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INVESTIGATION REPORT

Accident to the Piper PA-31 "Navajo" registered F-HGPS

on 21 August 2018
at Verneuil-sur-Vienne (Haute-Vienne)

Time	Around 15:25[1]
Operator	IMAO
Type of flight	Aerial photography
Persons on board	Pilot and operator
Consequences and damage	Pilot and operator seriously injured, aircraft destroyed

This is a courtesy translation by the BEA of the Final Report on the Safety Investigation published in February 2020. As accurate as the translation may be, the original text in French is the work of reference.

[1] Unless otherwise stated, all times given in this report are in local time.

Fuel exhaustion, forced landing, collision with vegetation, during an aerial photography flight

1 - HISTORY OF THE FLIGHT

At 09:48, the pilot started up the engines for a VFR aerial photography flight in the Peyrelevade (Corrèze) and Ussel (Corrèze) sectors, accompanied by an operator. He announced to the controller at Limoges-Bellegarde airport (Haute-Vienne) that the aircraft's endurance was five hours. At 10:09, the aircraft took off. The manoeuvres to take photographs began 20 minutes later at an altitude of 7,000 ft for the first sector, then 6,500 ft for the second sector.

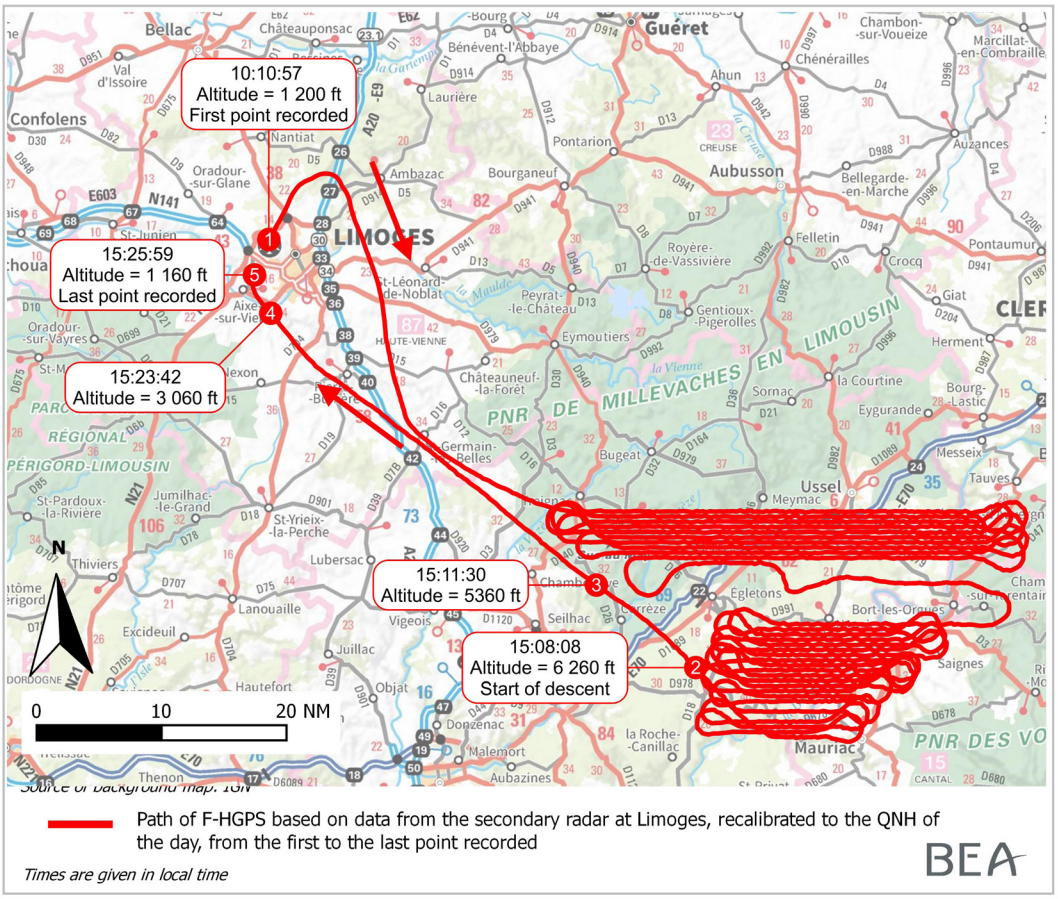


Figure 1: Flight path

At 15:06, the pilot announced on the frequency that the mission was finished and the aircraft was returning to Limoges-Bellegarde airport. The aircraft was about 52 NM south-east of the airport, at an altitude of 6,200 ft.

