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INVESTIGATION REPORT

Accident to the AIRBUS - AS350 - B registered F-GIBM

on 07 March 2021
at Touques (Calvados)

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BEA2021-0089.en/March 2022

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SPECIAL FOREWORD TO ENGLISH EDITION

This is a courtesy translation by the BEA of the Final Report on the Safety Investigation published in February 2022. As accurate as the translation may be, the original text in French is the work of reference.

Contents

Glossary

Abbreviation	English version	French version
AMC	Acceptable Means of Compliance	
AME	Aero-Medical Examiner	
ATO	Approved Training Organisation	
ATPL	Airline Transport Pilot Licence	
BPL	Hot air Balloon Pilot Licence	
CPL	Commercial Pilot Licence	
DGAC	French civil aviation authority	Direction Générale de l'Aviation Civile
DSAC-O	French civil aviation safety directorate - West regional office	Direction de la Sécurité de l'Aviation Civile - Ouest
DTO	Declared Training Organisation	
EASA	European Aviation Safety Agency	
EHST	European Helicopter Safety Team	
FCL	Flight Crew Licence	
FI	Flight Instructor	
GNSS	Global Navigation Satellite System	
HEMS	Helicopter Emergency Medical Service	
HLS	Helicopter Landing Site	
ICAO	International Civil Aviation Organisation	
ISA	International Standard Atmosphere	
LAPL	Light Aircraft Pilot Licence	
MEL	Minimum Equipment List	
MGB	Main GearBox	
NCO	Non-Commercial Operations	
OGE	Out-of-Ground Effect	
PPL	Private Pilot Licence	
QNH	Altimeter setting required to read an altitude	
SPL	Sailplane Pilot Licence	
TCM	Technical Crew Member	
TEM	Threat and Error Management	
TR	Tail Rotor	
UTC	Coordinated Universal Time	
VFR	Visual Flight Rules	

Synopsis

Time	Around 17:45[1]
Operator	Private
Type of flight	Own-account transport
Persons on board	Pilot, passenger
Consequences and damage	Pilot and passenger fatally injured, helicopter destroyed

[1]Except where otherwise indicated, the times in this report are in local time. One hour should be subtracted to obtain the UTC time in Metropolitan France on the day of the event.

Collision with a tree during take-off from a helicopter landing site

The pilot and passenger, on a private Helicopter Landing Site (HLS) at Touques, prepared to take off for a VFR flight bound for one of the passenger's properties south of Beauvais (Oise).

Shortly after the engine start-up, the helicopter was in hover flight and then climbed vertically facing trees, the highest treetop being at 23 m. The helicopter was at a height of around 19 m when the blades of the main rotor struck some branches. Under the impact, the tail boom separated from the helicopter. The helicopter yawed about itself while flying forward, fell and then struck the ground.

The manoeuvring area on the HLS, chosen the day before the accident when landing, restricted the possibilities of safely manoeuvring. This choice probably pushed the pilot to carry out a vertical take-off with a small safety margin with respect to the tree branches which were in the shade. The assessment of the distance to the obstacles may have been difficult in a shady environment with low light contrast.

The BEA has issued two safety recommendations addressed to EASA with respect to training in the use of confined areas and raising awareness about the consequences of ageing on the performance of the visual system.

1- FACTUAL INFORMATION

1.1 History of the flight

Note: The following information is based on the observations made on the accident site, the Brite Saver data recorder, the onboard geolocation system, statements, videos, radio communication recordings and radar data.

1.1.1 Flights on Saturday 6 March

On Saturday 6 March, the pilot, accompanied by the passenger, took off at around 09:30 from the Issy-les-Moulineaux heliport (Hauts-de-Seine). After an intermediate leg, they landed on the private HLS at Framicourt (Somme) at the beginning of the afternoon.

They left this HLS at around 17:45 bound for the Touques HLS[2], in the grounds of a private property, landing there at 18:27.

[2] It is to be understood that the term "Torques HLS" in this report refers to the private HLS used on the day of the accident.

The approach was started on a heading of 150° which offered the most obstacle-free final approach area to reach the centre of the HLS. There was a tailwind. The pilot who had the controls stopped the helicopter's forward flight with a nose-up input at a hover height in the order of 1.50 m, then immediately levelled off the helicopter and slowly flew forward to the touchdown point, in an area of the HLS lit by the sun. The tips of the main rotor blades were less than 1 m from a tree approximately 4.50 m in height, the branches facing the pilot were in the shade.

1.1.2 Take-off on Sunday 7 March

The take-off was carried out at 17:43 in light conditions similar to those when landing the day before. The helicopter rose vertically without backing up. A person on the ground indicated that they then saw the helicopter's pitch attitude decrease before the main rotor blades struck the branches of a tree at a height of approximately 19 m. The tail boom separated from the airframe of the helicopter which fell forwards turning about its yaw axis until impact with the ground.

The duration of the flight from the start of hover to the collision with the branches was 11 s.

1.2 Injuries to persons

	Injuries		
	Fatal	**Serious**	**Minor/None**
Crew	1		
Passengers	1		
Others	0		

1.3 Damage to helicopter

The helicopter was destroyed.

1.4 Other damage

The fuel from the helicopter's fuel tank spilled onto the ground.

1.5 Persons on board information

As required by the health rules in connection with the Covid 19 epidemic and in force at the time of the accident, the pilot and passenger held a document indicating that they were travelling for business purposes during the curfew hours.

The pilot and passenger were long-time friends.

1.5.1 Pilot

The 74-year-old pilot held:

- A valid CPL(H) licence;
- Valid Airbus AS350, EC130 and Robinson R22 and R44 type ratings;
- A valid helicopter flight instructor FI (H) rating issued on 9 August 2020.

The pilot also held an ATPL (A) licence with ratings including the Airbus A320, A330, A340 and A350 type ratings, all valid.

His pilot logbook was not found, nor was any other record found indicating his helicopter experience.

Statements made during flight checks and supported by the analysis of the logbook of F-GIBM on which the pilot exclusively flew enabled us to estimate that his helicopter flight time was around:

- 1,400 flight hours in total;
- 100 hours on the AS350;
- 15 hours and 45 minutes between 1 January and 14 February 2021 on F-GBIM.

The pilot held an approval to use HLS which was valid until 25 June 2021.

His class 1 medical fitness certificate was valid with a VML limitation which required him to wear a suitable correction for distant, intermediate and near vision when flying. This limitation also required him to carry a spare set of spectacles in the cabin. The pilot's medical file indicated that the vision disorders measured had been stable for several years. The pilot did not wear contact lenses instead of his spectacles.

1.5.2 Passenger

The 70-year-old passenger held an ATPL(A) licence with valid type ratings for different aeroplanes, in particular the Falcon 10 / 20 / 50 / 900 / 2000. He had logged approximately 5,000 flight hours as a pilot.

A logbook in the passenger's name was found on board the helicopter.

Started on 12 August 2020, this logbook listed 49 flights carried out between 18 August 2020 and 6 March 2021, representing a total flight time of 29 hours 26 minutes in dual flight, including a night flight of 50 minutes. In the "*Comments*" section, there was the name of the accident pilot, his FI rating and his signature. All of these flights corresponded to flights recorded in the F-GIBM logbook, including the flight the day before the accident.

He did not hold a helicopter pilot licence and was not registered with a training organisation as a student helicopter pilot.

1.6 Helicopter information

The Airbus AS350 B is a single-engine, five-seat helicopter with a maximum allowable weight of 1,950 kg.

The helicopter belonged to Dolijet, a company founded and managed by the passenger. He wanted to operate F-GIBM for a period of one year at the end of which he envisaged purchasing a similar more recent helicopter.

The pilot flew in the F-GIBM in a private capacity.

1.6.1 Version and certification basis

When delivered in 1981, F-GIBM was a D version equipped with a Lycoming LTS 101 turboshaft engine. The helicopter was then transformed into a B version with the installation of a Safran Helicopter Engine Arriel 1B turboshaft engine.

The helicopter was equipped with dual flight controls at the pilot's request.

1.6.2 Dimensions

The main dimensions of the aircraft are indicated in Figure 1.

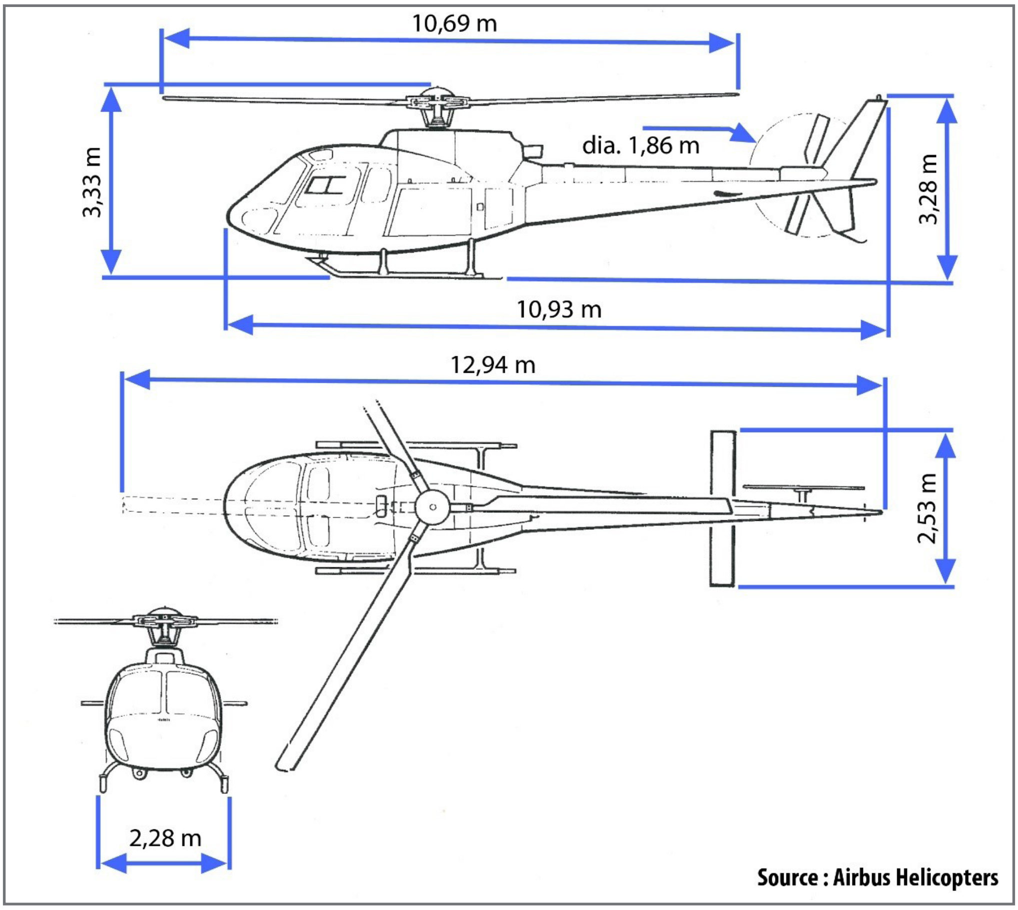


Figure 1: Helicopter dimensions

1.6.3 Airframe

Manufacturer	AEROSPATIALE		
Type	AS350 - B		
Serial number	1424		
Registration	F-GIBM		
Entry into service	1981		
Certificate of Airworthiness	*110903*	*14 April 2010*	
Airworthiness review certificate	*FC-001*	*From 15 July 2020*	*To 13 August 2021*
Hours logged as on 8 March 2021	8,011.52 hours		

The helicopter's front seats were bucket seats[(3)]. They were equipped with four-point harnesses. The lap belts were secured to the cabin floor and the shoulder harnesses were integral with the seat.

[(3)] Airbus Helicopters introduced a new generation of front seat in 1999 called "high energy absorbing seats". F-GIBM was not equipped with these new seats.

1.6.4 Engine

Manufacturer	Turbomeca
Type	Arriel 1 B
Serial number	375
Date of manufacture	21 July 1980
Total operating (cycle) time on 08 March 2021	*9,211.83 hours (14,473 cycles)*

1.6.5 Weight and balance

With two people on board, 75 kg of luggage and 340 litres of fuel, i.e. 63 % of the fuel tank's capacity[(4)], the helicopter's take-off weight was 1,718 kg (for a maximum weight of 1,950 kg). The helicopter was within the weight and balance envelope.

[(4)] This information was recorded in the helicopter's logbook by the pilot when preparing the flight.

1.6.6 Limitations and performance

Section 2.1 "Operating limitations" of the flight manual indicates the landing and rotor stopping limitations on slope for the F-GIBM:

- Nose-up: 10°
- Nose-down: 6°
- Sideways: 8°.

In the atmospheric conditions at the time of the accident and according to the Out-of-Ground-Effect (OGE) performance charts, the helicopter had sufficient power to carry out a vertical take-off above a pressure altitude of 10,000 ft.

1.6.7 Maintenance and faults observed

The last maintenance operations mentioned in the aircraft logbook were carried out between 27 February and 5 March 2021. They consisted of:

- Replacing the fuel pump;
- Replacing the fuel flow flexible ball control;
- Replacing the fuel pressure transmitter;
- Replacing the "*KLAXON*" fuse;
- Installing the short step.

On accepting the helicopter on Friday 5 March, the pilot and mechanic observed that the artificial horizon was inoperative. The failure was confirmed by the pilot during the positioning flight to Issy-les-Moulineaux heliport. He kept to his plan to fly specifying that he did not need this instrument as he would be flying by day and in VMC conditions.

During this positioning flight, the passenger who accompanied the pilot indicated that the artificial horizon was vibrating.

1.7 Meteorological information

Anticyclonic conditions generating a moderate northeasterly wind were present over the Normandy region from 6 to 7 March. A clear sky and visibility greater than 10 km were associated with these conditions.

The wind data recorded by the Deauville Normandie airport weather station, situated close to four kilometres north-east of the accident site was the following:

- At the time of the landing on 6 March: mean wind of 9 kt from 030°, gusts not exceeding 18 to 20 kt.
- At the time of the take-off on 7 March: mean wind of 5 to 10 kt from 010°, gusts not exceeding 15 to 16 kt, ground temperature of 5° C, QNH 1023.

The sun's azimuth angle and height on the approach to and departure from the accident site were the following:

Dates	Height	Azimuth angle
06 March 2021 at 18:27	3.19°	258.19°
07 March 2021 at 17:43	10.17°	249.87°

Sunset was at 18:52 on 7 March 2021.

1.8 Aids to navigation

No navigation aid was required to use this HLS.

1.9 Communications

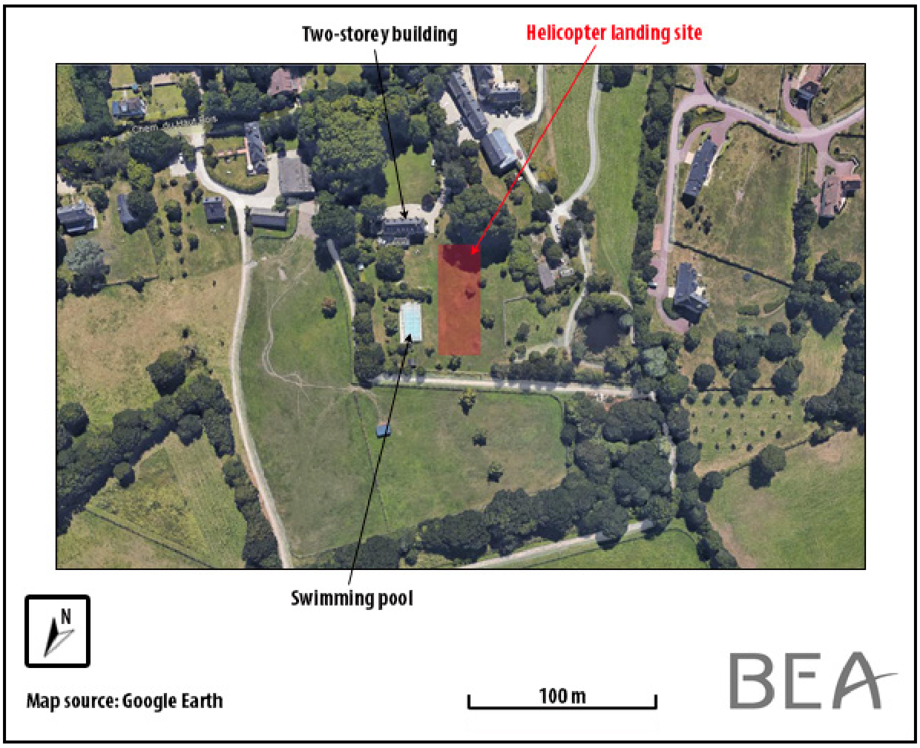
The pilot contacted the air traffic controllers of Deauville Normandie airport on:

- Saturday 6 March, at the end of the afternoon, to indicate his intention to land on the HLS.
- Sunday 7 March, before the accident flight, to indicate his intention to take off and head south of Beauvais. In return, the air traffic controllers gave him the wind information.

