MINISTERE DE L'EQUIPEMENT, DES TRANSPORTS, DU LOGEMENT, DU TOURISME ET DE LA MER - BUREAU D'ENQUETES ET D'ANALYSES POUR LA SECURITE DE L'AVIATION CIVILE

Accident on 24 March 2001 at Saint-Barthélemy (971) to the DHC-6-300 registered F-OGES operated by Caraïbes Air Transport

REPORT

f-es010324a

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 to the Convention on International Civil Aviation, with Directive 94/56/EC and with Civil Aviation Code (Book VII), *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.

S P E C I A L F O R E W O R D T O E N G L I S H E D I T I O N

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.

Table of contents

Glossary

AFIS	Aerodrome Flight Information Service
CEMPN	Aircrew Examination Medical Centre (Centre d'Expertise Médicale du Personnel Navigant)
CG	Center of Gravity
CMAC	Civil Aeronautical Medical Council (Conseil Médical de l'Aéronautique Civile)
CRM	Cockpit Resource Management
CVR	Cockpit Voice Recorder
DGAC	Directorate General of Civil Aviation (Direction Générale de l'Aviation Civile)
FDR	Flight Data Recorder
FLP	Full Low Pitch (propeller)
ft	feet
GPWS	Ground Proximity Warning System
hPa	hectoPascal
JAA	Joint Aviation Authorities
kt	knot
LDA	Landing Distance Available
MHz	MegaHertz
NM	Nautical Mile
OPS 1	Operational regulations for public transport
PF	Pilot Flying
PNF	Pilot Not Flying
Psi	Pounds per square inch
QNH	Altimeter setting to obtain aerodrome elevation when on the ground
RPM	Revolutions Per Minute
Shp	Shaft Horsepower
TRTO	Type Rating Training Organisation
VFR	Visual Flight Rules

SYNOPSIS

Date and time

Saturday 24 March 2001 at 20 h 28[1]

Aircraft

De Havilland DHC-6-300
registered F-OGES

Site of accident

Saint-Barthélemy (971), Vicinity of Public

Owner

Air Vendée Investissements SA

Type of flight

Public transport of passengers
Scheduled flight TX 1501
Saint-Martin to Saint-Barthélemy

Operator

Caraïbes Air Transport

Persons on board

2 pilots
17 passengers

Summary

Flight TX 1501 from the island of Saint-Martin was on final approach to runway 10 at Saint-Barthélemy aerodrome. Just before the La Tourmente pass, the aircraft took a sharp turn to the left and dived towards the ground. It crashed near a house and caught fire.

Consequences

	Killed	Injured	Uninjured	Equipment
Crew	2	-	-	Destroyed
Passengers	17	-	-	
Third parties	1	-	-	

A house was destroyed.

[1] Except where otherwise noted, the times shown in this report are expressed in Universal Time Coordinated (UTC). Four hours should be subtracted to obtain the time on the island of Saint-Barthélemy or one hour added to obtain the time in metropolitan France.

ORGANISATION OF THE INVESTIGATION

The BEA was informed of the accident on 24 March 2001 at around 22 h 00, Paris time. Two field investigators were nominated. On 25 March, four investigators went to Pointe-à-Pitre. On their arrival, they met local officials from the civil aviation authority and those responsible for the judicial inquiry. They also contacted the crisis group set up on the premises of Pointe-à-Pitre airport as well as officials from Air Caraïbes. The following day, they went to the accident site, on the island of Saint-Barthélemy, in coordination with those responsible for the judicial inquiry.

In accordance with international agreements, the aircraft being of Canadian manufacture, the BEA invited their Canadian counterpart, the Transportation Safety Board (TSB), to participate in the investigation by nominating an Accredited Representative. The latter joined the Investigator-in-Charge on Tuesday 27 March, accompanied by two technical advisers from the manufacturers, De Havilland Bombardier and Pratt & Whitney Canada. Subsequently, a correspondent of the National Transportation Safety Board was attached to the investigation, with a technical adviser from the propeller manufacturer, Hartzell.

During the first phase, the following work was carried out on the spot:

- examination of the site and the wreckage;
- determination of the final track;
- collecting testimony on Saint-Barthélemy and at the departure aerodrome;
- gathering available information relating to the aircraft and its operation, the crew, the meteorology as well as ATC;
- sampling and recovery of certain significant items in the wreckage, previously placed under judicial seal, with a view to future examinations.

On 6 August 2001, a preliminary report detailing progress in the investigation was published. At that time, a safety recommendation was issued.

During the investigation, the following work was performed:

- technical examinations and analyses of elements sampled;
- study and analysis of testimony collected;
- analysis of the film contained in a video camera found in the debris;
- audio and video recordings of several sequences on the ground and in flight on board an aircraft of the same type in the area of the accident and in metropolitan France;
- study on human factors.

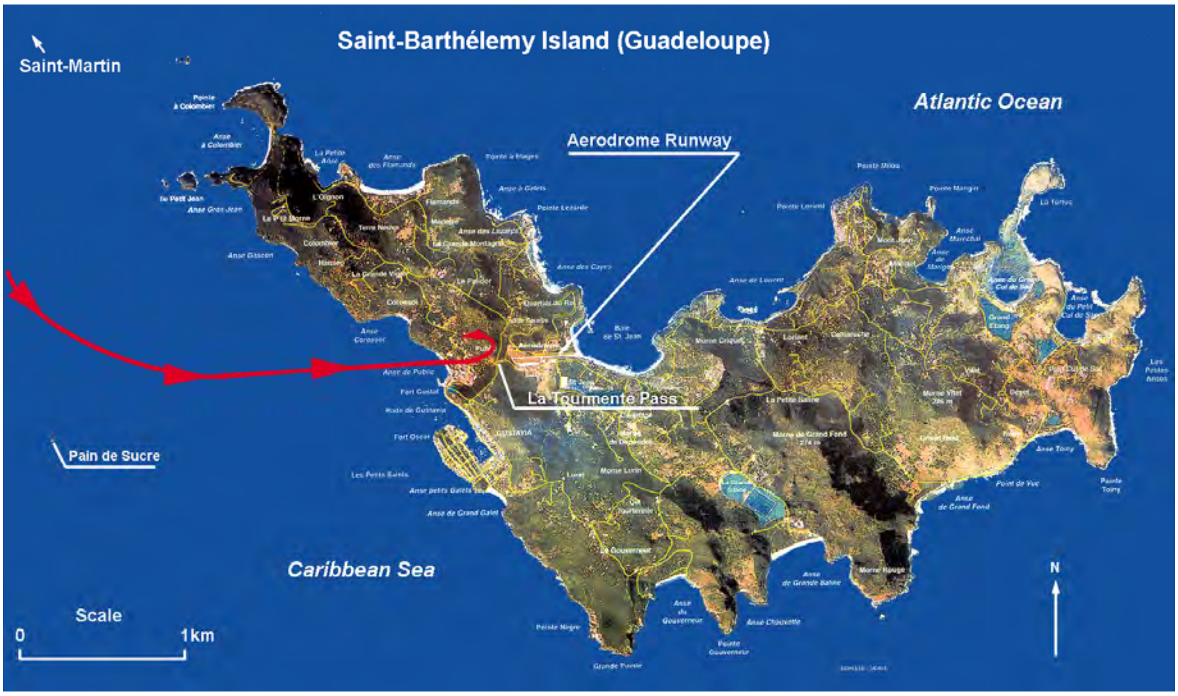
1 - FACTUAL INFORMATION

1.1 History of the flight

On Saturday 24 March 2001, the DHC-6-300 registered F-OGES was carrying out the scheduled service TX 1501 under a VFR flight plan between the island of Saint-Martin and the island of Saint-Barthélemy, nineteen nautical miles away. The aircraft was operated by Caraïbes Air Transport, on behalf of Air Caraïbes which undertakes commercial operations on the route. The Captain was pilot flying.

Cruise was performed at about 1,500 feet. The crew left the Saint-Martin Juliana aerodrome frequency when abeam of the island of Fourchue, the entry point of the aerodrome circuit located three nautical miles north-west of the island of Saint-Barthélemy. A few seconds later, they announced, on the Saint-Barthélemy Information frequency, that they were passing the "Fourchue" reporting point. Shortly afterwards, they announced passing the "Pain de Sucre" reporting point for a final approach to runway 10. That was their last communication.

When the aircraft began its short final before the La Tourmente pass, several people, including the AFIS agent, saw it turn left with a steep bank angle then dive towards the ground. It crashed near a house and caught fire. All of the occupants perished, along with one person who was in the house.



1.2 Injuries to persons

Injuries	Crew members	Passengers	Other persons
Fatal	2	17	1 (*)
Serious	-	-	-
Slight/none	-	-	-

(*) This person perished in the fire which broke out following the accident.

1.3 Damage to aircraft

The airplane was destroyed.

1.4 Other damage

The fire spread over three hundred square metres of land. It destroyed the vegetation and part of a dwelling.

1.5 Personnel information

1.5.1 Flight crew

1.5.1.1 Captain

Male, aged 38.

Aeronautical qualifications

- Commercial Pilot's License issued on 18 June 1987, valid until 30 November 2001.
- Instrument rating obtained on 3 November 1987, valid until 1 June 2001.
- Site rating to land at Saint Barthélemy obtained in June 1991.
- DHC-6 type rating obtained on 28 November 1988, revalidated on 17 November 2000, valid until 30 November 2001.
- Other type ratings: Dornier 228 and ATR 42.
- CRM refresher training course in April and June 2000.
- Last base check on 10 November 2000 on DHC-6.
- Last medical check, valid for one year, issued without restrictions by the Antilles-Guyane regional medical centre (CEMPN) on 10 May 2000.

Note: on 19 May 1994, this pilot received a notification from the civil aviation medical council (CMAC) allowing him a waiver with the following limitations:
- mandatory presence of a second pilot rated on the aircraft type;
- bi-annual check by the Pointe-à-Pitre medical commission;
- medical record to be re-submitted one year later.

Professional experience

- Experience: 9,864 flying hours of which 6,400 as Captain.
- Experience on DHC-6: around 5,000 flying hours of which 3,000 as Captain.

Aeronautical activity before the accident flight

- 179 flying hours in the previous ninety days, of which 169 on Dornier 228 and 10 on DHC-6.
- 57 flying hours in the previous thirty days, of which 47 on Dornier 228 and 10 on DHC-6. During this period, eighteen landings at Saint-Barthélemy, of which five on Dornier 228 and thirteen on DHC-6.
- On 22 and 23 March, eighteen flights on F-OGES between Saint-Martin and Saint-Barthélemy, including nine landings at Saint-Barthélemy.
- On the day of the accident, eight flights on F-OGES between Saint-Martin and Saint-Barthélemy, including four landings at Saint-Barthélemy.

Note: the ten hours on DHC-6 were all performed as Captain on F-OGES from 22 March onwards. The interruption in flights on DHC-6 lasted one hundred and twenty-four days. There is no mention, in the Captain's flight log, of any line flight performed under an instructor's supervision before the resumption of his flights.

The Captain had a full-time unlimited-duration contract. His contract limited the number of daily legs to be performed to ten. Having been a pilot for Air Guadeloupe, subsequently Air Caraïbes, since 1987, he had been transferred to Caraïbes Air Transport in July 2000 through an inter-group transfer.

1.5.1.2 Co-pilot

Male, aged 38.

Aeronautical qualifications

- Professional Pilot's License issued on 11 March 1999, valid until 31 December 2001.
- Multi-engine instrument rating issued on 9 September 1999, valid until 24 March 2001.
- DHC-6 type rating issued on 21 December 2000, valid until 31 December 2001.
- Flight engineer's License n°306196, not valid since 31 December 2000.
- Line flying under supervision performed the week before the accident. At that time, several take-offs and landings at Saint-Barthélemy were performed by his instructor.
- Last medical certificate, valid one year, issued without limitations by the Antilles-Guyane regional medical centre on 5 December 2000.

Professional experience

- 670 flying hours as a pilot of which 15 on DHC-6.
- about 4,000 flying hours as flight engineer on Transall for the French Air Force and on Boeing 727 in civil aviation.

Aeronautical activity before the accident flight

- 20 flying hours in the previous ninety days, of which 15 on DHC-6.
- 12 flying hours in the previous thirty days, all on DHC-6.
- On 22 and 23 March, eighteen flights on F-OGES between Saint-Martin and Saint-Barthélemy, including nine landings at Saint-Barthélemy as PNF.
- On the day of the accident, eight flights on F-OGES between Saint-Martin and Saint-Barthélemy, including four landings at Saint-Barthélemy.

The co-pilot was employed by Caraïbes Air Transport on a short-term full-time contract which was due to expire on 31 March 2001, when he was supposed to join another operator as a flight engineer.

1.5.2 Ground personnel

1.5.2.1 AFIS agent

Male, aged 29.

- Communal agent, employed by the commune of Saint-Barthélemy with a long-term appointment to the Guadeloupe aeronautical district.
- First provisional AFIS qualification in December 1991 (training course undertaken in April).
- Status of aerodrome supervisor obtained in December 1992.
- Provisional AFIS qualification valid until 30 March 2001 after the annual recurrent training course.

1.6 Aircraft information

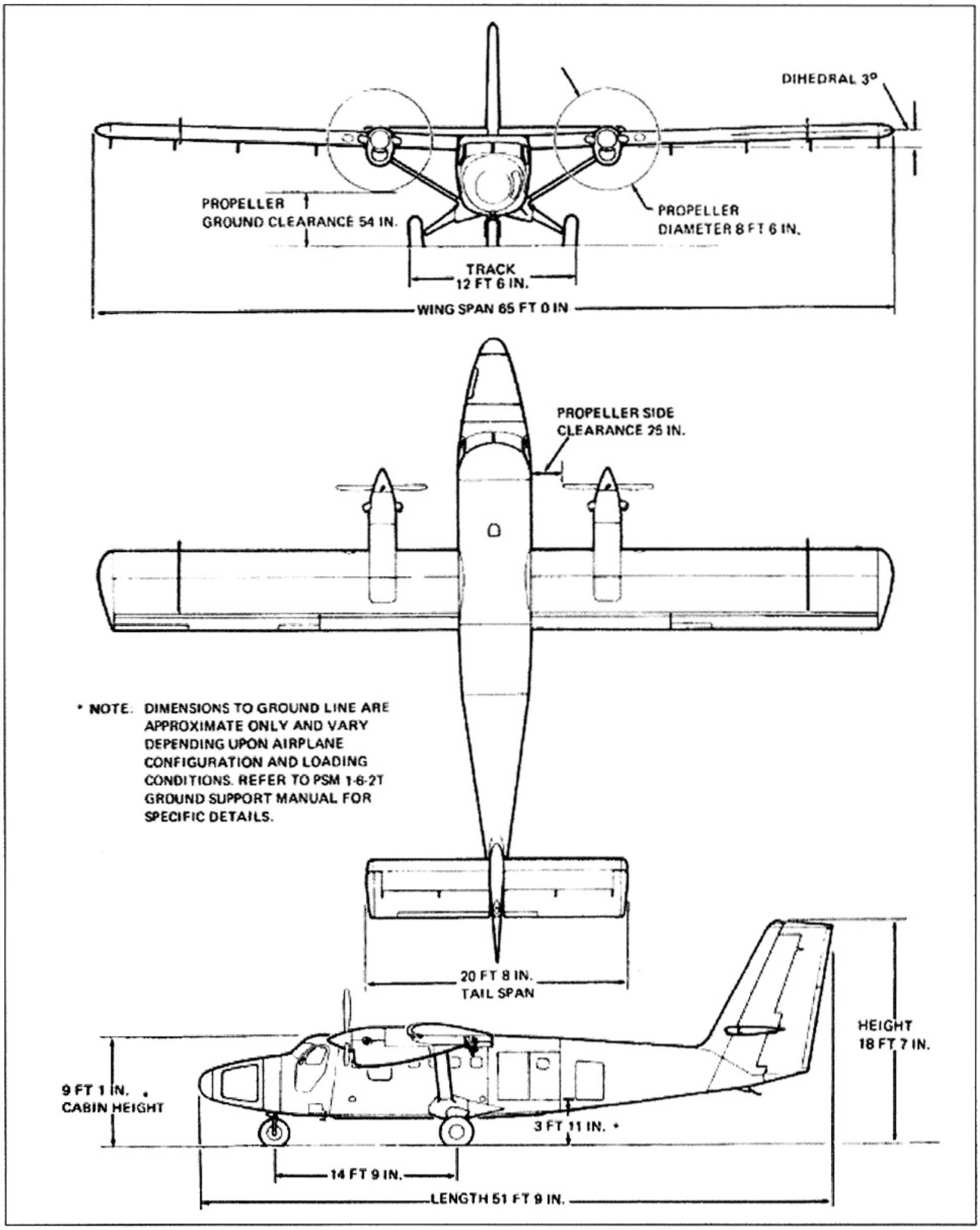
Equipped with two turboprops, the DHC-6-300 is a high wing aircraft. With a certificated maximum take-off weight of 5,670 kg, it can carry twenty passengers. Certificated to be flown by a single pilot, it is operated on public transport flights by a crew consisting of a captain and a co-pilot.

The DHC-6-300 is equipped with two cargo holds, the forward one having a maximum capacity of 106 kg and the rear divided into compartments with a maximum capacity of 226 kg.

1.6.1 Airframe

- Manufacturer: DE HAVILLAND AIRCRAFT of Canada.
- Type: DE HAVILLAND DHC-6 "Twin Otter".
- Model: DHC-6-300.
- Serial number: 254.
- Year of manufacture: 1969.
- Entry into service: 7 October 1970.
- Certificate of airworthiness valid until 2 October 2003.
- Utilization as of 24 March 2001: 35,680 hours and 89,331 cycles.
- Entry into service with Air Caraïbes on 16 October 2001.

F-OGES was equipped with two blue warning lights for operation of the propellers into reverse beta mode and a stall warning.



Three views of DHC-6-300 Twin Otter

1.6.2 Powerplant

- Manufacturer: PRATT & WHITNEY Canada.
- Type: Free-turbine.
- Model: PT6A-27.
- Power: 620 shp.

	Left	Right
Serial number	PCE40195	PCE41630
Total time	35,027 hours	21,852 hours
Time since general overhaul	2,711 hours	1,793 hours

1.6.3 Propellers

- Manufacturer: HARTZELL PROPELLER INC.
- Model: HC-B3TN-3/T 10282, three-blade.

	Left	Right
Serial number	BUA23158	BUA23159
Time since general overhaul	104 hours	104 hours

F-OGES was not equipped with the optional propeller synchronization system.

1.6.4 Weight and balance

The first table lists the data entered on the weight and balance sheet established by an agent of the assisting airline and signed by the Captain (see appendix 1). This sheet takes into account eighteen passengers, although there were only seventeen of them, a base index of 100 for the balance and an aircraft basic weight of 3,299 kg instead of 3,440 kg.

	Take-off	Landing	Take-off CG	Landing CG
Basic weight (kg)	3,299	3,299		
Baggage (kg)	200	200		
Fuel (kg)	550	500		
Passengers (kg)	1,550	1,550		
Total	5,599	5,549	32%	33.2%

The second table, established by the investigators using the operations manual, takes into account the basic weight of the aircraft in accordance with the operations manual weight sheet and the weight of the seventeen passengers checked in for embarkation[(2)]. The balance figures also take account of a base figure of 103.89 established the last time the aircraft was weighed and a standard distribution of the passengers, their exact distribution in the aircraft being unknown.

[2] Nine men at a fixed average weight of 92 kg and eight women at a fixed average weight of 74 kg.

	Take-off	Landing	Take-off CG	Landing CG
Basic weight (kg)	3,440	3,440		
Baggage (kg)	200	200		
Fuel (kg)	550	500		
Passengers (kg)	1,420	1,420		
Total	5,610	5,560	31.6%	31.8%
Limits set by the manufacturer	5,670	5,580	Forward 25% Aft 36%	Forward 25% Aft 36%

Comparison of the two tables shows negligible differences. For flight TX 1501, F-OGES was within the weight and balance limits set by the manufacturer.

