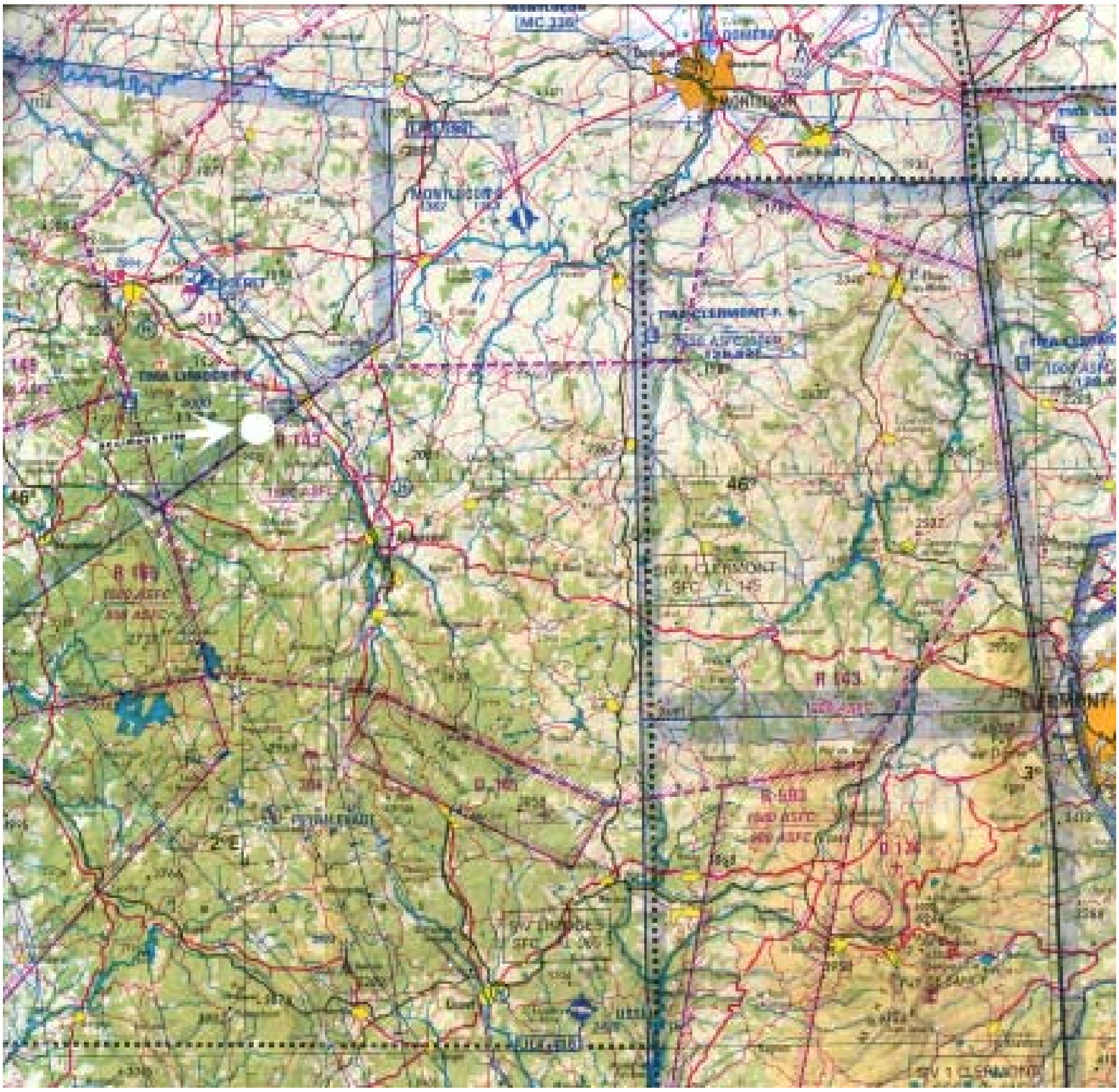
A pilot, employed by Jetcom S.A., who had been qualified on HB-LRX by the pilot who performed the accident flight, and who was used to flying with him on HB-LRX, reported the following fact:

« *During training flights, we carried out engine failure simulations. The procedure involved us first identifying the failed engine then reducing throttle on the failed engine, then rotation. Finally, we brought the throttle* [note: the propeller lever] *to the lowest position, after having gone through a notch. This position brought the propeller to feather without needing to cut off the engine*. *Indeed, as a general rule during training, we never really cut off the engine due to thermal shock problems ».*

1.18.2. Relative Positions of the Possible Diversion Aerodromes

Clermont-Ferrand aerodrome was on the flight path of the aircraft as provided for in the flight plan, fifteen nautical miles east at the moment the pilot declared the failure of the RH engine. This aerodrome, controlled and open to public air traffic, has a tarmac runway 3,015 m long equipped with an ILS. It is featured on low altitude and Jeppesen enroute charts.

When the aircraft was forty nautical miles from Limoges, the controller proposed the Ussel aerodrome as a possible alternative. The Ussel aerodrome, located twenty nautical miles south-east and open to public air traffic with an AFIS agent to ensure flight and alert information services, has a 1,350 meter tarmac runway and is equipped with a radio beacon. It does not feature on Jeppesen low altitude en-route charts.



Note: An ICAO 1/500,000 VFR chart was used in the accompanying illustration to show Ussel, Montluçon-Guéret and Guéret aerodromes, which are not shown on the Jeppesen low altitude en-route charts.

Having changed the aircraft's heading to the north, the aerodromes of Montluçon-Guéret and Guéret could have been used. In relation to the place of the accident, they were respectively at:

- Montluçon-Guéret aerodrome, eighteen nautical miles to the north, which is open to public air traffic where an AFIS agent provides flight and alert information services. It has a 1,450 meter tarmac runway. It is not featured on low altitude en-route charts but is featured on the Jeppesenchart.
- Guéret aerodrome, ten nautical miles to the north-west, which is not controlled and is reserved for locally-based aircraft, has a tarmac runway 675 meters long. It is not featured on low altitude en-route or Jeppesen charts.

Finally, for information, Limoges aerodrome, the aerodrome the pilot thought he could reach, was thirty-five nautical miles south-west of the place of the accident. This aerodrome, controlled and open to public air traffic, has a covered runway of 2,500 meters equipped with an ILS. It is featured on low altitude and Jeppesen en-route charts.

1.18.3. Organization of Search and Rescue

The French Air Force southern area Operations Center (COZ) informed the Lyon Mont-Verdun[4] national Center for Co-ordination and Rescue (CCS) at 9 h 12 that an aircraft was displaying transponder code 7700 after the pilot had indicated an engine failure.