1.10 HLS information

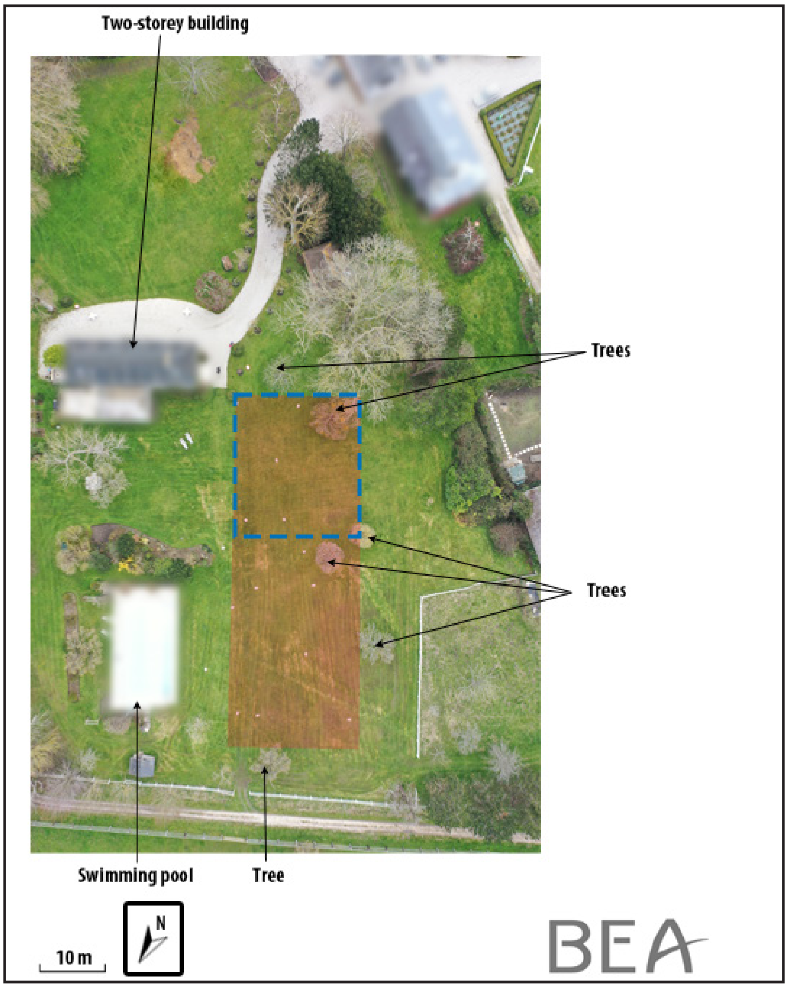
The HLS was a grass terrain situated in the wooded grounds of a private property.

The rectangular-shaped HLS was roughly oriented 150° and measured around 50 m by 18 m at its largest point. It was partly bordered by isolated trees, a building and a swimming pool.



(This view does not show the vegetation as it was on the day of the accident)

Figure 2: Overall view of HLS



Source: BEA. Aerial photo taken two weeks after the accident using the BEA drone

Figure 3: Detailed view of HLS

The HLS had two distinguishable areas: one, the furthest forward with respect to the approach path (see Figure 3, shown by blue dashes) measured around 20 m by 18 m, the second, the furthest back measured 30 m by 18 m. The ground of the lowest part of the terrain and the furthest from the building was spongy, making landing the helicopter and the boarding/disembarkation of passengers complex.

The HLS had variations in slope illustrated in Figure 4. These restricted the landing areas as specified in the aircraft flight manual.

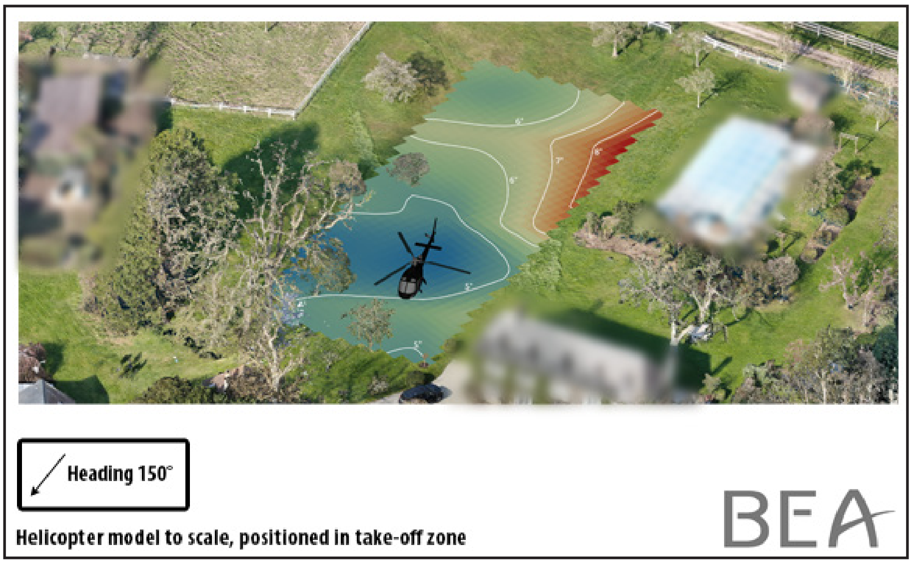


Figure 4: Accident site with areas of gradient

The gradation of colour indicates the slope:

- *in the blue coloured area, the surface is almost flat, it is the highest part of the site;*
- *In the red coloured area, the slope of the surface is outside the helicopter's limitations (see paragraph 1.6.6), it is the lowest part of the site.*

1.11 Flight recorders

The helicopter was not equipped with a flight recorder. It was not a regulatory requirement.

F-GIBM was, however, equipped with a *Brite Saver* system installed on the pedestal. This system recorded the engine parameters for maintenance aid purposes. The BEA was able to read out the data. No indication regarding a malfunction was recorded during the start-up and take-off. The engine was producing power until the impact with the tree. The recorded data is shown in graph form (see Appendix 1).

Note:
Two engine torque exceedances for a duration of one and two seconds were observed during the last flight on Saturday 6 March. The threshold used to determine the exceedances had been fixed by the maintenance workshop. The maximum values recorded were below the thresholds in the helicopter maintenance manual. On powering up the helicopter on the day of the occurrence, an amber EXC light would have flashed on the unit indicating this exceedance. The illumination of the light is inhibited when the helicopter leaves the ground.

The BEA also recovered the position data from several systems:

- The data from the geolocation system belonging to the maintenance workshop, France Copter. This system was kept in the pilot's flight bag. The position data (GNSS position, heading, track, speed) was sent to and recorded on a remote server. This data was saved for two months.
- The data from a *PowerFlarm* computer belonging to the pilot. The equipment was not on board the helicopter on the day of the accident. The flights recorded by the equipment were read out by the BEA.

The video data recorded on the helicopter's approach to the HLS on 6 March and at the time of its departure on 7 March was also retrieved. The result of the position data and video read out is given in paragraph 1.16.2.

The tablets and mobile phones belonging to the pilot and passenger could not be read out.

1.12 Site and wreckage information

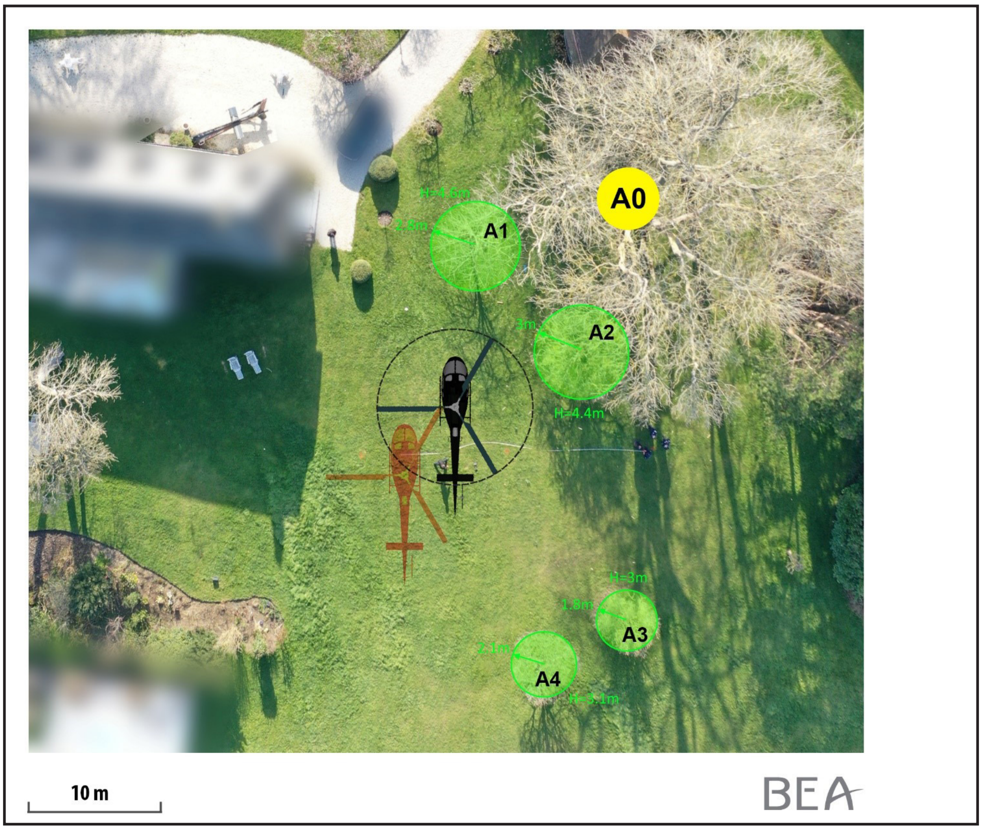
1.12.1 Accident site

The marks from the landing gear skids left by the helicopter when it landed the day before (see Figure 7, parallel marks shown in red) are the reference point for describing the accident site.

The helicopter was positioned in an area measuring around 20 m x 18 m within the HLS described in paragraph 1.10. The marks left in the ground by the skids made it possible to estimate that the helicopter was oriented on a heading of 140°.

The following figures show that the take-off point was situated close to leafless trees of various heights:

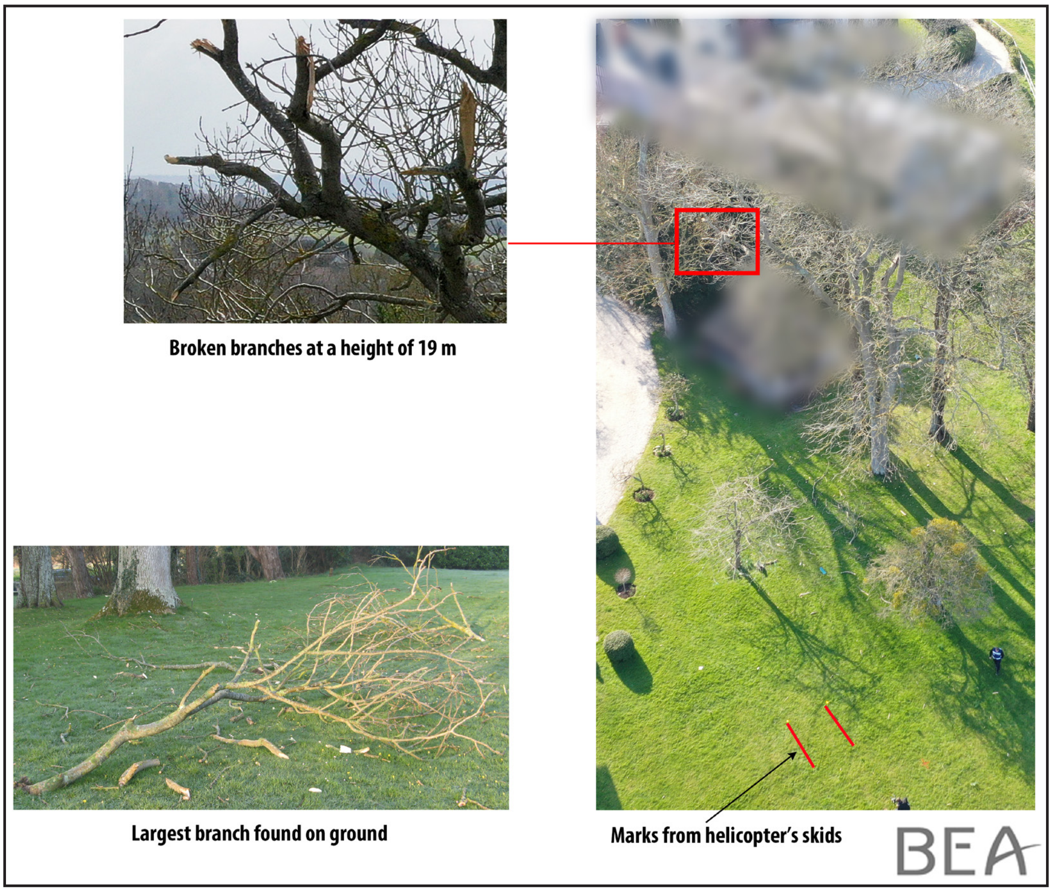
- ❒ Ahead of and to the right of the helicopter, two trees of a maximum height of around 4.60 m arbitrarily designated A1 and A2.
- ❒ Ahead of and to the right of the helicopter, beyond the first two trees described above, an ash tree around 23 m tall and the largest in the area concerned, arbitrarily designated A0.
- ❒ Aft of the helicopter, two trees of a maximum height of around 3 m arbitrarily designated A3 and A4.



Source: BEA. Aerial photo taken in the morning of 8 March 2021 using the BEA drone

Figure 5: Take-off area and its direct environment, with the position of an aircraft model, shown to scale, at the time of the take-off (black) and where it was usually parked (red).
The shade from the trees does not correspond to the shade on the day of the accident

The highest severed branches of the ash tree were situated at a height of around 19 m. These branches were all in the same small area of the tree covering a sector of around 140° (view from helicopter). When the aircraft was on the ground in its take-off area, the distance between the perpendicular of the severed part of the branches and the main rotor blade tips was around 8.50 m.

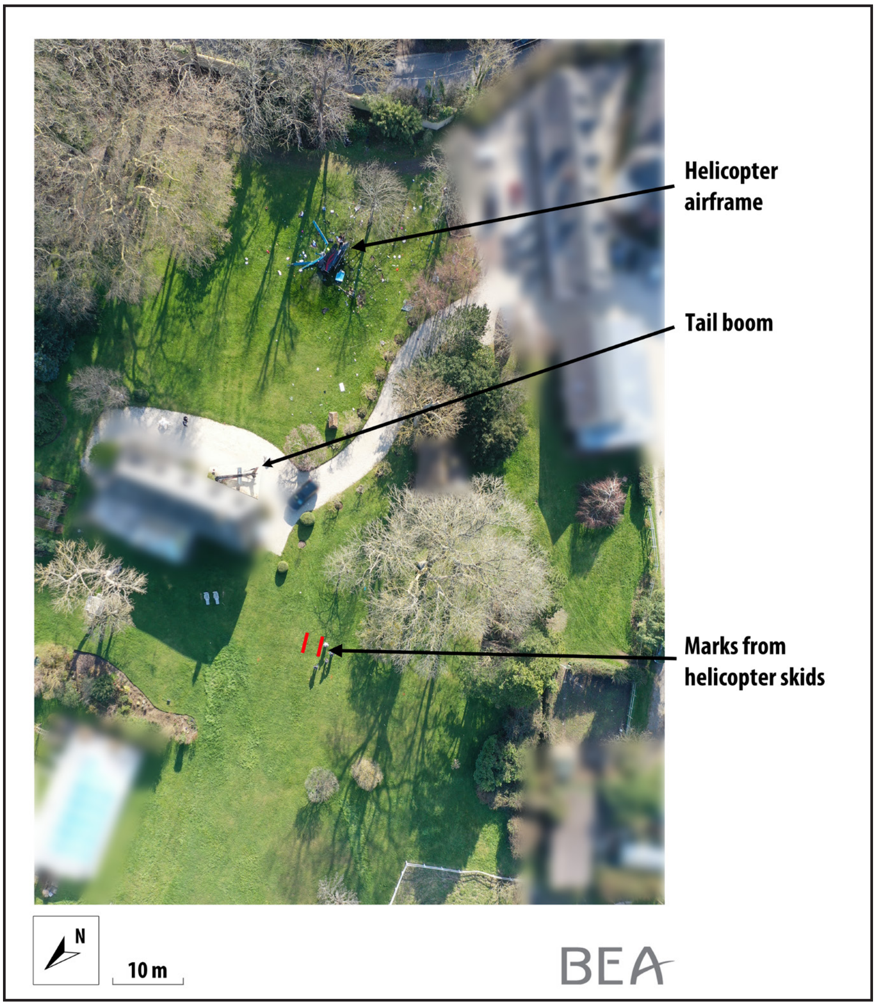


Source: BEA. Aerial photos taken on 8 and 9 March using the BEA drone

Figure 6: Severed branches

1.12.2 Wreckage information

The helicopter airframe was found around 50 m forward of the take-off point, the tail boom had separated from the airframe.