The pilot began the descent at 15:08.

At 15:19, the tower controller asked him to call back from the right-hand base leg for runway 03. The pilot replied that he estimated that he would arrive at the base leg four minutes later.

At 15:23, the aircraft descended below 3,000 ft. Two minutes later, the pilot announced: "*F-PS we're going to make an emergency landing, I've run out of fuel.*"

Shortly after this last message, the aircraft collided with trees and then with the ground 2 NM south of the threshold of runway 03. The pilot and the operator sitting in the rear were seriously injured.

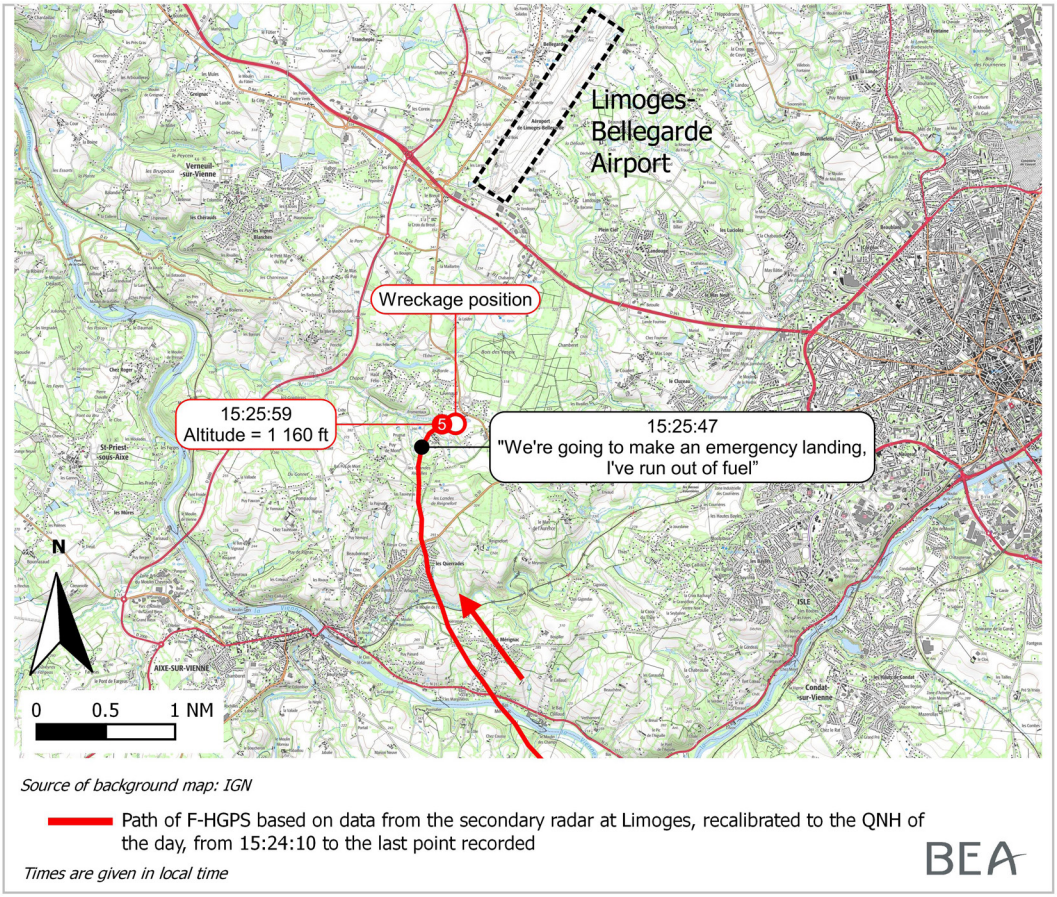


Figure 2: Wreckage position

2 - ADDITIONAL INFORMATION

2.1 Examination of the site and wreckage

The wreckage was grouped together and oriented at 077°, about 20 metres from a grove of trees at the bottom of a small valley. About 10 trees in this grove had been headed at a height of approximately 10 metres. The presence of open, flat fields about 700 m to the east of the accident site was noted.

