DATA SUMMARY

LOCATION

Date and time	**Saturday, 12 November 2011, at 11:12 local time[1]**
Site	**Andratx, wooded area in La Trapa (Balearic Islands)**

AIRCRAFT

Registration	**G-WOOW**
Type and model	**HUGHES 369E**
Operator	**Private**

Engines

Type and model	**ROLLS ROYCE 250-C20B**
Number	**1**

CREW

Pilot in command

Age	**53 years old**
Licence	**Private Helicopter Pilot (PPL(H))**
Total flight hours	**110 h**
Flight hours on the type	**40 h**

INJURIES

	Fatal	Serious	Minor/None
Crew	**1**		
Passengers	**1**		
Third persons			

DAMAGE

Aircraft	**Destroyed**
Third parties	**450 m² of low lands and shrubs**

FLIGHT DATA

Operation	**General aviation – Private**
Phase of flight	**Low level maneuvering – Flight**

REPORT

Date of approval	**28 November 2012**

[1] All times in this report are local unless otherwise specified. To obtain UTC subtract one hour from local time.

1. FACTUAL INFORMATION

1.1. History of the flight

On Saturday, 12 November 2011, a Hughes 369E aircraft, registration G-WOOW, took off from the Son Bonet Airport (Balearic Islands) at approximately 10:40 on a private flight with two persons onboard. The flight plan filed indicated the flight was to last 1 hour and 15 minutes. The destination was the same departure airport and the aircraft had enough fuel to last 2 hours and 40 minutes.

The aircraft's two occupants were the pilot, who flew this aircraft frequently due to his friendship with its owner, and a passenger, who was sitting in the free front seat next to the pilot's and who had been friends with the pilot for about 20 years. The passenger did not have a flight license but had flown previously on helicopters.

The flight's initial course was to the north of the island, leaving the town of Soller to the left, before heading northeast to Puig Mayor mountain, which they passed on their left side (see Figure 1). Further ahead the pilot made a 90° left turn and continued heading toward the sea, flying over the coastline in the vicinity of Sa Calobra. Once over the coast the course was parallel to the coastline on a southwesterly heading until the pilot turned inland on a southeasterly course over the valley of Es Ratjoli (north of Andratx).

Figure 1. General overview of the flight path

Some three minutes later the helicopter hovered over a valley known as Comellar de Sa Guixeria with the aircraft facing the southeast at an altitude above ground level of about 80 m, very close to kilometer marker 106 on the MA-10 road (wooded area some 4 km north of Andratx).

During this hover maneuver the aircraft became unstable and descended practically vertically while making two complete turns about its vertical axis to the right. After the second turn it crashed against the side of the mountain.

After the impact a fire broke out that completely destroyed the aircraft. The fire spread to cover an area of vegetation of about 450 m^2 before it was extinguished by firefighters.

The aircraft's two occupants died on impact.

1.2. Personnel information

The pilot in command had a private helicopter pilot license (PPL(H)) since 20 January 2011. It had been issued by the aviation authority of the United Kingdom and was valid until 19 January 2016. He also had the following type ratings:

- R44 valid until 7 December 2012
- Hughes 369E, issued on 3 June 2011 and valid until 2 June 2012.

He also had a class 2 JAA medical certificate that was valid and in force until 4 November 2012.

The aircraft's pilot was friends with its owner and had flown it regularly in the preceding months.

The pilot's log book could not be recovered as it was inside the aircraft and burned in the fire. As a result the pilot's total flight hours and hours on the type were estimated with the help of the personnel at the school where he did his training and flights while studying to obtain his licenses. The last entry available from the pilot's log book was dated 8 December 2010 when he had 66 flight hours.

1.3. Aircraft information

The Hughes 369E helicopter (also known as the MD 369E), registration G-WOOW, was manufactured in 1989 with serial number 0344E. It was outfitted with a Rolls Royce 250-C20 engine, serial number CAE 835726, that had a maximum takeoff power of 420 SHp[2].

[2] Shaft Hp: Horsepower output at the turbine shaft.

Figure 2. Picture of the accident aircraft

The aircraft was not equipped with flight data or voice recorders (they were not required on this type of aircraft).

The maximum takeoff weight is 3,000 lb (1,361 kg). On the day before the accident the aircraft had 3,116 flight hours and the engine 3,098 h. It could carry four people.

The main rotor has five blades and a diameter of 8.1 m. The tail rotor on this model has a diameter of 1.4 m and consists of two sets of two blades, each set being actuated via independent links to vary the pitch on all four blades at the same time when commanded by the pilot.

The main rotor turns counterclockwise as seen from above. The normal in-flight operating range of the main rotor is between 487 and 492 RPMs[3].

The aircraft is certified for single-pilot operations and in this case was configured to have the pilot fly in the left seat. There were also controls in the right front seat.

1.3.1. *Airworthiness and registration certificates*

The airworthiness certificate had been issued by the British civil aviation authority (UK CAA[4]) on 19 May 2011.

[3] Section 2-6 of the Aircraft Flight Manual.
[4] United Kingdom Civil Aviation Authority.

This aircraft had been purchased by its current owner (a British national) in the spring of 2011, and as a result the aircraft had been registered in the United Kingdom on 21 April 2011 as G-WOOW. It had previously had French registration F-GTLF. The airworthiness certificate associated with this registration, issued by the French authority, expired on 29 January 2012.

1.3.2. *Maintenance*

When the aircraft was purchased and registered in the United Kingdom, the maintenance stopped being performed in France and was transferred to the United Kingdom. The last maintenance activity carried out in France was the annual inspection, coinciding with the 100-h check. At the time, 1 April 2011, the aircraft had 6,062 cycles, 3,046:15 flight hours, 3,028:35 engine hours and 18277 TE[5].

A few days later, at the maintenance center in the United Kingdom, a new weight and balance measurement was taken and the airframe and engine subjected to a special overhaul, which coincided with the 50-hr or 6-month inspection. These activities were conducted between 6 April and 24 May 2011 with 6,080 cycles, 3,050:55 flight hours, 3,033:15 engine hours and 18,295 TE on the aircraft.

The Certificate for Release to Service signed on 24 May 2011 by the authorized center that did the maintenance noted that in 40 flight hours, or 200 TE, the aircraft had to undergo further maintenance so as to comply with FAA Airworthiness Directive (AD) 2005-21-02 & SB369E-095 R2 M/R blade torque event inspection[6]. This inspection was carried out on 12 July 2011 with 6,125 cycles, 3,084.4 flight hours, 3,066.8 engine hours and 18,446 TE on the aircraft. As a result the next inspection as per the directive was required prior to 3,119.4 flight hours or 200 additional TE.