1.6.5 Maintenance

The aircraft was maintained by Caraïbes Air Transport according to an approved maintenance program. The maintenance was of a fixed-schedule type, covering a cycle of forty-eight inspections over six thousand flying hours. This cycle allows the whole aircraft to be examined.

This maintenance schedule is defined for an average aircraft use of 1,200 flying hours per year. It also includes a corrosion-prevention program as well as a fatigue-prevention program.

F-OGES was grounded from 15 January to 28 February 2001 in order to carry out the installation of a Ground Proximity Warning System (GPWS). Advantage was taken of this period in order to align the power levers and fix a fuel leak on the left engine.

There were no deferred defects for the flight on the day of the accident. The technical log mentioned a problem for the previous five days with the operation of the aft cargo hold door; a repair had been carried out the day of the accident, before take-off from Saint-Martin.

1.7 Meteorological information

1.7.1 General situation

The island of Saint-Barthélemy was subject to a flow of dry light to moderate winds, fairly distant from the edge of a very cloudy and rainy area which stretched over the Dominican Republic, the north of Puerto-Rico and over the Virgin Islands.

On the islands of Saint-Martin and Saint-Barthélemy, the sky was slightly cloudy with relatively undeveloped cumulus which were not accompanied by rain.

1.7.2 Situation at the aerodrome

A 20 h 00, the wind was 110° / 6 kt on the Saint-Barthélemy aerodrome with gusts to 14 kt, visibility was over 25 km, the slightly cloudy cumulus not bringing any rain. The QNH was 1,013 hPa, the temperature 28°C.

Between 20 h 25 and 20 h 28, the wind dropped to two knots and shifted to the north-east, probably due to the passage of some cumulus near the aerodrome, and then it strengthened towards 20 h 30, the wind rising to 100°/10 kt with gusts to 17 kt.

Appendix 2 contains the regional weather documents, including a TEMSI chart (significant forecast weather chart) and three charts of winds forecast at 850/700/500 hPa. These documents had been given to Air Caraïbes agents by the meteorological centre at Raizet and had been passed on to the crew at the beginning of the afternoon.

Crews encountered during the investigation who had landed before F-OGES had not noticed any particular phenomena.

1.8 Aids to navigation

The Saint-Barthélemy aerodrome has no radio-navigation aids. There are no radar recordings of the flight.

1.9 Communications

1.9.1 Radio communications with Saint-Martin Juliana aerodrome

Transcript of radio communications made with flight TX 1501.

20:07:59	
AC	Juliana FWI ehh 1601 is ready to taxi
TWR	FWI 1501 you're a Twin Otter
AC	Yes Twin Otter
TWR	How much runway do you need?
AC	Bravo
TWR	OK Bravo Bravo Bravo Bravo Roger taxi enter and ahhh backtrack runway niner and ahhh if you have to use the 1601 taxi backtrack runway 9 and ahhh be ready
AC	(Unclear)
20:10:08	
TWR	Break FWI 1601 at Bravo runway niner cleared for takeoff wind check 120 at 8
AC	Roger clear 1501
TWR	Affirmative
20:10:45	
TWR	FWI 1601 report the circuit St Barth
AC	Will do
20:18:06	
AC	FWI 1601 abeam Fajou
TWR	1601 118 45 look out for traffic in the circuit
AC	(Unclear)

Note: flight TX 1501 was scheduled for 19 h 00 and flight TX 1601 for 20 h 00. This may explain the confusion in the operational call sign which occurred on several occasions. It should also be noted that the crew erroneously used the name Fajou (a reporting point on the Pointe-à-Pitre aerodrome circuit) instead of the Fourchue reporting point. These confusions had no bearing on the accident.

1.9.2 Radio communications with Saint-Barthélemy aerodrome

The co-pilot contacted the AFIS agent on duty in the Saint-Barthélemy control tower but these communications were not recorded due to the unavailability of the recording equipment and, on board, to the lack of a CVR.

1.10 Aerodrome information

Saint-Barthélemy aerodrome was inaugurated on 20 February 1961. In accordance with the State / Department convention signed on 17 April 1998, the aerodrome is officially managed by the Guadeloupe General Council. This management is delegated to the commune of Saint-Barthélemy.

The aerodrome is located 800 metres north-east of Gustavia, the main town on the island. Concrete runway 10/28 is six hundred and forty metres long and fifteen metres wide with a 2% down slope towards the sea; runway 10's threshold is at an altitude of forty-nine feet and the threshold of runway 28 at an altitude of seven feet. The landing distance available (LDA) on runway 10 is five hundred and fifteen metres.

The aerodrome is classified as category D and authorized for restricted use (list 3) by the regulation of 21 July 1972. This regulation specifies that the aerodrome is reserved for aircraft with appropriate characteristics and performance and to pilots whose competence has been recognized by an accredited flight instructor.

The list of pilots authorized to use the aerodrome privately is kept up to date by the Guadeloupe aeronautical district. The district recommends that pilots who have not landed there at least once in the year be checked by an accredited flight instructor.

The airlines operating at the aerodrome are responsible for the authorization of their pilots. For Caraïbes Air Transport, any pilot who has not performed at least two landings in the previous twelve months must be checked by an accredited flight instructor.

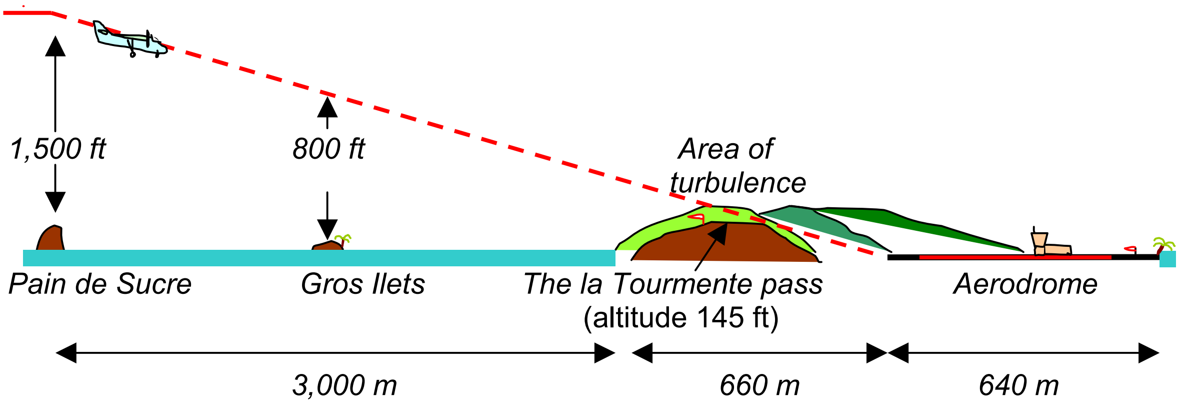
The aerodrome is prohibited to aircraft not equipped with a radio. It is also prohibited at night. The use of the English language is mandatory in the aerodrome circuit when there is a non-francophone pilot in the circuit.

The Rescue and Fire Fighting Service available is of a higher level than that of the regulatory requirements; it corresponds to category 3, against a requirement of category 2.

Since 15 November 1991 the aerodrome has had an aerodrome flight information service (AFIS) responsible for transmitting information on aerodrome traffic and runway availability. This service is provided between 11 h 00 and sunset plus fifteen minutes by a team of four people: one accredited agent from the department and three accredited agents from the commune. The radio frequency allocated to it is on 118.45 MHz.

Given the topography, the AFIS agent cannot see aircraft from his observation post until they are on final for runway 10, just before passing over the La Tourmente pass.

Aircraft landing on runway 10 fly over the La Tourmente pass at a very low height (less than ten metres). This area is subject to strong turbulence. A wind-sock, installed on the north side of the pass, indicates the direction and the strength of the wind going over the pass. These indications are not relayed to the tower.



Line drawing, not to scale, of the 12% approach gradient to the aerodrome

The beach covers the forty metres which separate the threshold of runway 28 from the sea. In accordance with the applicable communal regulations, signs indicate in French and English that the area is dangerous and that it is prohibited to remain there.

1.10.1 Statistics

The total number of passengers (including revenue and non-revenue passengers) changed from about 189,000 in 1996 to 191,300 in 2000 and 166,250 in 2001, with two peaks of 200,000 in 1997 and 1998. The total number of aircraft movements, which was at around 38,000 in 1996, has fallen regularly since then. There were 33,760 in 2000 and 30,000 in 2001. This fall can be partially explained by better organisation of commercial flights, which represent around four-fifths of movements and, for 2001, by the international situation.

The maximum daily number is 252 movements with a daily peak of 36 per hour. Air Caraïbes performs more than half of the daily movements while the Dutch operator Winair performs 41%.

In the ten-year period preceding the accident, no public transport accidents were notified to the BEA. In general aviation, fifteen accidents (one fatal accident on 3 March 1997), including eleven runway overruns on QFU 10 occurred over the same period.

1.10.2 Landing procedure on runway 10

The specific topography of the area with, in particular, a ridge line west of the aerodrome, led the authorities to restrict the use of runway 28:

- Landings prohibited to public transport aircraft.
- Take-offs and go-arounds on short final prohibited to all categories of aircraft.

The majority of landings are thus performed on runway 10 (see appendix 5): after the final turn near the Pain de Sucre, the last mandatory reporting point, the track leads aircraft north abeam “Les Ilets” for a subsequent fly-over of the La Tourmente pass at a very low height, often lower than ten metres.

The Caraïbes Air Transport operations manual specifies that any approach considered off track or outside of the usual descent slope must result in go-around on the extended centerline.

1.11 Flight recorders

Since the certificate of airworthiness of F-OGES pre-dated 31 December 1974 and its maximum take-off weight was less than 5,700 kg, the regulation of 12 May 1997 concerning technical conditions for aircraft by a public air transport operator did not require that it be equipped with flight recorders (CVR and/or FDR). Consequently, the aircraft was not equipped with such recorders.

1.12 Wreckage and impact information

1.12.1 Impact

The accident occurred north-west of the aerodrome, on the west slope of the La Tourmente pass, at around six hundred metres from the threshold of runway 10.

The aircraft struck the ground right next to a dwelling located along the Corossol road, on a steep, hard piece of land planted with trees and bushes. The wreckage was spread over an area of around nine hundred square metres.

Aerial view of the site and the aerodrome

The cuts made into the vegetation by the wings showed that the aircraft struck the ground with a nose-down attitude of around 60° and a left bank angle. The propellers left marks on the vegetation and in the ground characteristic of rotation on impact.

1.12.2 Wreckage

The main wreckage was grouped together. The fuselage, collected in an area of about five metres in diameter, was completely destroyed by the impact and the fire.

On either side, and in immediate proximity to the area of fire, the main wreckage found was the aircraft's two wings and tail assembly. Not much affected by the fire, they were separated from the fuselage and exhibited significant compression deformations. There were no traces of a bird strike. The rupture marks on the flaps show a symmetrical extension of 37.5% on impact.

No signs of anomalies in relation to the integrity of the controls and mechanical linkages were found.

The engines, separated from their nacelles, were severely damaged. The left engine was near the left wing and outside of the area of fire while the right engine was partially affected by the fire. A visual examination showed that they were delivering significant power on impact. The buckling of the propellers (significant twisting and bending) confirms the indication of thrust and its symmetry. There were no traces of a bird strike.

The engine instrument panel was severely damaged by the impact and the fire. The only usable indications related to the two gas generator indicators and the left propeller RPM indicator, blocked in the maximum position above 100%.

The engine control lever assembly was found buried in the ground. It was in very bad condition. The cargo hold door was found under the wreckage, still attached to the structure by its hinges.

Given the condition of the wreckage, no fuel or lubricant samples could be taken.

Two video cameras were found at the site.

1.13 Medical and pathological information

The autopsies revealed no medical and pathological elements having any bearing on the accident.

1.14 Fire

The aircraft caught fire immediately after the collision with the ground. Fuel was projected onto the house neighboring the site, which also caught fire.

The fire was controlled within twenty minutes of the accident by the Saint-Barthélemy fire service, despite the difficulties in accessing the site via the only road, which was very steep.

1.15 Survival aspects

The fire service teams found all of the occupants of the aircraft grouped together at the front of the wreckage in an area estimated at twenty square metres. Those seat belts which were found in the ashes were fastened.

The violence of the impact gave no chance of survival.

1.16 Tests and research

1.16.1 Examination of powerplant

In the context of the investigation, the various components of the powerplant were subject to workshop examinations at the Centre d'Essai des Propulseurs (Saclay – France).

1.16.1.1 Engines

The examinations carried out on the engines led to the following conclusions:

- Both turboprops were operating and producing significant power at the time of impact.

- Their inner components showed no signs of any damage prior to the accident which might have adversely affected their normal operation in flight.

1.16.1.2 Propellers

The examinations carried out on the propellers were aimed at determining their pitch setting on impact. The examinations showed:

- That the left propeller had a pitch setting of at least 20.4°, that is to say a pitch superior to that of flight idle.

- That the right propeller had a different pitch setting for each of the blades, settings likely due to less violent secondary impacts on the powerplant at the moment of the accident. Consequently, the values noted were unusable.

As a result of the similarity in the deformations and ruptures at the blade tips, it was possible to establish the symmetrical operation of both propellers before the impact.

1.16.1.3 Power levers

The engine control lever assembly (power, propellers and fuel), severely deformed by a lateral impact and subsequently damaged by the fire, gave no indications which might allow the position or adjustment of the levers to be determined. Examination did, however, show that no pre-existing fault affected the system (friction, linkage, control cables).

1.16.1.4 Engine parameter indicators

The dials on the engine parameter indicators had no usable marks which might allow the values shown at the time of the accident to be determined.

1.16.1.5 Summary of examinations

The examinations performed confirmed the observations which had been made at the accident site. They gave no indication of abnormal positioning of the power levers or malfunction of the powerplant.

1.16.2 Playback of a film found in the wreckage

Of the two video cameras found at the site (see 1.12.2), one, too damaged by the impact and the fire, could not be played back. The other, less damaged, contained a usable recording, although the part which covered the recording heads as well as one part which had likely been recorded on was damaged by the fire.

After cleaning, playing of the usable part of the film made it possible:

- To establish that the images had been filmed through a left-side window and that the film, with titles, had been made a few minutes before the accident.

- To identify three sequences: the first during initial climb with a view of Saint-Martin aerodrome and housing during the right turn, the second during cruise with a view of the tip of the island of Saint-Martin, the third on approach to Saint-Barthélemy with a view of the northern tip of the island.

- To see the aircraft's left propeller turning during the three sequences.

- To establish that the end of the usable part of the film corresponds to the moment when the aircraft passes across the Pointe à Colombier and the island of Petit Jean, north-west of Saint-Barthélemy.

A more precise analysis was undertaken in order to determine:

- The position and the attitude of the aircraft.

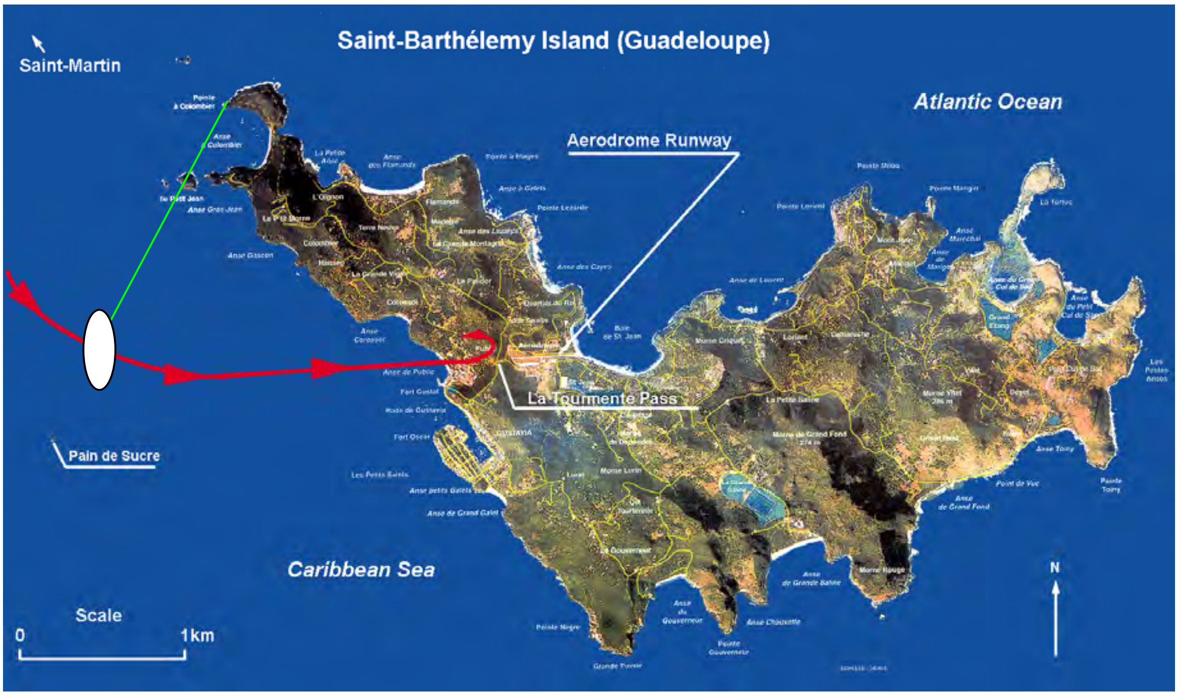
- Operation of the propellers and the engines.

1.16.2.1 Position and attitude of the aircraft

Playback of the film enabled F-OGES to be positioned on the trajectory which was leaning it to Saint-Barthélemy and to determine its attitude in relation to the horizon. This confirmed that the aircraft was flying at safety altitude.

1.16.2.1.1 Lateral position

One of the last images on the usable part of the film enabled F-OGES to be situated, by aligning the Pointe à Colombier and Petit Jean island on an aerial photo, on the last turn of the approach, across the Pain de Sucre. Taking into account the distance from the La Tourmente pass (1.3 NM), there remained about one minute of flight before the accident.



Orientation of the last image on the film

F-OGES estimated lateral position

Estimated path

1.16.2.1.2 Aircraft attitude

After this image, the camera continues to record for a few seconds, up to an image where the horizon with veiled cloud is seen through one of the windows on the right side, showing that F-OGES was in a zero-degree bank attitude.

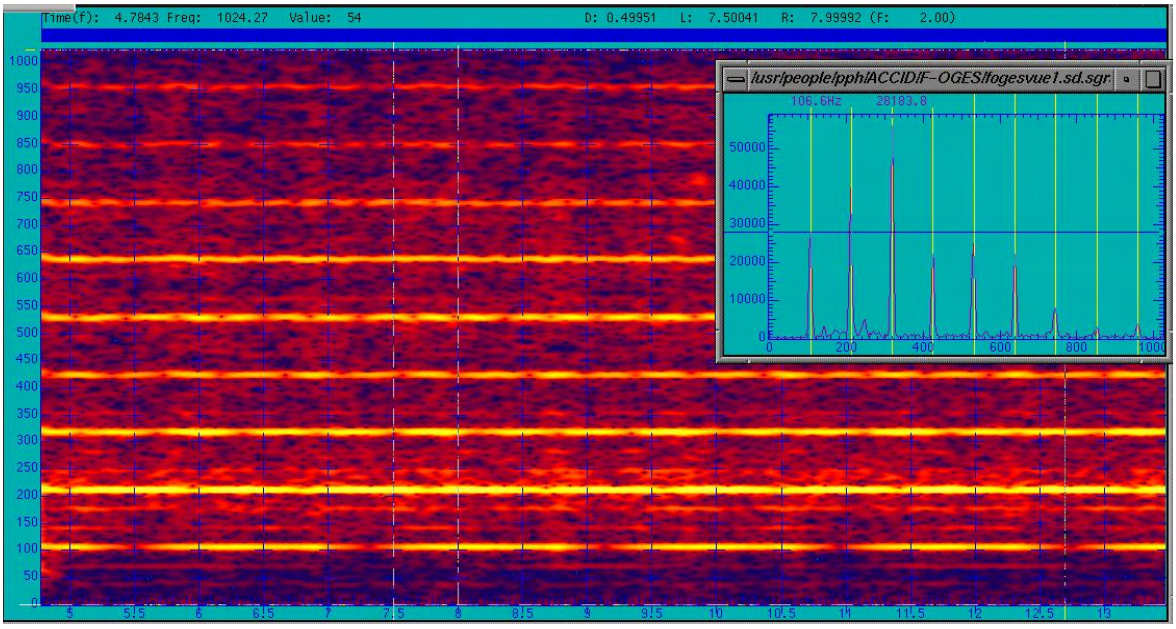
1.16.2.2 Operation of powerplant

The soundtrack of the film was analyzed in our laboratory to try to determine the precise operation of the propellers and engines during the flight.