The South-West CRNA triggered an ALERFA procedure at 9 h 14 and communicated with CCS. The latter asked for implementation of reinforced air facilities on alert position: a Puma SAR from the Air Force based at Cazaux and an Ecureuil from the brigade of the Limoges Gendarmerie were thus mobilized.

After the last radio contact and in the absence of a response from the pilot, the Limoges control services warned the Bordeaux CRNA and CODIS 87, CODIS 23 and COG 87 indicating the possible position of the aircraft inside a triangle formed by Guéret-Bourganeuf-Aubusson.

From 9 h 30, many inhabitants of the hamlet of la Roche warned the local rescue services and in particular the Ahun fire brigade services.

At 9 h 34, the DETRESFA procedure was put into action.

At 9 h 44, the helicopter of the Limoges Gendarmerie brigade received the order to take off and head towards the Vaud-Gelade Dam and take on board a doctor from the SAMU emergency medical organization. Takeoff took place at 9 h 57. A helicopter from the SAMU also took off.

At 9 h 50, the CCS triggered phase SATER/2[5] to the west of a line running through La Courtine-Aubusson-Guéret with the prefecture of the department of la Creuse. CODIS 23 asked CCS for information on a twin-engine aircraft accident that was assumed to have taken place at Donzeil south-east of Guéret.

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[4] The CCS determines the likely zone for the accident and search zones. It ensures how all searches are run and directly manages air facilities. Running land rescue is delegated to the prefect of the department.

[5] The SATER protocol agreement specifies three types of measures: SATER/1 request for information not involving movements, SATER/2 gathering information from the population of a given area and SATER/3 for further search facilities when the sector of the accident is known with reasonable certainty.

At 9 h 53, the first rescue services (firemen and gendarmes) arrived at the scene of the accident.

At 10.00, COG 23 confirmed the accident and its location to CCS. On request from CCS, the prefecture triggered phase SATER/3 centered on the place known as « la Naute ».

At 10.36, the helicopter of the Limoges Gendarmerie brigade specified the geographical co-ordinates of the accident site.

At 11.26, DETRESFA came to an end.

At 11.30, phase SATER 3 came to an end.

To summarize, the search was activated thirty minutes after ALERFA and the aircraft was found nine minutes later.

COZ drew up a table summarizing the work carried out during the search and rescue operations:

Nature of missions	Person involved	Vehicles mobilized	Operation time
Air missions			1 h 40
AS 350B Gendarmerie	2	1	0 h 40
AS 350B SAMU Guéret	2	1	1 h 00
Land missions			56 h
SAMU	13	6	
Gendarmerie	65	12	
Fire Brigade	67	27	
Air Force	6	3	
Total	155	50	57 h 40

2 - ANALYSIS

2.1. Flight Preparation

The investigation was not able to find the flight log. In fact, the flight log was destroyed in the fire that broke out in the cockpit and no copy was kept at the company's registered office in Geneva. This does, however, show that preparation for the flight was inadequate.

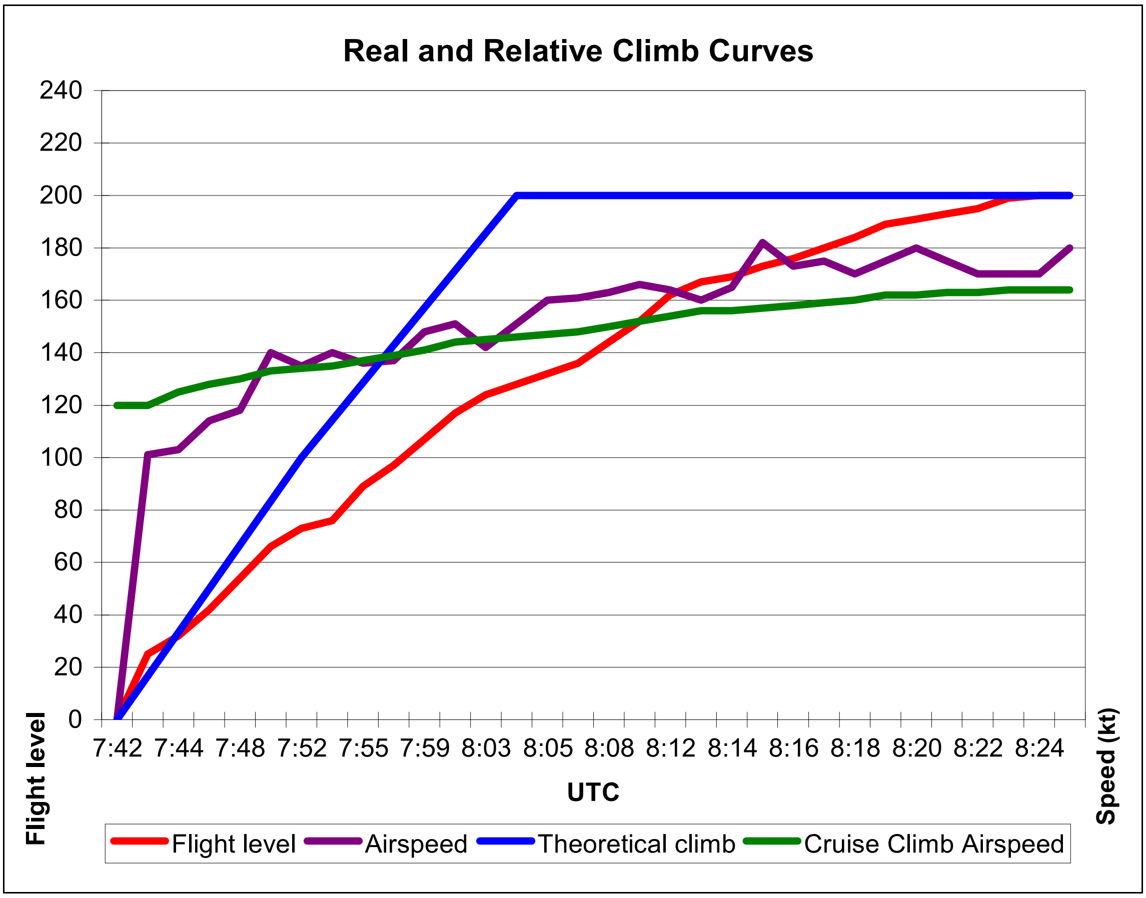
Indeed, even if the exact load was unknown, the calculations made in § 1.6.4. show that, in all likelihood, the aircraft was overloaded and balanced beyond the rear balance limit on departure from Geneva Airport.