Source: BEA. Aerial photo taken on 8 March 2021 using the BEA drone

Figure 7: Aerial view of accident site

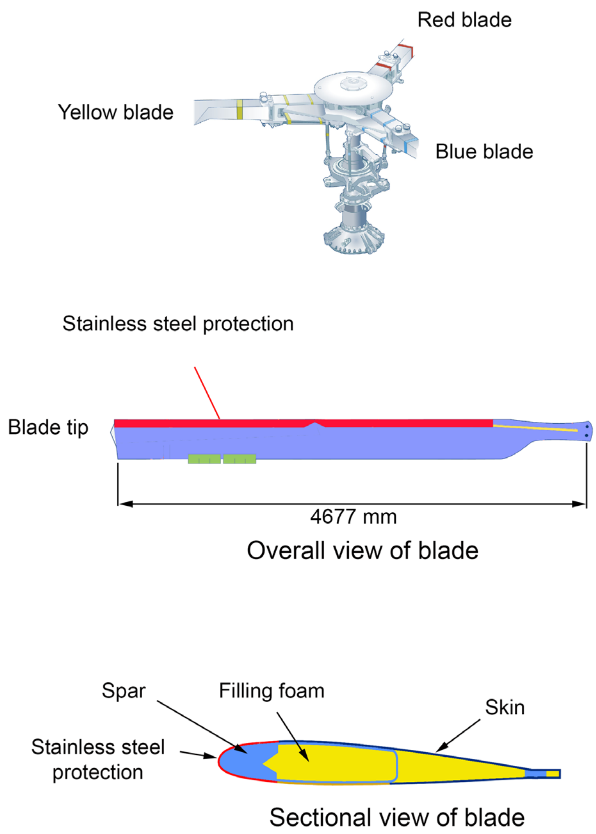
The blade roots were still assembled to the rotor hub which was integral with the Main GearBox (MGB) which was itself in position on the transmission deck. The blades had completely or partially ruptured at 3.70 m from their tip.

The three blades of the main rotor were substantially damaged. This damage was the consequence of the blades colliding with the tree branches and the impact with the ground.

Damage resulting from the collision with the branches was identified on the red and yellow blades over a length of around 2.60 m from the blade tips. The red blade had at least seven points of damage, the yellow blade had suffered at least one impact while the blue blade did not seem to have suffered an impact.

The distribution of the damage on the main rotor blades tends to show that it occurred during a single rotation of the rotor. A succession of impacts over several rotations would probably not have left the blue blade without visible impact marks.

The other damage observed on the red and yellow blades and the deformation of the blue blade was the result of the impact with the ground.



Source: Airbus Helicopters, translation: BEA

Figure 8: Elements of the main rotor of the AS350

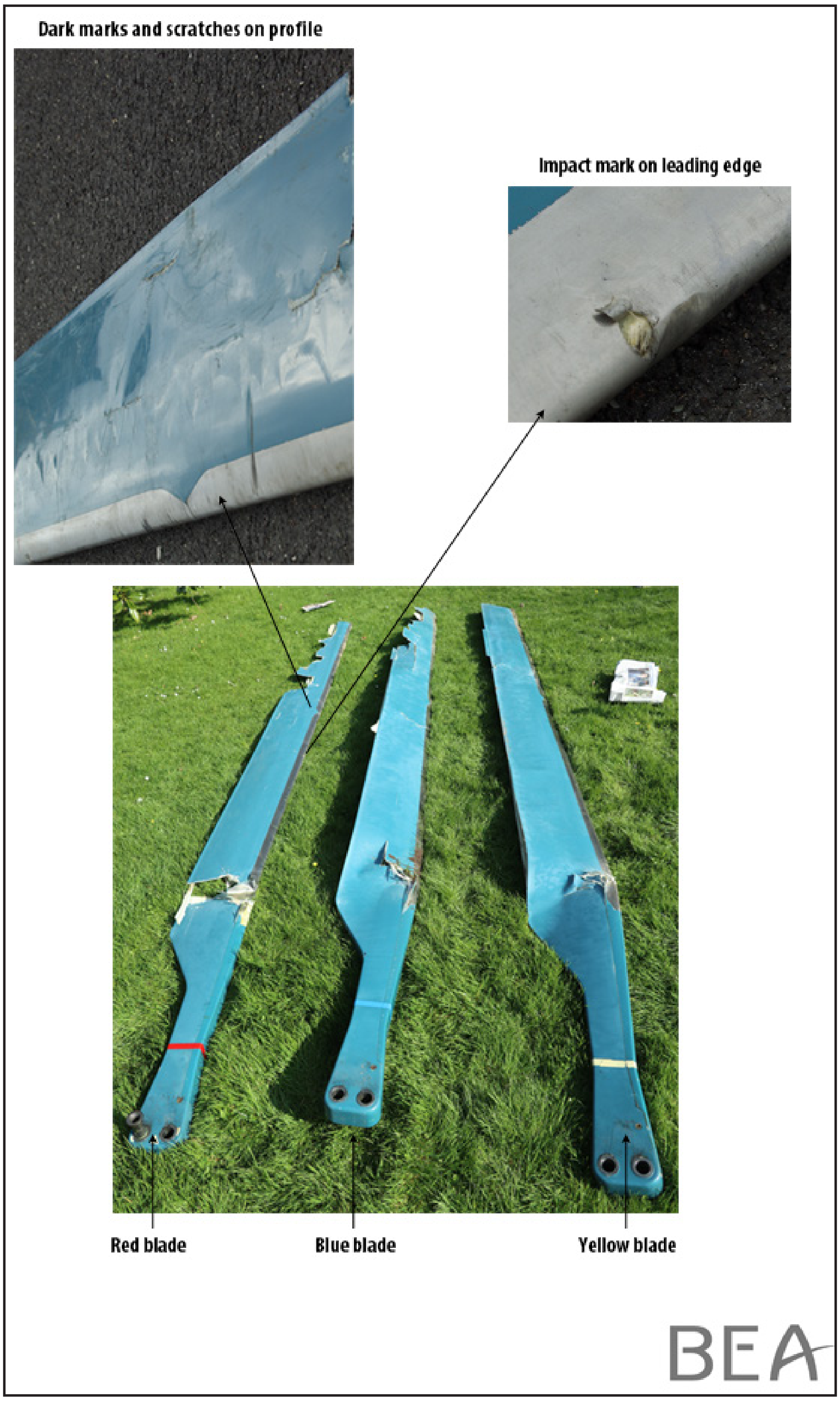


Figure 9: Main rotor blades, suction side

The area where the tail boom separated from the rest of the airframe can be characterized by:

- Shear failure of 90% of the rivets mechanically assembling the tail boom and airframe together. The skin around the remaining 10% of the rivets deformed, leading to the separation of the tail boom.
- The deformation of the left part of the tail boom.

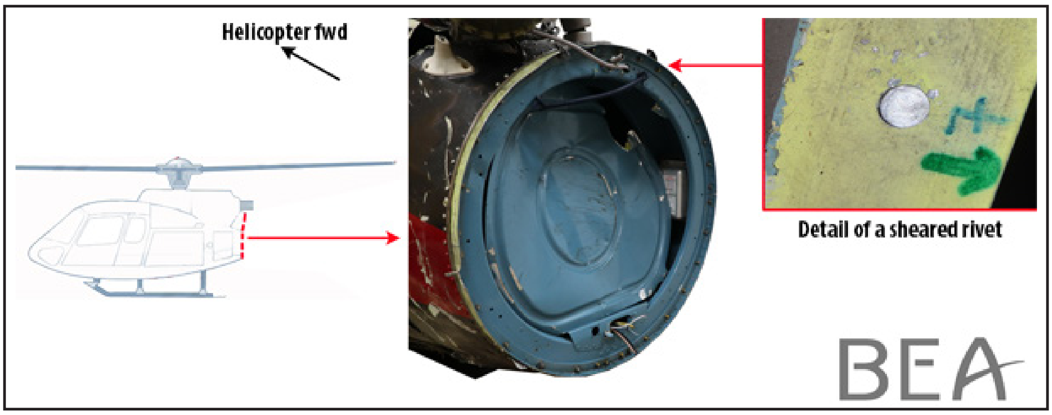


Figure 10: Junction between tail boom and airframe, airframe side

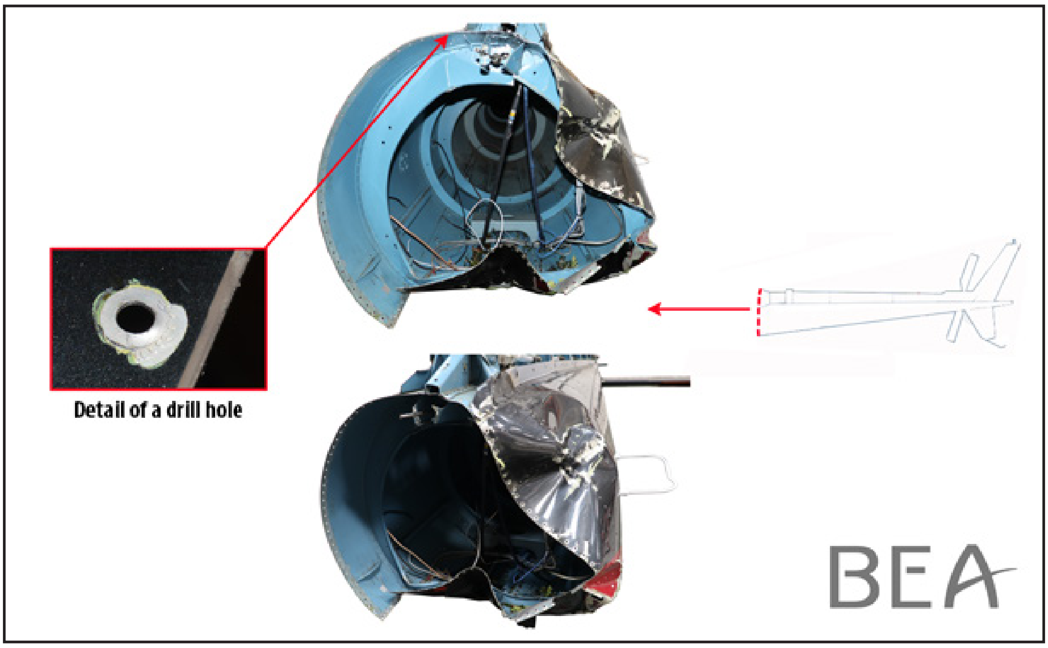


Figure 11: Junction between tail boom and airframe, tail boom side

The examination of the site and wreckage also showed that:

- The engine was producing power when the aircraft hit the branches and when it collided with the ground.
- The flight controls of the main rotor were continuous from the cabin to the rotor head.
- The tail rotor control was broken at the point where the tail boom had separated. The fracture face indicates principally tensile stress exceeding the ultimate tensile strength of the part concerned. This break occurred suddenly when the tail boom separated, without prior damage. The loads generated during the separation of the tail boom also led to damage to the tail rotor pitch-change unit which was found against its stop, practically blocked on the tail rotor drive shaft.
- The hydraulic system for the operation of the helicopter servocontrols was functional. The "seat-backrest" unit making up the front right seat had kept its usual shape. This assembly had been torn from the slide rails.
- The "seat-backrest" unit making up the front left seat had broken into several fragments. The slide rails were still associated with the fragments of the "seat-backrest" unit. They had been torn from the cabin floor.
- The failures and deformations observed on the seatbelt attachments indicate that the pilot was wearing the lap belt and in all likelihood, the shoulder harness. It was not possible to determine whether the passenger was wearing the shoulder harness and lap belt.

The detailed examination of the parts making up the helicopter did not bring to light damage prior to the accident.

1.13 Medical and pathological information

The examinations carried out during the autopsies of the two occupants of the helicopter revealed no pathology likely to explain the accident.

1.14 Fire

No fire broke out during the accident.

1.15 Survival aspects

The results of the autopsy showed that the internal injuries received by the two people on board, due to the acceleration experienced by their bodies when the main rotor collided with the trees followed by the rotation of the airframe about its yaw axis left no chance of survival.

1.16 Tests and research

1.16.1 Separation of tail boom and seats

Work was carried out in order to determine the consequences of the main rotor blades colliding with the tree branches and to explain the separation of the tail boom and the front seats. Detailed information about this work is given in Appendix 2.

This work was based on:

- Observations made on the helicopter components.
- A study carried out by the helicopter manufacturer.
- Dynamic calculation models. When using these models, various work hypotheses were chosen.

The diagram below illustrates the area where it was observed that the tail boom separated from the airframe.

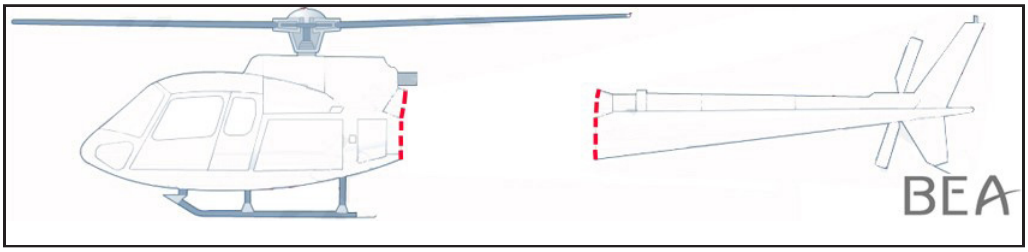


Figure 12: Diagram of tail boom separation area

The junction between the airframe and the tail boom is made according to the following geometry:

- The rear part of the airframe has a frame associated with an angle over 360° facing aft.
- The tail boom also has a frame in immediate proximity with this junction area. The tail boom skin is positioned over the outer surface of the angle on the airframe side. The junction is then secured by means of 99 rivets.

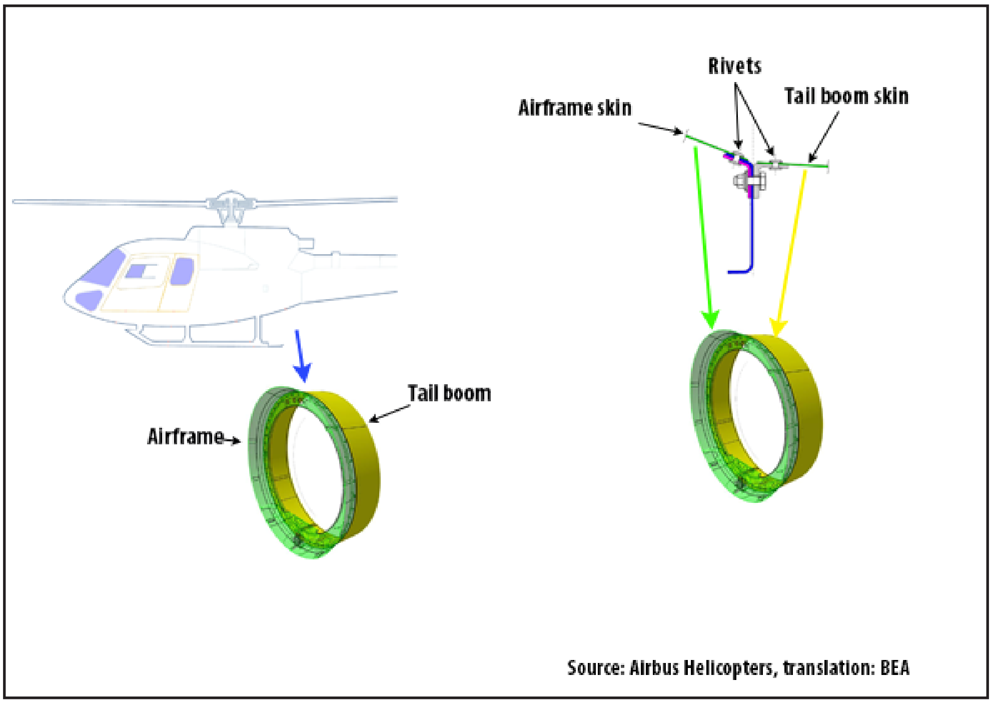


Figure 13: Diagram of junction between airframe and tail boom

The tail boom separated from the main part of the helicopter in line with this riveted junction. Ninety percent of these rivets were found to have sheared (see paragraph 1.12.2).

The collision of the main rotor blades with the tree branches led to an instantaneous and violent overtorque on the main rotor hub. This overtorque generated forces and moments on all of the helicopter's components, which were determined using its dynamic model.

The overtorque led to loads, in line with the riveted junction, greater than the ultimate shear strength of the most loaded rivet. When one of the rivets sheared, it overloaded the neighbouring rivets which failed in turn, until the remaining section of the tail boom skin bent.

The accelerations generated during the overtorque on the main rotor hub exceeded the lateral accelerations which could be borne by the two front seats, leading to them being torn from the helicopter cabin floor (see Appendix 2 paragraph A2.2).

The separation of the tail boom and the tearing away of the front seats were the consequences of the main rotor blades interacting with the tree branches. This damage was instantaneous and violent.