The displacement of air generated by the rotating blades induces energy peaks with a frequency proportional to the propeller rotation speed. The frequency measured, divided by three (the number of blades) and multiplied by sixty, gives the propeller rotation speed in revolutions per minute.

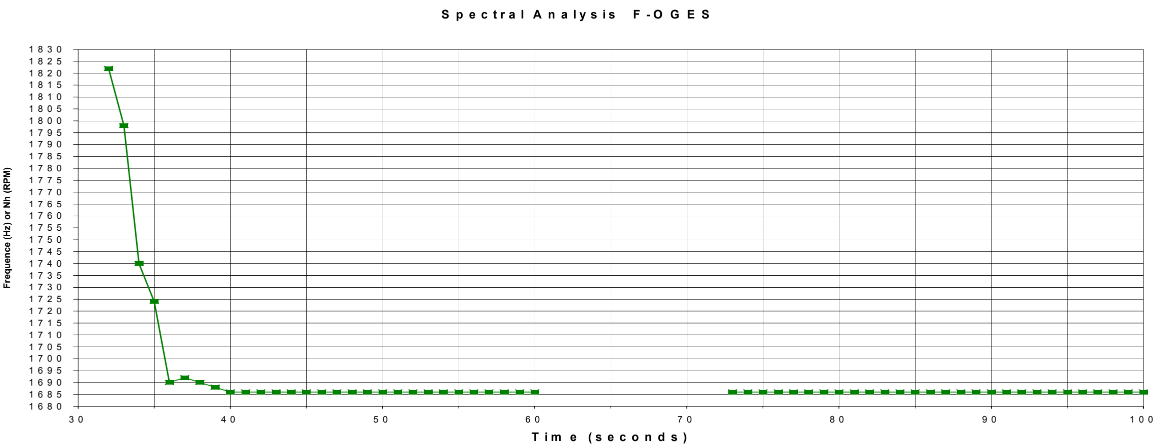
Spectral analysis of the flight sequences which were recorded (take-off, cruise and approach) revealed the following facts:

<u>Take-off</u>: the fundamental frequency measured on the soundtrack was 106 Hz with eight to ten visible harmonics. The propeller rotation speed deduced from this was 2,120 RPM (in this phase of flight the manufacturer specifies a rotation speed of around 2,110 RPM). The absence of a double peak shows that the propellers were turning at the same airspeed.



Spectral analysis of the soundtrack on take-off

Cruise: the sound signal indicates a slowing down of the propeller rotation speed from 1,825 to 1,690 RPM in five seconds, then stabilization at 1,685 RPM. This figure corresponds to the cruising speed specified by the manufacturer. Again, the absence of a double peak shows that the propellers were synchronized.



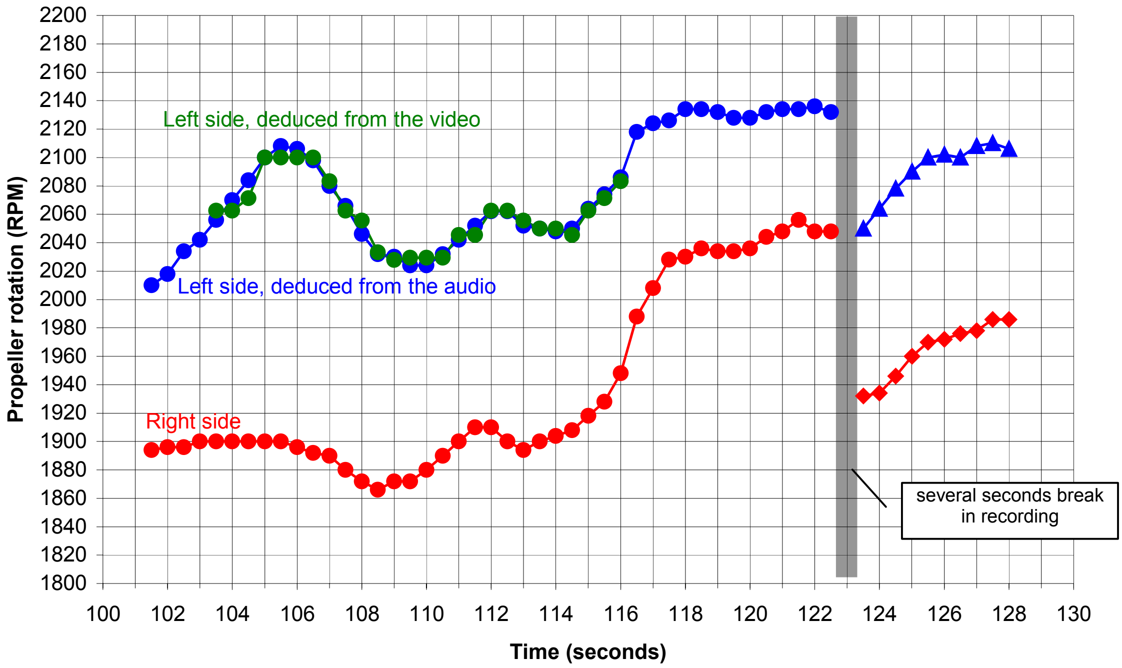
Propeller speed in cruise

Approach: the sound and visual data show significant fluctuations in the rotation speed of the propellers. They are no longer synchronized.

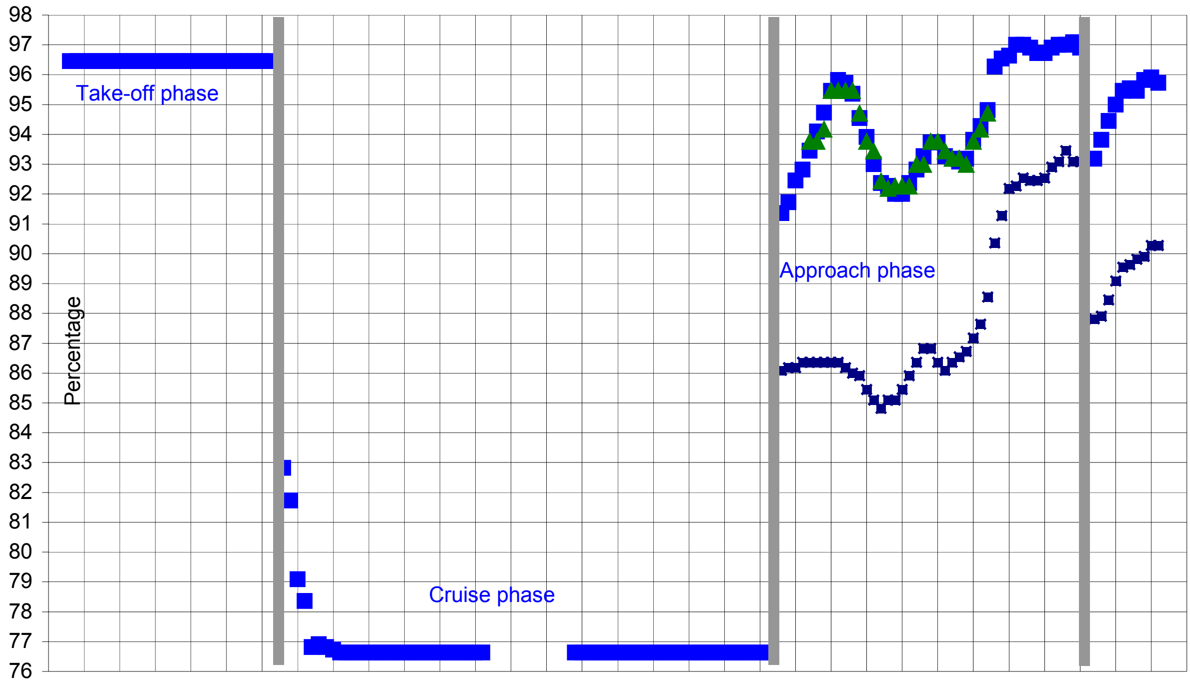
The spectral analysis of the soundtrack enabled the rotation speed of both propellers to be determined (red and blue curves on the following graph), without, however, allowing identification of which propeller corresponds to which curve.

Analysis of the video tape where the left propeller is visible enabled the green curve to be drawn: there are twenty-five images per second; it is possible to determine on each the position of the blades and thus the number of passages per second. Three photos taken from the film are presented below to illustrate the calculation.

Overlaying the green and blue curves shows that the latter corresponds to the left propeller.



The rotation speeds of the propellers during flight TX 1501, expressed as a percentage of the reference rotation speed as defined by the manufacturer, are represented on the following graph. The discontinuities between the points correspond to the ends of each recording.



The asymmetry between the two propellers during the approach phase was around 9%, which is consistent with normal use (see following). An increase in RPM of the order of 6% to 8% was also noted.

In conclusion, examination of the film found in the wreckage did not bring to light any malfunctions or anomalies for that part of the flight which was recorded.

1.16.3 Measurements on DHC-6

A series of measurements was undertaken, in the context of the investigation, on board an aircraft of the same type as F-OGES belonging to Winair airline. The investigators went to Saint-Martin and Saint-Barthélemy and carried out the following work:

- Filming with the same model of video camera as that found in the wreckage, from the left side second passenger row, during take-off, cruise and landing sequences, with the intention of estimating the track of F-OGES.
- Recording engine parameters during the same phases of flight in order to compare evolutions in propeller speed with those determined by the spectral analysis.
- Recording the position of the pilots' hands on the power controls during the flight, in both left and right seats. Since the controls were on the ceiling, the objective was to check how this configuration might influence the symmetry of the positions of the controls.

1.16.3.1 Observations on the flights

The observations made during the course of six commercial flights established the parameters normally used by flight crews, in terms of both the track and the conduct of the flight.

1.16.3.1.1 Aircraft track

With an easterly wind, which was the case on the day of the accident, the standard track for the Saint-Martin / Saint-Barthélemy leg is as follows:

- Take-off from runway 09 at Saint-Martin Juliana quickly followed by a right turn.
- Climb to cruise altitude, between one thousand and one thousand five hundred feet, following a direct route towards the Pain de Sucre islet (approximate heading 120°) via across the Fourchue islet. These two islets are mandatory reporting points: the position "across Fourchue" is a radio contact point with the AFIS, the position "overhead Pain de Sucre" is the beginning of the final approach to runway 10 on Saint-Barthélemy.
- Depending on the altitude selected, beginning of the descent before the Pain de Sucre, at the same time as the reduction in airspeed associated with the extension of the flaps to 10° then 20°.
- Overflight of the Pain de Sucre at around one thousand two hundred feet, followed by extension of the flaps to 37.5°, intercepting the approach path and associated start of descent.
- Before eight hundred feet, selection of propeller pitch to the full low pitch position.

1.16.3.1.2 Conduct of the flight

During the flights the following parameters were systematically used by Winair flight crews, and further investigation with several Caraïbes Air Transport crews confirmed that they also used these parameters.

For the take-off
- Torque pressure : 50 psi, i.e. maximum torque
- Propeller speed: 96% (FLP)

For the climb
- Torque pressure : 40 to 45 psi
- Propeller speed: 81%
- Indicated airspeed: 120 kt

For the cruise
- Torque pressure : 35 to 40 psi
- Propeller speed: 76%
- Indicated airspeed : 135 kt

For the landing
- Torque pressure : about 5 psi
- Propeller speed: about 80% (FLP)

For a normal descent, thrust does not generally exceed 80%. Selection of full low pitch is done between one thousand and eight hundred feet, with an indicated airspeed on short final of about 75 kt and flaps set at 37.5°.

Note: during the measurement flights, the asymmetry observed in propeller RPM reached a maximum of 8%.

1.16.3.1.3 Ergonomics of power levers

On the DHC-6-300, the power levers are located on the ceiling, slightly offset to the left.

When the PF is seated in the left position, his right forearm is located in the extended vertical axis of the levers, a position which is favorable to symmetric handling.

When the PF is seated in the right position, his left forearm is not vertical; he stretches slightly to the left and is thus not aligned with the axis of the levers, this “angle” being compensated by wrist movement.

During approaches to Saint-Martin Juliana, it was noted that certain pilots in the right position used short successive and separate movements on the engine n°1 lever, then on the engine n°2 lever, with the hand always remaining in contact with both levers.

1.16.3.2 Comparison with the film found in the wreckage

Watching the films made during the measurement flights enabled investigators to consolidate the data obtained from examination of the film found in the wreckage and to bring to light additional information.

1.16.3.2.1 Positioning of F-OGES

The images shot through the left passenger second row window confirmed that the film found in the wreckage was indeed shot from that position. Comparison of the films allowed investigators to:

- Confirm the last positioning of F-OGES, just after overhead the Pain de Sucre.
- Determine that F-OGES was then at a height of about one thousand to one thousand one hundred feet, which corresponds to the lower range of the usual altitudes, and that it had likely begun its descent.
- Determine on the last usable image that F-OGES was slightly right of the approach path.

1.16.3.2.2 Engine speed

Comparison of the engine parameters recorded during the flights and those determined for the accident flight showed that the engines of F-OGES were running normally from take-off up to the last image, recorded about a minute before the accident.

Towards the end of the film, the spectral analysis showed an increase in the propeller speed (see 1.16.2.2). This variation seems to correspond to the beginning of the descent towards the aerodrome, at the moment when the crew selected the propeller full low pitch position.

1.16.4 Orographic study of the Saint-Barthélemy approach path

In June 1984, the National Centre for Meteorological Research carried out a study of the approach path east of Saint-Barthélemy aerodrome. This study, performed as a hydraulic simulation, was intended to improve knowledge of the dynamic properties of the atmospheric flow of the lower layers in the vicinity of the La Tourmente pass with easterly winds in order to define the correct location for a wind measuring mast to make flight crews' work easier. In addition, the study gave details of improvements to flow which could result from partial flattening of the rocky outcrop located immediately to the south of the pass.

Only the conclusions with some relation to the average wind which was blowing on the day of the accident have been used in this report.

1.16.4.1 Effects of a wind from the 120° sector

The essential characteristic of a wind from the 120° sector is the channeling of the airflow by the high ground upwind, which leads to a relative regularity in the flows upwind of the pass. The high ground causes disturbances, more noticeable in this case to the south of the approach path. Consequently, the least disturbed approach line would be located slightly to the north of that planned and for the highest possible altitudes bearing in mind the thinness of the turbulent layer.

1.16.4.2 Effects of a partial flattening of the rocky outcrop

The possible modification of the high ground in the pass would have the general effect of an increased channeling of the flows and, consequently, greater homogeneity in the dynamic characteristics. This effect would, however, remain limited, both at altitude and downwind of the pass on the approach path.

For a wind from 100 to 120°, a significant reduction (from 5 to 7%) in the intensity of the turbulence can be measured over the first twenty metres at the top, more noticeably to the south than to the north of the approach path. The wind speed profiles over the first fifty metres are also more regular.

1.16.5 Principles of propeller control

The three-blade Hartzell propellers on the DHC-6-300 are reversible-pitch constant speed propellers.

In normal use for propulsion, propeller operation derives from the installed power from the gas generator through crew actions on the propeller levers. A hydraulic governor adjusts the pitch.

On approach or during ground maneuvering, as the reactivity of this mode of control is not satisfactory, there is a mode called "beta" in which the crew directly control the propeller pitch through the power levers. The gas generator governor ensures the required adjustments.

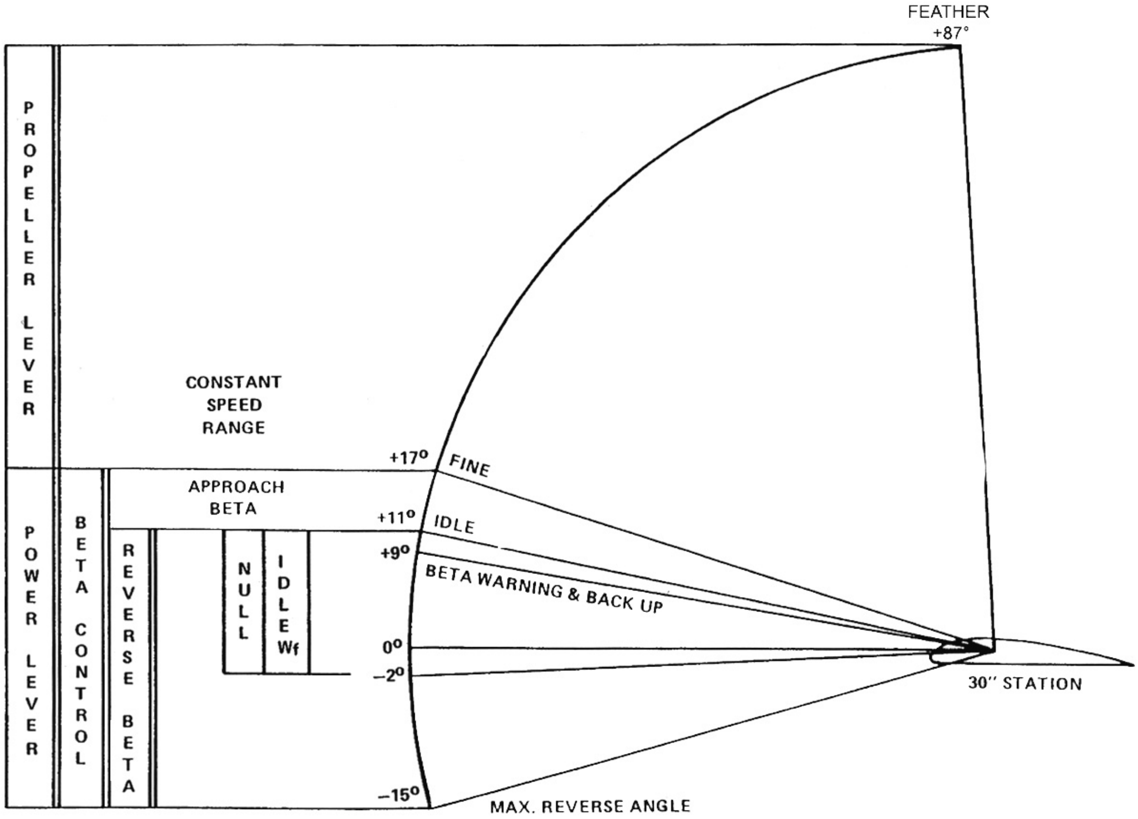
In this mode (see following drawing), the propeller pitch is between + 17° and - 15°, as follows:

- A range from + 17° to + 11°, called "approach beta" and permitted in flight. In this range, the propellers are tractive.

- A range from + 11° to - 15°, called "reverse beta" which is prohibited in flight. In this range, the propellers act as brakes, two different sub-ranges being identifiable: ground idle (9° to 0°) and traction reversal (0° to - 15°).

The manufacturer states that selection of reverse beta range in flight would immediately result in a significant loss in airspeed and lift, due to the high drag induced by the propeller settings. Thrust reversal would prevent the normal airstream flowing over the wings and tail and would likely lead the aircraft to stall.

Note: in the course of interviews undertaken, the investigators noticed a frequent confusion between "beta range" and "reverse beta range".



PROPELLER BLADE ANGLES

1.16.6 Preventing setting of reverse beta range in flight

The DHC-6-300 flight manual prohibits using the reverse beta range during flight (see appendix 3). Furthermore, a "Flight Safety Supplement", in which the manufacturer draws attention to the risks associated with selection of reverse beta range in flight, was circulated in October 1979. This document must be inserted in the flight manual and be known to all crew members (see appendix 4).