On the eve of the flight, the pilot had sent a flight plan that indicated the presence of seven people on board (see § 1.1). Before sending this flight plan, a document sent by one of the passengers listed those taking part in the seminar organized in Bordeaux. This list included eight names, those of the victims of the accident (see § 1.17.3.). This difference of one person resulted in the overloading of the aircraft.

This means either that the pilot knew this list before sending the flight plan and could not possibly have been unaware of the calculation stating that the aircraft was going to take off overloaded and balanced to the rear, or that he did not redo his calculations when the seventh passenger arrived. In either case, he failed to file a corrected flight plan.

2.2. Performance Observed on Climb

Climb to level 200, the final cruise level, took 42 minutes and was uninterrupted. Although the parameters for engine control used during this flight are unknown, a witness stated the pilot usually selected «cruise climb» flying parameters. As seen in § 1.6.5.1, the theoretical climb in this case takes twenty-one minutes.



The real climb therefore took exactly twice as long as the theoretical time. This variation is highly significant. How can it be explained?

- During the first twenty-one minutes of climb, there was little variation between the aircraft's airspeed and that called « cruise climb ». The aircraft would be expected to reach FL 200, but this was far from being the case as it only reached FL 130. What is even more surprising is the fact that the aircraft, which admittedly was flying faster than the theoretical 120 kt and thus was climbing less quickly, took another twenty-one minutes to reach FL 200. This very slow climb, which should have alerted the pilot, highlights a major shortcoming in the aircraft's performance.

- Here the influence of atmospheric parameters that could have degraded the aircraft's performance can be ignored: there was no indication of icing and the outside temperature at altitude was close to standard.

- Considering the age of the aircraft (twenty years) and engines (more than fifteen years with two thousand hours operation), the level of performance could be lower than the theoretical levels given for a new aircraft and engines. Nevertheless, the two engines were far from being at the end of their potential and their lack of performance due to age, which is predictable but difficult to quantify, cannot alone justify such a variation. It should be noted that these engines are certified to supply minimum certified thrust throughout its service life, i.e. operating period between two complete overhauls.

Only the excess load and poor balance appear to have been capable of contributing significantly to the degradation in performance illustrated by the slow rate of climb.

2.3. Analysis of the Technical Failure

2.3.1. Crankshaft Rupture

The examinations and analyses performed highlighted the rupture of the RH engine crankshaft in flight. This rupture followed cracking due to fatigue in rod journal No. 5.

The investigation showed that the rod journals had been reground. It is possible that the crack, which was already present, was not revealed during this operation due to the technique for Magnaflux inspection then used (see § 2.4.). The crack may also have appeared after this operation,
- either because the reconstitution of the nitride layer had been omitted or imperfectly performed in the connecting radius of rod journal No. 5, which would have led to a degradation in the quality of the surface of the material;
- or, due to damage to the rod journal between the time of the regrind and the day of the accident.

Note: there is no (non-destructive) way to check the thickness of the nitride layer during manufacture or overhauls.

Investigators also wondered about the possible consequences on the crankshaft of feathering the propeller without the engine being shut down, as was done during training. When questioned, TCM replied that, to their knowledge, there was no effect on the engine or the crankshaft, whatever the engine speed at which the engine failure exercise was undertaken.

2.3.2. Crankshaft Maintenance

As we saw in § 1.16.2.2., none of the measures taken by TCM and the FAA as from 1987 to ensure that crankshafts installed on TSIO-520 engines or LT 510-520 applied to the crankshafts of GT 510-520, since no cases of non-surface fatigue cracks were known. In other words, the manufacturer and the airworthiness authority considered that the recommended inspection methods made detection of any and all cracks possible, and that the time for the development of cracks on these crankshafts was always greater than the time between complete overhauls.

As no final time limit was set for crankshaft inspection before the check in the general overhaul, the crankshaft of the RH engine on HB-LRX, repaired for the last time in 1986, was not inspected in time and thus slipped through the safety net for a period of ten years.

When the accident happened, this engine had been in operation for a little more than nine hundred hours since the last general overhaul, meaning that it had almost seven hundred hours potential. Nothing prevented it from flying for several further years without an inspection of the crankshaft.

As of the date of issue of this report, no mandatory measures have been taken to define a schedule for the inspection of VAR crankshafts installed on GT 510-520 engines.

2.3.3. Scenarios for the failure of the RH engine

The investigation showed that after the rupture of the crankshaft, the propeller could not be set to feather, thus preventing the aircraft from maintaining level flight. A question might be asked as to whether the pilot managed to set the propeller to feather and that it subsequently got blocked when trying to restart the engine or whether he never managed to obtain feathering. On analysis, both hypotheses are acceptable, leading to the two following scenarios:

Scenario No. 1: the pilot never managed to obtain propeller feathering

1. Crankshaft rupture created significant friction that quickly slowed down the rotation speed of the propeller.
2. Normal operation of the governor reduced the propeller pitch.

3. The pilot did not realize the mechanical origin of this engine failure. He did not order feathering before the rotation speed of the propeller fell below six hundred rpm. The piston of the governor remained between low and high pitch. Without the effect of centrifugal force on the latch weight, it was no longer possible to set the propeller to feather even using the propeller control.
4. The propeller stopped, blocked irreversibly at intermediate pitch.
5. All attempts to re-start were in vain due to the structural damage to the crankshaft.

Scenario No. 2: the propeller set to feather became blocked during the start-up sequence

1. The pilot switched the propeller to feather before damage to the crankshaft created excessive friction.
2. During descent, he made an attempt to restart.
3. While the pilot was trying to turn the engine over, the oil pressure reached a high enough value to unfeather the propeller, but the propeller did not reach a rotation speed higher than or equal to six hundred r.p.m. before aggravation of damage to the crankshaft finally blocked the engine.
4. As in the previous hypothesis, the propeller was then at intermediate pitch with no possibility of being set to feather.

The common point in these two scenarios is the braking in rotation of the engine shaft which causes the centrifugal force, needed to switch the propeller to feather, to disappear. This is the special nature of the failure that occurred on HB-LRX. Indeed, if there was no internal mechanical rupture braking rotation of the engine shaft, the design of the propeller governing system means that, *theoretically*, windmill rotation of the propeller will ensure a sufficient rotational speed (about seven hundred rpm.) to allow feathering at any time.

2.4. Conduct of the Flight after Failure of the RH Engine

Failure of the RH engine occurred during cruise. Since the aircraft could not maintain level flight at FL 200 with one failed engine, the pilot had to descend.

The pilot then adopted a strategy based on a false premise: the possibility of being able to maintain level flight at a certain level. This is what he called the « recovery » level.