Once the aircraft was returned to service on 24 May 2011, the next 50-h inspection should have been scheduled for when the aircraft had 3,100:55 flight hours, though it was scheduled by mistake for the 3,146:15-hour mark, which was 100 h after the last annual inspection carried out in France.

The future maintenance inspections scheduled by the maintenance center in the United Kingdom were (scheduled by hours flown):

- 50-h inspection coinciding (by mistake) with the 100-h inspection
- 100-h inspection – airframe: 3,146.2 h

[5] Torque Event. MD Helicopters Inc. defines the term as a transition to hovering from horizontal flight or any external load operations. According to the manufacturer, said situations can contribute to generate fatigue in the helicopter and must thus be counted by the pilot and annotated in the helicopter log book for maintenance consideration purposes.

[6] Basically intended to detect cracks in the blades and signs of fatigue.

- 300-h inspection – airframe: 3,263.9 h
- 150-h/annual inspection – engine: 3,196.2 h/31 March 2012
- 300-h/annual inspection – engine: 3,263.9 h
- Annual overhaul of airframe and engine 31 March 2012

1.3.3. *Weight and balance*

Based on the last certified weight and balance measurement of the aircraft , taken on 24 May 2011 (dry weight of 1,606.60 lb at 109.21 in[7], giving a moment of 175,456.786 lb × in), and the following considerations:

- the aircraft took off with its fuel tanks full
- the estimated flight time before the accident was approximately 30 minutes, equivalent to a fuel consumption of about 100 lb[8]
- the fuel from the main tank is used first

Item		Weight (lb)	Lever arm (in)	Moment (lb × in)
Without fuel	Basic empty weight	1,606.60	109.210	175,456.786
	Pilot	200.00	73.500	14,700.000
	Front passenger	200.00	73.500	14,700.000
	Total weight and moment without fuel	**2,006.60**		**204,856.786**
	Center of gravity without fuel		**102.091**	
With maximum fuel at takeoff	Main tank	435.00	98.100	42,673.500
	Auxiliary tank	136.50	119.000	16,243.500
	Total weight and moment without fuel	**2,578.10**		**263,773.786**
	Center of gravity without fuel		**102.313**	
After 30 minutes in flight	Main tank	335.00	98.100	32,863.500
	Auxiliary tank	136.50	119.000	16,243.500
	Total weight and moment after 30 minutes in flight	**2,478.10**		**253,963.786**
	Center of gravity after 30 minutes in flight		**102.483**	

Table 1. Weight and balance

[7] The datum or reference for the balance is 100 in (2.54 m) forward of the main rotor axis.
[8] On a typical flight this aircraft was estimated to consume around 30 gallons (113.56 l) of Jet A-1 fuel per hour. Assuming a density of 0.8 kg/l for Jet A-1 yields the value for fuel consumed of 100 lb.

Item 2-4 on page 2-3 of the MD 369E Rotorcraft Flight Manual[9], *Weight Limitations*, contains the following graph (Figure 3) showing the center of gravity envelope with the points from the above table plotted on it.

The full fuel load at takeoff situation is shown in green, and the situation reached after a 30-minute flight is shown in red. In both cases the flight was being carried out within the limits established by the manufacturer.

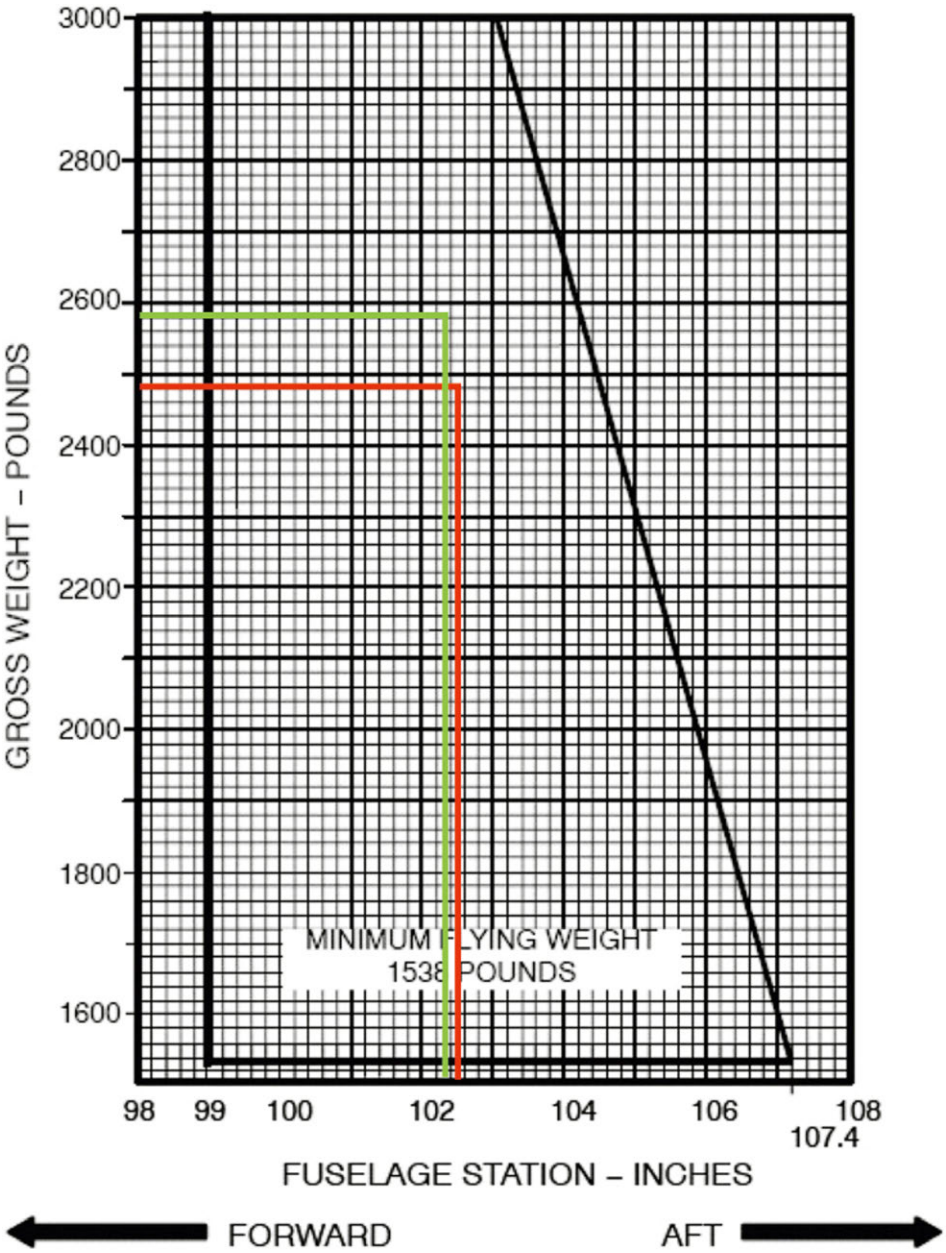

Figure 3. Center of gravity

[9] Manufacturer's flight manual.