1.16.2 Read-out of recorded data

1.16.2.1 Position computers

The read-out of the position computer data made it possible to identify the manoeuvres of the helicopter in confined areas during a flight on 15 December 2020. This flight corresponded to that carried out by the pilot of F-GIBM with an instructor from the company, ABC Hélicoptères. The instructor told the BEA that two distinct training areas had been used during this flight. One of the two areas was considered as the most straightforward (training area - standard level). The other corresponded to the most advanced training phase (training area - advanced level).

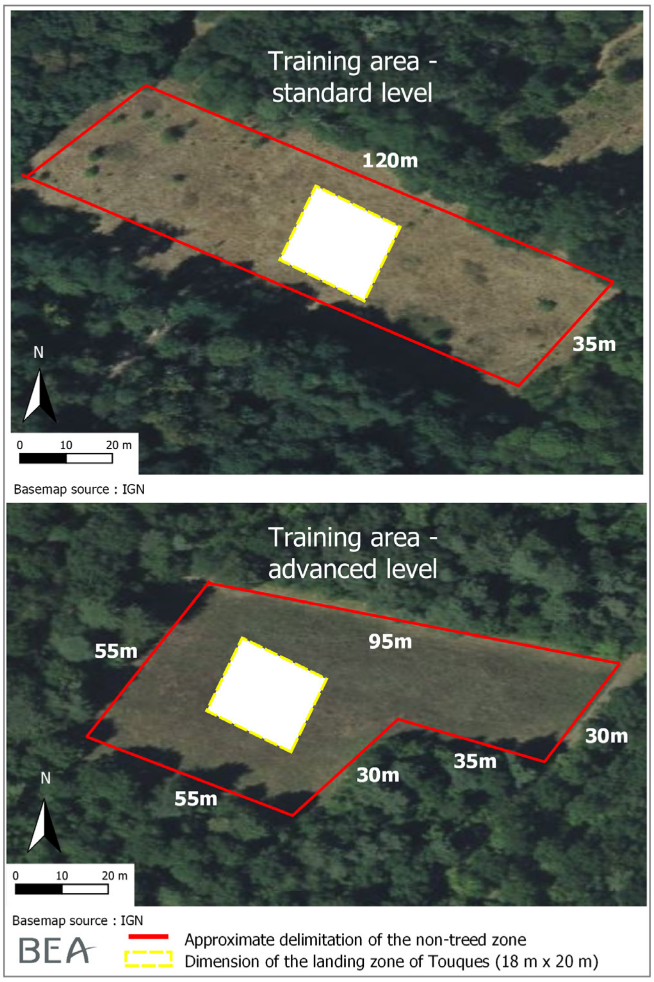
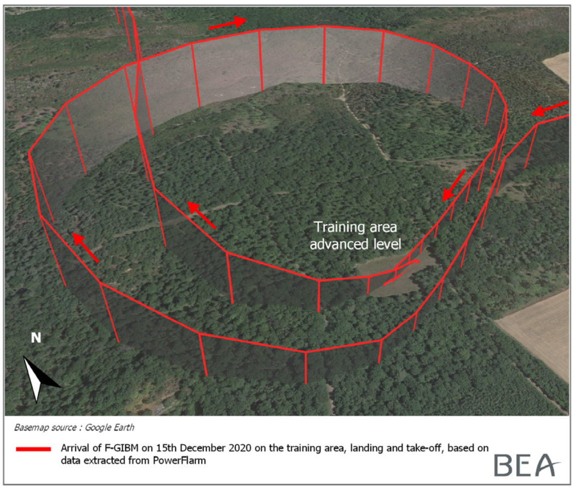


Figure 14: Training sites used by the pilot of F-GIBM during flight of 15 December 2020.
To make comparison easier, the HLS area used the day of the accident at Touques is represented by a white rectangle.



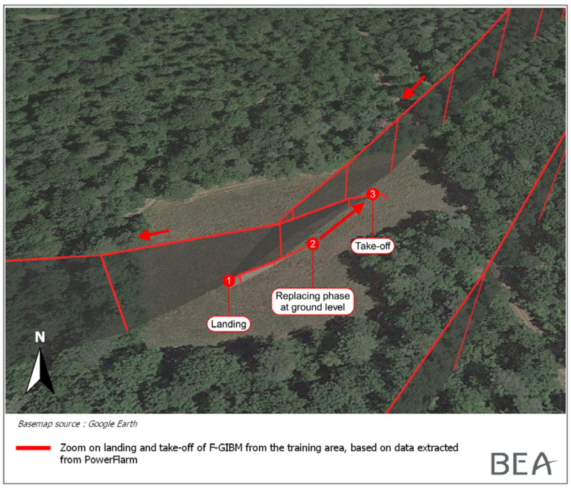


Figure 15: Landing and take-off in advanced training area
during flight of 15 December 2020 based on Power Flarm data

The analysis of the flight paths reveals that the manoeuvres on the ground, on landing and on take-off in the advanced training area were at a distance from visible obstacles.

1.16.2.2 Play back of video recording

1.16.2.2.1 Approach to HLS on Saturday 6 March

A person positioned next to a fence, on the right-hand side of the helicopter's inbound path, filmed and photographed the approach of the helicopter to the Touques HLS. It was possible to identify the following points:

- It was around 18:30 when the helicopter approached.
- The selected aiming point during the approach seemed to be positioned between the middle and the last third of the HLS in the upstream direction, on a roughly 140° heading.
- The forward speed was reduced after increasing the helicopter's pitch attitude and then, without marking a stop, the helicopter was positioned at a height of around 1.50 m and continued forward flight to touch down a few metres further on.
- The rays of the sun were perpendicular to the forward flight path, they struck the right side of the helicopter airframe.

- The aiming point and the touchdown point were in the sun, the tree branches struck the following day were in the shade (east side of touchdown path).
- The pilot was sat in the right seat in accordance with usual practices, the passenger in the left seat. It cannot be seen who was flying the helicopter in the video.

Source: Witness

Figure 16: Photos of the helicopter's approach on 6 March

1.16.2.2.2 Departure from HLS on Sunday 7 March

The play back of the video taken by witnesses positioned ahead of and to the right of the helicopter made it possible to identify the following points:

- After the start-up, the pilot in the right seat made a gesture with his left arm which seemed to indicate the take-off direction and which can be interpreted as "straight ahead".
- The pilot was not wearing glasses.
- The sunlight was almost identical to that of the day before.
- The passenger in the left seat repeated the pilot's gesture, with his right arm, seeming to indicate that he read back the intention to fly "straight ahead".
- The passenger was wearing glasses with tinted lenses.
- The helicopter took off at 17:43.

Source: Witness

Figure 17: Departure from HLS

The vertical climb and the collision with the branches were not filmed.

1.17 Organisational and management information

1.17.1 HLS information

1.17.1.1 Regulatory framework

The modified order of 6 May 1995 with respect to aerodromes and other sites used by helicopters[5] indicates that HLS are areas which are not necessarily prepared, located outside aerodromes[6] and which can only be used on an occasional basis. It specifies that the number of movements (landing and take-off) must be less than 200 per year and less than 20 per day in order to consider that the movements are few in number.

Except in specific cases (notably in built-up areas or in the vicinity of an aerodrome), the creation of an HLS is not subject to an administrative procedure. They must be identified beforehand by the pilot-in-command and be accessible to government services. The user or operator must obtain the owners' agreement and notify the services for immigration control and the prevention of employment of illegal immigrants when they are used[7].

The helicopter operator or owner must also hold an approval to use the HLS and have insurance or a sufficient guarantee to cover damage caused to third parties.

Article 15 of the modified order of 6 May 1995 specifies that the HLS are prohibited within built-up areas.

[5] Version in force on the day of the accident.

[6] Article D132-6 of the Civil Aviation Code

[7] The HLS used the day of the accident had not been declared to these services.

The order specifies that the built-up areas covered by this proscription are those shown on the latest issue of the ICAO 1/500,000 aeronautical chart. The civil aviation safety directorate west regional office (DSAC-O) is the competent authority for the area in which the HLS, used on the day of the accident, was situated. It indicated that the method to check this criterion is to position the geographical coordinates of the HLS on the ICAO 1/500,000 aeronautical chart and observe if the HLS is actually in a built-up area on this chart. The HLS used was considered to be outside of a built-up area.

Figure 18: 1/500,000 aeronautical chart
The position of the HLS is indicated by a red dot.
The surface area of the built-up areas is shown in yellow.

1.17.1.2 Approval to use an HLS

To obtain an approval the first time, the modified order of 6 May 1995 specifies that the pilot must be able to show a minimum flight experience of 70 hours and have followed training covering the use of confined areas.

The holders of a helicopter professional pilot licence, given their training programme, and holders of a helicopter private pilot licence able to show 300 flight hours as pilot-in-command are exempt from the supplementary confined area training.

1.17.1.3 Accident to the Alouette II registered F-GZFS on 7 January 2007

On 7 January 2007, at the beginning of the afternoon, the pilot of F-GZFS carried out a vertical take-off from an HLS. At the end of the climb, out of ground effect, the pilot started a left-hand rotation about the yaw axis. The helicopter moved backwards, descended and made a 180° turn while still moving backwards and then collided with the ground[8].

The 54-year-old pilot held a helicopter private pilot license (PPL(H)) obtained after a year's training. He had logged around 59 flight hours, of which 50 minutes as pilot-in-command in the previous 30 days. He held the prefectural approval to use HLS.

[8] Accident to Sud Aviation SE 313 B Alouette II registered F-GZFS on 7 January 2007 in the district of Arles (13).

The pilot had already used this HLS three times with an instructor. This was the first time that he took off from this HLS as sole pilot on board with what is more, a higher take-off weight than in the previous flights with the instructor.

The investigation showed that a limited experience regarding the use of HLS may have been a contributing factor. While the regulations stipulate that to use mountain landing areas, aeroplane private pilots must hold a specific rating ("wheel" rating and "snow" rating), there is no such requirement for the use of HLS. Consequently, the BEA recommended that the French civil aviation authority (DGAC) adapt the regulations concerning the use of HLS so that the pilots' experience is taken into account.

In response, the DGAC modified the order of 6 May 1995 regarding aerodromes and other surfaces used by helicopters. Since July 2008, to obtain an approval the first time, the holder of a helicopter pilot licence must be able to show a minimum number of flight hours as helicopter pilot and hold a training certificate issued by a helicopter flight instructor (see paragraph 1.17.1.2).

1.17.1.4 Confined area and HLS training

Regulatory aspect

The consolidated European regulation (EU) 1178/2011 (Aircrew)[9] indicates in part FCL (crew licence), paragraph FCL.210 (PPL) that the instruction must take into account the Threat and Error Management (TEM) principles and cover operations in a confined area, including the selection of and operations to and from unprepared sites, whatever the level of licence aimed at (LAPL, PPL, CPL or ATPL).

A syllabus describes a list of exercises designed as an Acceptable Means of Compliance (AMC). The exercise concerning confined areas (Exercise 29 for the PPL(H)) sets out various points to be covered during the instruction, in particular:

- (A) landing capability and performance assessment;
- (M) vertical take-off from hover.

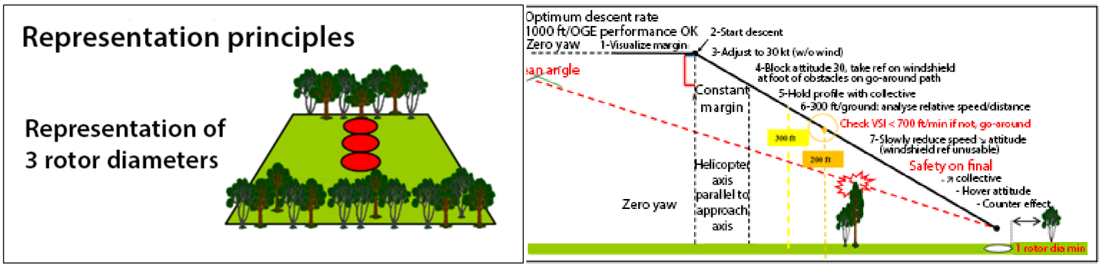
No criteria regarding the dimension of the confined area nor the distance to obstacles is specified. These basic exercises are the same whatever the type of licence aimed at (LAPL, PPL, CPL or ATPL). All the same, the expectations with respect to the pilot's performance of these exercises will be greater according to the type of licence being passed. No specific training is required in the European regulations to access a confined area.

Examples of training

In the scope of the investigation, two training organisations were contacted in order to obtain information about the content of their confined area training.

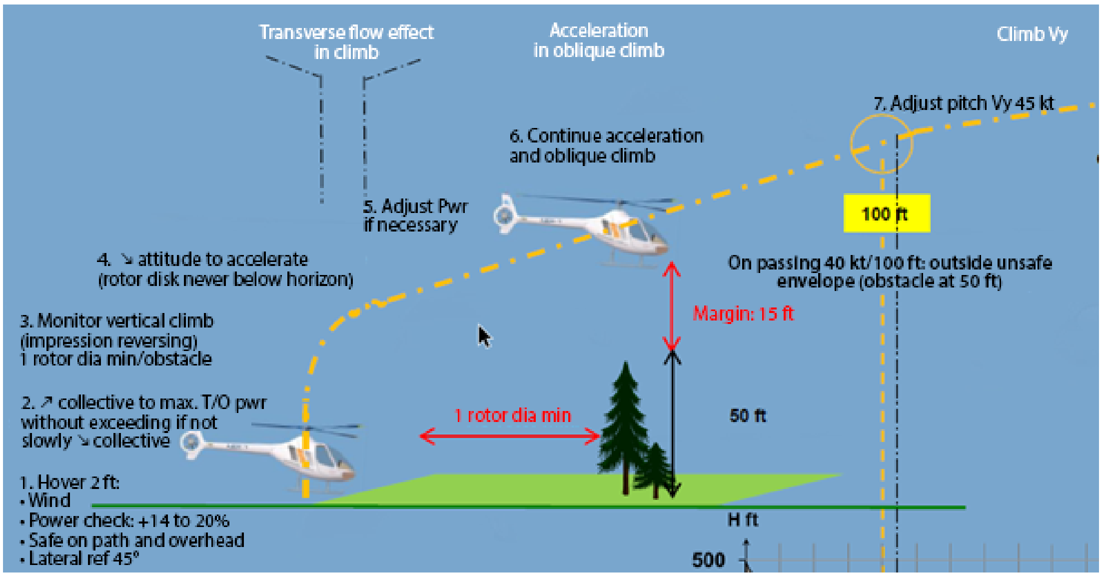
- The first organisation indicated that it had published a specific course information sheet. There was no mention of the safety distance with respect to obstacles.
- The second organisation had determined in its teaching material, a minimum safety distance with respect to obstacles of one rotor diameter for vertical take-offs and landings.

[9] Commission regulation (EU) No 1178/2011 of 3 November 2011 laying down technical requirements and administrative procedures related to civil aviation aircrew (Version in force on the day of the accident).



Source: HBG FHATO (translation: BEA)

Figure 19: Representation of dimension during an approach and safety distance



Source: HBG FHATO (translation: BEA)

Figure 20: Recommended safety distance during vertical take-off

Furthermore, companies carrying out Helicopter Emergency Medical Service (HEMS) missions define the minimum dimensions of the areas to be used for take-offs and landings in their operations manual:

- By day, around 2L x 2L, L being the overall length of the helicopter;
- By night, around 2L x 3L.

The pilot-in-command chooses the site based on the above criteria and where the person in need of care is located.

In the scope of an HEMS mission, the pilot-in-command is assisted by a Technical Crew Member (TCM) whose role includes monitoring obstacles.

By way of comparison, for F-GIBM with an overall length of 12.94 m, this would correspond to a minimum area of around:

- 26 m x 26 m by day;
- 26 m x 39 m by night.

The Torque HLS corresponds to a surface of around 50 m x 18 m with a usable landing surface of 25 m x 18 m.

1.17.2 Recommended practices for manoeuvres from an off-airfield landing site

The helicopter's ability to approach, manoeuvre, land and take off from an unprepared landing site is one of the most characteristic operational aspects in the use of helicopters. Best practices guides have been developed by the aeronautical community to accompany these types of manoeuvre.

EASA refers to the work by the EHEST[10] group and in particular, to the brochure, "OFF AIRFIELD LANDING SITE OPERATIONS"[11] which contains recommendations and advice for carrying out certain manoeuvres, in particular:

- ❒ The departure from an unprepared area;
- ❒ Manoeuvres within the area;
- ❒ Vertical take-offs.

This document describes helicopter manoeuvring techniques from a landing site without specifying the safety distance to be observed with respect to the obstacles.

When taking off with F-GIBM on the day of the accident, the pilot also had the possibility of backing up on the HLS to increase the distance from obstacles. However, it is difficult for a pilot, once installed in the aircraft, to decide to back up towards an area outside his field of vision even if he checked, before getting into his seat, that the area was indeed obstacle-free. As a consequence, this technique is rarely used, especially in a confined area.

1.17.3 Helicopter take-off technique

The pilot can choose between three types of take-off according to the obstacles. Each type of take-off has its advantages and drawbacks.