Although imposed, the descent did not worry him because he thought he would be able to restart the engine and thus continue his flight to the destination. Going through FL 190, he also informed control of his intentions, specifying that he was going to « *recover at 100 if possible to restart ».*

By doing so, the pilot rejected out of hand the possibility of a diversion, more precisely a return towards Clermont-Ferrand. Convinced that he would in any case be able to continue on one engine ([we] « *can hold level flight at 8,000 feet on one* *engine »*), he did not take into consideration the risk of failure to restart with a reduced margin of maneuver due to the loss of altitude.

When declaring the failure, the aircraft was fifteen nautical miles to the west of the Clermont-Ferrand airport. The latter was therefore extremely close and, descending from 20,000 feet, the pilot could have reached the runway without being obliged to maintain level flight. Although meteorological conditions at Clermont-Ferrand were not very favorable (ceiling at 3,000 feet), the pilot, who had already squawked code 7700, would have had assistance from air traffic control to facilitate his approach and landing.

It could be supposed that the pilot would first have tried to deal with the tasks of flying and managing the engine failure. In fact, the pilot's intellectual and physical resources were taken up by:

- efforts directly related to flying the aircraft: the aircraft had a failed engine, the pilot thus had to disconnect the automatic pilot by application of the procedure seen in § 1.16.5. Manual flight, with a RH propeller that was not feathered, required sustained vigilance as to roll and yaw control from him – despite compensation, in order to hold the aircraft on its flight path. These efforts were made all the more necessary because the aircraft was heavy and relatively unstable since it was in all likelihood balanced beyond the rear limit,
- efforts to identify, deal with and resolve the RH engine failure, which only the pilot could do, since none of the passengers had known aeronautical skills.

His unease must have increased gradually as he realized that he was not maintaining level flight. Despite an unsuccessful attempt to restart at FL 120, he nevertheless delayed reconsidering his strategy. Indeed, he confirmed a direct route for Bordeaux.

Several factors led the pilot to change strategy during descent and choose to divert to Limoges nearly twenty minutes after having announced the engine failure:

- the impossibility of restarting the RH engine despite several attempts,
- the impossibility of maintaining level flight on a single engine after the aircraft had descended through the flight level that the pilot believed he would be capable of holding,
- descending through the safety level given by control (FL 70),
- and, perhaps, the low ground speed of the aircraft that did not allow him to cover a significant ground distance, the pilot moreover confirmed that the on-board GPS indicated a ground speed of 75 knots. As a comparison, the radar indicated at that time values of 70 or 80 knots.

This decision to head for Limoges was made late. Since the announcement of an engine failure, the aircraft had lost a good deal of its altitude and thus a significant part of its potential energy resources. Its potential range was all the more reduced due to the head wind (30 kt), its descent slope was clearly more pronounced than the expected descent slope extrapolated on the vertical speed indicator display.

The pilot henceforth had to manage an emergency situation. The aircraft was continuing to descend with a rate of descent of six to seven hundred feet per minute and was now flying in a hilly region whose peaks were partly obscured. He knew that he would have to go under the cloud cover with little or no margin in relation to obstacles.

Visual contact with the ground was acquired at about 1,000 feet and was almost immediately accompanied by loss of radar contact. The visibility conditions were mediocre: horizontal visibility did not exceed three kilometers in the drizzle and as such reduced the pilot's ability to see the surrounding high ground. When the aircraft went below the cloud cover, the pilot realized that he could not continue on that heading. He then decided to take a heading directly north that would take him away from the Limoges aerodrome which he nevertheless wished to reach. Witness accounts indicate that in the last minute the aircraft flew along a valley between two wooded hills.

2.5. The Accident

Observation of the site did not show any traces of abrasion on the ground before final impact. It was not possible to determine whether the flaps were extended and if so at what angle. The wreckage was concentrated within an area corresponding to the dimensions of the aircraft. Observation of the wreckage showed that at the moment of impact the aircraft was slightly banked to the right. Traces of the leading edges of the wings were driven into the ground and the ruptures in the rear part of the fuselage indicate that the aircraft collided with the ground at high vertical speed and low horizontal speed. All these observations lead us to conclude that there was no attempt to make a forced landing, rather a loss of control.

The cause of this loss of control is difficult to determine: either a loss of control over yaw and roll at a speed close to V_{mca} or a stall in straight flight. The first hypothesis seems more likely:

- firstly, because the real minimum air control speed in the flight conditions was in reality slightly greater than the value of 80 kt given in § 1.16.5 with one propeller stopped, and was thus all the more penalizing for the pilot,
- secondly, because the aircraft was in all likelihood banked to the right in the last seconds of flight (angle of 30 degrees according to a witness 500 meters from the place of the accident), and thus to the side of the stopped propeller, which would have made control of the aircraft even more difficult.

In the absence of traces or contact with the surrounding trees, it is likely that the loss of control took place at a low height.

2.6. Analysis of the Pilot's Behavior

Considering the pilot's profile as an instructor and airline pilot, and with his overall experience, it is surprising to note that the mechanical failure of an engine on a twin-engine propeller driven aircraft resulted in the loss of the aircraft. A number of explanations can be proposed for this:

- The pilot did not realize the particular origin of the engine failure. In a more conventional situation, as with fuel supply failure or oil failure, the propeller would have been capable of windmilling, which would have been enough to ensure feathering of the propeller.
- The pilot was used to flying high performance jet aircraft (Jetcom S.A. Falcon 20's) within the scope of his professional activities. He had relatively few flying hours on the Cessna 421: an average of about 25 hours a year including half as instructor. To deal with the failure of the RH engine, he applied a strategy that first assumed sufficient altitude to restart the engine then an altitude to hold level flight. He thus transposed what he could have done if he had been flying an aircraft equipped with jet engines. But, the operation and performance levels of the Cessna 421 are very different. Further, none of the simulations of engine failure he had performed or ordered during training or instruction was comparable with the mechanical crankshaft rupture. This particular failure, which made feathering of the propeller impossible, affected the aircraft's performance to the extent of prohibiting continuation of the flight. The idea that there was an altitude at which you could restart the engine or maintain level flight was false.
- The decision to continue the flight towards Bordeaux for so long and the late choice of an alternative routing to Limoges were also perhaps motivated by the desire to reach the destination. The pilot, due to the nature and the context of the flight, had set himself the objective of succeeding in his mission, that is in arriving at his destination, with respect to the passengers among whom there were customers of Jetcom S.A., and with whom he enjoyed a sound professional reputation.