1.4. Meteorological information

Meteorological information was gathered from three weather stations 10, 22 and 23 km away from the accident site, as well as from eyewitnesses to the event. The METAR[10] for the Palma de Mallorca Airport, 28 km away from the accident site, was also available.

The data recorded at the weather stations indicate that at 11:10, the wind was from the east at between 3 to 6 kt and gusting to a maximum of 13 kt. The temperature was between 20 and 21 °C, relative humidity around 75% and there were few or no clouds.

The data from the Palma de Mallorca Airport indicate that at 11:00, the wind was from the northeast (predominantly from 50°, but varying between 10° and 80°) at 7 kt, the temperature 20 °C and QNH[11] 1,025 hPa. At 11:30 the wind was from the east (predominantly from 60°, but varying between 30° and 120°) at 6 kt, temperature 21 °C and QNH 1,025 hPa. No significant changes were forecast at either time.

There was no precipitation or other adverse phenomena and visibility conditions were excellent.

Statements from several eyewitnesses indicate that there was little wind in the area with some gusts. Light and visibility conditions were optimal as well with no clouds (the eyewitness accounts are supported by a video recorded by one of them in the area that confirms the conditions described).

1.5. Wreckage and impact information

The site where the aircraft impacted was a lowland hillside (with about a 20% gradient where the helicopter impacted) with shrub vegetation. The wreckage was confined to a rectangular area of approximately 20 × 15 m. The figure 4 in Section 1.7.2 shows a diagram of the accident.

A fire broke out after the impact that had to be extinguished by firefighters. The fire burned a much of the aircraft wreckage and the vegetation in the area.

The highest part of the area marked in the map corresponds to where the aircraft initially struck and where most of the glasses from the helicopter's windows were found. The right skid was also found there.

[10] Aerodrome weather report.
[11] Altimeter subscale setting to obtain elevation when on the ground.

The main wreckage (and heaviest fragments) was found in the lowest part of the area marked in the map. The wreckage was facing south. Smaller and lighter components were scattered between the highest and lowest part.

At the wreckage site it was found that:

- The as-found positions of the throttle handle and of the Bendix engine fuel control cam were consistent, with both being placed in flight positions.
- Of the two sets of dual blades that comprise the tail rotor, the outermost one had detached from its anchor points.
  The pieces that serve to attach the components that were found detached were recovered. The fractures they exhibited were analyzed and the findings indicated that they were caused by the impact with the ground, enabling investigators to rule out that the fractures had been caused by fatigue or had occurred in flight.
  The tail rotor and its detached components were found together. No tail rotor components were found outside the debris field that included the tail rotor.

1.6. Medical and pathological information

The forensic toxicological analyses showed that the aircraft's pilot had a blood ethyl alcohol content of 0.76 g/l ± 0.05 g/l.

1.7. Tests and research

1.7.1. *Fuel from the final refueling*

The aircraft was last refueled with Jet A-1 fuel on 11 November 2011 between 11:14 and 11:21, after returning from a flight. The tanks were filled to maximum capacity.

The fuel was provided by refueling unit U/R 302 at the Son Bonet Airport.

From the time U/R 302 was filled on 6 November 2011 at 12:00 until 14 November, it was used on 12 refuelings (four times for aircraft G-WOOW on 8, 9, 10 and 11 November). None of the aircraft refueled from this unit reported any problems involving the fuel supplied.

However, on 12 November, after the accident, fuel samples were taken from U/R 302 for analysis.

An initial urgent analysis was conducted on 12 November 2011, which showed the sample to be normal. A subsequent analysis was performed on 17 November 2011 that confirmed the quality of the fuel.

1.7.2. *Eyewitnesses*

Very close to the accident site there was a professional film crew taping an automobile commercial. The team was making videos and taking photographs of a vehicle parked at a scenic overview located on road MA-10, some 200 m south of kilometer marker 106, a vantage point with views of the valley and, in the distance, of the area where the valley meets the sea. From there the eyewitnesses had an unobstructed view of the aircraft from the time it arrived at their location and also later, when the accident occurred.

According to the account of one eyewitness who saw the entire sequence of events, the helicopter first flew into the valley from the sea (which he saw to the northwest). It then flew over the area where it would later crash and proceeded from there to the northeast along road MA-10 toward Estellencs, away from the eyewitness, who estimated the closest distance between himself and the helicopter at around 200 m. He also estimated the helicopter's altitude above the ground at approximately 100 m.

After a short while (several minutes in his opinion), the helicopter returned, appearing from the direction in which it had left. It flew back over the same area (closest to the eyewitness) and hovered. It was facing southeast and at an altitude above ground of about 70-80 m. The eyewitness saw the helicopter almost head on and stated that he stared at it the entire time,

The helicopter stayed in that position motionless in the air for about 20-30 seconds, after which it tilted forward somewhat sharply, followed by a tilt back before leveling