Finally, the manufacturer planned the following protective measures in the aircraft:

- A mechanical stop, installed on the power lever assembly, which stops the pilot from inadvertently passing[3] below flight idle (11°).

- A blue double repeating alarm (see appendix 8), which is optional, which indicates exceeding the stop position.

Note: if the propeller levers have not been placed in the full low pitch position in a symmetrical manner, a yellow warning light illuminates but passage into beta mode remains possible. This asymmetry would only have a notable effect in case of a go-around.

[3] In the opposite direction, towards increases in power, there is no stop. The course of the movement is continuous.

1.17 Organisational and management information

1.17.1 Caribéenne des Transports Aériens - Air Caraïbes

Caribéenne des Transports Aériens - Air Caraïbes resulted from the merger of Air Caraïbes SA, Air Guadeloupe, Air Martinique, Air Saint-Barthélemy and Air Saint-Martin. Its headquarters is at Les Abymes (Guadeloupe).

The operational specifications associated with its Air Operator Certificate were updated on 15 March 2001 for operations concerning transport of passengers of two EMB 145, three ATR 72, two ATR 42 and one Do 228. This certificate was valid on the day of the accident.

The airline holds TRTO approvals, issued by the DGAC, for Do 228, ATR 42/72 and EMB 135/145 type ratings.

Around four hundred people are employed by Caribéenne des Transports Aériens - Air Caraïbes, of whom forty-five are pilots and thirty-five cabin crew.

1.17.2 Caraïbes Air Transport

The headquarters of Caraïbes Air Transport is at Lamentin (Martinique); its Air Operator Certificate was issued on 2 June 1995. The associated operational specifications were updated on 16 October 2000 for operations concerning transport of passengers and freight for six Cessna 208B “Caravan”, eight Do 228 and one DHC-6-300 “Twin Otter” (F-OGES). This certificate was valid on the day of the accident.

1.18 Additional information

1.18.1 Training and checks undertaken by Air Caraïbes

The preparation for type rating on DHC-6 organized by Air Caraïbes in the context of its TRTO approval includes:

- Twenty-eight hours of theoretical training.
- Eight hours and twenty-five minutes of flying training, including twenty touch-and-go landings, fifteen take-offs and fifteen full-stop landings.

The type rating is issued following a ground check and a flight check. The program does not require a landing at Saint-Barthélemy. However, pilots destined to land at that aerodrome systematically receive specific previous training.

1.18.2 Witness statements

Many people who were in the area of the aerodrome, on the land and on the sea, were able to see and hear the aircraft before the accident. These people, including civil aviation professionals, described the positions and movements of F-OGES with enough precision to allow the final phase of the flight to be reconstituted.

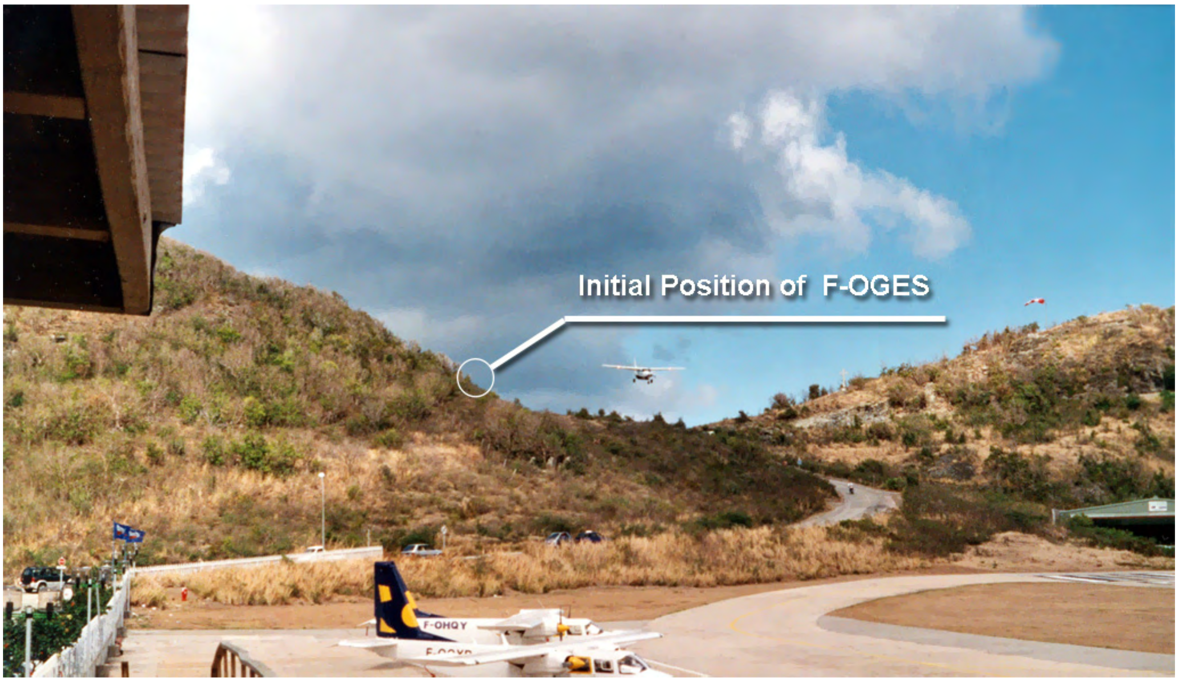
Thus, after an approach which appeared to the majority of them to be lower than those they usually saw, they all saw the aircraft with a nose-up attitude enter into a left turn then pitch down with a strong engine noise.

1.18.2.1 AFIS agent

The AFIS agent on duty in the tower stated that he had been contacted by the co-pilot by radio at 16 h 15 (local time) when F-OGES was passing across Fourchue. He provided the information required for the landing and asked the crew to contact him at about the Pain de Sucre. When he was contacted again, the AFIS agent gave them the latest wind and told them the runway was clear. The co-pilot acknowledged this. For the AFIS agent, everything appeared to be normal on board. A few moments later, when he looked towards the pass, the aircraft was on a left turn, belly visible, on a track lower than those usually followed by DHC-6's. He did not wait and immediately set in motion the emergency procedure.

The AFIS agent stated that the radio communications recorder in the tower had been out of order for about eighteen months.

With the assistance of the AFIS agent, the investigators were able to identify the initial position of F-OGES in the La Tourmente pass.



The photo shows an airplane belonging to another airline on passing the pass. The circle indicates the initial position of F-OGES during its turn to the left.

1.18.2.2 The Air Caraïbes supervisor

The Air Caraïbes supervisor at Saint-Barthélemy stated that the Captain had contacted him on the company frequency at about 16 h 15 (local time) and had told him that after the landing, he would himself open the cargo hold door which had been "fixed" before the take-off from Saint-Martin.

1.18.2.3 A flight instructor

A Caraïbes Air Transport flight instructor, with 1,500 flying hours experience on F-OGES, lives on the heights east of the Gustavia area, right of the approach track to runway 10. From his terrace, he can see aircraft between the Pain de Sucre and the La Tourmente pass. On the day of the accident, he saw F-OGES arriving on a track which seemed normal to him at the beginning but a bit low on short final compared to normal practice. For him, this track could be explained by downdraft winds which the aircraft can be subjected to at that place. He heard thrust being increased but at a much higher rate than for a simple correction, sufficient on approach. The aircraft then adopted a nose up attitude then turned slowly to the left before banking at about 60° to the left. The left wing then stalled and the aircraft dived towards the ground just before the La Tourmente pass.

This pilot reported being on the airfield in the company of other pilots from the airline. The Captain of F-OGES, who had joined them, said *that he had not found his feet for approaches and landings at Saint-Barthélemy*. The witness then told him how he proceeded, that is to say with an initial approach at one thousand five hundred feet then the descent keeping to the path until touchdown of the wheels, but the Captain indicated that he preferred to take a lower approach path.

1.18.2.4 The Manager of Caraïbes Air Transport

The manager of Caraïbes Air Transport is a flight instructor. He undertakes the type and site rating training. He knows the DHC-6 well and considers that in the flaps fully extended configuration, this aircraft requires a high level of anticipation. He thinks that certain pilots use the "beta range" during certain approach phases despite the manufacturer's ban.

The class rating revalidation flight that he undertook with the Captain on 17 November 2000 on DHC-6 was satisfactory. On section 6, Landing, he had commented "Why so late onto the Saintes centerline?". He explained this remark by the fact that the Captain, feeling comfortable on the aircraft, tended to approach in a U, that is to say in a turn, as opposed to a much higher and more distant lining-up with approach track. He stressed that the Captain had excellent handling skills and knew the DHC-6 perfectly.

He indicated that the Captain had had a break from flying the DHC-6 from 17 November 2000 to 22 March 2001. The day before the 22nd, the first day the pilot had carried passengers, he reminded him of the necessity of performing the three take-offs and landings imposed by the regulations in case of a break of more than ninety days. The Captain responded that he thought that the limit was one hundred and twenty days. He did not know if he had in fact performed these take-offs and landings.

An experienced pilot, the Captain was flight crew coordinator for the Point-à-Pitre base. As a person, the director found him to be vivacious, with a strong personality, highly skilled and always available.

After the last flight of the day, the Captain was supposed to ferry F-OGES to its operations base Saint-Martin Grand Case, where he was to participate in a football match.

The manager of Caraïbes Air Transport had qualified the co-pilot on DHC-6 the week before the accident. He considered that his flying was average, given his experience. He was aware of a disagreement between the Captain and the co-pilot on the morning of the accident during landing at Saint-Martin. He then asked the Captain, by telephone, to help his co-pilot rather than stressing him out.

The two pilots had never flown together before 22 March 2001.

1.18.2.5 A mechanic

On the morning of 24 March, a mechanic from the airline had gone to the island of Saint-Barthélemy on board F-OGES in the context of maintenance prior to return to service approval. He was seated in the right seat in the first row in the cabin. He found the landing to be quite hard and he noticed that the pilot had touched the nose wheel down immediately after the main gear, which is contrary to normal practice, which is that the aircraft be kept on the main gear during deceleration, which allows the nose wheel to touch down gently. During the stopover, he made a remark to the Captain in a jokey manner. The latter replied that he had not got back the “feeling” he had had at one time for the aircraft because he had only been flying it again for two days. He added that in the past he had used the “beta” on approach to slow down and that he was going to try that for the coming rotations. When the mechanic commented that passage into “beta range” was prohibited during flight, the Captain replied sharply that he was not going to teach him how to fly a Twin Otter.

1.18.2.6 The Air Caraïbes maintenance manager

The Air Caraïbes maintenance manager stated that, three weeks before the accident, an adjustment had been made to the power lever alignment at the request of the pilots. He added that the “beta range” was used by certain pilots to stick the aircraft to the ground after the flare and stated that the manufacturer prohibited passage into "beta range" in flight because of the risk of the propellers passing into "reverse beta" mode. In addition, in case of a go-around, the engine response times not being identical, there was a risk of a lateral excursion.

The mechanic in charge of maintaining F-OGES reported the conversation to him which he had had with the Captain on the morning of the accident flight, when the latter had told him that he was going to use the "beta range" for the following flights.

1.18.2.7 Inhabitants

A half-dozen people living in the area west of the La Tourmente pass saw the aircraft, lower than those they usually saw in that part of the approach. Practically all of them heard a loud engine noise (which is what drew them to look) and saw the aircraft with its “nose up” go into a left turn, bank sharply on the left wing then dive towards the ground.

One person whose home is to the right of the approach centerline when aircraft land towards the east described the same facts with one extra detail: the aircraft was too far to the right of the arrival line compared to aircraft which he usually saw approaching.

A sailor who was working on a boat in the Gustavia harbour observed the aircraft with a pair of binoculars and noticed that it was turning back on the left. The aircraft then banked sharply on the left wing, dived and crashed. There was immediately an explosion and a fire.

1.18.2.8 A Captain

A Caraïbes Air Transport DHC-6 Captain stated that one of the problems of the DHC-6 was the fact that, to follow steep approach paths like that of Saint-Barthélemy, pilots quickly find themselves with the control column fully forward, even when the power is fully reduced. The problem is even more critical when the aircraft CG is to the aft. This is one of the reasons why some pilots use the "beta range" during the approach. In this case, it is possible to pass under the path with a low airspeed. If the power levers are mistakenly pulled beyond the "beta range", the propellers pass into "reverse" mode in a more or less symmetrical way. It is then necessary to increase power and a possible propeller unfeathering asymmetry can end up in a loss of control. Pilots avoid being in "full idle" so as to keep some extra power in case of a go-around. He added that another difficulty on this aircraft was the low V_{fe} (maximum flap extended airspeed). This requires reducing airspeed a lot before being able to extend the flaps and there is a great temptation to select the "beta range" to be able to achieve this.

1.18.2.9 A retired pilot

A retired Caraïbes Air Transport pilot, with about 10,000 flying hours on Twin Otter, stated that pilots, including him, sometimes used the "beta range" to maintain airspeed and the descent path during approach phases to Saint-Barthélemy, mainly due to the turbulence caused by the terrain.

1.18.2.10 Two passengers

Two passengers, including a private pilot, who had taken the Saint-Barthélemy Saint-Martin flight TX 1200 on the day before the accident with the same crew, reported that on take-off from runway 10, the pilot sitting in the right seat being at the controls, they heard what they thought to be a stall warning sounding on two occasions and both times the Captain took back control vigorously and remonstrated with the co-pilot. The landing at Saint-Martin was hard and the Captain once again made remarks to the co-pilot with a notably reproachful tone.

1.18.2.11 A Winair mechanic

A Winair mechanic reported that he had carried out work on F-OGES with two other mechanics before it took off for Saint-Barthélemy. The work had consisted of unblocking the rear cargo hold door locking system, and had taken ten to fifteen minutes. This had been done in the presence of the co-pilot, the Captain having stayed on board. The mechanic added that the co-pilot was hurrying them and, once the repair was completed, the conversation between him and the Captain had seemed to be stormy.

1.18.3 Regulatory requirements relating to recent experience

Paragraph OPS 1-970 (recent experience) of the annex to the regulation of 12 May 1997 concerning the technical conditions for operation of aircraft by a public transport company (OPS 1) prescribes that:

(a) - "*An operator shall ensure that*:

(1) Commander - a pilot does not operate an aeroplane as commander unless he has carried out at least three take-offs and three landings as pilot flying in an aeroplane of the same type or a flight simulator, […] in the preceeding ninety days; and

(2) Co-pilot – […]."

(b) – "*The ninety day period prescribed in sub-paragraphs (a)(1) and (2) above may be extended up to a maximum of one hundred and twenty days by line flying under the supervision of a type rating instructor or examiner. For periods beyond one hundred and twenty days, the recency requirement is satisfied by a training flight or use of an approved flight simulator."*

Note: the wording of condition (b) is confusing. When consulted, the DGAC stated that it should be understood that condition (a) was replaced by other conditions when the length of the break exceeded ninety days.

1.18.4 Operational requirements relating to Saint-Barthélemy

Landing at Saint-Barthélemy aerodrome requires a site rating for pilots-in-command. At Caraïbes Air Transport, this rating is issued by an accredited flight instructor from the airline to pilots who have logged at least 2,000 flying hours.

The operations manual specifies that the site rating on DHC-6 is valid on the Dornier 228 and vice versa. It also indicates that pilots with the site rating must have performed at least two landings on Saint-Barthélemy in the previous twelve months. If this is not the case, a check on the destination must be performed by a flight instructor.

The operations manual also specifies that an over-flight of the airfield is mandatory before landing[(4)] and that the Captain performs the take-off[(5)].

[4] The investigators were told that the operator allowed crews who perform many Saint-Martin / Saint-Barthélemy rotations not to overfly the field before landing.

[5] In practice, pilot instructors may let the co-pilot take off under supervision.

	CARAÏBES AIR TRANSPORT	ÉDITION I Oct 00
C.A.T.	MANUEL D'EXPLOITATION	AMENDEMENT N°0
DHC6	PERFORMANCES	PAGE B.4/23

4.5 UTILISATION PISTE SBH

La compagnie C.A.T est autorisée à utiliser l'aérodrome de ST Barthélémy au QFU 10

Voir procédure ci-après.

4.5.1 PROCEDURE A ADOPTER A ST BARTHELEMY

NB : Cette destination est réservée aux pilotes ayant suivi l'entraînement spécifique.

1) ATTERRISSAGE :

- Le survol du terrain est obligatoire même si il y a eu contact radio préalable avec l'AFIS
- L'atterrissage est interdit en cas de vent de travers supérieur à 15Kts
- Si l'avion n'a pas touché à la deuxième bretelle, remettre la puissance.

2) DECOLLAGE

- Conditions sur site : Pas de vent arrière, vent travers inférieur à 10 kts, avion aligné en début de piste.
- Remplir le carton de décollage :Après avoir déterminé la V1 Réduite, (Tableau en annexe) et le torque max.
- Aligné sur la piste : Bien s'assurer du bon fonctionnement de la mise en drapeau Automatique et des inverseurs de pas d'hélice.

3) LE CDB EFFECTUE LE DECOLLAGE DANS TOUS LES CAS.

- Il met et vérifie la puissance sur les freins
- Le copilote annonce V1, VR, V2

4) PANNE AVANT V1 :

Le CDB annonce l'arrêt décollage
Réduit la puissance, freine et maintient l'axe de piste avec la dirigeabilité de la roulette avant, si nécessaire.

5) PANNE APRES V1

- Le CDB annonce : On continue
- Maintien l'avion au sol jusqu'à VR en s'aidant du nose wheel steering
- L'OPL vérifie et effectue les affichages de puissance sur le moteur vif et annonce VR et V2.
- Aucune action n'est entreprise avant 400ft. A 400ft l'OPL traite de la panne, dans ce cas, garder les volets 10° jusqu'à 1000FT et dégager ST MARTIN JULIANA.

1.18.5 Crew actions on approach and at landing

The crew's tasks during approach and before landing are included in the two following check-lists (pages B2/19 and 20 of the operations manual). They present no special difficulties for a seasoned crew. For Saint-Barthélemy, these check-lists are completed when the aircraft is between one thousand and eight hundred feet, which leaves sufficient time for the pilot to devote himself to flying and keeping to the descent path (12%), the main difficulty of the site.

	APPROCHE	
PNF.	Taxi light	**ON.**
BOTH.	Circuits hydrauliques	**VERIFIES.**
BOTH.	Freins	**EN PRESSION.**
PNF.	Système carburant	**VERIFIE.**
CDB.	Steering	**VERIFIE.**
BOTH.	Altimètres	**VERIFIES.**
PNF.	Annonce pax	EFFECTUEE.

	AVANT ATTERRISSAGE	
PNF.	Phares	EN FONCTION.
BOTH.	Volets	ANNONCES.
PNF.	Hélices	PLEIN PETIT PAS.
PNF.	Panneau alarmes	VERIFIE.
PNF.	Radar	STBY.
PNF.	Vitesse approche	ANNONCEE.

1.18.6 Measures taken since the accident

Work began in the second quarter of 2001, meant to lower by six metres the height of the La Tourmente pass and to move the road that passes there to the south. The aim is to both allow a safer approach to runway 10 for aircraft and to limit orographic turbulence.

A new tower equipped with updated radio equipment has been constructed. This allows the AFIS agent to get a better view of the arriving and departing traffic.

1.18.7 Selection of beta range in flight

For the DHC-6 fleet, Bombardier - De Havilland has no knowledge of any accident due to selection of reverse beta in flight.

Further, three events which occurred between 1994 and 1996 on DHC-8 were brought to the attention of the manufacturer, without it having been possible to prove whether selection of reverse beta range in the course of the flight had been done inadvertently or whether it was deliberate.

The ASRS (NASA/FAA) database shows that in February 1998, a DHC-6 crew experienced a passage of the right propeller into the reverse position in flight while the aircraft was flying at three thousand five hundred feet. The check-list applied allowed the propeller to be feathered. The aircraft landed with no further problems.