2.7. Analysis of the Operational Context

Even if nothing in the investigation has established that the Geneva-Bordeaux flight was undertaken within the framework of a paying flight, a certain number of facts show that the Cessna 421 C HB-LRX had been used for paid transport of passengers. This use of the aircraft was not authorized, since the aircraft was registered with the Swiss Federal Civil Aviation Office as an aircraft operated for private flights. Control over application of operational regulations should have been sufficient to quickly correct any failures observed. This use, which may only have been occasional, was nevertheless detectable in that, for example, the Cessna 421 C HB-LRX was registered in the commercial fleet of Jetcom S.A. as published in the JP airline-fleets international, a non-contractual and unofficial review but which, in certain respects, constitutes a reference document.

This failure to respect operational regulations applicable to public transport, which guarantee a minimum level of safety, raises the question of passenger safety. The companies that hired the Cessna 421 had no reason to doubt that this aircraft's safety level in operation was comparable, for example, with that of the Falcon 20s also operated by Jetcom S.A. It is likely that those taking part in the Bordeaux seminar believed that the use of an aircraft occasionally hired by companies for commercial use guaranteed a certain level, not only of service, but also of flight safety.

3 - CONCLUSIONS

3.1. Findings

- The pilot possessed the requisite qualifications to undertake the planned flight.
- The aircraft had not had a major incident since being imported into to Switzerland in 1992, with the exception of a LH propeller impact in January 1993 which led to the removal and replacement of the LH engine and propeller. The aircraft log correctly took into account the propeller change, but the log for the LH propeller did not correspond to the propeller installed.
- The aircraft took off slightly overloaded and was balanced beyond the rear limit.
- The RH engine suffered a rupture in the crankshaft while the aircraft was cruising at flight level 200. This resulted from a crack which had developed on rod journal No. 5.
- This rupture led to braking in rotation of the propeller, which prevented it from windmilling and prevented engine restart.
- Below six hundred r.p.m., the propeller governing system prevented the propeller from being feathered.
- Given the conditions for the RH engine failure, the aircraft was not able to hold level flight at any flight level at all.
- The pilot initially thought he would restart the engine below level 100 and did not consider this diversion to be necessary.
- The pilot finally decided to divert to Limoges aerodrome after 15 minutes descent although the aircraft had just passed through level 75.
- At the time of the decision to divert, the aircraft was too low to reach Limoges, bearing in mind the rate of descent caused by the blocking of the RH propeller.
- The pilot caught sight of the ground at about 1,000 feet, just as the controller lost radar contact.
- The site of the accident and the concentration of the wreckage indicate a loss of control at low height.

3.2. Probable Cause

The accident is due to inappropriate management of the flight following jamming of the propeller in an intermediate position after RH engine crankshaft rupture. The inappropriate management was due to:

- the pilot's relative lack of experience on this aircraft type;
- his false notions about the aircraft's performance and about the existence of a flight level to maintain level flight with an unfeathered propeller and an heavy aircraft;
- a series of misjudged strategies to attempt to continue the flight then to land at Limoges when the aircraft's altitude no longer made this possible.

The lack of instructions relative to inspections by a reliable method for detection of cracks on crankshafts installed on GTSIO-520 engines was a contributory factor.

4 – SAFETY RECOMMENDATIONS

1- The crankshaft rupture, a rare but unpredictable failure, can prevent propeller feathering on the Cessna 421 and make level flight impossible. It would therefore be desirable for pilots to be warned against continuing a flight with a blocked propeller.

In addition, this accident showed that it was possible, in certain cases of crankshaft rupture, that an attempt to restart the engine could subsequently make it impossible to feather the propeller. It is therefore necessary to consider this as a possibility in the event of an engine failure a long way from an aerodrome, such as when flying over the sea or over inhospitable area, since an emergency landing at an aerodrome would be impossible in such cases.

Further, since many twin piston-engine aircraft's propeller governing systems work in the same way as that of the Cessna 421, these measures should be extended to cover those aircraft. Consequently, the BEA recommends:

- **that the FAA require Cessna to modify the emergency procedures for the Cessna 421 to take into account, in all phases of flight, the fact that maintaining level flight may be impossible in the event of a seized propeller, and that Cessna specify the steps to be taken in such circumstances.**

- **that the FAA require Cessna to modify the engine restart procedures for the Cessna 421 to allow the pilot to determine the pre-conditions for continuing the flight in the event of a propeller blockage.**

- **that the FAA and other airworthiness authorities responsible for the certification of twin piston-engine aircraft extend these measures to all aircraft equipped with propeller governing systems of the same design.**

2. The investigation showed that the absence of any inspection over a period of ten years meant that the flaw, which caused the cracking of a rod journal and subsequently the rupture of the crankshaft, was not detected. A very similar incident occurred on an engine of the same type in Great Britain in September 1997 and the investigation into this incident showed that Magnaflux inspection was inadequate to detect cracks. More generally, ultrasonic crankshaft inspections which were made mandatory by two FAA airworthiness directives did not include crankshafts on GTSIO-520 engines installed on Cessna 421's and set no time limit for the inspection of other engines. Consequently, the BEA recommends:

- **that the FAA amend Airworthiness Directive AD 97-26-17 in order to take into account all crankshafts on all six cylinder TCM engines, including those installed on GTSIO-520 engines and to set a time limit for inspection of crankshafts.**

- **that as a precautionary measure the DGAC, in liaison with the JAA's, implement this measure in the context of CN 98-077-IMP (A).**

3. The investigation showed that HB-LRX had occasionally been operated without authorization for paid transport of passengers. Inspections by OFAC, did not lead to identification and correction of this failing. Consequently, the BEA recommends:

- **that OFAC and the JAA's define ways and means to reinforce application of operational regulations for air transport companies which also have other types of operations.**

List of Appendices

APPENDIX 1
Transcription of radio communications

APPENDIX 2
Weight and balance chart

APPENDIX 3
Performance graphs for single-engine operation

FREQUENCY : 126.7 MHz

FROM	TIME	COMMUNICATION
HB-LRX	8 h 01 min 22 s	HRX, Marseille Hotel Bravo Lima Romeo Xray good morning.
ATC		RX good morning
HB-LRX		On, level 120 for, err, passing 190 heading 230
ATC		Roger Romeo Xray maintain heading 230 towards 190, will report.
ATC	8 h 04 min 07 s	HRX climb flight level 2 0 0 proceed to Lyon Clermont-Ferrand
HB-LRX		Lyon Clermont-Ferrand level 200 HRX
ATC	8 h 15 min 33 s	HRX maintain 200 2 0 0
HB-LRX		HRX cleared to level 200 for err Clermont-Ferrand
ATC	8 h 15 min 46 s	And report stable please
HB-LRX		Report stable HRX
ATC	8 h 16 min 47 s	HRX contact Marseille 133 42 goodbye
HB-LRX	8 h 16 min 53 s	133 42 goodbye