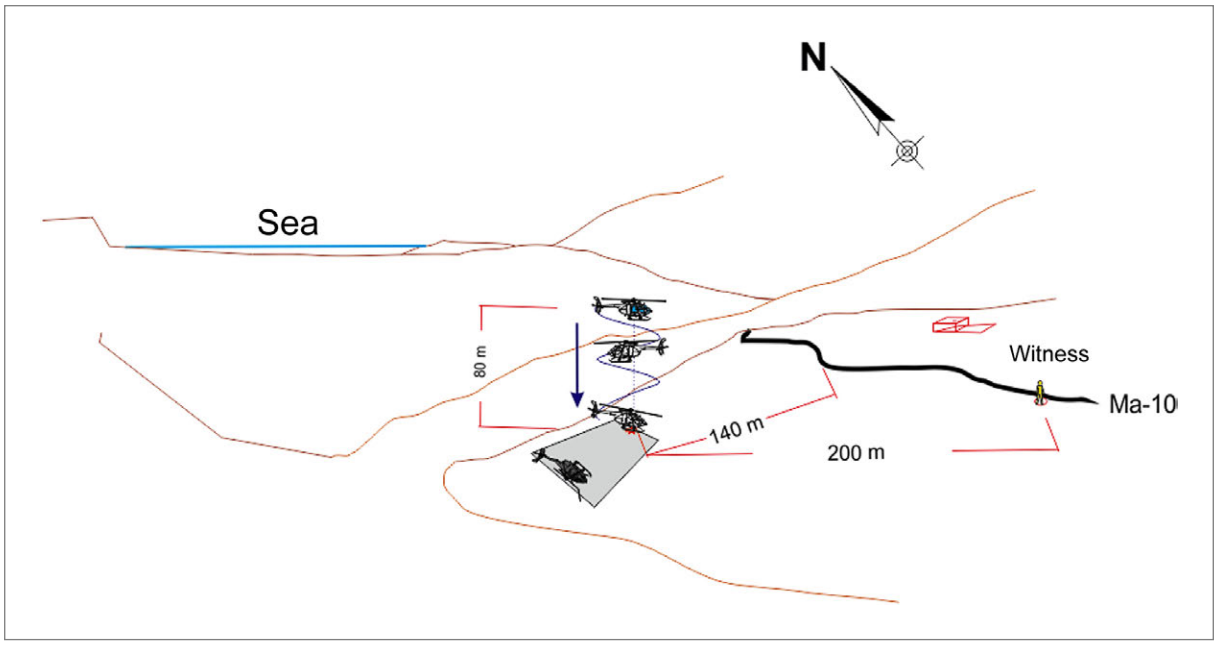

Figure 4. Diagram of the accident sequence

off more or less as it had been. It then immediately started turning about its own axis to the right as it descended vertically, losing altitude. It completed one turn and started another as it continued to fall. It was at the completion of the second full turn that it struck the side of the mountain in a slight nose down and right bank attitude.

The diagram above (not to scale) shows the locations of the various sites mentioned.

The eyewitness remembered that the engine sound was uniform throughout. He did not notice any type of discontinuity or change in the noise while it hovered before crashing. He also did not hear any other noise indicative of any banging or components breaking. He did not see anything detach or ejected from the helicopter, nor did he see smoke or flames.

When it struck the ground, it exploded into flames. The wreckage slid a few meters downhill before stopping.

The eyewitness estimates that seven seconds elapsed from the time the helicopter started to become unstable until it crashed.

The video camera was recording, focused on the vehicle. When one of the eyewitnesses realized that the helicopter was starting to fall, he tried to focus on it and managed to record the instants before the crash (about 3 seconds), but the image was out of focus and remained so until after the impact. The recording includes the ambient sound.

The footage was provided to the CIAIAC by the eyewitness for the investigation.

Also available were 13 photographs taken from the scenic overview. The first seven were taken with the helicopter in flight and the eighth was taken just after the impact. According to the timestamps, the first and second photographs were taken in the same minute, the third through seventh in the next minute, and the eighth within one minute of the previous five.

In the second photograph the helicopter is heading east. In the third, it had returned and was hovering, as described earlier.

Relative altitudes between the eyewitness, the hovering helicopter and the crash site

The eyewitness was on a site located at an elevation of 345 m above sea level.

The elevation of the impact point on the mountainside is 320 m.

The helicopter was hovering some 80 m above the impact point, or 400 m above sea level, equivalent to 1,312 ft.

1.7.3. *Analysis of the sound on the video recording*

The sound from the video recording provided by the eyewitness, particularly the hover phase until the impact with the ground, was isolated at the CIAIAC laboratory and subjected to a spectral analysis.

The base frequencies for the main and tail rotors, along with their first harmonic, were identified in the analysis.

These frequencies were continuous and did not change during the portion of the recording that was analyzed.

1.7.4. *Operation of the helicopter throttle control*

On the top end of the collective lever, where the pilot provides the inputs to said lever, is the handle for the throttle control.

The power supplied by the engine is increased by rotating the throttle handle outward. The rotation of the throttle handle is transmitted mechanically to the Bendix fuel control unit (located next to the engine), which features a cam located above a graduated arc to indicate its position. The handle can be rotated through 90°. At the 30° point, a cam or catch[12] on the collective head is released that prevents returning the handle to 0° without intentionally resetting the cam. Reaching 30° implies placing the throttle lever in ground idle.

In the 90° position (limit for rotating the handle), the turbine RPMs (N_2) are increased to 100%. This is the flying position.

Inputs by the pilot to the collective lever demanding more or less power generate a reaction in the engine that is overseen by the governor, which is designed to maintain the main rotor RPMs within certain limits.

1.7.5. *Ability of the aircraft to hover out of ground effect*[13]

Graph 8-1 in the manufacturer's Flight Manual (Figure 5) shows the helicopter's ability to hover out of ground effect as a function of weight, pressure altitude and outside air temperature.

Under the conditions at the time of the accident (weight of around 2,500 lb, outside air temperature of 18 °C[14]), the maximum hovering altitude is 9,000 ft.

[12] Known as the idle ring.
[13] Ground effect in helicopters is characterized by an increase in lift when at an altitude above the ground that is less than or equal to the main rotor diameter.
[14] Since the temperature was around 21 °C at sea level, a negative altitude correction of around 3 °C is required since the helicopter was hovering at an altitude above sea level of about 1,300 ft.

