CIAIAC

COMISIÓN DE INVESTIGACIÓN DE ACCIDENTES E INCIDENTES DE AVIACIÓN CIVIL

# Report A–026/2014

Accident involving an AGUSTA AW 119, registration EC-KSD, operated by the company FAASA, in the municipality of Alpera (Albacate, Spain) on 13 September 2014

GOBIERNO DE ESPAÑA

MINISTERIO DE FOMENTO

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# Foreword

This report is a technical document that reflects the point of view of the Civil Aviation Accident and Incident Investigation Commission (CIAIAC) regarding the circumstances of the accident object of the investigation, and its probable causes and consequences.

In accordance with the provisions in Article 5.4.1 of Annex 13 of the International Civil Aviation Convention; and with articles 5.5 of Regulation (UE) n° 996/2010, of the European Parliament and the Council, of 20 October 2010; Article 15 of Law 21/2003 on Air Safety and articles 1., 4. and 21.2 of Regulation 389/1998, this investigation is exclusively of a technical nature, and its objective is the prevention of future civil aviation accidents and incidents by issuing, if necessary, safety recommendations to prevent from their reoccurrence. The investigation is not pointed to establish blame or liability whatsoever, and it's not prejudging the possible decision taken by the judicial authorities. Therefore, and according to above norms and regulations, the investigation was carried out using procedures not necessarily subject to the guarantees and rights usually used for the evidences in a judicial process.

Consequently, any use of this report for purposes other than that of preventing future accidents may lead to erroneous conclusions or interpretations.

This report was originally issued in Spanish. This English translation is provided for information purposes only.

# Contents

# Abbreviations

| | |
|---|---|
| % | Percent |
| ° ′ ″ | Sexagesimal degrees, minutes and seconds |
| °C | Degrees centigrade |
| AC | Alternating current |
| ACO | Coordination airplane |
| AEMET | Spain's National Weather Agency |
| AESA | Spain's National Aviation Safety Agency |
| AMT | Aviation maintenance technician |
| AVSEC | Aviation Security |
| BEA | Bureau d'Enquêtes et d'Analyses France |
| BIFOR | Forest firefighting brigade |
| BRIF | Heliborne Reinforcement Brigade |
| BOE | Official Journal of Spain |
| CAMO | Continuing Airworthiness Management Organization |
| CIAIAC | Civil Aviation Accident and Incident Investigation Commission |
| CLIF | Forest Firefighting Committee |
| CMA | Air resources coordinator |
| CMR | Certificate of Maintenance Review |
| COE | Special air operator certificate |
| COP | Provincial operations center |
| COR | Regional operations center |
| CPL (H) | Commercial helicopter pilot license |
| CRM | Cockpit resource management |
| DC | Direct current |
| DGAC | Spain's Civil Aviation General Directorate |
| EASA | European Aviation Safety Agency |
| EDU | Engine display unit |
| ELT | Emergency locator transmitter |
| EUROCAE | European organization that is charged with standardizing electrical and electronic devices for aircraft and land-based systems for aerial location and navigation, and that writes standards and documents bearing the ED abbreviation |
| FAA | Federal Aviation Administration of the United states |

| | |
|---|---|
| FAASA | Company that operated the accident aircraft |
| FAR | Federal Administration Review |
| FCU | Fuel control unit |
| FF | FireFighting |
| FL | Flight Level |
| Ft | Feet |
| ft/min | Feet per minute |
| G | Acceleration due to gravity |
| GPRS | Global positioning reporting system |
| GPS | Global positioning system |
| h | Hours |
| hPa | Hectopascals |
| HIS | Horizontal situation indicator |
| IC | Integrated circuit |
| INFOCAM | Plan to fight forest fires |
| JCCLM | Board of communities of Castilla – La Mancha |
| K/min | Kilograms per minute |
| Kg | Kilograms |
| KIAS | Indicated airspeed in knots |
| Km | Kilometers |
| Km/h | Kilometers per hour |
| l | Liters |
| LLS | Fuel low-level sensor |
| M | Meters |
| m/s | Meters per second |
| MAPAMA | Ministry of Agriculture, Fishing, Food and the Environment |
| mb | Millibars |
| MCP | Maximum continuous power |
| MHz | Megahertz |
| Min | Minutes |
| mw | Megawatts |
| N | North |
| $N_1$ | Gas producer shaft revolutions per minute |
| Nm | Nautical miles |
| $N_R$ | Main rotor revolutions per minute |
| OM | Operations Manual |

| | |
|---|---|
| OM-FF-SAR | Firefighting-Search and Rescue Operations Manual |
| OAT | Outside air temperature |
| PCB | Printed Circuit Board |
| PPL (H) | Private helicopter pilot license |
| PUM | Pump switch |
| QNH | Altimeter subscale setting to obtain elevation when on the ground |
| RCC | Air Force's rescue coordination center |
| Re | Reynolds number |
| ROV | Remoted operated vehicle |
| rpm | Revolutions per minute |
| S | Seconds |
| SAR | Search and rescue |
| SHP | Shaft Horsepower |
| SMD | Surface mounted device |
| S/N | Serial number |
| SOIC | Small outline integrated Circuit |
| TSB | Transportation Safety Board of Canada |
| UMMT | Mobile Meteorology and Broadcasting Units |
| UTC | Coordinated universal time |
| V | Volts |
| W | West |
| W | Watts |

# Synopsis

| | |
|---|---|
| Owner and Operator: | FAASA |
| Aircraft: | AGUSTA AW 119 |
| Date and time of accident: | 13 September 2014 at 17:01[1] |
| Site of accident: | Alpera (Albacete, Spain) |
| Persons onboard: | 1 (killed) |
| Type of flight: | Aerial work – Commercial aviation - Firefighting |
| Phase of flight: | Cruise flight |
| Date of approval: | 29 March 2017 |


## Summary of accident:

On 13 September 2014, an Agusta AW 119 helicopter, registration EC-KSD, took off from the base at Villahermosa (Ciudad Real) to take part in fighting a fire in Almansa (Albacete).