- ❒ The conventional or normal take-off, also called in-ground-effect take-off, is used the most often. The helicopter accelerates in level flight in-ground-effect to reach the climb speed. This is maintained during the initial climb. This type of take-off guarantees a safety margin in the event of an engine failure and requires less power.
- ❒ The yaw take-off is used to fly over obstacles situated in the climb-out area. As the helicopter is no longer in ground effect and has a low flight speed, a sufficient power reserve is required to maintain a constant safety height during the take-off. This type of take-off requires good knowledge and good experience of the performance of the helicopter being flown.
- ❒ The vertical take-off, also called out-of-ground-effect take-off is generally used when the surrounding obstacles do not permit a forward take-off. The pilot must have a substantial power reserve to carry out vertical flight. When the safety height above the obstacles has been reached, the aircraft is put into horizontal flight. If the pilot cannot clear the obstacles during this exercise, he aborts the take-off.

In the case of a vertical take-off, to ensure a vertical climb and avoid any nearby obstacle, the pilot must choose good visual references, one ahead of him and one at an angle of 45° to where he is seated (on right side if in right seat).

[10] *European Helicopter Safety Team*: European working group bringing together manufacturers and operators to promote best practices when flying helicopters.

[11] https://www.easa.europa.eu/document-library/general-publications/ehest-leaflet-he-3-helicopter-airfield-landing-sites

1.17.4 Instructor privileges

The regulatory requirement FCL.900 of the Aircrew regulation indicates that a person shall only carry out flight instruction in aircraft when he/she holds a pilot licence and an instructor certificate appropriate to the instruction given.

The privileges of a flight instructor are to conduct flight instruction for the issue, revalidation or renewal of:

- PPL, SPL, BPL and LAPL in the appropriate aircraft category.
- Class and type ratings for single-pilot, single-engine aircraft, except for single-pilot high performance complex aeroplanes; class and group extensions for balloons and class extensions for sailplanes.

The BEA interviewed pilots with instructor ratings. These interviews revealed that some of then appropriated the privilege of proposing to passengers to take the flight controls during various flight phases, arguing that their instructor rating permitted them to provide instruction in all circumstances with an aircraft equipped with dual flight controls.

The Aircrew regulation indicates that persons receiving flight instruction must be registered with an Approved Training Organisation (ATO) or Declared Training Organisation (DTO). The training programme must be drawn up so that the pilot receives training which will permit the licence or rating to be issued, revalidated or renewed. This programme must be approved (ATO) or declared (DTO).

1.18 Additional information

1.18.1 Statements

It transpired from the various statements collected by the BEA that:

Instruction

- The accident pilot had expressed his intention to renew his flight instructor (FI) rating so that with the accident passenger, they could carry out dual flights.
- He had also reported that the accident passenger intended to register with an ATO.

Use of Touques HLS

During previous take-offs from Touques HLS, after hovering, the pilot turned 180°, climbed vertically to a low height and then flew away in the opposite direction to the approach.

- This was the first time, on 6 March, that the pilot had landed on the Touques HLS so close to the trees.
- This was the first time, on the day of the accident, that the helicopter took off vertically in the approach direction, facing the trees.
- When another pilot accompanied the passenger, the dual flight controls were removed.

- People present on the ground the day of the accident indicated that the pilot knew the Touques HLS. He was reported to have landed there a dozen times in the last ten years or so, initially with a lighter helicopter. However, he landed further south in the same grounds. Then, to limit the noise pollution from operating the AS350, the pilot landed in the grounds closer to the main building and further away from the neighbours. The pilot had landed in this spot four to five times but not as close to the trees as on 6 March.
- These same people indicated that generally the pilot flew the approach towards the centre of the HLS and landed on the part that was closest to buildings where the slope was less and the ground more stable, as less spongy. These same people indicated that the pilot was in the habit of leaving the HLS by, in-situ, turning 180° in hover close to the ground, climbing vertically to a short height to reach a certain safety height above the trees and flying away in the opposite direction to the approach.
- They reported their fear that the helicopter might strike a tree on landing the day before the accident. They added that neither the pilot nor the passenger had made any comments about this. They could not specify who was flying the helicopter for the landing.
- When the helicopter collided with the tree branches, two people on the ground moved away to protect themselves. Neither of them saw the tail boom separate from the helicopter or the collision of the airframe with the ground.
- They added that they had run towards the victims to try and provide first aid.

1.18.2 Eyesight and vision

The BEA consulted medical experts in vision to understand the mechanisms implemented when flying a helicopter at the end of the day, close to the start of the aeronautical night, in the light conditions of the accident.

Sight is a sense characterized by different properties of the eyeballs taken into account separately or together. Each of these properties is related to the anatomical and functional characteristics of different constituents of each eyeball as well as the degree of conjugation of the two:

- Distance, intermediate and near visual acuity;
- Transparency of media;
- Eye mobility;
- Binocular vision;
- Visual field;
- Colour vision.

Eyesight is also characterized by the capacity to accommodate, and by sensitivity to contrasts and glare. These properties are those retained by the Aircrew regulation for the pilots' eye examination[12].

[12] Annex IV Part-MED, MED.B.070 and MED.B.075.

Vision is the result of the eyes perceiving light information and the processing of this by the brain. It is linked to the environment and conditions in which sight is called upon. Vision is divided into photopic vision in bright light conditions (for example, daytime vision with the cones processing the light), scotopic vision in low light conditions (for example, night vision with the rods processing the light) and mesopic (twilight) vision (combination of photpic and scotopic vision). At the beginning and end of the day, and all the more so in shaded areas, mesopic vision particularly comes into play.

Vision implements complex interdependent, extremely dynamic processes as illustrated by the adaptation mechanisms:

- The adaptation to light relies on two systems: variation in pupil diameter and retinal adaptation. The adaptation to light by pupil reaction may interfere with focusing to ensure sharpness of the image according to the characteristics of refraction. The retina's adaptation to extreme types of luminance depends on the light characteristics of the different parts that make up the environment being viewed (for example, those of a shaded branch against the luminous background of the sky), as well as chemical reactions at the level of the retinal cells. The latter can take a few minutes to a few hours.
- The adaptation to the distance to the object, or focusing, characterizes the power to accommodate. It depends on the suppleness of the lens and the muscles that act on it, as well as the pupil diameter which has an effect on the depth of field of the optical image formed on the retina.

In the case of sunglasses without an optical correction, the reduction in the quantity of light transmitted to the retina leads to an increase in the pupil diameter which reduces the capacity of adaptation to the distance of the object. The high indexes frequently adopted by pilots, generally 3, to avoid being dazzled, increase the darkness of the least lit areas, such as the instrument panel or, as here, the shaded area of the tallest tree. For pilots subject to the VML limitation, the wearing of uncorrected sunglasses is prohibited.

Much work has also been done on ageing and its consequences. One of the abilities the most impacted by ageing is vision, and some trials show the nullifying character of contrast. The sensitivity to contrast is a fundamental part of pattern vision and refers to the ability to discriminate variations in luminance in an image.

Visual acuity, the ability to discriminate fine details in an object with 100% contrast, will naturally decrease. Stable until reaching an age of around 40 years, visual acuity decreases linearly after that, with the decrease becoming more pronounced after the age of 70 years. This decrease is accentuated in low contrast and low light situations.

Light sensitivity in scotopic conditions decreases with age, resulting in a longer adaptation time to darkness.

Natural ageing progressively modifies the neurophysiological, perceptual and cognitive aspects of vision.

1.18.3 Medical fitness examination

Paragraph MED.B.070 of the Aircrew regulation and the associated AMCs and guides contain the requirements with respect to the medical examinations of the visual system.

European regulations stipulate that the examination is based on the collection of the medical history, the observation of the anatomical characteristics of the eye, and the evaluation and the estimation of parameters which characterize the sight properties given in paragraph 1.18.2. It is carried out under standardized conditions, using scales, atlases or devices that enable reproducible measurements and the pilot to be monitored. Measuring visual acuity is only one particular way of testing for sensitivity to contrast. In France, this information is collected in part in the medical examination report as well as on a sheet inserted in the medical fitness file (see Appendix 3).

The regulations impose a static ophthalmological assessment in that they do not expressly require the measurement of the accommodation capacity, and the assessment of the sensibility to glare and night vision. The assessment of sensitivity to contrast in mesopic conditions is only required during the first fitness examination. The routine examination includes the possibility of performing further examinations in the presence of clinical signs, the choice of which is entirely up to the Aero-Medical Examiner (AME). AMC2 MED.B.070 specifies that the "*Conditions which indicate further ophthalmological examination include but are not limited to a substantial decrease in the uncorrected visual acuity, any decrease in best corrected visual acuity and/or the occurrence of eye disease, eye injury, or eye surgery.*"

1.18.4 Influence of age and ageing

The performance of the visual system varies with age. Its deterioration is gradual from the end of adolescence and accompanies the ageing process. Until now, as there was no precise correlation between the chronological age and the onset of age-related changes, combined with the gradual appearance of these changes, it was difficult to propose rules which could be uniformly applied to pilots in order to control the impact of ageing in aviation safety.

However, on getting older, more time is required to process light information and the thresholds for detecting objects is higher. Visual acuity decreases as does the sensitivity of the retina, sensitivity to contrasts, and resistance to glare. These impairments make it difficult to detect small objects. Accommodation decreases to almost zero at around the age of 70; from this point, the wearing of progressive corrective lenses becomes essential in aviation. Generally speaking, adaptive abilities decrease in terms of speed and strength. This results, in particular, in a deterioration of the reaction to a stimulus in peripheral vision as well as greater difficulty in quickly shifting attention from one object to another (flexibility).

2 - ANALYSIS

2.1 Introduction

The day before the accident, the pilot and passenger, long-time friends, left by helicopter bound for the Touques HLS. During the approach, the pilot who had the controls aligned with the centre of the HLS. There was a tailwind. He brought the helicopter into hover at a medium height and without stopping, continued forward to the touchdown point in a sunlit area of the HLS, near a line of trees. The blade tips were less than 1 m from a tree around 4.5 m in height which was itself in front of a tree measuring 23 m in height. According to witnesses, it was the first time that the helicopter had been parked so close to the trees. It was not possible to determine whether the landing with such a small margin to the obstacles was deliberate or fortuitous.

On 7 March, the day of the accident, at the end of the afternoon, the light conditions were nearly identical to those during the approach carried out the day before. Visibility was greater than 10 km, there were no clouds. The sun was low on the horizon, the sun rays lit the right side of the helicopter. During the vertical take-off, at a height of around 19 m, the rotor of the helicopter collided with the branches of a tree measuring 23 m in height. The overtorque generated by this collision led to the airframe violently entering a rotation around its yaw axis. The helicopter's tail boom separated from the airframe which fell to the ground turning about itself around the yaw axis.

The examination of the wreckage did not reveal any malfunction which could explain the accident.

The investigation showed that the pilot of F-GIBM, who was also an instructor, asked for the dual flight controls to be installed on the helicopter for flights carried out in the company of the passenger in order to give instruction to the latter. A pilot logbook in the passenger's name was found on board the helicopter and seemed to show that the flights carried out by the passenger and pilot together, on F-GIBM, were instruction flights given by the pilot to the passenger.

The investigation was not able to determine who was flying the helicopter during the landing the day before the accident and during the take-off. Consequently, the vertical take-off carried out the day of the accident could have been carried out:

- ❒ By the pilot only.
- ❒ By the pilot for demonstration purposes for the passenger's benefit.
- ❒ By the passenger, under the supervision of the pilot acting as instructor.

In the hypothesis of a demonstration or instruction, the instructor pilot had to ensure that the safety distance to obstacles was complied with while calling on additional resources to give information to the passenger in instruction.

The analysis covers the following aspects:

- ❒ Landing and taking-off in confined areas.
- ❒ Low contrast and low light vision limitations: impact of ageing on vision during dynamic phases.
- ❒ Flight Instruction.

2.2 Landing and taking-off in confined areas

European regulation No 1178/2011 (Aircrew) indicates in part FCL that the instruction must take into account the Threat and Error Management (TEM) principles, for example the dangers represented by obstacles. A pilot must receive instruction in landing on off-airfield sites and exercises are recommended so that he can safely land and take-off from such a site.

Dimensions and access

The various training organisations propose, in their training programs, exercises in landing and taking-off using terrains which have increasingly difficult characteristics, in particular using sites of smaller and smaller dimensions. The techniques to approach and use the sites thus become more and more demanding. The regulations do not impose dimensions for the landing and take-off areas for private pilots whereas professional pilots may be required to comply with standardized dimensions predefined in the operations manual of the company for which they work. The private pilot thus finds himself free to use any landing site without surface limits and without safety margins with respect to obstacles.

The investigation showed that the accident site was nearly six times smaller than the area used during the pilot's last training in landing on an off-airfield site. This area, designated an advanced training area, was devoid of any obstacle apart from the forest at its edge.

In 2008, following the accident to F-GZFS, France imposed flight experience through a quota of logged flight hours or proof of having followed training in the use of confined areas to obtain an approval to use HLS in France. A pilot's recorded experience, given as a number of flight hours, does not specify his expertise in using confined areas, the number of sites used nor the frequency of his training.

Safety margins with respect to obstacles

The regulations do not impose safety standards by the application of a minimum manoeuvring distance with respect to the obstacles. The pilot can therefore fly close to obstacles on the site, from the approach to the landing, and during all ground manoeuvres. He may thus authorize himself to access landing sites that have no margin for error with respect to piloting or unforeseeable technical or environment-related events. Pilot training does not impose compliance with safety distances. As a consequence, practices are transmitted during the training without specific references. On 6 March 2021, when the helicopter had landed, the tips of the main rotor blades were one meter from the first trees.

Technicality of vertical take-off

The vertical take-off, when not in instruction, is performed when the conventional take-off is not possible. This type of take-off requires a substantial power reserve and great rigour in performing it.

The pilot could have manoeuvred on the HLS to carry out a conventional take-off or even a low-height vertical take-off, on the approach path. This type of take-off would have required the pilot once in hover, to back up before turning about the yaw axis. This backing-up manoeuvre is not very common and it is difficult for the pilot to continuously guarantee a safe distance from the obstacles located to the rear, as he cannot see them.

It is thus likely that the landing the day before forced the pilot to carry out the vertical take-off. According to the witnesses, during the previous take-offs from the HLS, he turned about his yaw axis and then took off in the opposite direction to the approach direction.

The vertical take-off performed on the day of the accident offered few safety margins because of the proximity of the trees plus a tailwind.

With a reference point in front of him and at a 45° angle to either side, a pilot performing a vertical take-off in a confined area must ensure that the helicopter does not drift once in hover and does not approach obstacles, while monitoring his power parameters. The pilot should only pick up speed in forward flight once the helicopter is clear of obstacles on its flight path.

On the day of the accident, as the helicopter climbed, the space in front of the pilot opened up between the tree and the building, which may have prompted the pilot to increase horizontal speed although the helicopter was not yet above the highest treetop.

If the passenger had the flight controls in this phase of the take-off, sitting in the left seat, the space between the building and the tree would have opened up even sooner for him. From the left seat and hampered by the cabin ceiling, it was more difficult to see the tree to his right. In addition, on his left side he had fewer close and lateral references to climb with perfect verticality.

The distance travelled by the helicopter from the point of take-off to the point of impact with the tree branches, of approximately 8.50 m, suggests that, irrespective of a possible drift of the helicopter, it was probably deliberately put into forward flight in order to start horizontal acceleration. The helicopter's manoeuvre with a nose-down attitude, observed by a witness, is in line with this hypothesis of the helicopter deliberately being put into forward flight.

The proximity of the obstacles at the end of the blade, the tailwind and the tree branches in an area of shade, with low light contrast, required the pilot to react promptly and appropriately to any deviation from the flight path. This is especially true if the passenger was in instruction and the pilot had to take the controls to correct deviations.

Difference between instruction and operational flights

The investigation found that there was a difference between the instruction provided and the flights performed by pilots in an operational framework. The helicopter pilot license gives the holder the freedom to access sites without size or safety distance standards, whatever the size of the sites that he may have used during his training.

A specific training course for confined areas can compensate for the general character of the initial training for landing on off-airfield sites.

In addition, certain technical constraints may limit, in all or in part, the use of the areas, such as the slope limitations of helicopters when they are on the ground.

Site reconnaissance is defined in the regulatory texts and adopted by the various training organisations. No site size or safety distance reference frame is required, leaving all pilots the freedom to determine the distance to obstacles they wish to impose on themselves.

Following the accident to F-GZFS in 2007, French regulations evolved so that the approval to use HLS is associated with a technical requirement of experience and training in the use of confined areas.

A guide aimed at training organisations which would indicate distance-to-obstacle reference values adapted to the initial training, and how these can be made to evolve according to the pilot's experience and ratings could help in the drawing up of training adapted to the practices associated with a confined area.

2.3 Low contrast and low light vision limitations: impact of ageing on vision during dynamic phases

Visual abilities evolve during life and deteriorate with age.