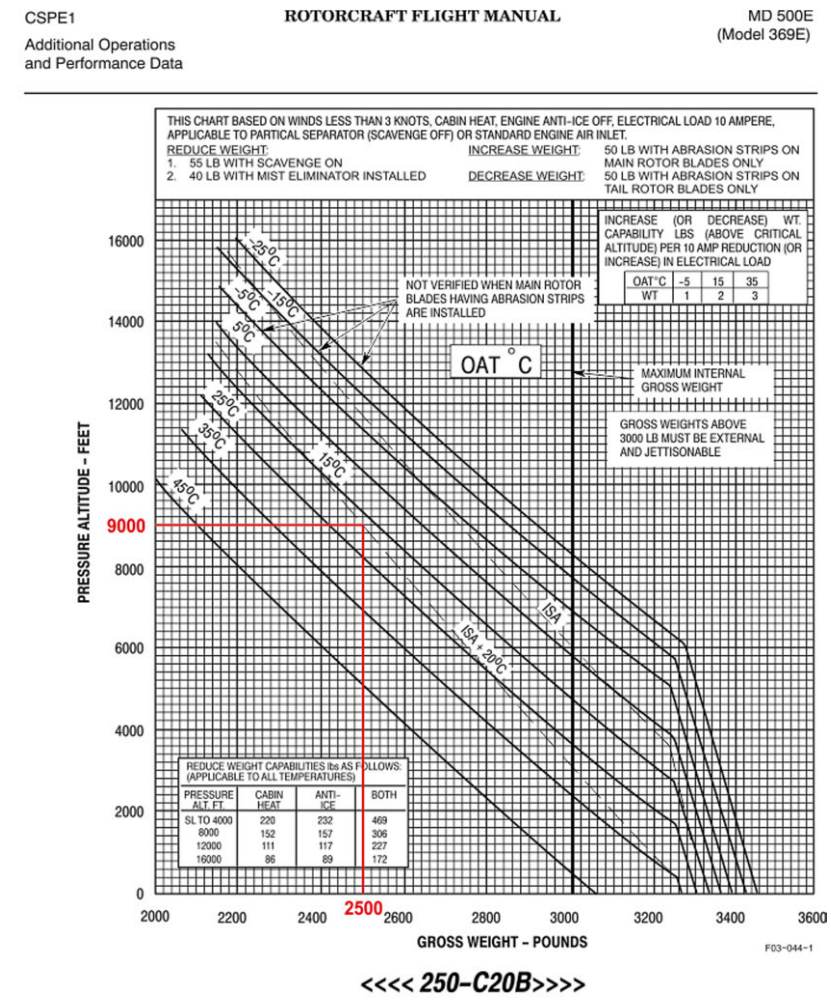

Figure 5. Hover out of ground effect

Under these hovering conditions, the collective control is usually in the upper third of its range of motion.

As for the torque, it is difficult to give a precise value for hovering, though in the opinion of experienced flight instructors for this aircraft type, a value of around 65-70 psi[15] would be required. Since the maximum continuous pressure[16] is 81.3 psi, this would be equivalent to a torque demand of around 80-85% of the maximum continuous rated value.

[15] psi is a unit of pressure (pounds per square inch), not of torque; however, the manufacturer expresses torque in psi units for the pressures generated in the engine.

[16] As long as the turbine outlet temperature (TOT) is equal to or less than 738 °C. If it is above 738 °C, the maximum continuous value is 74.3 psi. The TOT value reached during this specific maneuver is not known, but is estimated to have been below 738 °C.

1.7.6. *Flights before the accident flight*

The aircraft was equipped with a Garmin 695 GPS unit, which was recovered from the wreckage.

The analysis of its internal memory yielded information regarding the accident and preceding flights that made it possible for investigators to reconstruct its flight path, speeds and headings at the different points where the GPS recorded data.

Specifically, on 8 and 9 November 2011 (four and three days before the day of the accident), this same aircraft made flights around the island that included flying at low speed over the area where the accident would take place. The pilot on these flights was not the pilot who died in the accident, but rather the owner of the aircraft. The accident pilot, however, was known to have been onboard during one of those flights. The two friends were considering purchasing a structure[17] in the area that could be seen by flying over the site where the accident would take place some days later.

Copies of the flight plans for the flights made over the island by the aircraft in the days before the accident were also obtained. These revealed that the accident pilot flew the aircraft twice on 10 November on flights lasting 1.1 and 0.3 hours. He also flew on the day before the accident as a passenger on a 0.9-hr flight in which the owner was the pilot flying.

1.7.7. *Accident flight*

The data extracted from the GPS unit allowed investigators to reconstruct the accident flight until seconds before impact.

The altitudes and speeds[18] used before reaching the area where the accident took place were typical for this type of flight and aircraft.

Specifically, as regards the speeds, in the segment of the flight over the sea during which the island was to the left, the speed was a more or less constant 120 kt.

Once the aircraft flew inland, leaving the sea at its back, the speed dropped to 80 kt and continued to fall to around 45 kt while the aircraft was flying southeast in the valley (it was then that the eyewitness saw the aircraft flying "toward him"). The aircraft then changed heading to the northeast, maintaining a speed of around 45 kt, before leaving the area where the accident would later take place.

[17] Information provided by the victim's family.
[18] Since the speeds were taken from a GPS unit, they are ground speeds.

As it left the area to the northeast, flying away from the eyewitness, the speed increased to around 55 kt. This speed was maintained until the aircraft returned to the valley, at which point the eyewitness saw it again. The speed then dropped continuously until the aircraft reached a point over the eventual accident site, where the translational speed dropped practically to zero as the helicopter transitioned into a hover.

1.7.8. *Helicopter's Height – Velocity diagram*

Graph 5-15 in the manufacturer's Flight Manual shows a diagram (typically known as the H-V diagram, Figure 6) that specifies the combinations of velocity and height (above