FREQUENCY : 133.42 MHz

FROM	TIME	COMMUNICATION
HB-LRX	8 h 17 min 22 s	Marseille HBLRX good morning
ATC		HBLRX good morning climb to level 200 2 0 0 for err Clermont-Ferrand
HB-LRX	8 h 17 min 35 s	HRX level 200 for Clermont-Ferrand
ATC	9 h 00 min 42 s	HRX contact Bordeaux control 1 3 3. 1 goodbye
HB-LRX		1 3 3 goodbye sir thank you

FREQUENCY : 133.10 MHz

FROM	TIME	COMMUNICATION
HB-LRX	9 h 01 min 04 s	HBLRX good morning level 200
ATC		HBLRX good morning maintain 200 direct LIBRU the 23 is ir service
HB-LRX		Direct LIBRU for the 23 RX
HB-LRX	9 h 02 min 40 s	HRX ready for descent
ATC		Say who wishes to descend ?
HB-LRX		HRX
ATC		Say again who wishes to descend?
HB-LRX		HBLR X
ATC		R X maintain flight level 200 will call back
HB-LRX		HRX
ATC	9 h 03 min 15 s	HRX climb to level 200 please 2 0 0
HB-LRX		HRX we have an engine failure, I have to descend, I absolutely must descend, I'm sorry

ATC		H R X squawk 7700
HB-LRX		7700
ATC	9 h 03 min 40 s	R X what level are you passing through on descent ?
HB-LRX		185 for err (*) we're going to level off at 100 if possible to recover
ATC		Roger RX
HB-LRX		RX
ATC	9 h 04 min 14 s	HRX contact Bordeaux on 127.67 immediately
HB-LRX		127.67 goodbye thanks

<u>FREQUENCY</u> : 127.67 MHz

FROM	TIME	COMMUNICATION
ATC	9 h 05 min 10 s	HBLRX ?
HB-LRX		Yes good morning HRX
ATC		Good morning you have an engine out don't you ?
HB-LRX		Yes I will have to descend a bit to recover
ATC		Say what you want at the moment
HB-LRX		Request continue towards Velin for Bordeaux
ATC		What I can suggest is for you to head towards Limoges initially and if you have problems you you can maybe land at Limoges
HB-LRX		For me, it would suit me better to maybe go on to Bordeaux
ATC		Yes I understand that but at the moment Limoges is closer can you confirm that you have no problem in restarting the engine ?
HB-LRX		Wait a bit longer I have to descend a little it's a bit high here where we are
ATC		For the moment you are on a magnetic heading 2 7 0 To avoid a military zone you can pass the military zone in twenty miles
HB-LRX		HRX we are taking heading 2 70 and we are on descent at 500 feet per minute we are passing through 160
ATC		Keep me informed if you have any problems
HB-LRX	9 h 06 min 07 s	We will keep you informed HBLRX
ATC	9 h 06 min 55 s	RX for my information can you maintain level flight with one engine ?
ATC	9 h 07 min 08 s	HBLRX ?
HB-LRX		Yes go ahead
ATC		I would like to know if you can manage to maintain level flight with one engine and at what level you can maintain it
HB-LRX		Well we can maintain level flight at 8000 feet on one engine
ATC		Roger
ATC		For the moment you are descending without restriction towards the level which suits you best and you report
ATC	9 h 08 min 04 s	HRX for information we have 70 kt ground speed

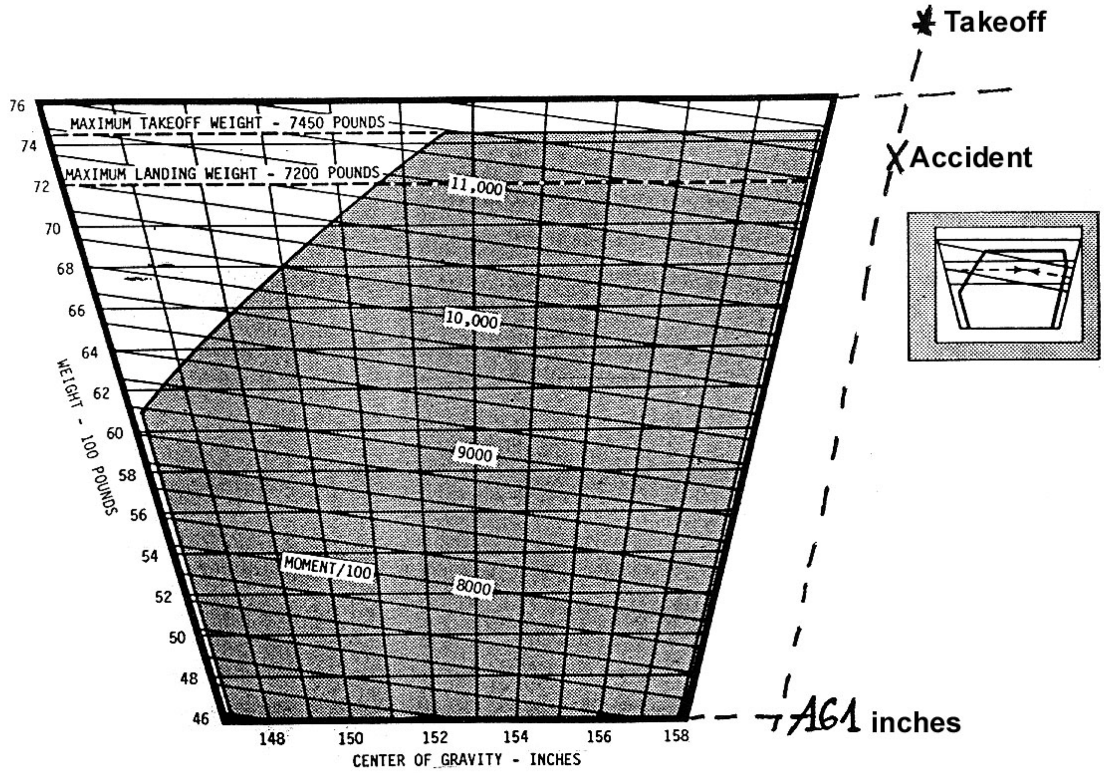
HB-LRX		HRX yes thank you
ATC	9 h 10 min 05 s	HLRX for my information say if you are equipped with a GPS?
HB-LRX		Affirmative we are equipped with a GPS
ATC		OK fine
ATC	9 h 11 min 05 s	HRX have you tried to restart the engine
HB-LRX		Yes we tried it once… it didn't work
ATC		Do you have any idea of the reason for the failure?
HB-LRX		Not yet no I'm trying to see
HB-LRX	9 h 11 min 52 s	HRX can you give me the latest forecast for Bordeaux please
ATC		I will call you back right away
ATC	9 h 13 min 05 s	HRX you can head towards Bordeaux directly if you wish we can negotiate with Merignac on arrival
HB-LRX		That's nice thank you Bordeaux direct
ATC	9 h 13 min 40 s	HBLRX I have the 9'o'clock forecast are you ready to copy?
HB-LRX		Not right now just a moment
HB-LRX	9 h 13 min 56 s	HRX… go ahead
ATC		So Bordeaux at 9'o'clock wind 220 degrees 12 kt visibility above ten few at 3000 feet broken at 9000 temperatures 17 degrees and 13 degrees dewpoint QNH is 1021 and NOSIG
HB-LRX		HRX thanks very much
ATC		Are you perhaps interested in the Limoges forecast?
HB-LRX		Go ahead yes
ATC		We'll call them and inform you
ATC	9 h 15 min 20 s	HRX say what level you want to descend to
HB-LRX		(*) can you give me the safety level? It's 50 here, isn't it?
ATC		I think it's 70 I can give you that without restriction I'll look for the rest
HB-LRX		Thanks very much
ATC	9 h 16 min 03 s	HRX are you in sight of high ground
HB-LRX		Not yet 'm just going into a little layer here
ATC		For me 70 is fine there's no problem
HB-LRX		Thanks very much
ATC	9 h 16 min 35 s	HRX check your speed anyway I have quite low speeds I don't know if you
HB-LRX		HRX yes I have... 115 kt now
ATC		I have okay ground speeds there's maybe the … the wind between 70 and 100 kt
HB-LRX		That's right the GPS indicates 75 kt
ATC	9 h 17 min 47 s	HRX are you maintaining level flight now?
HB-LRX		Yes that should just about do it now
ATC		OK and still no prospect of a restart ?
HB-LRX		No not for the moment we have the …. It's a bit blocked so can't restart for the moment