1.18.8 Accident in the United States to a CASA C-212

On 4 March 1987, the CASA C-212-CC registered N-160FB belonging to Fischer Bros. Aviation, Inc., performing scheduled flight F 2268 on behalf of Northwest Airlink between Cleveland (Ohio, USA) and Detroit (Michigan, USA), crashed while it was on final (Metropolitan Wayne County Airport, Romulus, Michigan).

The aircraft was destroyed by the impact and the fire which broke out. Nine of the nineteen persons on board perished, including the two pilots.

The absence of a flight recorder led investigators to use mainly clues from the wreckage, the final track taken from radar recordings and witness statements. The survivors and witnesses had heard unusual engine noises just before the loss of control.

The NTSB report contains the following probable cause: "the captain's inability to control the airplane in an attempt to recover from an asymmetric power condition at low airspeed following his intentional use of the beta mode of propeller operation to descend and slow the airplane rapidly on final approach for landing".

1.18.9 Validity of the Captain's license

On 19 May 1994, by decision number 19652 of the CMAC (Civil Aeronautical Medical Council) the Captain was granted a waiver with limitations. These imposed the mandatory presence of a second pilot rated on the aircraft type, a bi-annual check by the Pointe-à-Pitre medical commission and the re-submission of his medical record to the CMAC one year later.

In November 1994 and May 1995, this pilot was examined in accordance with the bi-annual check imposed. On the second occasion, he was declared fit without exemption or limitations by the Pointe-à-Pitre medical commission. Since that date, the bi-annual check had been abandoned, without the CMAC having made this decision.

However, since limitations are the sole responsibility of the CMAC, as specified in the modified regulation of 2 December 1988, they may only be lifted by that organization. Thus, though he had been recognised as medically fit for service, the Captain's licence was not valid from an administrative standpoint.

Note: the regulation of 29 March 1999, entered into force on 1 July 1999, deleted consideration of the medical certificate by the aeronautical district for the revalidation of the license. A separate document is henceforth considered, subject to retrospective checks. Further, copies of the medical examination records for all pilots, both private and professional, must from then on be sent to the CMAC. However, the material means available to this organization have not been modified and it is unsure whether the organization has adequate resources to handle the large number of files received in a satisfactory manner.

2 - ANALYSIS

Summary of findings

The investigation did not bring to light any medical evidence which might have a relation to the accident. Although, from the administrative viewpoint, the Captain's license was not valid on the day of the accident, this fact did not contribute to the sequence of events which caused the accident.

The findings at the site, a study of the aircraft maintenance logs and flight preparation documents and examinations carried out on the airframe, the engines and the propellers did not bring to light any specific malfunctions or anomalies which might have led to the accident or contributed to it.

In the absence of flight recorders, the investigators possessed none of the basic parameters (airspeed, heading, altitude…) with which to analyze the aircraft track or identify the crew's actions on the flight controls and/or the power levers. The absence of a recording of the conversations with the Saint-Barthélemy tower and the absence of any radar track also complicated the investigation.

The only available information relevant to an understanding of the accident were the clues found in the wreckage and the results of the work carried out with the film found on the site, in addition to the observations made by those who witnessed the flight and to the witness testimony obtained from the professional environment of the crew.

Consequently, the analysis will be based on:

- Elements from the operational context for this type of operation.

- Scenarios which could have led to the aircraft maneuvers described by the witnesses.

2.1 Elements from the operational context

2.1.1 The pilots' experience

The two pilots flew as a crew, on board F-OGES, on the day of the accident and on the previous two days, on twenty-six flights, all between the islands of Saint-Martin and Saint-Barthélemy.

The Captain had extensive experience of the DHC-6 and of the site but he had only flown on the Dornier 228 in the previous three months. The flight and handling characteristics of this aircraft are different from those of the DHC-6, the approach speeds are not the same, the feel at the controls is not the same and the ergonomics of the cockpits is notably different. Habits naturally acquired during these three months probably disturbed the Captain during approaches and landings at Saint-Barthélemy. He did not feel at ease, as he had confirmed to his colleagues on the day of the accident itself. The hard landing in the morning confirms this.

On the day when he re-started flights on the DHC-6, the Captain no longer met the conditions concerning recent experience. To be authorized to undertake his role as Captain, he should have undertaken a flight under supervision. This check-ride was not, however, performed, as appears from the Captain's logbook (see 1.5.1). It is surprising that the operator did not check this. However, it should be noted that there was no obligation to land at Saint-Barthélemy during the check-ride and that the accident occurred after three days of intense activity.

Further, the co-pilot's operational experience on the aircraft was limited, since his type rating obtained in December 2000, to a little more than ten flying hours, all performed in the right seat. His role during approach and landing at Saint-Barthélemy consisted of checking certain instruments, placing the propeller levers in full low pitch position, making the technical callouts and passenger announcements and carrying out radio-communications. In no case did he need to touch the power levers or the flight controls.

2.1.2 Context of the flight

Approaches and landings at Saint-Barthélemy are particularly delicate and the margins are tight: in case of an incorrect track, only a go-around is possible. For a short flight, such a maneuver represents a considerable increase in flight time. F-OGES was already an hour behind schedule. The Captain probably wanted to avoid increasing this delay (this is perhaps the reason why he stayed at the lower range of the usual heights for flights between the two islands, see 1.16.3.3.2). Perhaps he even wanted to try a particularly short landing to avoid having to turn around at the end of the runway and thus make up a little of the lost time.

He himself also had both professional and personal constraints. In fact, after this last rotation he was supposed to ferry F-OGES to the Saint-Martin Grand-Case aerodrome, then to participate in a football match.

Amongst other things, the incident with the cargo hold door closure had annoyed him, as shown by the testimony of the mechanics at Saint-Martin and the radio message which he sent to Caraïbes Air Transport Operations before the landing at Saint-Barthélemy.

Thus, the flight appears to have been marked both by the pressure of time and by more intense stress than for a normal flight.

2.1.3 Relations between crew members

Despite his qualities, recognized by all, the Captain was reputed to have a strong personality. This manifested itself on at least three occasions:

- During a flight on the day before the accident, when he was heard to reproach his co-pilot quite sharply during the take-off and the landing.
- During his discussion with a mechanic after the hard landing in the morning.
- During the incident with the cargo hold door closure at Saint-Martin.

Bearing in mind the strong personality of his Captain and the remarks that the latter had made to him on several occasions, it is likely that the co-pilot, who also had only limited experience on the DHC-6, was not inclined to intervene in the conduct of the flight but rather to restrict himself to the execution of his tasks.

2.1.4 Short repetitive flights

The accident flight was the eighth leg of the day between the two islands, which represents about four hours of flying. This figure is not high in the absolute sense, but when reduced to the number of legs, and including the tasks to be performed before and after the flights, represents a high workload, liable to generate fatigue rapidly.

In addition, the repetitive aspect of the flights and the fact of often landing at the same aerodromes may allow certain deviations, contrary to flight safety, to creep in. These deviations become routine, safety limits are pushed back without the crew being conscious that there is a progressive slip into a form of logic where risks are increased.

In-flight use by certain crews of the propellers in reverse beta range illustrates this type of deviation from standard procedures. Another example is the take-off from Saint-Barthélemy performed by the co-pilot the day before the accident.

2.1.5 Difficulty of the approach to runway 10

The turbulence upstream of the La Tourmente pass can affect flying; it therefore requires vigilance and permanent attention during approaches to runway 10. Pilots are conscious of this phenomenon but cannot completely avoid it. Thus, some adopt a track with which they are more at ease, given their habits, feelings, skills and their knowledge of the aircraft; some offset to the right or to the left, while others prefer to start high relative to the normal approach path.

There is an additional difficulty. As soon as they have gone over the pass, pilots must adopt a nose down attitude, which is not natural so near to the ground, in order to guarantee as short a landing as possible, taking into account the infrastructure. The unease exhibited by some pilots may also occasionally lead to a runway overrun.

It was these difficulties which led the authorities to lay down a mandatory requirement for a site rating before using the aerodrome.

2.1.6 Confusion between "beta range" and "reverse beta range"

The confusion made by many people between "beta range" and "reverse beta range" is more related to an over-simplification of language or improper professional jargon than a lack of knowledge of the propeller control characteristics. In fact all of those encountered by the investigators knew that the range prohibited in flight corresponds to the override of the mechanical stop and knew of the risks described by the manufacturer. However, because of this linguistic imprecision, the intention mentioned by the Captain to use the "beta" should not be understood as necessarily implying going beyond the stop. Even if this interpretation is highly likely, some doubt persists.

2.2 Hypothesis tree

All of the facts amassed confirm that the loss of control happened suddenly, immediately before passing over the pass. The common points in the observations of what can be called the “pivotal event” are:

- A nose-up attitude and a left turn with a steeper and steeper bank angle, up to nearly 90°, followed by the aircraft diving.
- A loud noise from the engine.

The method used consisted of identifying the possible hypotheses on what triggered the event, studying the resulting scenarios, on the basis of logical branches, and checking their correspondence with the mass of facts established by the investigation. Appendix 9 contains a tree diagram of the analysis.

The first logical branch stems from the distinction between a triggering event external to the crew and a factor which would be linked to the crew.

2.2.1 The triggering event is external to the crew

Several external events could be the origin of a nose-up attitude followed by a left turn with a high bank angle.

Intervention of a passenger

Intervention by a passenger in the cockpit would have led to a reaction from the crew, leading to erratic aircraft attitudes and track, which no witnesses reported. This can be eliminated.

Specific turbulence

During the approach to runway 10, pilots generally encounter turbulent flying conditions which require particular vigilance. These expected conditions cannot however lead to a loss of control without the existence of another factor, and in this case it is only a contributory factor. The hypothesis of a triggering event linked to turbulence can therefore only be accepted if the phenomenon is particularly intense. However, neither the meteorological conditions on the day nor the testimony of other crews brought to light any such phenomenon.

Bird strike

This hypothesis can be eliminated because no marks of such an impact were revealed during examination of the propellers and the leading edges of the airfoils, and no traces of ingestion of foreign bodies was observed in the engines.

Loss of a structural element in flight

This hypothesis can be eliminated since all the elements of the airframe, the flight controls and the control surfaces were found at the site, including the rear cargo hold door which had been subject to maintenance work. In addition, all of the ruptures were of the static type.

Malfunction of a control surface or a flight control

No signs of any anomalies were identified in the wreckage; the rupture marks on the flaps show a symmetrical setting. This hypothesis can thus be eliminated.

Weight and balance of aircraft becoming abnormal during the flight

For flight TX 1501, each cargo hold contained one hundred kilos of baggage. It was established that no doors had opened in flight. In addition, longitudinal or lateral displacement of loads in small holds cannot fundamentally modify the aircraft's CG position. The same applies to the possible movement of one or two passengers, especially since at the time of the approach they are normally seated and strapped in.

This hypothesis can thus be eliminated.

Engine malfunction

Technical examinations showed that both engines were running correctly and that they were developing significant and practically symmetric thrust at the moment of impact. They also showed that the propeller pitch settings were practically symmetrical at the moment of impact. The hypothesis would thus rest on a momentary technical glitch on one or other of the engines causing a transitory asymmetry leading to a final loss of control. However:

- On the one hand, a momentary drop in power on one engine alone, notably at approach power setting, cannot lead to such a loss of control, even if there were a sudden feathering.
- On the other hand, an increase in power on the right engine on a scale likely to lead to a loss of control could only be linked to a type of turbine runaway. No such signs of overspeed or excess temperature were brought to light.
- Finally, a failure in propeller governing on final, with the engine at low power, would only lead to a slight asymmetry, which would result in a slight yaw axis movement that could easily be countered with the rudder pedals.

This hypothesis can thus be eliminated.

In conclusion, no scenario originating from a triggering factor external to the flight crew can be identified.

2.2.2 The triggering event is linked to crew action

The second logical branch originates from the deliberate or unintentional nature of a crew action leading to the aircraft movements which have been described.

2.2.2.1 Involuntary action

Loss of control through stall

The Captain could have allowed the aircraft's airspeed decay, in particular below approach speed, the co-pilot not noticing this or hesitating to intervene (see 2.1.3). An excessive loss in airspeed or an encounter with turbulence or gust could then have led to a stall. With this hypothesis, the noise heard by the witnesses would correspond to an unsuccessful attempt to recover from the stall by increasing power.

This hypothesis, though quite unlikely, cannot be completely eliminated, the absence of a flight data recorder and radar recordings meaning that it was impossible to determine the aircraft's airspeed during the approach phase.

Sudden incapacitation in flight

The autopsies revealed no medical factors having any bearing on the accident. However, a sudden and brutal incapacitation, which an autopsy would not be able to identify, cannot be ruled out, though it can be excluded that such a thing would happen simultaneously to both pilots. In this case, it would have happened at the most critical moment in the flight, making it impossible for the other crew member to react.

This hypothesis can thus not be formally eliminated, in particular if it relates to the pilot flying. It should be noted that, in this case too, an onboard flight recorder would likely have made it possible to pronounce on this hypothesis with certainty.

Inadvertent setting of propellers into the reverse beta range

The design ergonomics of the power lever handles makes it impossible for the pilot to inadvertently select reverse beta range, since to do that it is necessary to make a very different gesture from the simple movement of the arm or the hand.

This hypothesis can thus be eliminated.

2.2.2.2 Deliberate action

A deliberate action, that is to say linked to a specific intention on the part of the person who does it, can be within the field of normal use or correspond to a divergence from standard procedures for aircraft operation or from the operator's practices. This particular logical branch is examined hereafter.

2.2.2.2.1 Deliberate action corresponding to a normal maneuver

Slight track corrections such as those normally performed on final approach cannot explain the loss of control of the aircraft. It is therefore necessary to examine a maneuver with substantial inputs.

Missed approach on short final

As the aircraft was on short final, near the pass, the Captain could have decided to abort the approach, which would explain the increased engine noise heard, and could then have lost control of the aircraft in the course of the maneuver. Without knowing the flight parameters at that moment, it is impossible to choose one loss of control mode in a dynamic phase of that nature, but this general hypothesis would be compatible with the attitudes described. Thus, for example, an excessive nose up attitude when the aircraft airspeed would have been low, associated with a gust of wind, could have led to an asymmetric stall. Or, for purposes of illustration, an undetected asymmetric positioning of the propeller levers towards full low pitch, which would have led to thrust asymmetry to the point of causing a loss of control.

The hypothesis of a loss of control in the course of a go-around cannot therefore be excluded. The likelihood of it is small, however, in the absence of any anomalies on the aircraft, a go-around being a normal maneuver during operations for which crews are prepared and trained.

2.2.2.2.2 Deliberate action corresponding to an unexpected maneuver

Use of propellers in reverse beta range

According to this hypothesis, the pilot would have selected the reverse beta range for the propellers with the intention of losing energy to correct the airspeed, regain the descent path or shorten the landing as much as possible. In fact, as has been described in chapter 1.16.5, the propeller then acts as a powerful brake.

It is possible that an asymmetry developed at that moment, though it would have been of relatively low amplitude, given the low thrust setting on approach, and could have been detected and likely quickly countered. However, following entry into reverse beta range, the aircraft may have developed undesirable behavior (stall warning, buffeting, etc.) or have reached the target airspeed, which would have been the desired result. In either case, it is necessary at that moment to de-select reverse beta range. Then the pilot would have pushed the levers energetically back to their normal use range by increasing the thrust, which would explain the change in the engine noise. Asymmetry in the power levers movement, or in the operation of the propeller mechanism, or even in the position of the propeller levers, would then have led to asymmetry between the engines, to an extent that would have led to a violent yaw movement, inducing a sharp roll to the left, possibly associated with a stall of the left wing, then a dive. The pilot would not have been able to regain control of the aircraft, which would have been both too slow and too near the ground at that moment.

This hypothesis, which corresponds to a practice whose existence is known and whose potential consequences are well identified, seems to be supported by the statement made the same morning by the Captain.

Approach performed by the co-pilot

In the same way as for the take-off from Saint-Barthélemy performed the day before, the Captain could have authorized his co-pilot to perform the approach to Saint-Barthélemy, without himself taking over radio communications with the tower. In this case, there is every reason to believe that he would have been very vigilant with regard to his co-pilot.

The appearance of significant asymmetry between the power levers, possible since their movement by the pilot in the right seat is not easy from the point of view of ergonomics, or a stall caused by excessive reduction in airspeed logically would both have been detected and corrected by the Captain.

Only in the case of a go-around, with all that is implied in terms of speed of action and amplitude of action on the power levers, could there have been some inaccuracy on the part of the co-pilot which might have escaped the Captain's vigilance. However, this scenario implies that he not only would have handed over the approach to the co-pilot, but that he would also have let him perform the go-around.

An accumulation of quite unlikely events leads this hypothesis to be excluded, though it should be noted that, in this case, a flight recorder would by itself probably have enabled this hypothesis to be eliminated or confirmed with certainty.

* *
*

To summarize, among the various hypotheses which were analyzed, only four can be retained: two relating to involuntary action by the crew – sudden incapacitation of a crew member or a stall due to excessive airspeed decrease – and two relating to deliberate actions by the crew – loss of control during a go-around or in-flight use of the reverse beta range, with, nevertheless, significantly different levels of probability.

Of the four hypotheses retained, the first three have a low probability. The most probable is that of a deliberate selection of the propellers in the reverse beta range.

3 - CONCLUSION

3.1 Findings

- The aircraft possessed a valid Certificate of Airworthiness.
- The co-pilot held a valid license and the ratings required for the flight.
- The Captain, though medically fit for service, did not possess a valid license from the administrative perspective.
- The Captain had mainly flown on Dornier 228’s in the course of the three months which preceded the accident.
- The Captain did not fulfill the conditions relating to recent experience on DHC-6 at the time he started flying one again, two days before the accident.
- During his last line check on DHC-6, the Captain had not had the opportunity to land at Saint-Barthélemy.
- According to the witness testimony, the Captain did not feel at ease when landing this aircraft at Saint-Barthélemy.
- The weight and balance sheet established before the take-off was erroneous. However, the load and the balance were within the limits defined by the manufacturer and this error did not contribute to the accident.
- Flight TX 1501 was an hour late because of the late arrival of certain passengers in transit.
- After the start-up, an incident relating to the closure of the rear cargo hold door required maintenance work which delayed the departure time by a further ten minutes.
- The approach to runway 10 at Saint-Barthélemy involves flying over the La Tourmente pass at a very low height and dealing with orographic turbulence, which requires great vigilance at the controls. Nevertheless, the meteorological conditions at the time of the accident presented no dangerous phenomena for aviation.
- No anomalies were reported by the crew before the accident.
- Several people saw the airplane on short final, just before the La Tourmente pass, pitch up, start a left turn with a steeper and steeper bank angle then dive; they also heard a loud engine noise.
- The aircraft crashed with a steep nose down attitude near a house, then caught fire.
- All of the occupants of the aircraft were killed on impact, an occupant of the house died in the fire.
- Examinations of the wreckage, both at the site and in the workshop, brought to light no malfunctions previous to the accident.
- No medical or pathological factors having any bearing on the accident were brought to light.

- The aircraft was not equipped with flight recorders, which deprived the investigation of important information, complicated it and slowed it down. The absence of recordings of radio communications in the control tower and the absence of a radar track also deprived the investigation of clues which might have proved useful.

- Playback of a video film found in the wreckage confirmed that the aircraft was operating normally throughout the filmed part of the flight, up until across the Pain de Sucre, and that everything seemed normal on board.

- The Captain was considering using the “beta” on final for the accident flight.

3.2 Probable Causes

The accident appears to result from the Captain’s use of the propellers in the reverse beta range, to improve control of his track on short final. A strong thrust asymmetry at the moment when coming out of the reverse beta range would have caused the loss of yaw control, then roll control of the aircraft.

The investigation could not exclude three other hypotheses which can nevertheless be classified as quite unlikely:

- A loss of control during a go-around.

- A loss of control due to a stall.