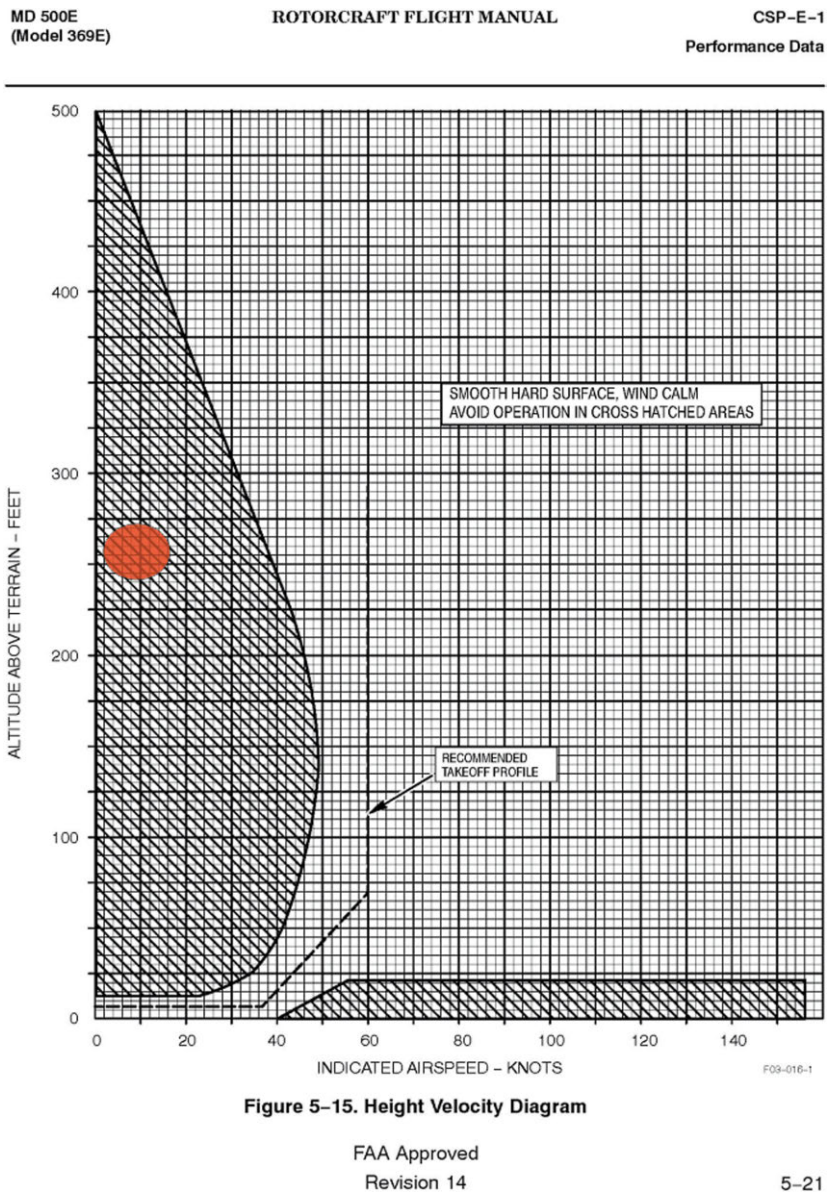

Figure 6. H-V diagram

terrain) that must be avoided in order to properly respond to an engine failure. The two shaded areas in the graph represent combinations of height and velocity where an auto-rotation maneuver would be difficult to execute successfully.

Operating within the shaded areas is not prohibited by the manual, but it does specify that they should be avoided.

The remaining areas show combinations in which a safe auto-rotation maneuver can be completed by a pilot with normal skill and reaction time.

The area shaded in red shows the conditions under which the pilot was hovering before the loss of control of the helicopter and the subsequent accident.

1.8. Additional information

1.8.1. *The loss of tail rotor effectiveness phenomenon*

The loss of tail rotor effectiveness, or LTE, is a critical condition typical of low-speed flying that can result in an uncommanded and rapid[19] uncontrolled yaw that does not go away by itself and requires corrective actions by the pilot. It can lead to a loss of control of the aircraft. It is one of the main causes of accidents involving a loss of control of the helicopter and can manifest itself in any helicopter with an anti-torque rotor. More information on this phenomenon can be found in FAA AC 90-95 *Unanticipated Right Yaw in (US Manufactured) Helicopters*.

A factor that contributes to the occurrence of LTE when a helicopter (whose main rotor turns left) is flying at low speed (IAS below 30 kt) is a wind direction from 210 to 330 relative (i.e. taking as vertex the center of the helicopter and its longitudinal axis forward as start of the sector and opening the angle rightwards). By opposing the thrust generated by the tail rotor, it can result in a vortex ring state (VRS, explained in 1.8.2) in the tail rotor that destabilizes flow and causes the thrust generated by the tail rotor to oscillate.

In July 1994, the NTSB published four safety recommendations for the FAA involving the need to educate and train pilots on this phenomenon. All of them led to actions taken by the FAA, including the publication of an advisory circular (AC) on LTE and its inclusion in the standard pilot training textbook, "*Rotorcraft Flying Handbook*".

In an effort to increase awareness among operators and pilots of this phenomenon, including the need to incorporate LTE in pilot training programs, other accident and incident investigation commissions, such as the AAIB[20] in the United Kingdom and the

[19] Yaw speeds in excess of 30 degrees per second are not recommended under normal operations; however, during LTE or a failure of the tail rotor, yaw speeds on the order of 90-120 degrees per second are possible.

[20] Accident of a Bell 206B Jet Ranger III, G-BAML on 30 May 2003. Final report EW/C2003/05/07. Accident of a Robinson R44, G-SYTN on 8 May 2005. Final report EW/G2005/05/07.

AAIU[21] in Ireland, have issued various recommendations in the wake of accidents caused at least in part by LTE. These recommendations were directed at both national authorities (the CAA and IAA, respectively) and the EASA as the supranational authority at the European level.

The CIAIAC also, in the wake of an accident involving a Bell 206 in 2005[22], issued a safety recommendation along these lines to the DGAC. More recently the CIAIAC also issued a similar safety recommendation to the National Aviation Safety Agency following an accident involving another Bell 206 in 2011.

Both the CAA and the IAA proceeded to issue publications[23] intended to familiarize operators with the LTE phenomenon and to recommend that they distribute this information among their crews.

For its part, the EASA issued a safety bulletin[24] in 2010 that recommended to national authorities that they ensure that helicopter pilot training programs include material on LTE and recovery techniques.

1.8.2. *Vortex ring state*

A vortex ring state is a temporary condition in which the rotor flies through its own wake and a significant portion of the blades is operating at angles of attack in excess of the maximum (the helicopter falls into its own downwash). The wingtip vortices grow until they form a ring around the rotor. A large, unstable flow engulfs much of the rotor disc, causing a loss in rotor efficiency even when driven by the engine; in fact, VRS can occur during high-power vertical descents. As a result, the rate of descent (ROD) increases rapidly for a given engine power.

VRS can occur during a drop in power at a speed below 30 kt and a rate of descent close to the main rotor's "induced velocity". The induced velocity depends on the type of helicopter and its gross weight, but in general, the ROD is generally considered to be dangerous when it exceeds 500 ft/min[25].

1.8.3. *Height profile during hover operations*

The diagram below shows a profile of the terrain to scale, with the hovering altitude on the left axis and the direction in which it was heading.

[21] Accident of a Bell 206B Jet Ranger II, G-AYMW on 5 April 2004. Final report No. 2004/0021.
[22] Final report A-068/2005.
[23] Flight Operations Department Communication (FODCOM) 1/2004.
[24] EASA SIB 2010 12 February 2010 revised by SIB 2010-12R1 of October 2010.
[25] European Helicopter Safety Team (EHEST of the EASA).