Older pilots who undergo a medical examination for professional or even leisure reasons may come across as believing that they have the right to have an aeronautical activity and that they have the know-how. They may have an apprehension that they will be discriminated against on the basis of age. It is therefore difficult for an aviation medical examiner to discuss with a pilot requesting a fitness certificate, the impact of ageing on his visual abilities without the help of a test.

Aeronautical fitness is standardized and is a guarantee of flight safety. The approved medical examiner could call for specific tests in order to more easily make a diagnosis on the consequences of ageing.

The medical examiner can also address general decreases in performance from a safety promotion or advisory perspective, or by mentioning practices which would become unreasonable with age, such as performing aerobatics, carrying out glider flights for long periods or landing in confined areas.

For example, during the fitness examination for mountain sport activities, the medical examiner makes his diagnosis via specific tests. The consultation also includes an interview and a clinical examination. At the end of the consultation, the patient may or may not obtain his approval with or without restrictions. During the interview, the medical examiner gives advice on the prevention and treatment of disorders, having tried to identify the possible risk factors of these disorders during the examination.

Similar exchanges can also be carried out by the Aero-Medical Examiner (AME) during the pilot's fitness examination: as soon as he detects the first signs of a decline in sight associated with ageing, the AME can make the pilot aware of the need to pay attention to any change, even minimal, in his visual perception, in particular by using examples taken from daily life. The AME can also invite the pilot to reflect on the limits he might set for himself in carrying out his flying activities.

Ageing and visual perception

Ageing affects the visual perception of the environment. It is accompanied by a decrease in the power of accommodation and contrast vision. The time needed to focus on and to detect small objects is longer, and may even be impossible. The same is true for the discrimination of elements of similar shade, dark objects in the semi-darkness or light objects in a bright environment; the perceived contrasts are attenuated or even non-existent, reducing the environment to light or dark zones in extreme cases.

In the conditions of the day of the accident, the tallest tree may have been problematic for the occupants in two respects.

- ❒ Firstly, the branches had no foliage, making it difficult to determine the actual volume of the thinner branches.
- ❒ Secondly, this tree created a shaded area on the departure path. Combined with the sun's rays which were perpendicular to the initial portion of this path, this meant that a fast adaptation to the contrast was required.

In these conditions, it could be difficult for the occupants to evaluate the characteristics of the obstacle, namely the tree, and thus its distance and, above all, to have the necessary time to adapt the departure path once the obstacle was detected.

VML and corrective lenses, practical scope

When age dictates that near vision has to be corrected, the small correction is often presented as a comfort correction. However, the low numerical index of the initial correction glosses over the complexity of the ongoing alterations to the vision and, for those carrying out risk activities, the need to scrupulously follow the prescriptions. In general, reducing the results of the sight test to a few numerical parameters of visual acuity and the prescription of corrective devices obscures the extent of the deterioration of the vision, drastically limiting the implementation of countermeasures and adaptation strategies. From then on, the deterioration of the vision over the years and its progressive and inexorable character become a sort of fatality that the pilot might passively accept. This prejudicial deterioration can suddenly appear during final approaches into the sun or if associated with a cataract.

The indication "VML" applied as a limitation to the pilot's medical fitness imposes the wearing of corrective lenses. The objective is to ensure that the pilot is able to perceive a clear image using his distant, intermediate and near vision. The change of focal length is achieved by the eyeball scanning the lens mainly vertically. The movements of the eyeball must be accompanied by movements of the head to position the zone of the lens with the appropriate correction between the eye and the object being looked at. The wearing of such lenses must be assiduous in order that the visual perception strategy of the environment becomes as automatic as possible, as quickly as possible.

When the distance vision is relatively preserved, certain subjects think that they can omit wearing glasses, except if they are forced to do so by necessity (reading on-board documents or instruments for pilots). This choice, made here by the pilot, necessarily implies accepting the significant deterioration of the near vision and intermediate vision. The result of this is that, unlike a subject who does not need such a correction, it is more difficult to detect and identify an apparently moving object which may "enter" the field of vision. Thus the monitoring of the flight parameters and outside obstacles during the take-off may have been slowed down by the adaptation time caused by the alternation between intermediate and distant vision.

Medical fitness examination and "*visual*" ageing

The ophthalmic examination performed by the AME is identical from one medical renewal to the next and is based primarily on visual acuity under given contrast conditions. This has two detrimental consequences for flight safety.

Contrast perception may only be assessed at the time of the first fitness examination, despite the essential role it plays throughout a pilot's aviation career and the deterioration of this perception with age. As a result, pilots may be wrongly reassured by the evaluation of their visual acuity and not give weight to the impact of the deterioration of contrast perception on their performance and flight safety.

The same is true when the accommodation capacity decreases and its corollary, corrective lenses have to be worn, which are not better understood.

2.4 Flight instruction

Instruction is a regulated activity which organizes pilot training. This training is entrusted to instructors (FI). The investigation showed that certain instructors taught how to fly outside of any structure, without any formalized progression or the issuing of a diploma.

The investigation revealed that the pilot of F-GIBM, who was also an FI, asked for the dual flight controls to be installed on the helicopter for flights carried out in the company of the passenger in order to give instruction to the latter. Moreover, a pilot logbook in the passenger's name and found on board the helicopter seemed to show that all the flights carried out by the passenger and pilot together, on F-GIBM, were instruction flights given by the pilot to the passenger.

The investigation did not find any pilot training record or document that might make it possible to determine the conditions under which the sessions were organized, to evaluate the passenger's level or to know if the accident flight was carried out in this scope. The passenger was not registered with an ATO or DTO.

3 - CONCLUSIONS

3.1 Findings

- The pilot held a valid helicopter commercial pilot licence CPL(H) and a valid helicopter flight instructor rating.
- The pilot held a valid medical fitness certificate with a restriction requiring him to wear corrective lenses when flying.
- The pilot was not wearing glasses during the take-off on the day of the accident.
- The passenger was wearing sunglasses.
- The pilot was familiar with landing and taking off from the Touques HLS.
- A pilot logbook in the passenger's name was found showing a number of instruction flight hours which was consistent with the hours logged in the helicopter's logbook.
- The flight hours shown in this logbook were signed by the pilot as helicopter flight instructor (FI(H)).
- The passenger did not hold a helicopter pilot licence but did hold a valid aeroplane pilot licence with the required medical fitness certificate.
- The pilot was aged 74 years and the passenger 70 years.
- The helicopter was equipped with dual flight controls.
- The helicopter's artificial horizon was inoperative. It was not necessary to undertake a VFR flight.
- The investigation was not able to determine who was flying the helicopter during the take-off from the HLS the day of the accident and during the landing the day previously.
- The day before the accident, the aiming point of the approach path corresponded to the centre of the HLS. The pilot who had the controls continued forward flight to the touchdown point close to the trees.
- Once on the ground, with the engine shut down, the tip of one of the blades was at around 1 m from a tree 4.40 m tall. The investigation was not able to determine whether the landing at this distance from the tree was deliberate or fortuitous.
- The regulations do not impose safety distance rules with respect to obstacles for HLS.
- During the take-off on the day of the accident, the weather conditions were similar to those for the landing the day before.
- The sun was low on the horizon and right abeam the helicopter.
- The trees ahead of the helicopter were leafless and in the shade.
- Before the take-off, with the engine started up and the rotor spinning, the pilot used his left arm to indicate taking off straight ahead.
- The helicopter, on its skids in the part of the grounds in the sun, took off vertically.
- The helicopter did not reach a height exceeding the top of the tallest nearby tree.
- The helicopter had sufficient power to take off vertically to a sufficient height to clear the obstacles.
- The helicopter moved a distance of around 8.50 m and two blades collided with branches at a height of around 19 m. The branches were on a tree that rose to a height of 23 m.
- The violence of the airframe's rotating movement arising from the rotor's collision with the branches left no possibility of survival for the two people on board.

- Upon the main rotor blades colliding with the tree branches, the pilot and passenger seats separated from the deck, the junction between the tail boom and the helicopter airframe failed and the airframe fell turning about itself until it collided with the ground 50 m ahead of the take-off spot.

3.2 Contributing factors

The loss of control of the helicopter during the take-off was the result of the main rotor blades colliding with a tree situated close to the helicopter's take-off spot. The manoeuvring area on the HLS, chosen the day before the accident when landing, restricted the possibilities of safely manoeuvring. This choice probably pushed the pilot to carry out a vertical take-off with a small safety margin with respect to the tree branches which were in the shade.

The assessment of the distance to the obstacles may have been difficult in a shaded environment with low light contrast. In particular, the following factors may have contributed to difficulties in detecting the tree branches which were in the shade:

- The pilot not wearing corrective lenses.
- A sensitivity to contrasts attenuated by age.

In the absence of criteria regarding distances to obstacles to be taken into account not only when manoeuvring on a HLS but also when training in using confined areas, pilots may not have safety references when using unprepared and confined areas.

It was not possible to determine if the piloting was performed in the scope of an instruction flight and who had the helicopter controls during the take-off.

What is more, the passenger was wearing tinted glasses which was not likely to facilitate the detection of objects in low contrast and low light situations.

4 - SAFETY LESSONS

Instruction carried out outside the scope of an approved organisation

Instruction is a regulated activity which organizes pilot training. This training is entrusted to instructors (FI). The investigation showed that certain instructors taught how to fly outside of any structure, without any formalized progression.

The investigation revealed that the pilot of F-GIBM, who was also an FI, had asked for the dual flight controls to be installed on the helicopter for flights carried out in the company of the passenger, and a pilot logbook in the passenger's name was found on board the helicopter recording the dual flight hours carried out. The pilot in all likelihood provided instruction to the passenger, owner of F-GIBM, during private flights.

This instruction carried out outside an approved organisation could have deprived the instructor and the pilot in instruction of a structured progression. A structured instruction framework in which skills are progressively acquired and manoeuvres carried out with a difficulty adapted to the level of proficiency reached, can provide a better level of safety.

5 - SAFETY RECOMMENDATIONS

Note: in accordance with the provisions of Article 17.3 of Regulation No 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation, a safety recommendation in no case creates a presumption of fault or liability in an accident, serious incident or incident. The recipients of safety recommendations report to the issuing authority in charge of safety investigations, on the measures taken or being studied for their implementation, as provided for in Article 18 of the aforementioned regulation.

5.1 Safety margin on Helicopter Landing Site (HLS) and training in use of confined areas

The regulations draw pilots' attention to the subject of obstacles when using HLS and confined areas, without providing safety distance references. Some commercial operators impose on their pilots, in their operations manual, dimensions (width/length) for unrecognised landing sites based on the helicopter's overall length or rotor diameter.

Helicopter pilot training for off-airfield landings and the use of HLS is heterogeneous and imprecise in terms of safety margins with respect to obstacles.

Consequently, the BEA recommends that:

- **in the absence of references regarding safety margins with respect to obstacles when using HLS or confined areas for Non-Commercial Operation (NCO);**
- **whereas the diversity of HLS and confined areas used in NCO by pilots with varying degrees of experience and proficiency;**
- **whereas the difficulty in associating flight experience measured in flight hours with practical experience of operations in confined areas;**
- **whereas companies carrying out commercial operations impose on their pilots, in their operations manual, dimensions for unrecognised landing sites;**

EASA publish a guide aimed at training organisations which indicate distance-to-obstacle reference values adapted to initial training and how these can evolve according to the pilot's experience and ratings [Recommendation FRAN 2022-001].

5.2 Ophthalmological tests of contrast vision, raising awareness of the consequences of ageing

Physiological age is not to be correlated with chronological age.

With advancing age, the time required to process light information increases and the object detection thresholds are higher. Visual acuity decreases as does the sensitivity of the retina, sensitivity to contrasts, and resistance to glare. These impairments make it difficult to detect small objects.

On the day of the accident, the 74-year-old pilot and the 70-year-old passenger were facing a tree whose branches struck by the main rotor were in the shade. The helicopter and the treetops were lit by low sunlight under a clear, cloudless sky. In these conditions, it was difficult for the two people on board to detect the immobile obstacles represented by the leafless branches of the tree in a shaded area with low light contrast, in the presence of better lit areas in the field of vision.

Furthermore, accommodation decreases, becoming almost zero at around the age of 70; from then on, wearing progressive lenses becomes essential in aviation. Generally speaking, adaptive abilities decrease in terms of speed and strength. This results, in particular, in a deterioration of the reaction to a stimulus in peripheral vision as well as greater difficulty in quickly shifting attention from one object to another (flexibility).

Vision is not the only function affected by ageing. Psychomotor responses are also affected in terms of speed and quality. As a result of this, the response to a visual stimulus is impaired in its entirety. For tasks which require finesse and skill, such as a helicopter take-off from a confined area, adapted training and experience in these situations can limit the impact of ageing on their safe performance, provided that the pilots concerned are aware of these effects of ageing and the limits of the compensation mechanisms they can implement.

While the current regulations do not prohibit the Aero-Medical Examiner (AME) from informing pilots of this process, it seems necessary to provide the AME with a framework which will enable him or her to characterize, as needed, the beginning of this deterioration, in order to permit him or her to discuss with the pilots more freely, the consequences of ageing on their flying activities.

This information is at the heart of the role that the AME can have to raise awareness and promote safety.

Consequently, the BEA recommends that:

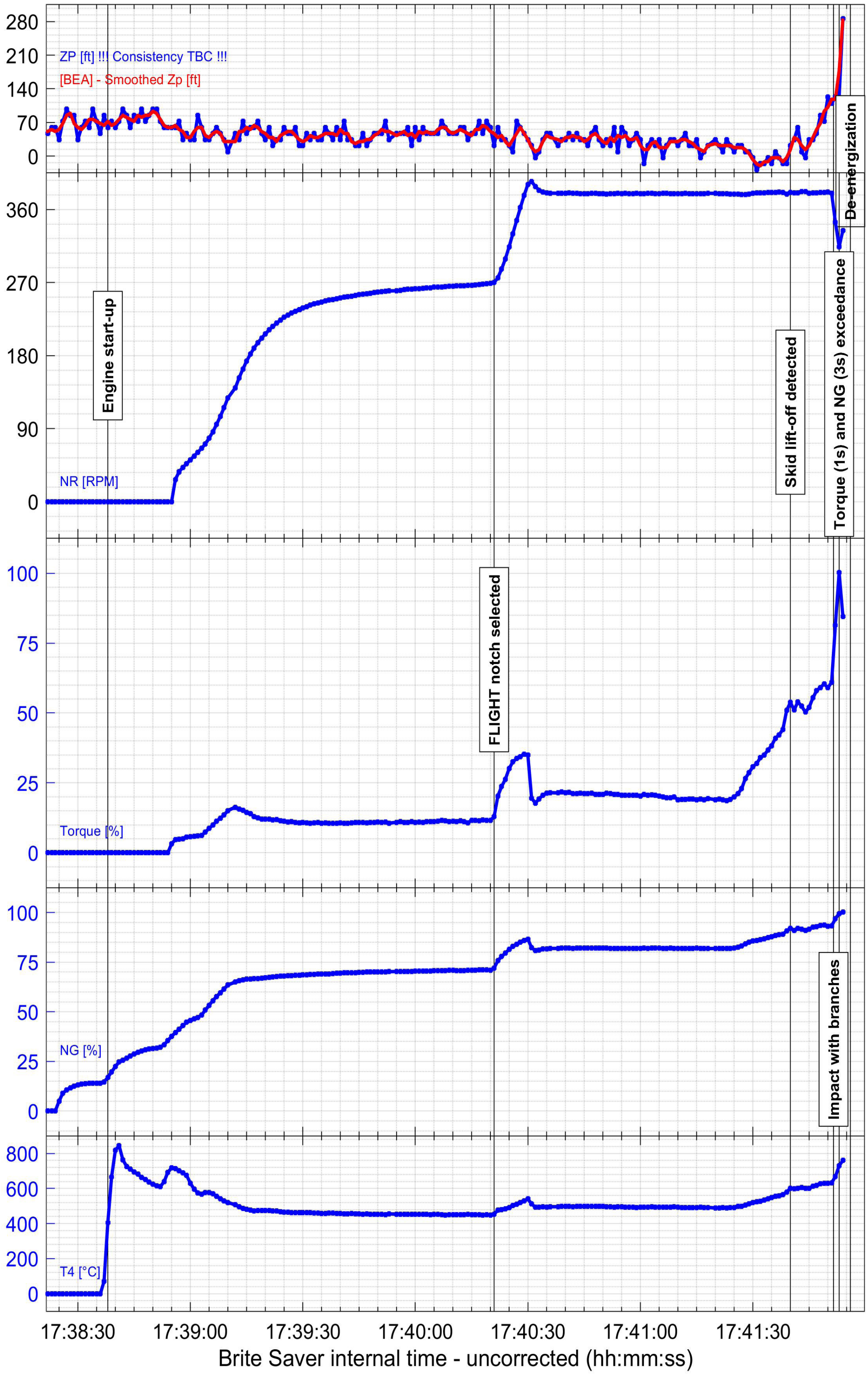
- **whereas one of the most characteristic physiological consequences of the beginning of ageing is the impairment of vision;**
- **whereas chronological age is not to be correlated with physiological age;**
- **to characterize all of the pilot's vision performance which degrades irremediably with age and in which visual acuity is only one element;**
- **whereas the regulations may encourage AMEs to limit the aero-medical examination to one where the result is reduced to the person being declared fit or unfit, to the detriment of raising the pilot's awareness and promoting safety when the latter meets the fitness criteria;**

EASA include in Part MED of EU regulation No 117/2011, a guide or Acceptable Means of Compliance (AMC) proposing an awareness module that will encourage AMEs to freely address, during renewal medical examinations, the physiological consequences of ageing, using in particular, a contrast sensitivity assessment test as a support, with the objective of promoting safety [Recommendation FRAN 2022-002].