Serious damage as a result of the impact with the trees and the ground was observed. On each half wing, the portion from the engine to the wing tip was severed at the time of impact with the trees. Because of the damage to the fuel tanks, the remaining fuel level could not be determined.

The visual examination of the propellers found that the power being provided by the engine on impact with the trees was low.

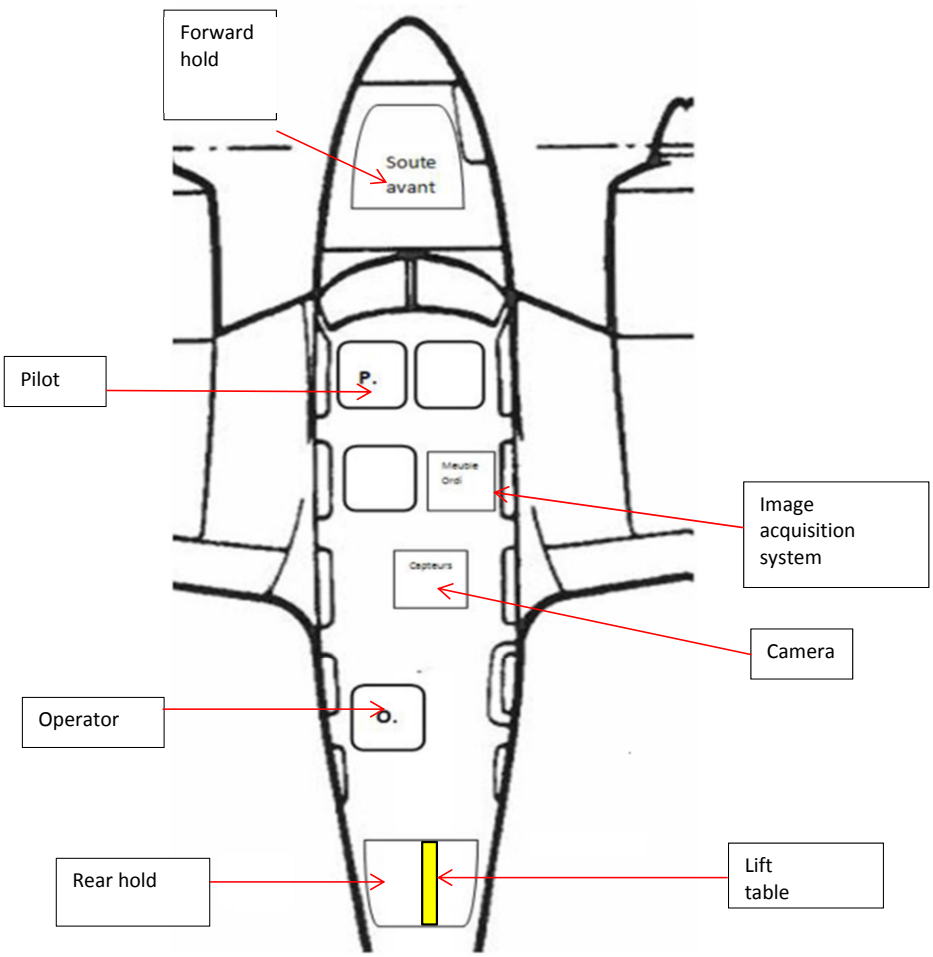
The examination of the wreckage did not find any pre-accident technical failures.

The engine power, propeller pitch and mixture controls were all in the forwards position. The fuel pump switches were in the ON position. The fuel tank selectors were set to the inner tanks[(2)]. The fuel tank crossfeed was set to *ON*.

[(2)] See Section 2.7 PA-31 aircraft information, Fuel Consumption.

The camera used for the photography, positioned in the centre of the aircraft, had become detached from its base, which broke during the impact[3].