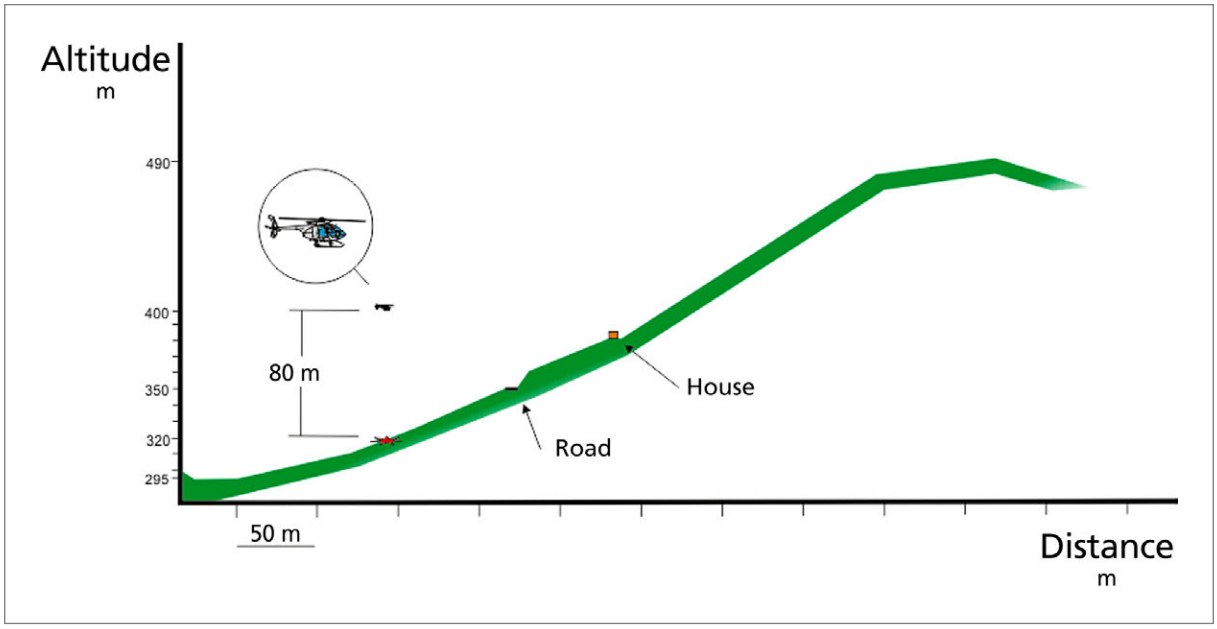

Figure 7. Altitude profile of the terrain

1.8.4. *Stipulations of the Air Traffic Regulations*

Articles 6.1.5 and 7.2.3.13 of Spain's Air Traffic Regulations, approved by Royal Decree 57/2002 of 18 January, expressly prohibit piloting while under the influence of alcohol.

2. ANALYSIS

2.1. General observations

The flight that led to the accident was a private flight taken for the purpose of touring over the island of Mallorca.

The flight proceeded normally in good weather conditions over areas that were known to the pilot.

The reconstruction of the path taken by the aircraft on the day of the accident revealed that the speeds and altitudes were typical for this type of flight and aircraft until the arrival at the eventual accident site.

Both the accident pilot and his friend, the owner of the helicopter[26], had flown over the accident area several times in the days before the accident. The two were interested in

[26] These were the two individuals who typically piloted the aircraft.

acquiring a structure very close to the accident site that could be seen by flying over the valley. That was very likely the reason for the initial pass, to see the area at a speed lower than usual. They then returned to the valley to hover while facing the southeast, toward the same structure.

The violence of the impact with the terrain and the intensity of the ensuing fire ruled out any chance of survival.

The aircraft's documentation was in order and the pilot had a valid and in force license, rating and medical certificate.

2.2. Aircraft maintenance

The aircraft had been maintained in accordance with the approved maintenance program, except for the mistake involving the last 50-h inspection, which was not carried out at 3,100:55 h. The accident flight occurred 16 flight hours later, with approximately 3,116 h on the aircraft, 30 h short of the 100-h inspection.

Aside from this scheduling mistake, there is no evidence that the maintenance was performed incorrectly.

2.3. Toxicological analysis of the pilot

The results of the forensic and toxicological analyses showed that the pilot's blood alcohol content was incompatible with the piloting of an aircraft. However, the possibility that some or all of this alcohol may have been produced post mortem as part of normal decomposition could not be excluded.[27]

Therefore, it cannot be assured the presence of alcohol in pilot's blood at the time of the accident.

2.4 General observations on the operation

During the takeoff and the entire flight, until the accident, the weight and balance of the aircraft were correct and within the limits established by the manufacturer.

[27] Kugelberg and Jones (2007). Interpreting results of etanol analysis in postmortem specimens: a review of the literature. *Forensic Science International, 165,* p. 10-29.

The aircraft's range at takeoff was the maximum, about 2 hours and 40 minutes (assuming a typical fuel consumption of 30 gallons per hour of flight time), as evidenced by the fact that the aircraft was fully refueled before the flight, which was scheduled to last 1 hour and 15 minutes. This same range was specified on the flight plan. At the time of the accident the aircraft had been flying some 30 minutes, meaning there was no shortage of fuel. The explosion of the aircraft after the impact and the amount of surface area burned by the fire confirm the presence of a significant amount of fuel onboard.

The quality of the fuel taken on the day before the flight did not exhibit any quality abnormalities, as confirmed by the analyses.

The weather on the day of the accident was perfect for the flight. The visibility was excellent and the wind was moderate.

2.5. Analysis of the wreckage

A study of the wreckage revealed that:

a) The helicopter controls responsible for managing fuel flow to the engine were in the flight position and consistent with one another.
b) The detachment of one of the two 2-bladed units that comprise the tail rotor from its anchor points took place when the aircraft struck the terrain.

The debris was confined to a small area, measuring approximately 20 × 15 m. There were no components found outside this area.

The way the wreckage was arranged is compatible with a highly vertical impact with little or no translational speed against the highest terrain in the area (a hillside), followed by the wreckage falling down the hillside and coming to a stop approximately 20 m below.

The glass from the cockpit and the helicopter's right skid were found at the highest part, which confirms the point of impact and the right bank attitude at the moment of impact, since the right skid detached and remained upslope.

After the impact and explosion, the aircraft wreckage slid downhill and came to rest facing south. The aircraft's final orientation and the damage to the tail cone indicate that as the aircraft was sliding down the hill, the aircraft could have turned right about its longitudinal axis but that it did not turn about its other axes. This confirms the little or no translational speed present at the moment of impact.

Components that were smaller in weight and size were scattered between the high and low terrain in the area.

2.6. Maneuver prior to the aircraft destabilization

The information extracted from the memory on the GPS unit, plus that provided by the eyewitness, indicates that the pilot started to hover while facing the southeast, toward the property he was interested in.

The hover was being conducted at an altitude of about 400 m above sea level, equivalent to 1,312 ft, and some 80 m above ground level, meaning the helicopter was out of ground effect.