- A loss of control due to sudden incapacitation of one of the pilots.

The Captain’s lack of recent experience on this airplane type, the undeniable difficulty of conducting an approach to runway 10 at Saint-Barthélemy and the pressure of time during this flight were contributory factors.

The low height at which the loss of control occurred was an aggravating factor.

4 - SAFETY RECOMMENDATIONS

4.1 Recommendation Issued in July 2001

In July 2001, the BEA issued a first safety recommendation in the context of this investigation:

It is regrettable that the absence of flight recorders on the aircraft made it impossible to make a rapid determination of the conditions of the last minutes of the flight. More than ten years after the publication of the regulation of 5 November 1987, the waivers granted for older aircraft no longer appear to be justified. Consequently, the BEA recommends that:

- ***the DGAC and the JAA make mandatory the installation of at least one flight recorder on board public transport aircraft authorized to carry more than nine passengers and whose maximum certified take-off weight is less than or equal to 5,700 kg, whatever the date of certification may be.***

On the basis of observations received by the BEA, it appears useful to underline the urgency and the scope of application of this recommendation. It should, in particular, be noted that the objective of the recommendation is an improvement in the efficiency of investigations for safety in air transport. Consequently, the BEA recommends that:

- **the DGAC and the J.A.A. urgently take into account, for safety reasons, the need for flight recorders for the rapid determination of the causes and circumstances of accidents which occur in public air transport and that, to this end, these organizations:**
    - **impose as soon as possible, without any possible exemptions, the carriage of at least one flight recorder on aircraft operating for public transport with a maximum certificated takeoff weight lesser than 5,700 kg and whose maximum approved passenger seating configuration is ten seats or more, whatever the date of certification may be;**
    - **extend these provisions to airplanes of the same type transporting cargo;**
    - **study the extension of these provisions to helicopters operated for public transport.**

4.2 Even though its representative made a verbal comment to the person concerned, the operator did not formally ensure that the Captain actually met the conditions on recent experience required by the regulations before starting to transport passengers on the DHC-6. Consequently, the BEA recommends that:

- **the DGAC encourage operators to equip themselves with the tools necessary, within the regulatory framework, to ensure rigorous follow-up of their pilots' aviation activity.**

4.3 The wording of paragraph OPS 1.970 of the appendix to the regulation of 12 May 1997 (OPS1) leads to confusion with regard to the means of compliance with the requirements concerning recent experience. In addition, it does not take into account particular requirements relating to the possible holding of a site rating. Consequently, the BEA recommends that:

- **the DGAC, in liaison with the JAA as appropriate, improve the wording of paragraph OPS 1.970;**

- **the DGAC, in liaison with the JAA as appropriate, take into account the possible holding of site ratings when setting the requirements relating to recent experience.**

4.4 The absence, for several months, of equipment for recording radio communications at the Saint-Barthélemy tower deprived the investigation of clues and technical data which could have completed those found on the video tape. Consequently, the BEA recommends that:

- **the DGAC put in place the necessary means so that recordings of allocated radio frequences be ensured without notable interruptions.**

4.5 Orographic turbulence generated by the easterly wind above the La Tourmente pass leads certain pilots to follow an offset track rather than the normal extended centerline approach track. A wind-sock is installed on the north side of the pass. By contrast, pilots have no information on the velocity and direction of the wind in the southern part. Consequently, the BEA recommends that:

- **the DGAC install a wind-sock on the southern part of the La Tourmente pass.**

4.6 The investigation showed that the Captain's license was not valid from an administrative standpoint on the day of the accident, due to the non-respect of the limitations imposed by the Civil Aeronautical Medical Council (CMAC) in May 1994. It is important, for the sake of aviation safety, that approved doctors and organizations responsible for medical checks on pilots scrupulously apply exemption procedures as they are defined by the regulations. The recent implementation of the JAR FCL does not appear to have been accompanied by an assessment of the resources required, in particular information technologies resources, for retrospective checks. Consequently, the BEA recommends that:

- **the DGAC determine the resources required for retrospective checks on medical records by the CMAC and ensures that they are put in place if necessary.**

List of Appendices

CARAIBES AIR TRANSPORT → CAR OPS PTP 002

DHC6-300 TWIN OTTER

AIR CARAÏBES

DEVIS de MASSE et de CENTRAGE

N° VOL : R 501
IMMAT : F-OGES
DATE : 24-03-01
DESTINATION : SBH
CDB : [illegible]

MASSE DE BASE	3299
Corrections (+/-)	
Masse de base Corrigée	3299
CARBURANT AU DÉCOLLAGE +	550
Masse en Opérations	3849

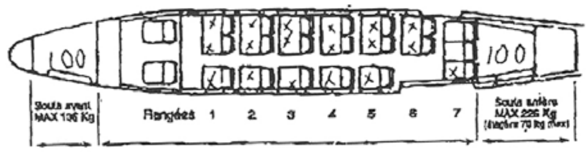
INDICE DE BASE		100
Correction de l'indice de base	+	-
ZONES		
Indice de base corrigé		100

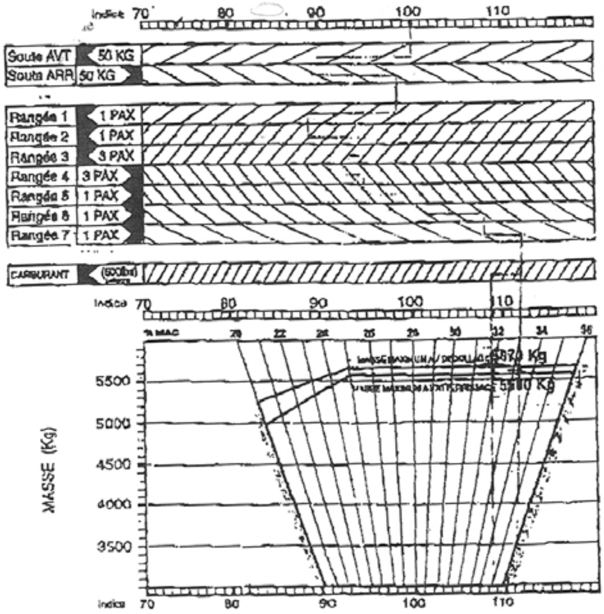
	SANS CARBURANT	DÉCOLLAGE	ATTERRISSAGE
MASSES MAXIMALES			5580
CARBURANT au DECOLLAGE (+)		DÉLESTAGE →	50
LIMITATION UTILE (la plus faible des trois)		5670	5630
MASSE en OPÉRATION (-)			3849
CHARGE OFFERTE			1781

INDICE CORRIGE 100.

DEST	AD	CH	IN		MASSE TOTALE	AV.D	ARR	RMK
				TR				
				B				
				C				
				M				
				T				
				TR				
				B				
				C				
				M				
				T				
				TR				
				B				
				C				
				M				
				T				
SBH				TR				
				B	200	100	100	
				C				
				M				
				T				
TOTAUX 18								

(REPARTITION PAR SOUTE: AV.D / ARR / RMK)





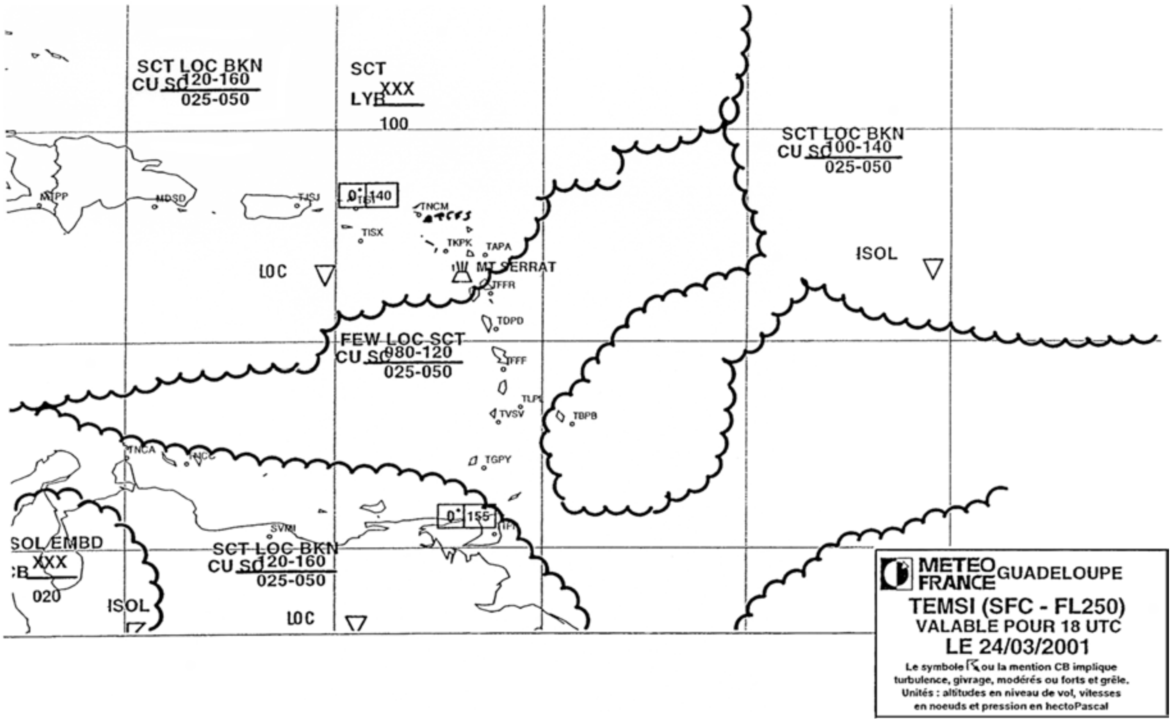
		Masses corrigées
MASSE EN SOUTE (Kg) A	200	
MASSE PASSAGERS (kg) B	1550	
CHARGE TRANSPORTÉE A+B	1750	
MASSE DE BASE CORRIGÉE +	3299	
MASSE SANS CARBURANT =	5049	
CARBURANT AU DÉCOLLAGE +	550	
MASSE AU DÉCOLLAGE (5670) =	5599	
DELESTAGE	50	
MASSE A L'ATTERRISSAGE (5580) =	5549	

RECTIFICATION DE DERNIÈRE MINUTE : L.M.C.

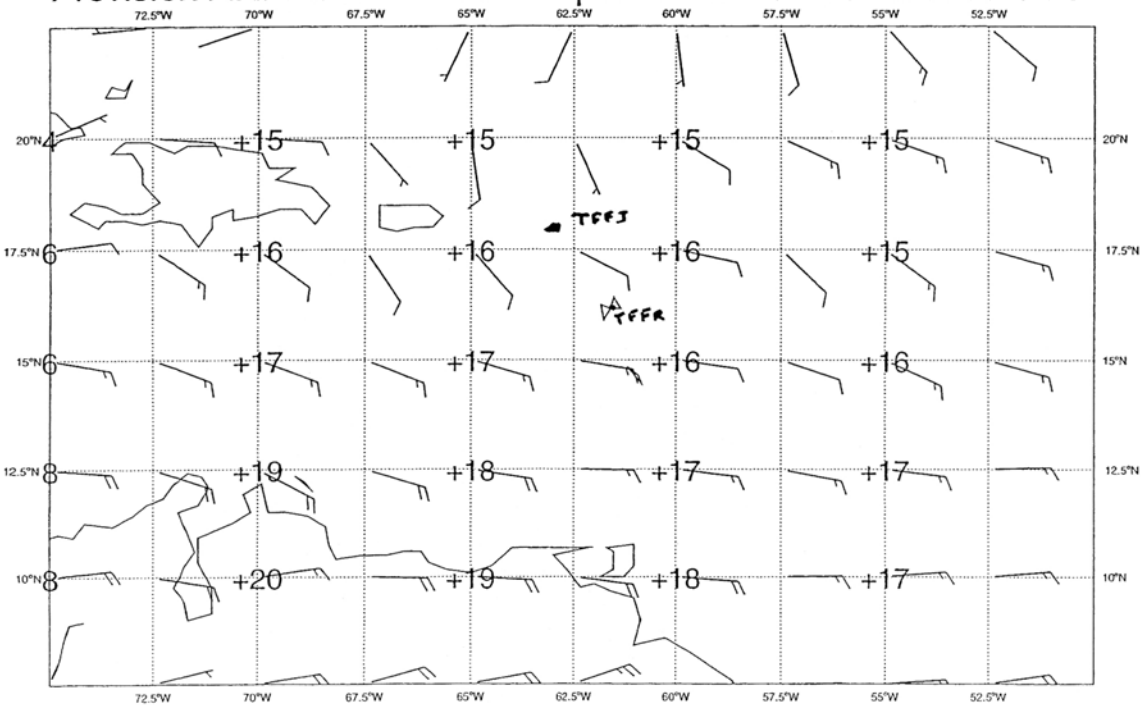
DEST.	AD	CHD	INF	B.C.M	MASSE +/-	CORR. I +/-	Centrage Corr.
							ZFW
							DEC
TOTAL							ATT

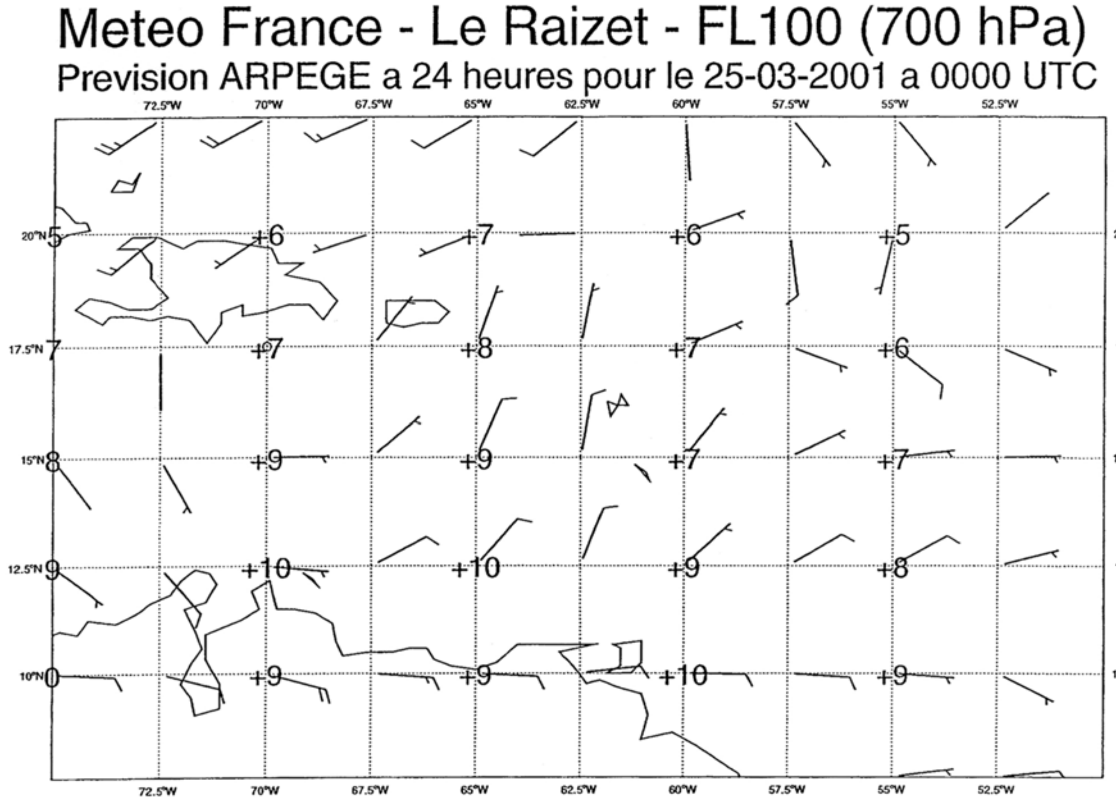
CENTRAGE % MAC		
ZFW	TOW	LAW
	32.1	32.2

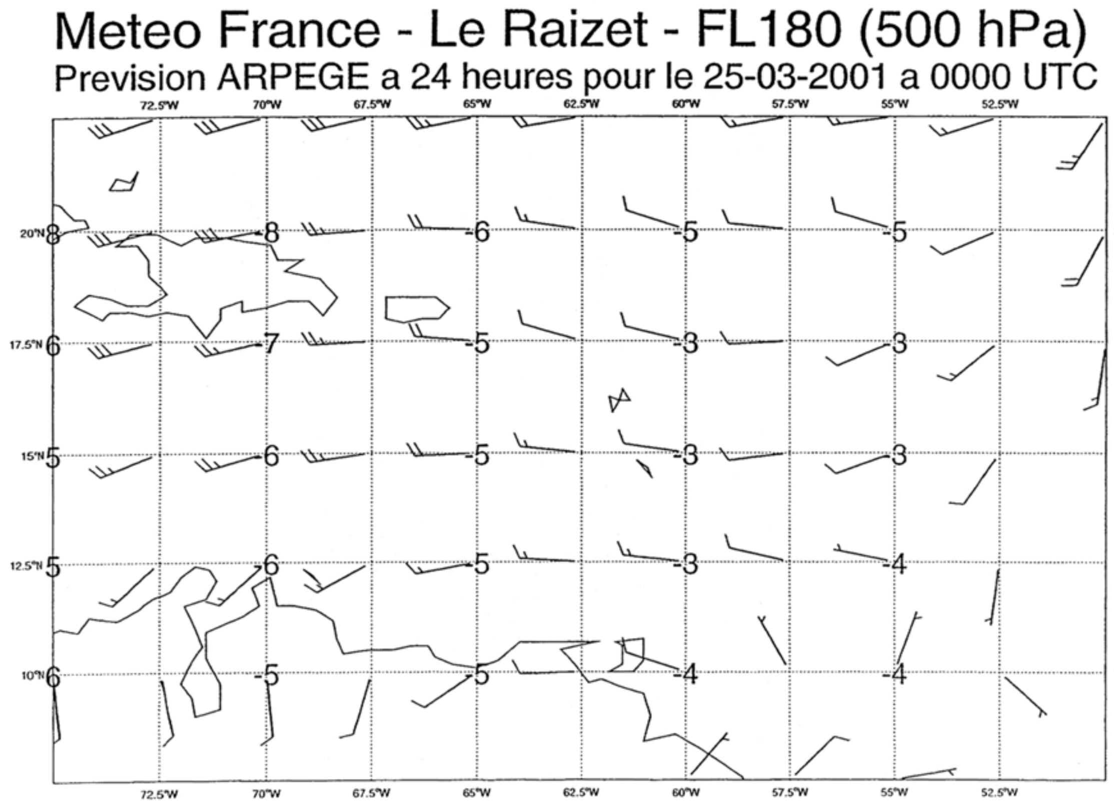
DEPN : 069731 PREPARE PAR : SIGNATURE DU CDB :



Meteo France - Le Raizet - FL050 (850 hPa)
Prevision ARPEGE a 24 heures pour le 25-03-2001 a 0000 UTC







Readings for Saturday 24 March 2001 between 16 h 15 and 16 h 25
as provided by GUSTAVIA station

Local Time	2 minutes wind		10 minutes wind		Variation in wind direction	Max. velocity (m/s)	Pressure at sea level (hPa)	QNH	Temp. °C
	Dir.	Velocity (m/s)	Dir.	Velocity (m/s)					
16 : 15	110	3.0	140	2.6	50/290	5.9	1014,0	1013	28.2
16 : 16	130	2.7	140	2.7	50/290	5.9	1014,0	1013	28.1
16 : 17	140	3.5	140	2.9	50/210	5.9	1014,0	1013	28.1
16 : 18	120	3.4	130	3.0	50/210	5.9	1014,0	1013	28.0
16 : 19	140	2.5	130	2.9	50/210	5.9	1014,0	1014	28.0
16 : 20	130	2.2	130	2.7	20/270	5.5	1014,0	1014	28.0
16 : 21	130	2.2	130	2.7	20/270	5.5	1014,0	1014	28.0
16 : 22	120	2.5	130	2.7	20/270	5.5	1013,9	1014	27.9
16 : 23	130	2.2	130	2.7	20/300	5.5	1014,0	1013	28.0
16 : 24	150	2.5	130	2.6	20/300	5.5	1014,0	1014	27.9
16 : 25	120	2.3	130	2.5	20/300	5.5	1014,0	1014	27.9

Variation in wind direction = extent of directions adopted by the vane during the last three minutes.