HB-LRX	9 h 18 min 32 s	HRX I can't maintain the level I will have to descend anyway can you tell me for Limoges how far we are from Limoges?
ATC		I will call you back
ATC	9 h 18 min 46 s	Limoges is 38 to 40 miles with a heading of 2 7 0 you can enter it on the GPS
HB-LRX		Yes I'll do that right away
ATC		For me there is also Ussel which is nearby it's a slightly smaller field but I don't think there's any problem for a Cessna 4 2 1
HB-LRX		No we will try to make Limoges Give me the Limoges four letter code again please
ATC		You enter LFBL
HB-LRX		LFBL thanks
ATC	9 h 19 min 31 s	HBLRX say if there is an icing problem
HB-LRX		No, thank you
ATC		Say when you come out of the cloud layer
HB-LRX		Affirmative
HB-LRX	9 h 19 min 51 s	Can you confirm 2 7 0 at 42 miles for Limoges ?
ATC		Yes I don't have the exact position of the field but It's approximately that yes
HB-LRX		Thanks very much
ATC		Were you able to enter it on the GPS ?
HB-LRX		Absolutely
ATC	9 h 20 min 40 s	HBLRX ?
HB-LRX		Yes go ahead
ATC		Yes it's not great there's 7 k's visibility runway 22 wind 230 degrees at 11 kt gusting to 16 kt broken at 300 feet and 1019 QNH
HB-LRX		HRX thanks
ATC		Do you think you can perform an ILS or does that seem impossible?
HB-LRX		No.... for an ILS I'm going to see if I can maintain on one engine if not we will perform an ILS at Limoges
ATC		In that case the arrival beacon is NOL
HB-LRX		HRX
ATC	9 h 21 min 24 s	HBLRX display and plan Limoges 119.2 frequency and I will transfer you to Limoges as soon as possible
HB-LRX		119.2 for Limoges HRX
ATC	9 h 21 min 58 s	HRX still in the cloud layer ?
ATC	9 h 22 min 08 s	HBLRX ?

FREQUENCY : 119.2 MHz

FROM	TIME	COMMUNICATION
HB-LRX	9 h 22 min 57 s	When we descend again H RX we must continue to descenc a bit because the propeller is blocked… we can't feather it so …
HB-LRX	9 h 23 min 02 s	Can you give me another safety there please ?
ATC	9 h 23 min 15 s	…X Good morning descend 4000 feet QNH 1019 and nc lower… I have radar contact
HB-LRX	9 h 23 min 21 s	RX 1019 at 4000 feet
HB-LRX	9 h 23 min 41 s	RX perhaps the ILS frequency?
ATC	9 h 23 min 46 s	RX say again
HB-LRX	9 h 23 min 50 s	The ILS frequency please
ATC	9 h 23 min 56 s	109.3 1 0 9 . 3
HB-LRX	9 h 23 min 57 s	109.3 thanks!
ATC	9 h 24 min 01 s	N0L frequency 339
HB-LRX	9 h 24 min 10 s	RX... cannot maintain 4000 feet you can continue the descent
ATC	9 h 24 min 16 s	What are your conditions... RX
HB-LRX	9 h 24 min 24 s	Yes... HRX it's hard to maintain 4000 feet … can you give me another altitude please ?
ATC	9 h 24 min 25 s	I will call you back
ATC	9 h 25 min 16 s	RX can you hold at 3500 feet QNH ?
HB-LRX	9 h 25 min 20 s	RX negative for the moment I can't manage to maintain 3500 feet
ATC	9 h 25 min 28 s	Roger... say what you can maintain
ATC	9 h 25 min 33 s	Are you in sight of the ground RX ?
ATC	9 h 25 min 48 s	RX are you in sight of ground ?
ATC	9 h 26 min 19 s	H ... RX Limoges
HB-LRX	9 h 26 min 55 s	RX ground in sight ... but I don't think that we'll get through that way … do you have radar contact for us ?
ATC	9 h 26 min 57 s	Negative we have just lost radar contact
HB-LRX	9 h 27 min 02 s	RX
ATC	9 h 27 min 13 s	RX say your intentions
HB-LRX	9 h 27 min 32 s	I'm on heading 350 to switch to... I'm below the high ground. Right now, I can just hold 2500 feet... and have you got a distance for Limoges? I've got 36 nautical for the moment, I'l try to get there but I'll keep you informed... I'm below the clouc layer".
ATC	9 h 27 min 50 s	Roger so below the cloud layer … I had a last radar contact at about 28 nautical en route for Limoges and so now I'm checking VFR charts for obstacles situated in your region at 2700 feet on QNH... max. obstacles, that I can see north of the Lac de Vassivière"
HB-LRX	9 h 27 min 52 s	RX
ATC	9 h 28 min 43 s	RX do you have a distance to LMG