For the weight and outside air temperature conditions at the time, it is estimated that the aircraft can hover out of ground effect up to a pressure altitude of 9,000 ft, meaning that this maneuver, from an aircraft performance standpoint, did not pose any problem.

According to the manufacturer's height-velocity diagram, however, the combination of speed (none) and height above terrain (about 80 m) at which the aircraft was hovering did involve risk in the sense that if the aircraft lost power, it would be difficult to carry out an auto-rotation maneuver safely. When the parameters are plotted on the H-V diagram, the point is inside one of the two shaded areas that the manual specifies are to be avoided during flight. According to the H-V diagram, hovering would have required being at double the actual height above terrain.

Hovering out of ground effect demands high power, and this implies placing the collective control in the top third of its range of motion. The aircraft's estimated weight at the time was approximately 2,500 lb, equivalent to 83% of its maximum takeoff weight (3,000 lb). As for the torque, the situation described would be equivalent to a demand of between 80 and 85% of the maximum continuous torque. The net result of these effects is that the power demand was high.

2.7. Destabilization of the aircraft

When the aircraft became unstable, there was no change to the rotation rate of the main or tail rotor blades, as determined by the analysis of the sound recorded on the video by the eyewitness. The analysis of the fractures present in the tail rotor ruled out a failure of this component.

Despite this, the aircraft started to descend sharply while turning right about its vertical axis. Considering that seven seconds elapsed between the destabilization and the impact

and that it made two complete turns about its vertical axis, this yields an average descent rate of 2,254 ft/min and an average yaw rate of 103 degrees per second. Both values are extraordinarily high to have been commanded in a situation so close to the ground.

The wind in the area is estimated to have been from the east and northeast (if, in addition, the geography of the valley is taken into account, then the wind blowing through it would be expected to come from the northeast). If the helicopter was facing the southeast, then the incident wind would have been coming from 270° relative (i.e. taking as vertex the center of the helicopter and its longitudinal axis forward as start of the sector and opening the angle rightwards).

The wind speed recorded was on the order of 6 kt with nominal gusts reaching up to 13 kt, a value that could have been even higher if the constricting effect of the valley is taken into account.

Under these wind incidence, high power demand and practically zero speed conditions, the appearance of the LTE phenomenon would explain the yaw to the right (at such high rotation rates) without a failure of the tail rotor. Once in this condition, the application of left pedal and/or more power through the use of the collective would aggravate the situation even more, leading to a loss of main rotor lift with the immediate loss of altitude and the ensuing appearance of vortex ring state, which would explain the high descent rate despite flying under high demanded power conditions.

There is another possible explanation[28] for the loss of altitude experienced after the appearance of the LTE phenomenon: when the right yaw occurs, the rate of rotation of the main rotor with respect to the airframe increases, which would result in the governor reducing power in an effort to maintain the rotor turn rate. This could trigger the descent.

This effect is more pronounced as the angular yaw rate increases due to the loss of tail rotor effectiveness (note that 103 degrees per second of yaw is equivalent to 17 rpm, which is around 3.5% of the typical value for the main rotor RPMs in this aircraft while in flight).

The lift provided by the main rotor is proportional to the square of its rotation rate, meaning that losing 3.5% of the main rotor RPMs would result in the rotor providing 7% less lift.

Dealing with the destabilization would have required quickly identifying the emergency and applying forward cyclic. The close proximity of the ground, however, along with the

[28] Coyle, S. (2003). *Cyclic and collective*. Mojave (California): Helobooks.

even greater proximity of the hillside and the scarce flying experience of the pilot, could have had an adverse effect on the handling of the emergency, causing the helicopter to drop vertically until it impacted the terrain.

3. CONCLUSIONS

3.1. Findings

- The helicopter had a valid and in force airworthiness certificate and had been maintained in accordance with the approved maintenance program, except for a 50-h check that should have been performed 16 h before the accident.
- The error in this missed inspection is not believed to have caused or contributed to the accident.
- The helicopter's weight and balance were within limits throughout the flight.
- The pilot had a valid and in force license, type rating and medical certificate.
- The weather and visibility conditions were adequate for flying.
- There were no signs of any faults between takeoff and the sudden loss of control.
- There was more than enough fuel onboard the aircraft for the flight in question. An analysis certified the quality of the fuel.
- The aircraft's occupants were interested in looking at a specific property located in a part of the island. Said property can be seen from a certain altitude above the ground, which is why they made an initial pass over the area at low speed (about 45 kt) and returned to the area a few minutes later, this time to hover.
- The pilot hovered at an altitude above the ground that is explicitly advised against in the manufacturer's manual. The geography of the area and the fact that the helicopter was so close to and facing the mountainside complicated the emergency since pushing the cyclic forward immediately following the destabilization would have meant moving toward the close mountainside.
- The aircraft had sufficient power to hover as intended given the prevailing weight, atmospheric and altitude conditions.
- The aircraft became unstable while hovering some 80 m above the ground on a southeasternly heading.
- The destabilization resulted in a right yaw at a high angular velocity (on the order of 103 degrees per second) accompanied by a sudden vertical descent at an average rate of 2,245 ft/min. Both maneuvers are believed to have been uncommanded, meaning they occurred without any input from the pilot.
- The wind in the area where the helicopter was hovering at the time of the accident was moderate (3 to 6 kt), but it was gusting to almost triple those values. The wind was striking the helicopter from around 270° relative (i.e. taking as vertex the center of the helicopter and its longitudinal axis forward as start of the sector and opening the angle rightwards), which contributed to diminishing the effectiveness of the tail rotor thrust.

- The conditions of the flight as regards the speed, weight, demanded thrust and wind were identified as risky in terms of the likelihood of the appearance of the loss of tail rotor effectiveness (LTE) and vortex ring state (VRS) phenomena.
- The tests and inspections carried out on the aircraft wreckage did not provide any indications of a mechanical failure in the tail rotor system.
- The analysis of the sound of the rotors in the video recording provided by an eyewitness did not reveal any changes in the rotor frequencies and indicates that both were operating normally under power.

3.2. Causes

The accident was likely caused by the loss of control of the aircraft, resulting from the appearance of the loss of tail rotor effectiveness phenomenon, which caused the helicopter to yaw sharply to the right and then to enter a vortex ring state under power, which made the aircraft lose lift and descend rapidly.
The following are regarded as having contributed to the accident:

- Hovering at a low altitude above ground level, which left little margin for responding to any potential emergencies.
- The pilot's lack of experience, which prevented him from handling the emergency better.

4. SAFETY RECOMMENDATIONS

None.