[3] The camera was no longer in operation at the time of the accident.



Source: IMAO operations manual

Figure 3: diagram of the interior of F-HGPS

A lift table[4] in the aircraft's rear hold, behind the operator's seat, was used to install the camera in the aircraft, or to unload it. Although not necessary, it was usually kept onboard the aircraft during missions.

[4] In the lowered position, this lift table is 96 cm long, 45 cm wide and 22 cm high. It weighs 45 kg.

It was not secured during the flight. When the aircraft hit the trees and then the ground, it was thrown against the operator's seat. The operator's seat then folded forward and was torn from the floor. The operator was trapped between the camera and the lift table, which remained on the back of her seat.

The aircraft's clock stopped at 12:10[5], about four hours after the start of the flight, and about 1 hour and 15 minutes before the accident. The take-off time (red hands) indicated is 08:11 UTC[6], which is consistent with the actual take-off time. It is company practice to use the clock during flights, according to statements given by other company pilots, including the chief pilot.

[5] The clock is normally set to UTC time, 14:10 local time.

[6] 10:11 local time.

Figure 4: Photo of the clock at the accident site

An X-ray examination of the clock showed that the spring was completely slack[7]. The examinations and checks carried out on the clock did not reveal any significant failures, either in its operation or in its mechanism.

[7] As long as it is sufficiently tight, the spiral spring keeps the clock running.

2.2 Meteorological information

The weather conditions were anticyclonic and the air was hot and dry. There was a light north north-easterly wind in the morning, which veered to the east, remaining light, in the middle of the day. The temperature was around 16° at 5,000 ft.

2.3 Information about IMAO

IMAO acquires aerial data for customers in France and abroad.

At the time of the accident, the company was operating a fleet of eleven aircraft, including three PA-23s and four PA-31s, based in France or abroad. It employed five pilots.

The company's operations manual, written before it acquired the PA-31 F-HGPS, states that during flight preparation, the pilot-in-command must calculate the fuel required for the mission[8]. This fuel calculation must include taxi fuel, planned trip fuel and fuel reserves. The fuel reserves shall include at least the contingency fuel, the final reserve fuel and the additional fuel in accordance with current regulations.

[8] IMAO operations manual, section A.8.1.15.4 Fuel calculation.

Section A.8.1.15.1 Definition of the operations manual defines the contingency fuel as the amount of fuel required to cover the differences between the actual flight conditions and those taken into account during flight preparation (wind, ISA, planned or foreseeable holding). It is the higher of:

- 5% minimum of the planned trip fuel;
- five minutes at holding speed at 1,500 ft above the destination aerodrome in standard conditions.

The operations manual states that the final reserve fuel is the amount of fuel required to fly for 30 minutes. This is taken from the current European regulations: Part SPO – IR, paragraph SPO.OP.130 *Fuel and oil supply – aeroplanes*:

"*The pilot-in-command shall only commence a flight if the aeroplane carries sufficient fuel and oil for the following*:

(1) For VFR flights:
(i) by day, to fly to the aerodrome of intended landing and thereafter to fly for at least 30 minutes at normal cruising altitude;"

The amount of extra fuel is decided by the pilot-in-command to take account of:

- economic considerations (cheaper fuel at certain airports);
- a double trip if it is not possible to refuel during a stopover;
- additional margins, at his discretion, to facilitate flight management.

If necessary, the pilot can add the additional fuel and the alternate fuel to this. The operations manual also specifies how the fuel should be managed during the flight[9]. During the flight, the pilot must regularly check the fuel gauges in order to detect any anomalies (particularly leaks). He must know the aircraft's average hourly consumption in the current flight configuration in order to check the amount of fuel remaining. This must be converted into flight time to check the remaining endurance. The pilot is thus able to assess the amount that will be left onboard when the aircraft reaches its destination, which must be as much as or more than the planned final reserve.

The operations manual is based on current regulations. These regulations indicate in SPO.OP.190 In-flight fuel management that:

"*(a) The operator of a complex motor-powered aircraft shall ensure that in-flight fuel checks and fuel management are performed.*
(b) The pilot-in-command shall check at regular intervals that the amount of usable fuel remaining in flight is not less than the fuel required to proceed, with the planned reserve fuel remaining as required by SPO.OP.130 (…), to a weather-permissible aerodrome or operating site."