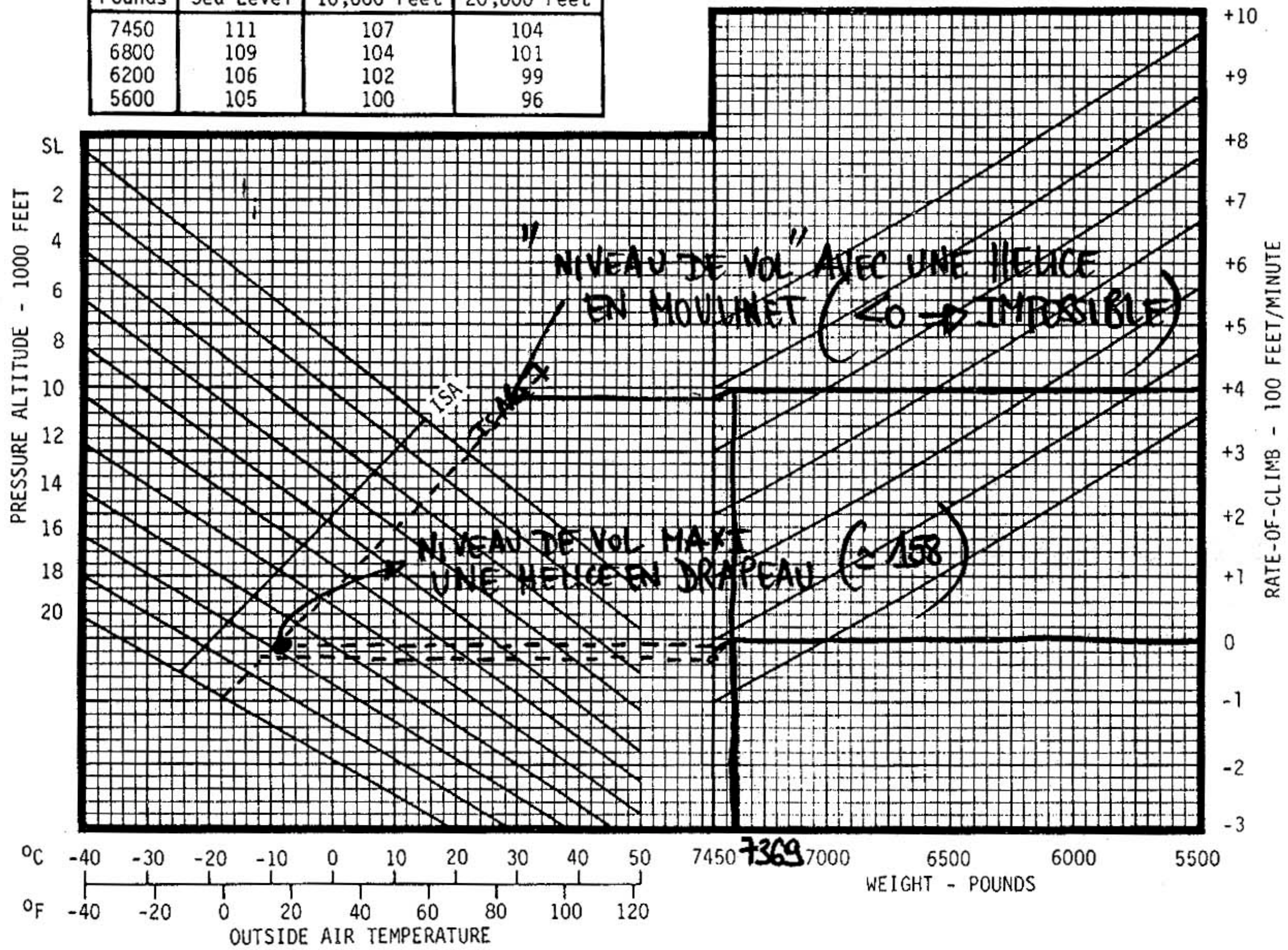
ATC	9 h 28 min 53 s	H RX are you on route to NOL ?
ATC	9 h 29 min 18 s	H RX on the frequency ?
ATC	9 h 29 min 55 s	HBLRX Limoges!
ATC	9 h 30 min 19 s	HBLRX Limoges!
ATC	9 h 30 min 48 s	HBLRX Limoges!
ATC	9 h 31 min 44 s	HBLRX Limoges!
ATC	9 h 32 min 08 s	HBLRX Limoges!
ATC	9 h 33 min 24 s	HBLRX Limoges!
ATC	9 h 34 min 30 s	HBLRX Limoges!

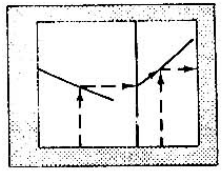


Takeoff
Accident
161 inches
MAXIMUM TAKEOFF WEIGHT - 7450 POUNDS
MAXIMUM LANDING WEIGHT - 7200 POUNDS
11,000
10,000
9000
8000
MOMENT/100
WEIGHT - 100 POUNDS
76
74
72
70
68
66
64
62
60
58
56
54
52
50
48
46
148
150
152
154
156
158
CENTER OF GRAVITY - INCHES

RATE-OF-CLIMB - SINGLE ENGINE

WEIGHT	CLIMB SPEED - KIAS		
Pounds	Sea Level	10,000 Feet	20,000 Feet
7450	111	107	104
6800	109	104	101
6200	106	102	99
5600	105	100	96





CONDITIONS:
1. 2235 RPM and 39.0 Inches Hg. to 20,000 Feet. Use Placarded Manifold Pressure Above 20,000 Feet.
2. Mixture - CHECK Fuel Flow In the White Arc.
3. Landing Gear - UP.
4. Wing Flaps - UP.
5. Inoperative Propeller - FEATHERED.
6. Wings Banked 5° Toward Operative Engine With Approximately 1/2 Ball Slip Indicated on the Turn and Bank Indicator.
7. Cowl Flaps - CLOSED on Inoperative Engine (If Installed).

NOTE: Approximate Effect of Configuration on Single-Engine Rate-of-Climb.

Subtract values listed below from value obtained in above graph. Effects for a combination of gear, flap or windmilling propeller may be obtained by adding the effects for each.

Inoperative Engine Windmilling	400 Ft/Min
Gear Down	350 Ft/Min
Flaps Down 15°	200 Ft/Min
Flaps Down 45°	800 Ft/Min