APPENDICES

Appendix 1

Brite Saver data - Accident flight



Appendix 2
Examinations carried out on tail boom and front seats

A2.1 Foreword

The work to explain the separation of the tail boom initially consisted of determining the overtorque generated in the main rotor during a collision with an obstacle. This work used experimental results and the helicopter manufacturer's dynamic model of the rotor.

The overtorque measured at the rotor mast was then used, by means of a dynamic model, to determine the resulting forces and moments at the junction between the airframe and tail boom. These forces and moments thus calculated were then compared with the design forces and moments of this junction.

Furthermore, this work explains the failure sequences of the seats and the fatal injuries to the occupants.

A2.2 SEPARATION OF TAIL BOOM

The Tail Rotor (TR) controls the helicopter on its yaw axis. The resulting aerodynamic force of the TR acts in a horizontal plane in opposition to the reaction torque of the main rotor.

The TR is positioned at the end of the tail boom which is attached to the airframe aft of the cabin.

The diagram below illustrates the area where it was observed that the tail boom separated from the airframe.

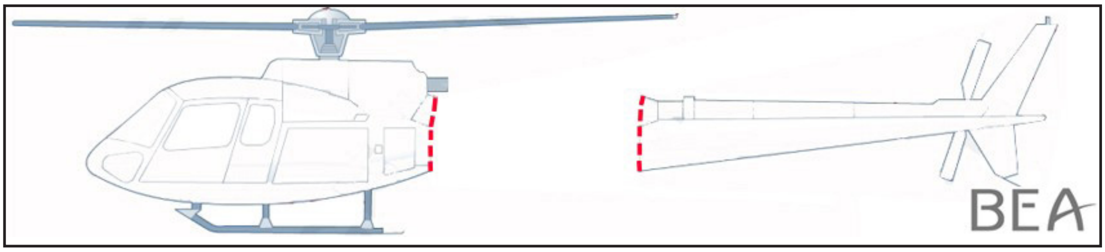


Figure 21: Airframe/tail boom junction diagram

Test campaign

Airbus Helicopters had carried out tests, prior to the accident, on the main rotor of the SA 341 Gazelle in order to study its behaviour and the consequences of it coming into contact with obstacles such as tree branches. The blades of this helicopter are similar to those of the accident helicopter in terms of materials and dimensions.

This study consisted of inserting branches in the spinning rotor of the helicopter (fixed to the ground) near the blade tips, the rotor speed remaining constant. The cyclic and collective pitch controls were fixed in neutral. The branches were oriented to be perpendicular to the main rotor disk.

The branches, both dry and green, came from a mulberry tree. They had a diameter varying between 20 and 200 mm.

The helicopter rotor mast used for these tests was equipped with instruments to measure the torque generated on the axis of the main rotor as a function of time.

Before inserting the tree branch in the main rotor, the torque measured with the rotor in an established rotation speed was taken as the "*nominal*" torque for the given rotor. This torque was nearly static.

When the branch was inserted in the main rotor, a dynamic pulsation was generated. The torque measured during this pulsation was called "*overtorque*".

During the tests carried out, no overtorque was measured for a branch diameter of less than 70 mm whether the wood was dry or green.

The tests also showed that, in the same configuration, the overtorque generated when the wood was green was greater than when the wood was dry.

Data for each wood "*calibre*", dry or green, was acquired by means of the tests, indicating the maximum amplitude of the overtorque as a function of the diameter of the branch inserted.

The following graph shows the results obtained. On this graph, for each wood calibre, dry or green, these points are situated on a curve represented by a mathematical law.

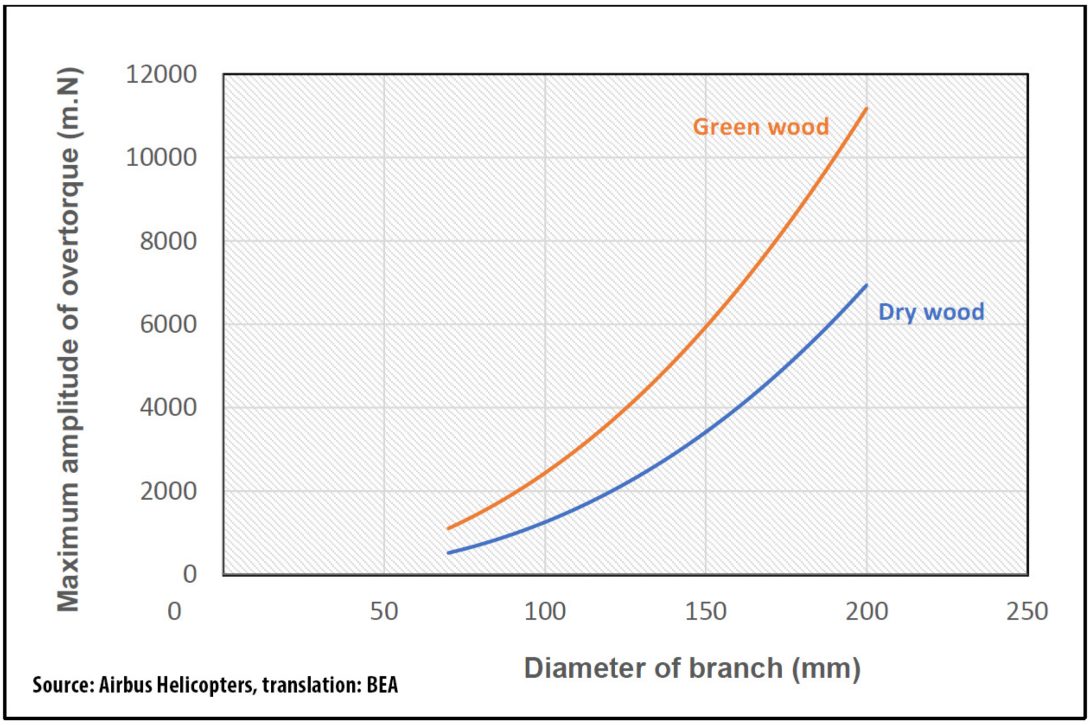


Figure 22: Representation of overtorque as a function of diameter of branch inserted in main rotor

Dynamic model of rotor to observe cutting force of an obstacle (branch)

The work carried out after the accident to F-GIBM first consisted of creating a dynamic model of the main rotor of the helicopter used during the tests described above. This model was representative of the main rotor of the helicopter in terms of weight, stiffness and absorption.

The purpose of this model was to calculate the overtorque on the main rotor mast based on the modelling of an impulsive force on a blade.

This impulsive force represented a branch striking a blade. It was represented in the form of a periodic sinusoidal signal. The period of the signal corresponded to the time to cut the branch, the amplitude of the signal decreasing with time.

This model established a linear law between the impulsive force and the diameter of the branch inserted in the main rotor as illustrated in the graph below.

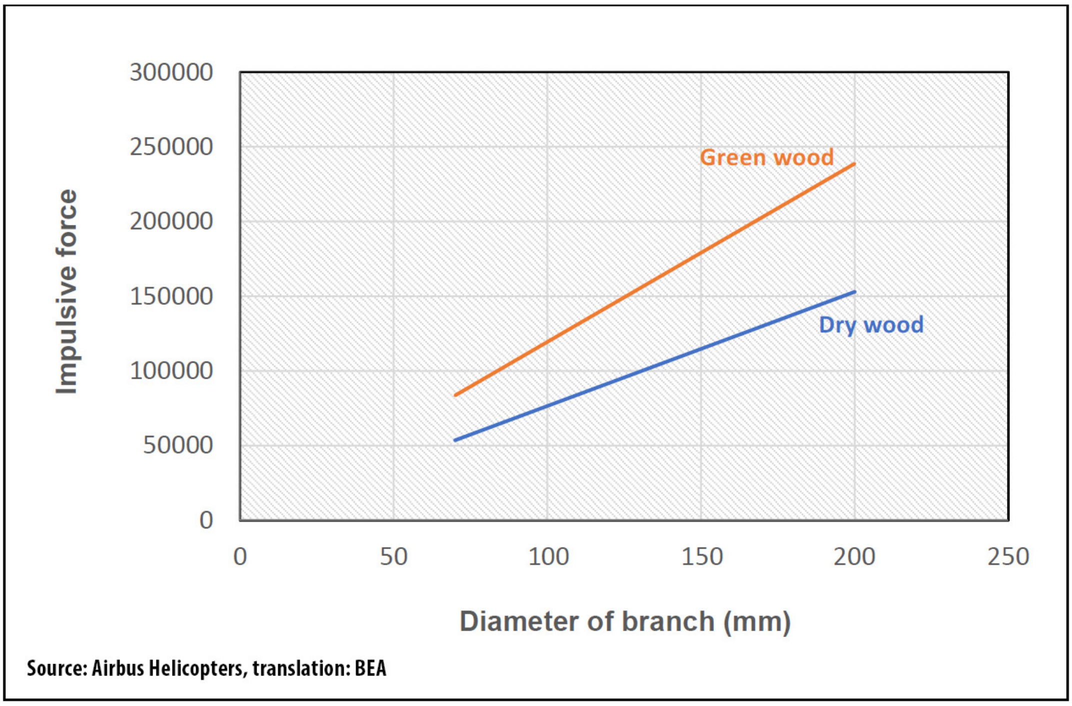


Figure 23: Representation of impulsive force as a function of diameter of branch inserted in main rotor

Determining overtorque generated on main rotor mast of F-GIBM during accident

Airbus Helicopters adapted this dynamic model to the AS350 B, taking into account its characteristics.

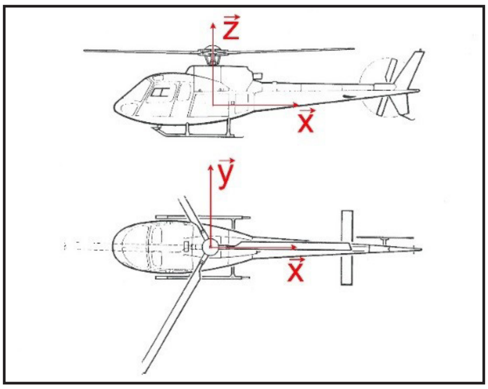


Figure 24: Reference used during study

As indicated above, this model was created based on tests carried out using mulberry branches. The theoretical physical and mechanical properties of the ash tree (tree stuck by F-GIBM) are close to those of the mulberry.

The first hypotheses chosen for the calculation of the overtorque on the main rotor of the accident helicopter are those listed below:

- **Hypothesis 1: Impacts with blades**

The distribution of the number of impacts between the branches and the blades is given below:

- Red blade: 7 impacts
- Yellow blade: 1 impact
- Blue blade: 0 impact

- **Hypothesis 2: Distribution of impacts**

On the tree, the broken branches covered an estimated sector of around 140°.

If the number of impacts in hypothesis 1 is taken, the arbitrary distribution of these impacts over the 140° sector gives an impact every 20° of rotation of the rotor (0°, 20°, 40°, 60°, 80°, 100°, 120°, 140°).

An impulsive force was considered for each impact, i.e. a sinusoidal wave per impact. The passing frequency of the main rotor blades of 19.3 Hz (rotor equipped with three blades spinning with a rotation speed of 385 rpm) was well above the frequency of the dynamic response signal of the overtorque (around 2.5 Hz). As a result, the successive impulsive forces built up.

- **Hypothesis 3: Branch diameter**

The branch diameter taken for each interaction was 14 cm.

If these hypotheses are taken and the model adapted to the main rotor of the AS350 B, the torque on the rotor axis, i.e. $\overrightarrow{M_z}$, had a maximum amplitude of 92,000 m.N.

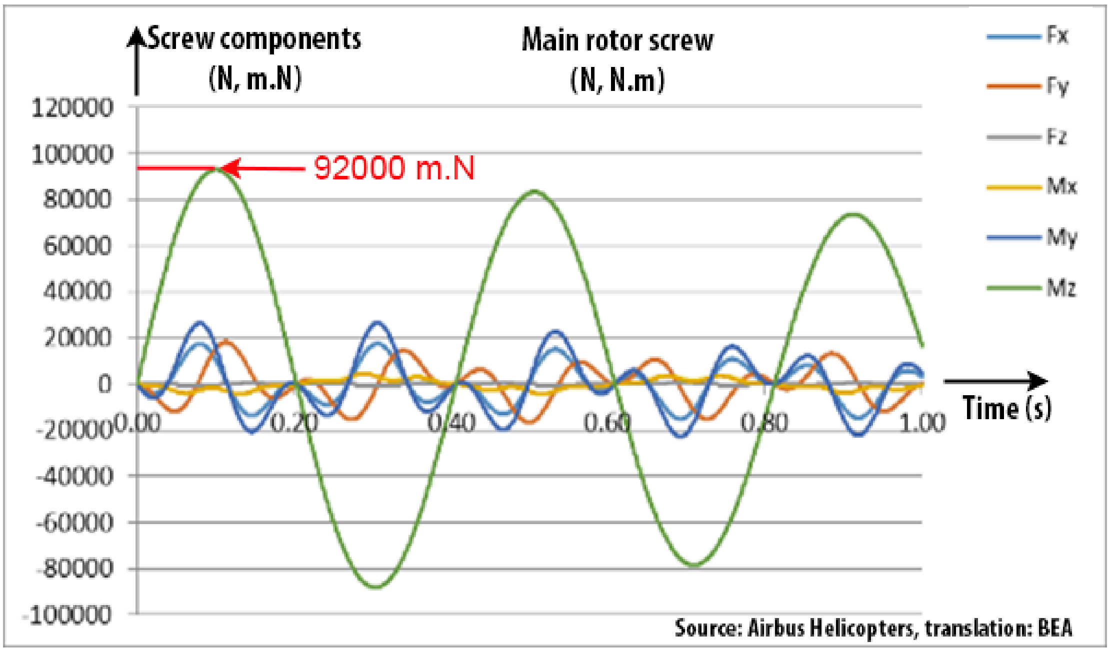


Figure 25: Representation of forces and moments in rotor head

Analysis of rupture of tail boom

The junction between the airframe and the tail boom is made according to the following geometry:

- The rear part of the airframe has a frame associated with an angle over 360° directed aftwards.
- The tail boom also has a frame in immediate proximity with this junction area. The tail boom skin is positioned over the outer surface of the angle on the airframe side. The junction is then secured by means of 99 rivets.

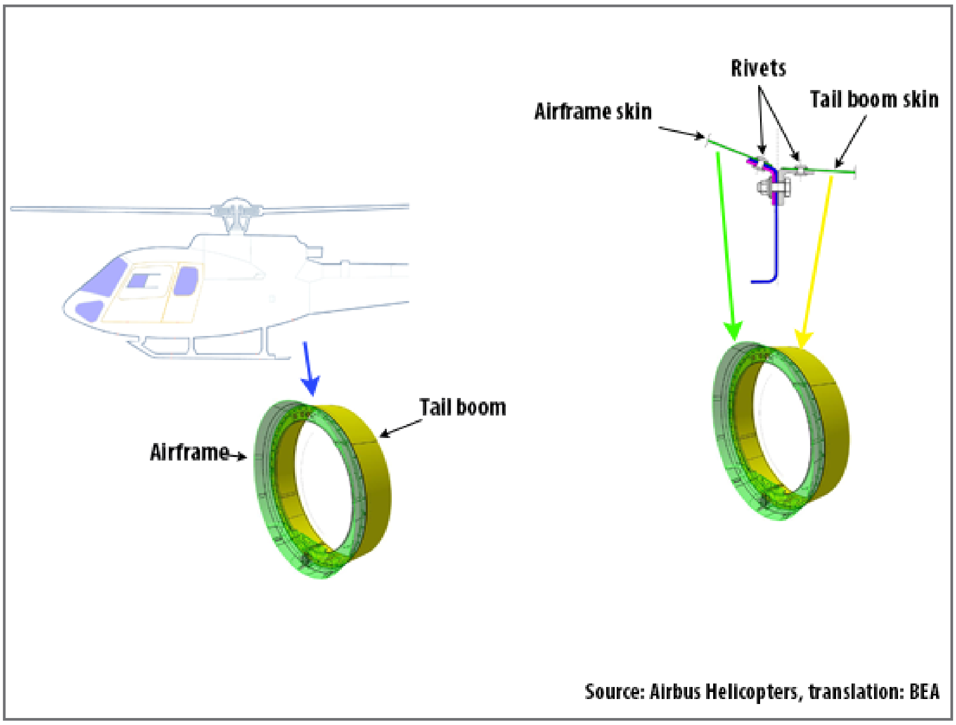


Figure 26: Diagram of junction between airframe and tail boom

The graph below shows the shear strength envelope of the most loaded rivet ensuring the mechanical junction between the airframe and the tail boom. In this figure, the envelope is represented in terms of moments generated (on the $\vec{y}$ and $\vec{z}$ axes) in line with this junction.