[9] IMAO operations manual, section A.8.3.7.1. Comparison of planned and actual.

2.4 Pilot experience and information

The pilot, aged 58 years, is the CEO of the company that owns the aircraft. He has held a CPL(A) commercial pilot licence since 23 May 2006, flew infrequently and replaced pilots according to the mission.

He had about 1,250 total flight hours, including 758 hours on multi-engine aircraft.

In the last two years, the pilot had flown the majority of his flights in a PA-23. His last flight in a PA-31 was on 3 November 2016 for 1 hour and 30 minutes, i.e. about 22 months before the accident flight.

In the last 12 months, he had flown about 80 hours, of which 72 were in PA-23s. The duration of these flights in PA-23s ranged from 1 hour 10 minutes to 7 hours 10 minutes. At the end of the flight lasting 7 hours 10 minutes, on 24 June 2018, the pilot added 673 litres of additional fuel. Only about 30 litres remained in the tanks at the time of landing[10]. The average endurance of the PA-23s used by the company is 6 hours 30 minutes.

[10] Source: the company's daily flights report, calculation of the quantity of fuel remaining carried out with the flight manual of F-HKHZ, the PA-23 used, belonging to IMAO.

Regarding in-flight fuel management, the pilot indicated that he checks that the tanks are full before the flight. He then monitors the consumption per tank, making consumption calculations on a sheet of paper during the flight. To perform this monitoring, he uses the time indicated by his watch and cross-checks it with a digital tablet. He specified that he is not in the habit of using the aircraft's clock. He indicated that he always finishes the mission with enough fuel for the return flight, including the regulatory reserves.

He indicated he was sure he had done the fuel consumption monitoring calculations for the accident flight[11].

[11] No documents relating to flight preparation or fuel management were found at the accident site or in the company's archives.

2.5 Operator information

The operator, aged 26 years, did not hold an aviation licence. She was an employee of IMAO and was responsible during the flight for checking that the photos were taken correctly on the different axes. She did not take part in the flight management.

She indicated that she and the pilot had agreed before the flight to stop the mission once the nine photo storage hard drives were "*full*".

During the flight, the operator asked the pilot for the remaining flight time. He said that the aircraft's endurance was 5 hours 30 minutes. The operator specified that, on other flights in the PA-31, the pilots had said the endurance was 4 hours 30 minutes. Since she had no aviation knowledge, this did not strike her as odd.

The operator added that this was the first time the return to the airport had taken place once the hard drives were full.

She indicated that the right engine stopped first, when the aircraft was near the airport. The pilot seemed surprised. However, she specified that the pilot gave the impression that he could land on the runway without any problem. The pilot then announced to the controller that the aircraft had run out of fuel. The operator indicated that she had sent a message with her phone to warn her colleagues. When the left engine stopped, the pilot asked her to check her seat belt.

The operator explained that the pilot did not lose control of the aircraft. She was seated behind the camera in accordance with the instructions in the operations manual. She was not aware of an instruction regarding the use of another seat during take-off, landing or in an emergency. The instruction she had been given was to sit in the seat at the rear and fasten her seat belt[12].

[12] See Section 2.7 PA-31 aircraft information, Survival aspects related to the Supplemental Type Certificate.

2.6 Witness statement

A witness on the ground, who lived approximately 500 m from the accident site, heard a very faint engine noise as if the engine were idling. He saw the aircraft fly over a hamlet at low height in a nose-down attitude. The aircraft disappeared from his field of vision and then he heard the noise of the accident. He rushed to the scene and called the emergency services at 15:27. As he approached the aircraft, he saw the pilot first and called the emergency services again. He then heard the operator who was behind. When he entered at the rear of the aircraft, having opened the door, he saw that the operator's seat was folded forward, trapped between the camera and the lift table. He cut the seat belt and released the trolley. As he was unable to completely remove the camera, he held it until the emergency services arrived, to take the weight off the operator.