Note: the wind, in particular when it is weak, as was the case, is often turbulent and changing at Gustavia meteorological station, which explains the extent of its variability. The direction indicated for the 2 minutes wind (aeronautical wind) or the 10 minutes wind (meteorological wind) correspond to the direction of the wind averaged over 2 or 10 minutes.

Chart references:

(1) Maximum permissible sustained torque is 50 psi.

(2) For every 10°C below −30°C ambient temperature, reduce maximum allowable Ng by 2.2%.

(3) Normal oil pressure is 80 to 100 psi at gas generator speeds above 72% with oil temperature between 60 and 70°C. Oil pressure below 80 psi is undesirable and should be tolerated only for the completion of the flight preferably at reduced power setting. Oil pressure below normal should be reported as an engine discrepancy and should be corrected before next take-off. Oil pressure below 40 psi is unsafe and requires that either the engine be shut down or a landing made as soon as possible, using the minimum power required to sustain flight.

(4) For increased service life of the engine (i.e. time between oil changes) an oil temperature between 74 and 80°C is recommended. A minimum oil temperature of 55°C is recommended for fuel heater operation at take-off power.

(5) At 51% rpm (Ng) minimum, increase Ng as required to stay below idle temperature limit.

(6) These values are time-limited to two seconds.

(7) Reverse power operation is limited to one minute.

CAUTION

When ground running engines (except during maneuvering or taxiing) in ambient temperatures of 32°C (90°F) and above, the aircraft must be headed into wind and operation in other than forward thrust must be kept to a minimum and in no case exceed one minute. At temperatures below 32°C, ground operation in reverse thrust with aircraft headed into wind is limited to one minute.

(8) Inflight operation of the power levers aft of IDLE is prohibited.

1.1.2 TORQUEMETER PRESSURE – POWER CALCULATIONS. Calculation of shaft horsepower may be made as follows:

$$SHP = \frac{\text{rpm (Np) x Torque Pressure}}{172.17}$$

SAFETY OF FLIGHT SUPPLEMENT

NO. 3

1 OCTOBER 1979

Insert this Safety of Flight Supplement at the front of the DHC-6 Supplementary Operating Data.

SUBJECT - IN-FLIGHT SELECTION OF REVERSE THRUST

It has come to the attention of de Havilland Canada that a recent accident may have been caused by the in-flight selection of reverse thrust, which require's the pilot to first remove the flight idle stop by twisting the power lever handles to permit access to the reverse (thrust) range.

WARNING

Pilots are advised that the Twin Otter flight manual permits the use of reverse power only when water or groundborne, and does not describe any procedure which permits the selection of reverse while airborne.

The in-flight selection of reverse thrust can cause serious changes in aircraft handling characteristics with possible loss of control, together with significant changes in stalling speeds and engine behaviour.

It is suggested that all pilots read and sign this Safety of Flight Supplement.

APPROCHE - ATTERRISSAGE A VUE
VISUAL APPROACH AND LANDING

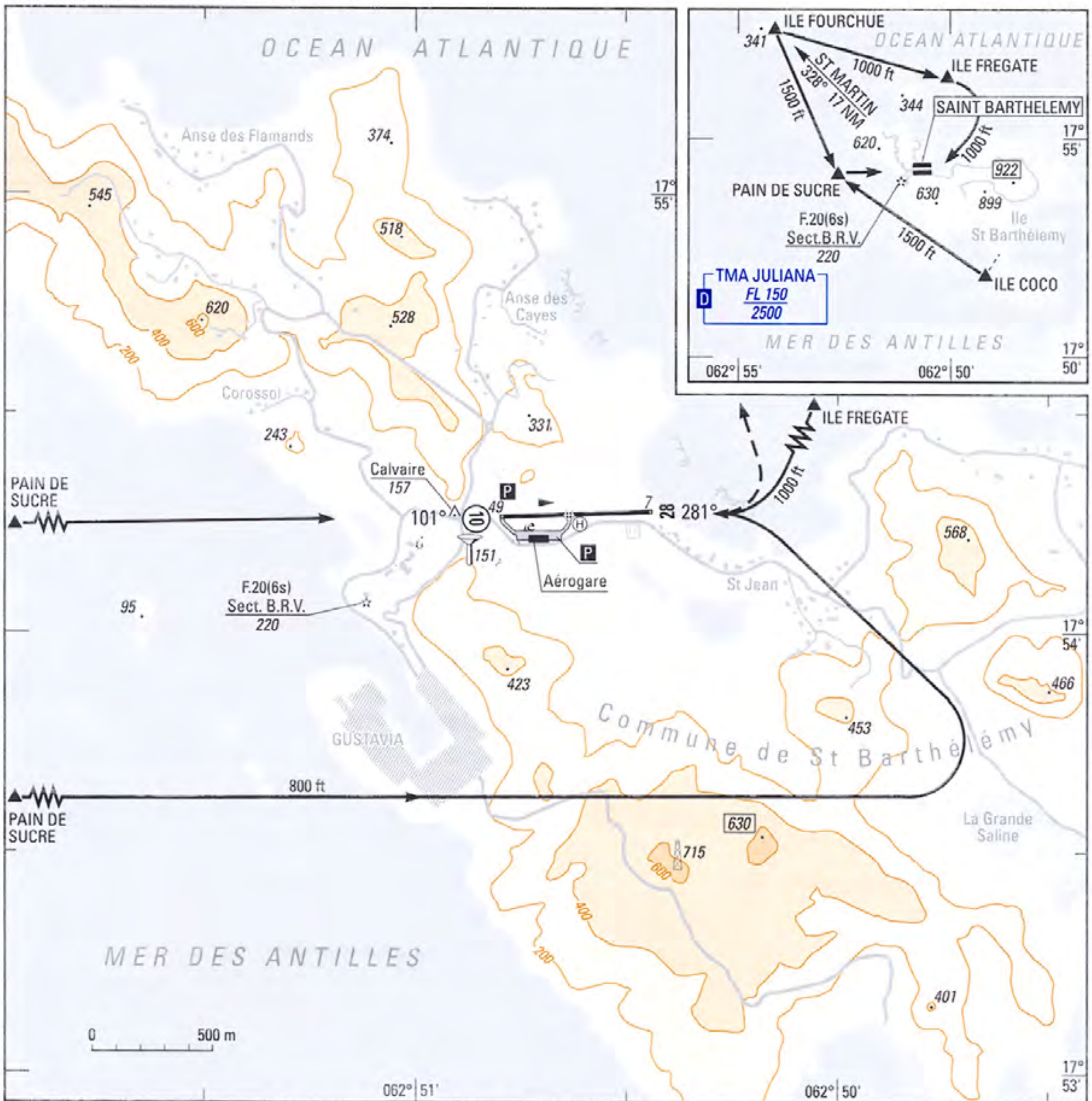
USAGE RESTREINT
RESTRICTED USE

SAINT BARTHELEMY

Coord. WGS-84
ALT et HGT en ft
ALT AD : 49 ft (2 hPa)

LAT : 17 54 16 N
LONG : 062 50 37 W
VAR 13° W (97)

APP : JULIANA Approche 128.95
TWR : NIL
AFIS : SAINT BARTHELEMY Information 118.45



RWY	QFU	Dimensions *Dimension*	Nature *Surface*	Résistance *Strength*	TODA	ASDA	LDA
10 28	101 281	650 x 15 m	Béton *Concrete*	5.7 t	650 650	650 650	650 650

Aides lumineuses :NIL

Lighting aids *: NIL*

SAINT BARTHELEMY

Consignes particulières / *Particular instructions*

AD interdit aux ACFT non munis de radio et autorisé pour l'utilisation permanente par hélicoptères.

AD réservé aux aéronefs de caractéristiques et performances appropriées et aux pilotes d'avions ayant réellement utilisé l'aérodrome sous le contrôle d'un pilote instructeur qui les aura reconnus aptes. Ces pilotes doivent figurer sur la liste des pilotes habilités tenue par le District aéronautique de Guadeloupe.

Utilisation systématique de la langue anglaise dans la circulation d'aérodrome dès qu'il y a un pilote non francophone dans le circuit.

PISTE 10 :

* Compte rendus de position obligatoires :
  - → à "FOURCHUE" ou travers "FOURCHUE" si provenance N ou NW
  - → à "COCO" ou travers " COCO" si provenance S ou SE
  - → à "PAIN DE SUCRE" à 1500 ft
  - → en courte finale ("LES GROS ILETS")
* Approche délicate (relief et turbulences)
* Au décollage, virage à gauche obligatoire

PISTE 28 :

* Circuit de piste à droite ou à gauche
* Compte rendus de position obligatoires :
  - → à "FOURCHUE" ou travers "FOURCHUE" si provenance N ou NW,
  - → puis à "FREGATE" (1000 ft) ou "PAIN DE SUCRE" (1500 ft)
  - → à "COCO" ou travers "COCO" si provenance S ou SE
* Remise de gaz interdite en courte finale
* Décollage interdit
* Raquette QFU 28 inutilisable

AD prohibited for ACFT without radio and authorized for permanent use by helicopters.

AD reserved for ACFT with suitable performances and characteristics and airplane pilots who have previously performed LDG and TKOF at AD and been acknowledge fit to do so by an instructor. These pilots must appear on an official list held by District aeronautique de Guadeloupe.

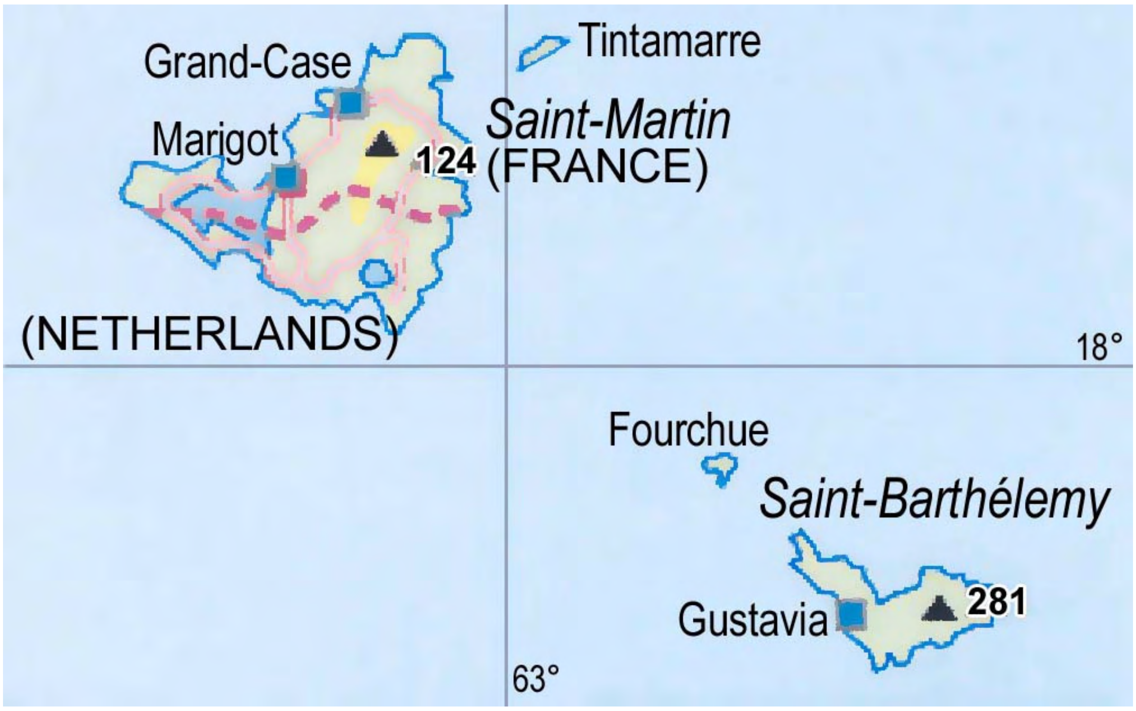
English language is systematically used in the aerodrome traffic circuit when a non speaking french pilote is in the circuit.

RWY 10:

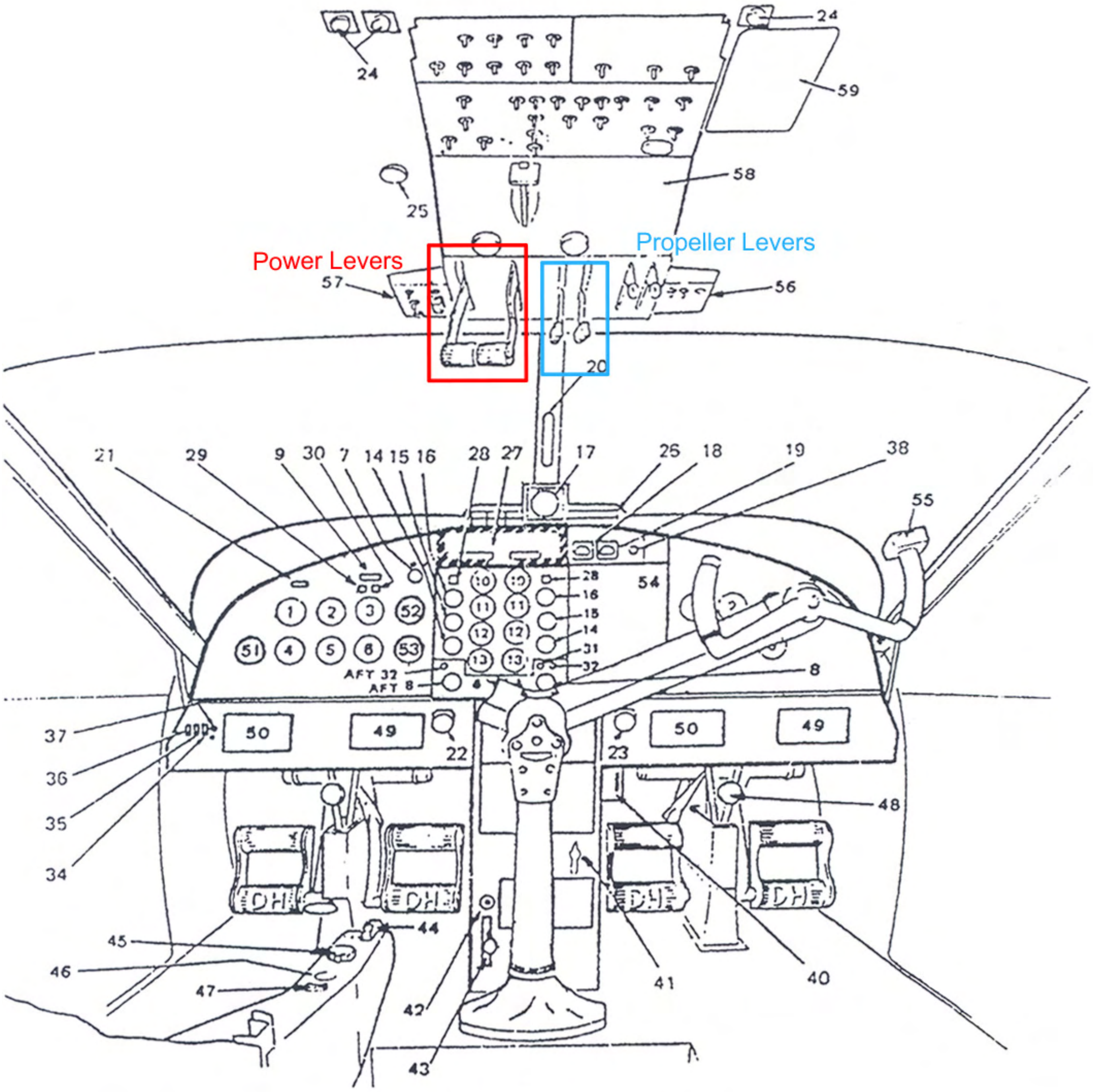
* *Airposition reports mandatory :*
  - → *over " FOURCHUE" or abeam "FOURCHUE" when coming from N or NW.*
  - → *over "COCO" or abeam " COCO" when coming from S or SE.*
  - → *over "PAIN DE SUCRE" at 1500 ft*
  - → *in short final ("LES GROS ILETS")*
* *Difficult approach (obstruction and turbulence)*
* *After take off, mandatory left turn .*

RWY 28:

* *Right hand or left hand AD traffic circuit..*
* *Mandatory air position reports :*
  - → *over "FOURCHUE" or abeam "FOURCHUE" when coming from N or NW*
  - → *then over "FREGATE" (1000 ft) or "PAIN DE SUCRE" (1500 ft)*
  - → *over "COCO" or abeam"COCO" when coming from S or SE.*
* *Going around is prohibited in short final.*
* *Take off prohibited*
* *Turn around areas QFU 28 unusable*


Tintamarre
Grand-Case
Saint-Martin
Marigot
124
(FRANCE)
(NETHERLANDS)
18°
Fourchue
Saint-Barthélemy
281
Gustavia
63°