The failure of the most loaded rivet leads to an overloading of the neighbouring rivets which are going to fail in turn, until the remaining section of the tail boom skin becomes too weak and bends.

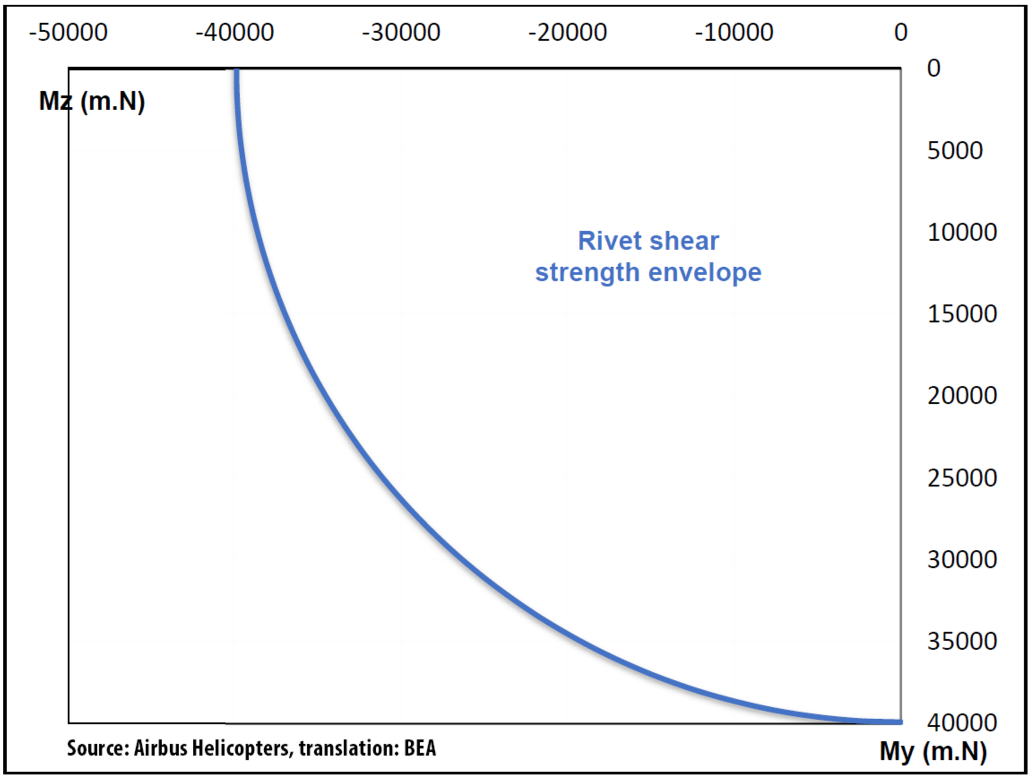


Figure 27: Shear strength envelope of 99 rivets

The dynamic model for the AS350 B was used to calculate the associated screw in line with this junction. The components of this screw are represented in the diagram below.

As the forces and moments generated on the main rotor are periodical sinusoidal signals whose amplitude decreases with time, the components of the screw, in line with the tail boom junction, are represented by curves. On taking the AS350 B, in hover flight, in standard atmospheric conditions (ISA), close to the ground, the expected moments in line with the airframe-to-tail boom junction are indicated by the red spot in the following diagram.

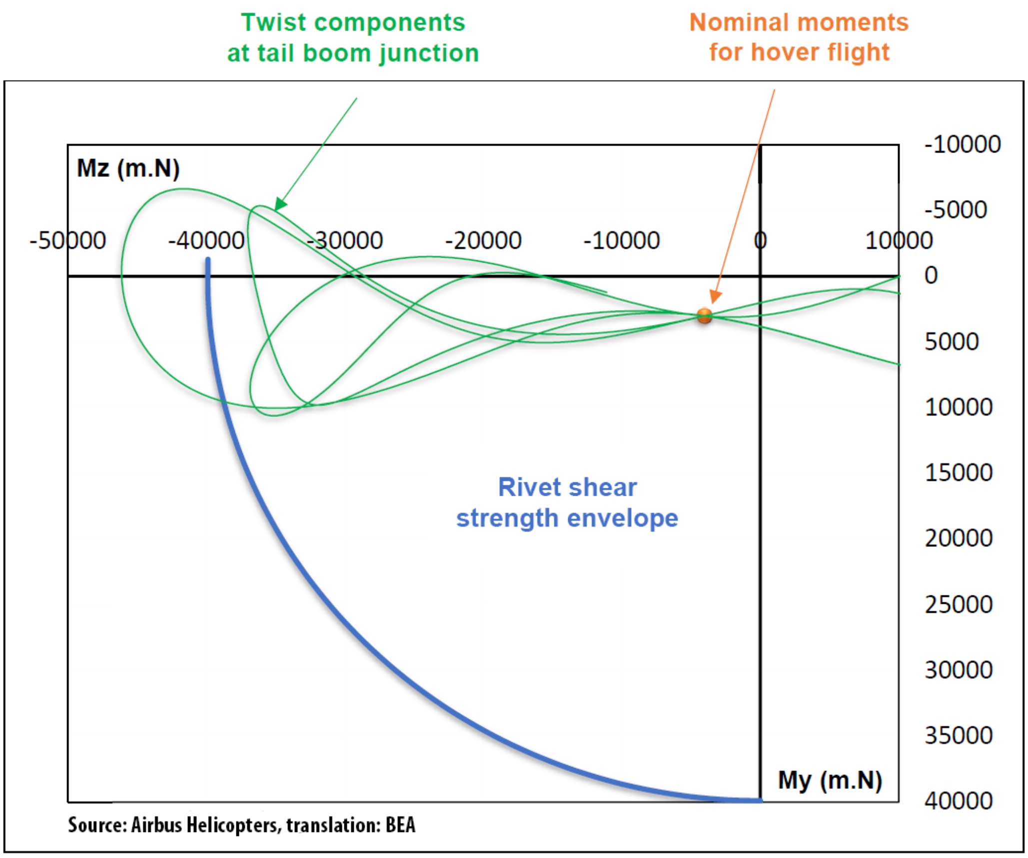


Figure 28: Point of rivet failure

The amplitude of the first moments generated at the junction between the airframe and the tail boom by the overtorque on the main rotor is outside the shear strength envelope of the most loaded rivet. In these conditions, and based on the hypotheses retained, the failures, leading to the separation of the tail boom, occur 0.072 s after the main rotor blades' interaction with the branches.

Additional work was carried out which determined that to exit the shear strength envelope of the most loaded rivet, the diameter of the branches had to be more than or equal to 11 cm.

Likewise, this work determined that to exit the shear strength envelope of the most loaded rivet, the number of impacts on the red blade had to be more than or equal to 5.

Analysis of video and work relating to the accident to the AS350 registered ZK-HIG on 23 November 2011

During this accident, after putting a tower into position, the pilot descended the helicopter vertically, the cable still being connected to the tower and the helicopter hook.

A rotor blade struck the cable and under the impact, the tail boom separated from the cabin, the helicopter then turned about its yaw axis before falling and hitting the ground.

A video[13] shows the failure sequence along with the effects of the centrifugal force on the pilot.

[13] https://www.youtube.com/watch?v=v5aMT9MBfZI

Although the hypotheses retained to model the moments generated in line with the tail boom were different to those of F-GIBM, the safety investigation showed that the moments calculated were outside the shear strength envelope of the attachment rivets.

https://www.aviation.govt.nz/assets/publications/fatal-accident-reports/zk-hig_final_rep.pdf

A2.2 SEPARATION OF SEATS

The illustration below shows the seat worthiness envelope to vertical accelerations (on the Z axis oriented upwards) and lateral accelerations (on the Y axis) for the type of seat which equipped F-GIBM, in accordance with the certification file of the aircraft equipped with this type of seat.

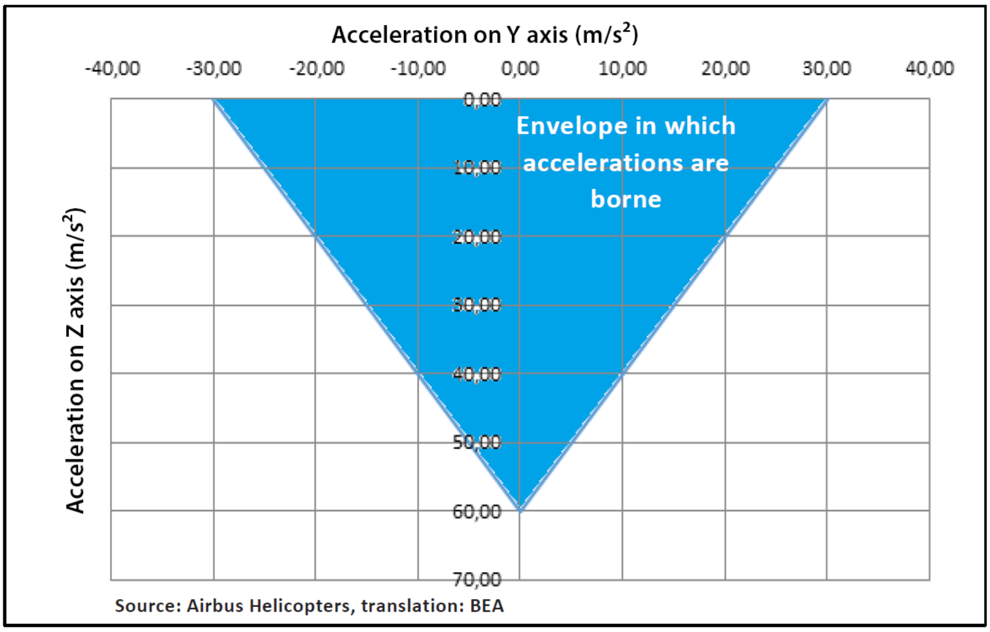
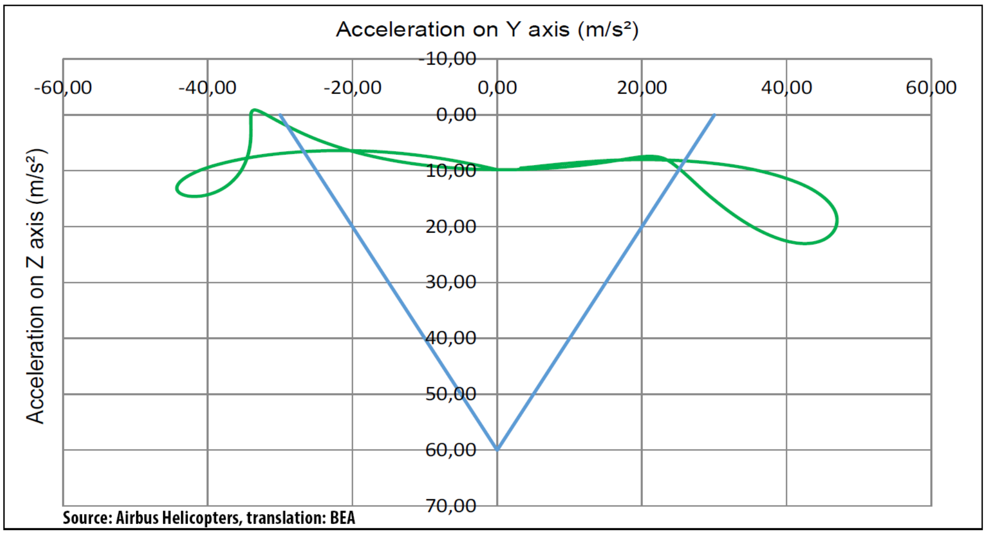


Figure 29: Representation of envelope in which accelerations are borne by seats equipping F-GIBM

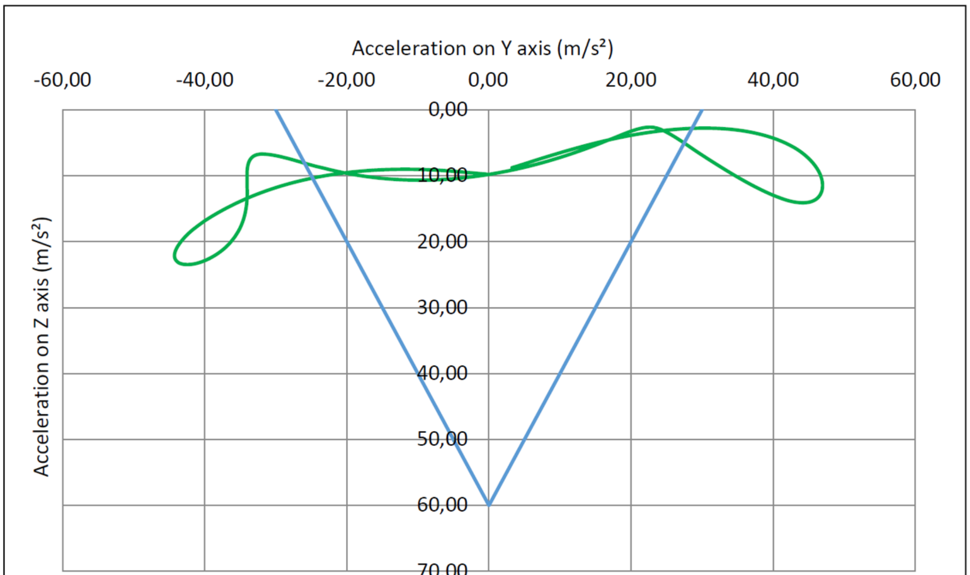
Using the dynamic model for the AS350 B, the screw in line with each front seat, generated by the overtorque on the main rotor was calculated. The associated accelerations are shown in green in the diagrams below.

- **Front right seat**



Source: Airbus Helicopters, translation: BEA

- **Front left seat**



Source: Airbus Helicopters, translation: BEA

Taking the hypotheses described in paragraph A2.1, the lateral accelerations, generated when the main rotor blades interacted with the branches, exceeded the envelope which could be borne by the seats. The seats would have been torn from the deck around 0.03 s after the main rotor blades came into contact with the tree branches.

Note:
Airbus Helicopters introduced a new generation of seat in 1999, called "high energy absorbing seats". It was possible to install this type of seat in F-GIBM. However, given the circumstances of the accident, such an installation would probably not have improved the chances of survival for the occupants of the aircraft.

Appendix 3
Ophthalmological examination report

COMPTE-RENDU D'EXAMEN OPHTALMOLOGIQUE

Nom usuel	
Prénom	

Date de naissance	.... / .... /	
Sexe	☐ M	☐ F

ANTÉCÉDENT D'INTERVENTION OPHTALMOLOGIQUE :

Date : Type : Réfraction antérieure :

ŒIL DROIT	ŒIL GAUCHE
Acuité visuelle à 5 mètres sans correction : /10 avec correction : /10	**Acuité visuelle à 5 mètres** sans correction : /10 avec correction : /10
Acuité visuelle Parinaud 6 à 60 cm oui ☐ non ☐ → P =	**Acuité visuelle Parinaud 6 à 60 cm** oui ☐ non ☐ → P =
Acuité visuelle Parinaud 2 à 30 cm oui ☐ non ☐ → P =	**Acuité visuelle Parinaud 2 à 30 cm** oui ☐ non ☐ → P =
Correction actuelle (en dioptries) :	**Correction actuelle (en dioptries) :**
Puissance réfractive sous cycloplégie :	**Puissance réfractive sous cycloplégie :**
Port de lentilles : oui ☐ non ☐ **Réfraction stable :** oui ☐ non ☐	**Port de lentilles :** oui ☐ non ☐ **Réfraction stable :** oui ☐ non ☐
Tonus :	**Tonus :**
Biomicroscopie : **1) Segment intérieur :** **2) Fond d'œil** (verre à trois miroirs) **:** -État de la papille : -État du pôle postérieur : - État de la périphérie rétinienne :	**Biomicroscopie :** **1) Segment intérieur :** **2) Fond d'œil** (verre à trois miroirs) **:** -État de la papille : -État du pôle postérieur : - État de la périphérie rétinienne :

Équilibre oculomoteur : (si anormal, joindre un bilan orthoptique) PPC : **Phories :** T.N.O. :

Champ visuel binoculaire normal : oui ☐ non ☐ (joindre alors les copies des schémas)

Sens chromatique (tables d'Ishihara) **normal :** oui ☐ non ☐

DATE DE L'EXAMEN OPHTALMOLOGIQUE :

NOM, TAMPON D'IDENTIFICATION ET SIGNATURE DU MÉDECIN OPHTALMOLOGUE QUI A PRATIQUÉ L'EXAMEN :

NB : le verso est utilisable pour tout renseignement utile qui n'aurait pas trouvé sa place au recto

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