2.7 PA-31 aircraft Information

The Piper PA-31 Navajo is a five- to seven-seat aircraft with two 310 hp Lycoming engines. Before its acquisition by IMAO in 2015, F-HGPS was registered OY-BHF. It was equipped with a camera for aerial photography missions. It had two front seats and two rear seats, one behind the pilot's seat, the other at the rear of the aircraft[13].

[13] See Figure 3: diagram of the interior of F-HGPS.

On the accident flight, the aircraft remained within the weight and balance limits established by the manufacturer.

Fuel consumption

The PA-31 Navajo has four wing tanks[14] with a total capacity of 192 US gallons, of which 186 are usable. Its mean endurance is about 4 hours 30 minutes, according to the company's chief pilot. This corresponds to the mean endurance of the PA-31's flights. Over the last twelve months, the mean endurance calculated from the PA-31's logbook was 4 hours 27 minutes. It was noted that on photography missions, because lower engine speeds are used, the PA-31's endurance can increase significantly, sometimes above five hours.

[14] Each wing has two tanks, one "*outer*" tank (at the wing tip) and one "*inner*" tank (near the airframe).

Each engine is supplied with fuel by the inner "*IN*" tank or the outer "*OUT*" tank of the associated wing. A selector for each engine is used to choose between these two tanks.

A tank crossfeed selector can be used to supply fuel to the engine on the opposite side from the tanks. This is used where necessary to balance the aircraft during flight by supplying both engines from the left and right tanks simultaneously.

During contact with the tower controller at start-up, the pilot announced an endurance of five hours of flight. Spectral analysis of the exchanges between the pilot and the controllers did not detect any engine malfunctions from take-off at 10:09:20 until the last contact at 15:23:13, i.e. for 5 hours, 13 minutes and 53 seconds. As the last exchange, at 15:25:46, with the tower controller at Limoges-Bellegarde airport was too brief, it was not possible to determine whether the engines were still in operation.

For the flight on the day, the consumption[15] was estimated by calculation to be 183 US GAL out of the 186 usable gallons, not including start-up and taxiing. Spectral analysis of the radio communications between the pilot and air traffic controllers during the flight indicates that the engine speed was 2200 rpm while cruising at an altitude between 6,500 and 7,000 ft.

[15] Calculation based on information from the flight manual, the flight conditions on the day and previous flights of F-HGPS.

Supplemental Type Certificate (STC)

A *Supplemental Type Certificate* (STC) is a document issued by the U.S. Federal Aviation Administration (FAA) confirming authorization to modify an aircraft or aircraft equipment. By extension, the European authorities use similar terminology.

An STC describes the authorized modifications and the consequences of these modifications for the performance or behaviour of the aircraft compared to its original certification. These modifications may be the subject of additional instructions, and are then added to the flight manual as a supplement. Passenger/operator positioning and evacuation instructions may be changed if they are affected by technical modifications. The STC also states exactly which versions of the basic aircraft model are concerned. It is issued by name to the company or design office that submitted the technical file and it bears a number. It is the property of whoever holds the technical file and it is necessary to obtain their agreement before making any modifications that affect the STC. An STC may be sold on or transferred, but the transfer of ownership must be approved by the supervisory authority.

F-HGPS was modified for aerial photography by an approved workshop in 2010, before it was acquired by the company. The instructions associated with this modification were approved by the FAA in the form of an STC included in a flight manual supplement entitled "*Flight Manual Supplement, Modification 2022914, Aerial Survey Equipment*". This supplement was approved by the European Aviation Safety Authority (EASA) in 2010.

Since this modification, there has been a passenger seat behind the pilot and another seat at the rear facing the camera[16].

[16] See Figure 3: diagram of the interior of F-HGPS.

Camera equipment installed onboard

The camera installed onboard is a unique prototype designed by IMAO, which developed it specially for photometric photography. The camera is a floor camera, installed on a gyro-stabilized mount. The camera weighs about 85 kg and the mount 30 kg. The camera is connected to a rack comprising an image acquisition system that includes the nine storage hard disks, a computer and its screen. This modification to the aircraft was approved by the DGAC.