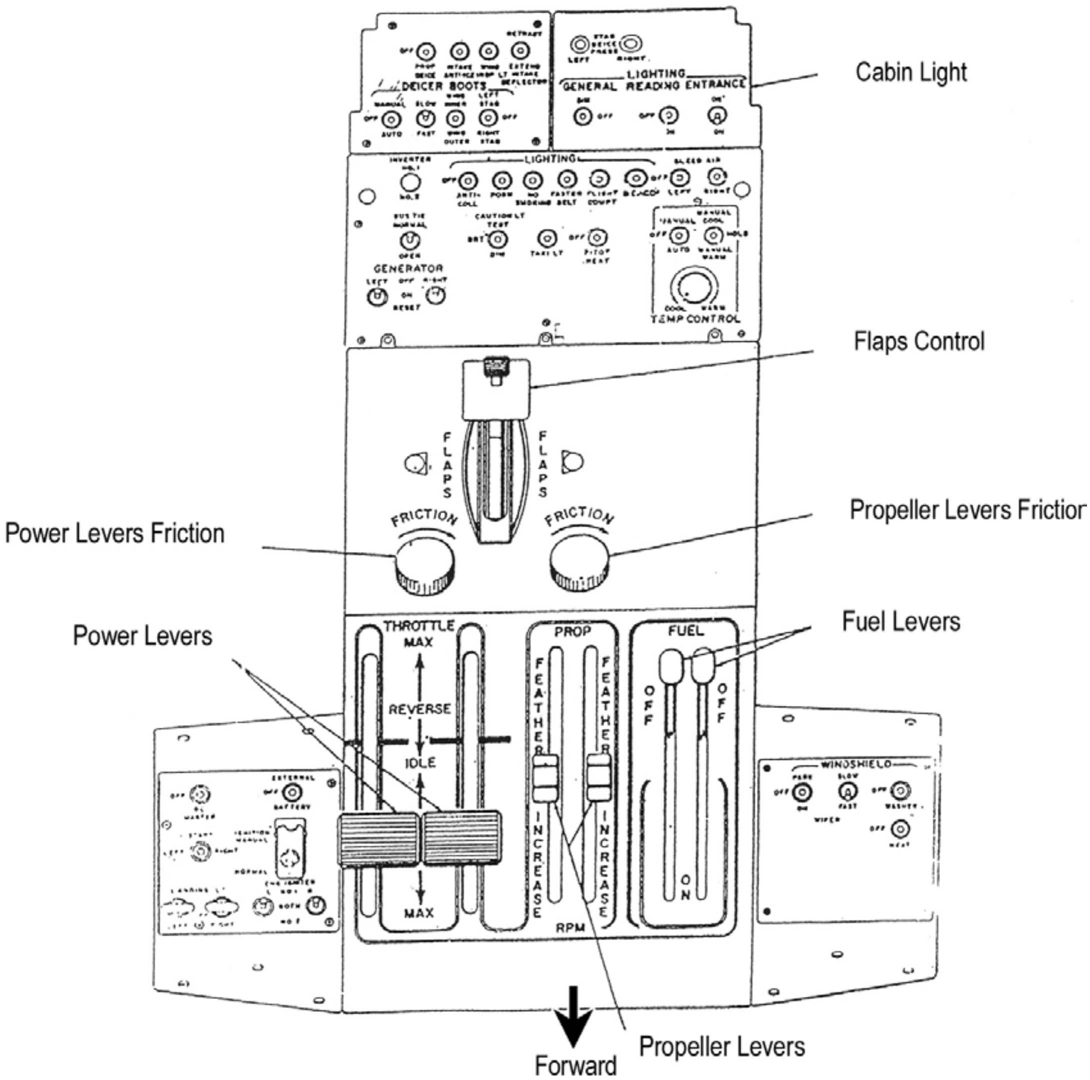
VUE GENERALE DES PANNEAUX POSTE



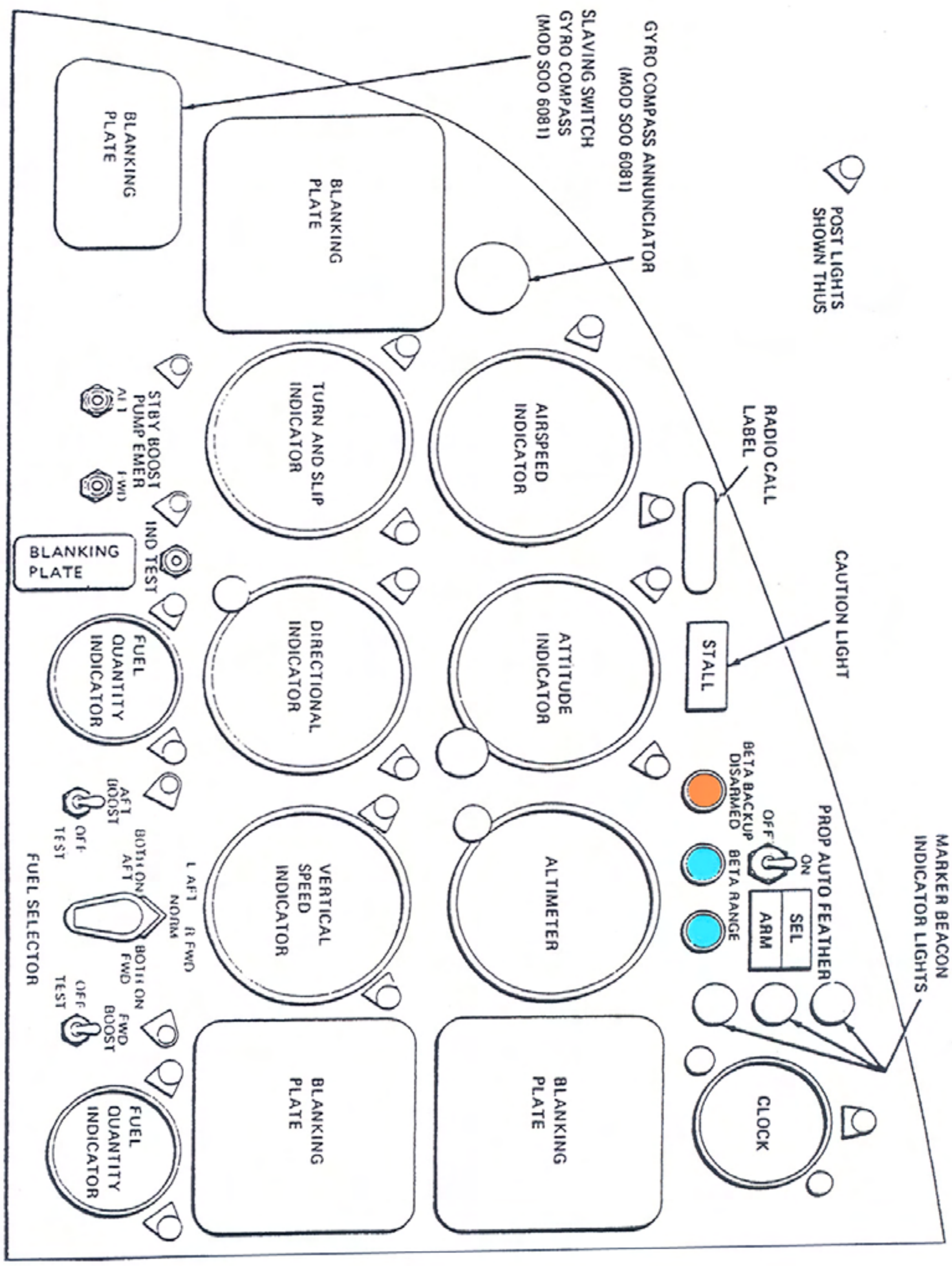
Légende de la page précédente

1. Anémomètre
2. Horizon artificiel
3. Altimètre
4. RMI
5. Plateau de route
6. Variomètre
7. Montre chronomètre
8. Jauges réservoir carburant
9. Alarme (lumineuse) décrochage
10. Indicateurs de torque
11. Tachymètres hélices
12. Indicateurs température turbine
13. Tachymètres turbine
14. Indicateurs pression huile
15. Indicateurs thermomètre huile
16. Débitmètre
17. Compas de secours
18. Voltmètre courant continu
19. Indicateur de débit génératrice
20. Indicateur de position des volets
21. Indicatif avion
22. Indicateur pression circuit frein
23. Indicateur pression circuit hydraulique
24. Potentiomètres d'éclairage
25. Indicateur température extérieure
26. Tableau de pannes
27. Panneau secours
28. Indicateurs de position de déflecteurs d' entrée d' air
29. Voyants bêta
30. Voyants drapeau automatique
31. Test jauges carburant
32. Interrupteurs pompes carburant cours
33. Interrupteurs pompes carburant
34. Interrupteur test régulateur survi-tesse
35. Interrupteur test drapeau automatique
36. Interrupteur arrêt alarme sonore incendie
37. Interrupteurs test bêta
38. Interrupteur sélection d'identification de débit génératrice
39; Sélecteur carburant
40. Surveillance température batterie
41. Robinet secours circuit statique
42. Interrupteur ventilateur
43; Commande ram air
44. Trim de profondeur
45. Trim de direction
46. Indicateur trim d'aileron
47. Trim d'aileron
48. Réglage palonnier
49. Boîtes de mélange radio
50. Panneaux oxygène éclairage
51. Bille/aiguille
52. Indicateur VQR
53. Indicateur DME
54. Panneau radio
55. Interrupteur micro
56. Panneau dégivrage pare-brise
57. Panneau de démarrage
58. Console supérieure
59. Panneau électrique supérieur

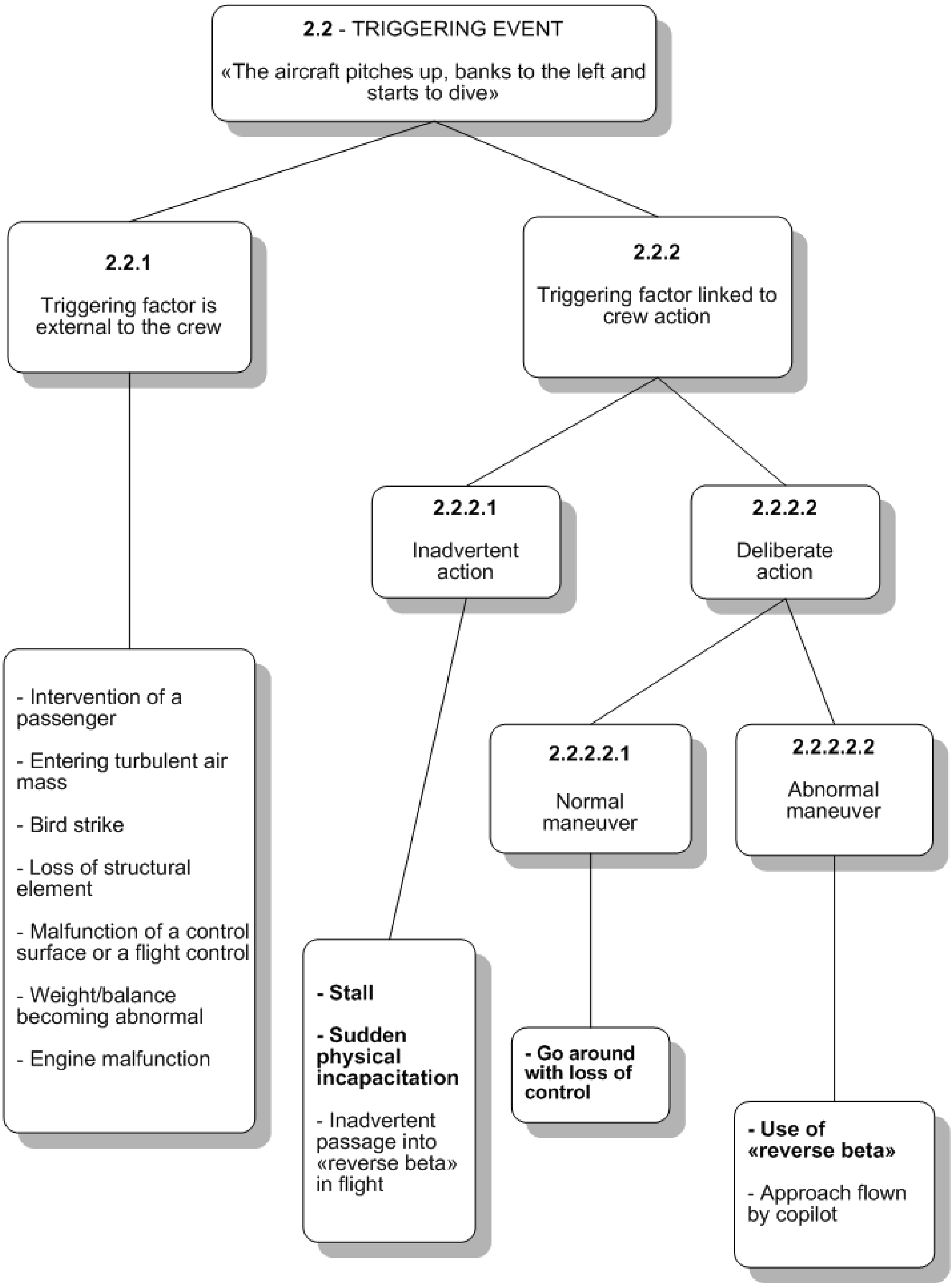
CONSOLE SUPERIEURE



PANNEAU INSTRUMENTS DE VOL



HYPOTHESIS TREE



Note: the description of the system included in paragraph 12.8.1 of the operations manual contains an error: the second clause indicates that the “beta system …. through action on the propeller lever” whereas it should in fact say “on the power lever”.

	CARAÏBES AIR TRANSPORT	ÉDITION I Oct 00
	MANUEL D’EXPLOITATION	AMENDEMENT N°0
DHC6	SYSTEMES AVION	PAGE B12/65

12.8 HÉLICE

12.8.1 Généralités

L’hélice tripale Hartzell équipant le DHC6/300 est une hélice à pas réversible dont la vitesse constante est contrôlée hydrauliquement par un régulateur combinant les fonctions d’un régulateur d’hélice, d’une valve bêta et d’un régulateur de carburant.

Le système bêta est le système permettant de commander la variation de calage de l’hélice par action sur la manette d’hélice. En fonctionnant en bêta, la régulation se fait sur l’angle de calage hélice et non sur la vitesse de rotation hélice.

L’ensemble de régulation hélice fait varier le calage de l’hélice :
- de la position drapeau (+ 87°)
- à la position pas totalement inversé (- 15°)

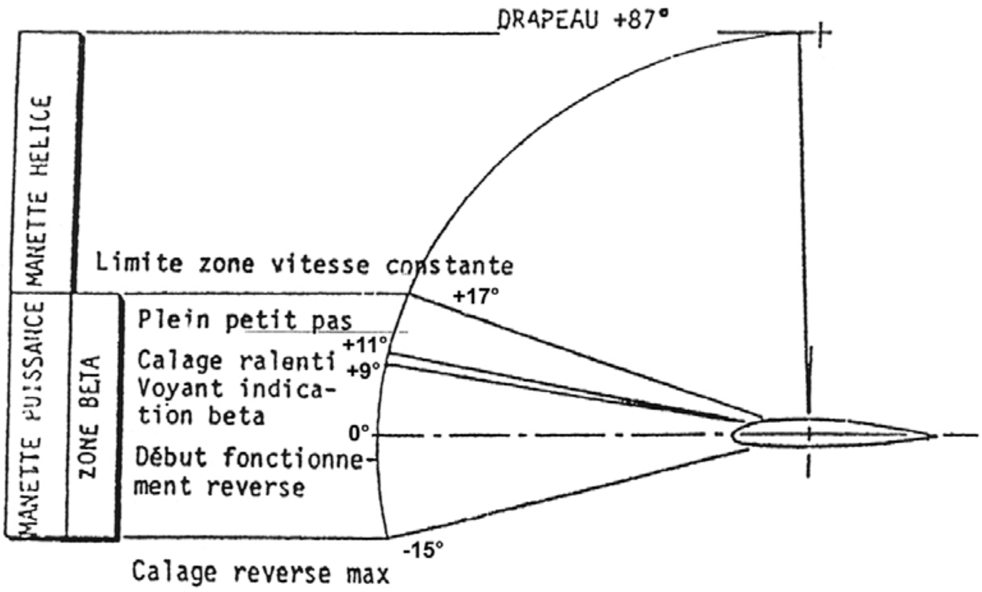
avec les positions particulières indiquées sur le schéma ci-dessous.

Le passage de la position drapeau à la position reverse est effectué par pression d’huile et le mouvement en sens contraire sous l’effet de masselottes en pied de pales et de ressort.

L’ensemble moteur/hélice est donc commandé par trois manettes qui ont les fonctions suivantes :
- Levier carburant : contrôle les fonctions de démarrage, d’étouffoir et de purge du circuit carburant.

- Manette de puissance : sélectionne un régime Ng du générateur de gaz, régime atteint seulement si le régulateur hélice l’autorise (voir ci-après le fonctionnement) ; choisit également l’angle de pale hélice dans la zone bêta.

- Manette d’hélice : permet la régulation à vitesse constante de l’hélice hors de la zone bêta.



12.8.3 Régulation hélice

☞ Notations

Les régimes générateur de gaz et hélice sont repérés par les symboles suivants :

Ng Régime générateur de gaz

Np Régime hélice

Nf Régime turbine motrice contrôlé par action directe sur le générateur de gaz (plus d'action régulateurs carburant (FCU) ni hélice (CSU)).

☞ Fonctions du régulateur d'hélice

En vol normal, il agit comme un régulateur de vitesse constante en maintenant la vitesse sélectionnée : la régulation se fait en faisant varier le pas des pales pour absorber la puissance en réponse aux modifications des conditions de vol.

Pendant le vol à faible vitesse propre, le régulateur peut être utilisé pour choisir l'angle de pale désiré (contrôle Bêta). Dans cette plage de contrôle, la puissance du moteur est réglée par le FCU et la partie carburant du régulateur d'hélice pour maintenir le régime turbine Nf à une vitesse légèrement inférieure à celle choisie.

☞ Actions des différents éléments sur la régulation hélice

● Le CSU (constant speed unit, régulateur à vitesse constante) agit hydrauliquement pour réguler Np entre 0 et 96 %.

● Le QSG (overspeed governor, régulateur de survitesse) agit hydrauliquement pour réguler Np de 96 à 101 %.

● Le régulateur Nf agit sur le générateur de gaz pour réguler Np de 101 à 106 % en traction et jusqu'à 95 % en reverse.

☞ Fonctionnement à vitesse déterminée

Pendant le fonctionnement à vitesse déterminée, les forces agissant sur l'ensemble hélice-régulateur-moteur sont en équilibre. La manette d'hélice a été placée à la position désirée, mettant ainsi le levier de commande du régulateur à la position correspondant au régime choisi et les pales sont au pas convenable pour absorber la puissance délivrée par le moteur. La force centrifuge des masselottes, alors en position verticale, équilibre exactement la tension du ressort. De ce fait, le tiroir de la vanne est dans une position où les orifices de passage d'huile de la pompe au servopiston sont fermés et l'huile revient à l'entrée de la pompe du réducteur.

Si la vitesse augmente, les masselottes pivotent vers l'extérieur en surmontant la tension du ressort, provoquant ainsi le soulèvement du tiroir de vanne ; en conséquence, l'huile passe du servopiston au puisard du carter des accessoires. L'augmentation du pas d'hélice en résultant provoque l'augmentation de charge sur le moteur, donc la diminution de la vitesse de rotation. La force centrifuge sur les masselottes est alors réduite et le tiroir ferme à nouveau les passages d'huile.

Si, au contraire, la vitesse diminue, la tension du ressort devient plus importante que la force centrifuge décroissante des masselottes qui pivotent vers l'intérieur provoquant ainsi la descente du tiroir et l'ouverture des orifices d'huile. L'huile passe ainsi au servopiston qui, surpassant les forces combinées des contrepoids et des ressorts de rappel, diminue le pas des pales : la charge sur le moteur diminue alors, d'où augmentation de la vitesse de rotation jusqu'à ce que les masselottes, sous l'action de cette augmentation de régime, ramènent le tiroir en position fermée.

☞ Démarrage à décollage

Le déplacement vers l'avant de la manette de la manette de puissance déplace progressivement la commande du régulateur de carburant (FCU) pour procurer l'augmentation de puissance. Dans le même temps, le mouvement de la came de commande bêta peut faire varier l'angle de pale.

La came bêta détermine l'angle de pale hélice jusqu'à ce que la combinaison vitesse/puissance soit telle que le régime hélice choisi soit atteint. A partir de ce point, l'augmentation de l'angle de pale sera déterminé par le régulateur pour maintenir la vitesse constante lors de l'augmentation de puissance.

☞ Croisière

En croisière, le régulateur d'hélice assure les variations de calage pour maintenir le fonctionnement à vitesse affichée.

☞ Descente et approche

Durant l'approche, le ralenti est réglé de manière à maintenir une puissance suffisante pour conserver une vitesse hélice constante et le calage de pale est modifié pour procurer un freinage aérodynamique.

☞ Dans le cas du contrôle bêta, lorsque la vitesse de rotation de l'hélice en moulinet est en dessous du point de début de régulation de CSU, les pales prennent le calage voulu sous l'action de la manette de puissance et par l'intermédiaire de la came de commande d'hélice. La vitesse de rotation est alors limitée par la section carburant du régulateur d'hélice.

● Section carburant du régulateur d'hélice

Cette section carburant est réglée en-dessous de la vitesse maximale du régulateur, vitesse qui est donc contrôlée via le circuit d'asservissement (Py) du régulateur carburant (FCU) et la puissance fournie par le générateur de gaz est ainsi réduite en-dessous de celle demandée dans le but de maintenir un régime hélice inférieur de 5 % environ au maximum, Un renvoi ouvre un orifice de passage d'air quand la vitesse est augmentée : l'ouverture de cet orifice, en communication avec le système pneumatique d'asservissement du FCU, réduit la fourniture de carburant régulé au moteur.

●Si, par contre, la vitesse propre est trop élevée, l'hélice continuera à tourner en moulinet à la vitesse déterminée même si la puissance n'est pas appliquée et que le moteur fonctionne au débit minimum.

● Pendant l'approche bêta, afin d'améliorer la précision du contrôle de la poussée et de la traînée, le calage de l'hélice est modifié par une came conçue de manière à obtenir un calage plus faible au ralenti qu'au décollage.

☞ Reverse

La reverse peut être sélectionnée pendant le roulement au sol après atterrissage .

Le calage de la pale hélice est alors déterminé de la même façon que pendant le contrôle bêta en traction normale.

La vitesse d'hélice est limitée par la section carburant du régulateur d'hélice (Nf) (par l'intermédiaire de Ng, dont la valeur peut aller jusqu'à 100 %) à une vitesse inférieure à celle choisie.

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