Source: IMAO

Figure 5: installation of the camera equipment onboard F-HGPS

Survival aspects related to the Supplemental Type Certificate

In paragraph "*A.8.3.12. Use of the vacant crew seat*", the operations manual states that the operator must be seated next to the systems in the rear seat. It states that during ferry flights or if the pilot-in-command becomes incapacitated, the operator may be required to sit in the right front seat.

However, with the modification made in 2010 and the associated STC, instructions were added to the flight manual specifying, among other things, that during take-off, landing and in emergencies, the operator must be in the "*copilot*" seat to the right of the pilot, or in the seat behind the pilot's seat. The instructions specify that a label[17] must be positioned in full view of the operator, at or near the operator's position when taking photographs. In the flight manual supplement, this instruction has also been added to the take-off and landing checklists.

Prior to 2015, two other PA-31s that had already undergone similar modifications before they were acquired by IMAO, were also in operation. Since these modifications do not have the same STC references, there are no such instructions in the flight manual for these PA-31s.

When F-HGPS was acquired in 2015, the company operated the aircraft in the same way as the other two PA-31s. It had not realised this instruction existed, and therefore had not implemented it when carrying out these flights. Nor had it affixed the labels in full view of the operator onboard F-HGPS. The operator always sat in the rear seat for the entire flight in accordance with the company's operations manual.

[17] Text taken from the flight manual supplement to be displayed in full view of the operator: "*OPERATOR HAS TO BE SEATED ON L/H OPERATOR SEAT (BEHIND PILOT) OR COPILOT SEAT DURING TAKE OFF, LANDING AND IN EMERGENCY*".

3 - LESSONS AND CONCLUSION

On the flight towards Limoges-Bellegarde airport, the aircraft found itself short of fuel. Fuel exhaustion occurred after about 5 hours and 15 minutes of flight. During the forced landing, the aircraft collided with the trees and then with the ground. The pilot and the operator, sitting in the rear, were seriously injured.

When the fuel exhaustion occurred, the pilot performed the emergency actions and turned right. The tank crossfeed was found in the "*ON*" position. The pilot could have set it thus either to prevent fuel exhaustion or as part of the emergency actions performed when the fuel exhaustion occurred.

The airport's altitude is 1,300 ft. The altitude of the aircraft at the time of the fuel exhaustion was 1,460 ft, which meant that it could not reach the airport safely.

The decision to turn right could be explained by the pilot's attempt to reach flat fields approximately 700 m east of the accident site.

The following could have contributed to the fuel exhaustion:

- The endurance indicated at start-up being exceeded, which may be explained by the fact that the pilot was used to flying the PA-23, which has a greater endurance.
- The priority of taking as many aerial photographs as possible to use up the full capacity of the storage hard drives before returning to the airport, stated during flight preparation with the operator.
- Although the pilot said that he did not use the clock, which was stopped at 12:10, one hour before the accident, it may have given him a false indication and reinforced his assessment of the remaining endurance.

The following could have contributed to the operator's serious injuries:

- Differing instructions for the operator's seating position in the operations manual and in the F-HGPS manual, with the F-HGPS manual recommending the use of the seats to the right of or behind the pilot rather than near the equipment installed on the aircraft.
- The fact that the lift table was carried on a mission flight and was not secured.

Measures taken by the company since the accident

Following the accident, the company has implemented the following measures:

- Mandatory briefing before and after each flight with the chief pilot, covering fuel consumption.
- Introduction of a bimonthly written theory examination for all pilots on knowledge of the company's aircraft, including in particular the performance, endurance and fuel consumption of the aircraft.
- Introduction of a monthly meeting with pilots and operators including the presentation and analysis by a pilot/operator pair of an incident or accident involving an aircraft doing aerial work. The event presented could be one that happened outside the company.

- Pilot testing of a smart clock with audible and visual reminders to help monitor consumption. The test results could lead to the installation of these clocks throughout the fleet.
- Amendment of the operations manual to incorporate the instructions added to the F-HGPS flight manual. These instructions on where operators should sit will be applied during take-off and landing and in emergencies for all missions.
- Carrying of the lift table, secured in the aeroplane's rear hold, only on ferry flights.