After conducting several activities in the area of the fire, it proceeded to the base in Carcelén to refuel. As it was flying over Alpera (Albacete) in cruise flight, it fell to the ground. The pilot, who was the sole occupant, was killed on impact.

The aircraft was located two and a half hours after the accident by chance by a passerby who advised the authorities upon seeing the pilot inside.

No one employed by the Operator or by the institution that had hired it, the Board of Communities of Castilla - La Mancha, had noticed the disappearance of the helicopter.

At the start of the investigation, some deficiencies in the coordination were identified that warranted the issuing of two preliminary safety recommendations, directed at the Operator and the Board of Communities of Castilla - La Mancha, to keep a similar situation from happening again during the 2015 forest firefighting campaign.


[1] Unless otherwise specified, all times in this report are local. To obtain UTC, subtract two hours from local time.

Both recommendations were published on 25 March 2015, and both entities took measures to implement them, measures that were deemed satisfactory by the CIAIAC in terms of their intended results.

The investigation has concluded that the accident was caused by the faulty execution of an autorotation maneuver after the helicopter's engine stopped due to fuel starvation.

The improper management of the fuel onboard by the pilot is considered a contributing factor.

In addition to the two preliminary recommendations, a further three have been issued.

# 1. FACTUAL INFORMATION.

## 1.1. History of the flight

The AGUSTA AW 119 helicopter, registration EC-KSD, operated by FAASA AVIACIÓN, was under contract to the regional government of Castilla – La Mancha, and was providing services as part of the Firefighting Plan (INFOCAM). Its callsign was H23.

Its base of operations was in Villahermosa (Ciudad Real) and it was tasked with transporting forest firefighting brigades (BIFOR) and making water drops from a Bambi bucket.

On 13 September 2014, it was used to transport the BIFOR from Villahermosa (Ciudad Real), which consisted of a specialist technician and six operators, to Almansa (Albacete) to take part in firefighting activities.

The pilot started the engine at 15:43 and took off at 15:47. The last flight had been on 9 September.

During the flight, the pilot told the technician (who was seated to his left) that he would not be able to do shifts longer than 1:30 h, meaning that during the first flight period, he would only be at the fire site for a maximum of about 30 minutes.

Upon arriving at the fire, the pilot contacted the Air Resources Coordinator (CMA), who was onboard the coordination airplane (ACO). The CMA informed him of the location to drop off the BIFOR. They disembarked at 16:30 and the CMA then told the pilot that he had to take the firefighting director on a reconnaissance flight, which he did from 16:46 to 16:54.

At 16:57 he left the fire site and headed to the base in Carcelén (Albacete). Before taking off, the pilot informed the CMA that he was going to said base to refuel and take his rest period. There is no record of any additional communications.


**Figure 1.** Aircraft's flight path

The helicopter was equipped with a satellite fleet tracking system that sends position, altitude and speed signals. There was also a portable GPS unit onboard with the same features. The units stopped recording at 17:02 and 17:01, respectively.

The aircraft was found in Alpera (Albacete) by someone who chanced upon the accident site and reported it at 19:20 to the emergency number for the Civil Guard (062), which dispatched a unit to the site. The officers verified that the pilot had been killed and reported the event to the Castilla – La Mancha emergency coordination center.

This center placed a call to the Regional Operations Center (COR) to ask if they were aware of the accident, to which they replied no and that they would look into it.

The COR later informed the coordination center that the accident aircraft was H23.

During the almost two and a half hours that elapsed between the time the helicopter left the fire site and when it was found, there is no record that any attempts were made by the Operator, or by anyone from the Agriculture Office of the Board of Castilla - La Mancha involved in the firefighting efforts, to communicate with the pilot.


**Figure 2.** Final condition of the aircraft

## 1.2. Injuries to persons

| Injuries | Crew | Passengers | Total in the aircraft | Others |
|---|---|---|---|---|
| Fatal | 1 | | 1 | |
| Serious | | | | N/A |
| Minor | | | | N/A |
| None | | | | N/A |
| TOTAL | 1 | | 1 | |

## 1.3. Damage to aircraft

The aircraft was destroyed.

## 1.4. Other damage

There was no additional damage.

## 1.5. Personnel information

The 44-year old pilot had had a commercial helicopter pilot license (CPL(H)) since 20 February 2002. Before that, on 3 October 2001, he had obtained a private helicopter pilot license (PPL(H)).

He had a type rating for the AGUSTA AW 119 that was valid until 31 January 2015, and a type rating for the Bell 212 and Bell 412 helicopters that was valid until 30 November 2014. He also had an agricultural (firefighting only) rating that was valid until 31 May 2016. His medical certificate was valid until 24 November 2014.

He had a total of 3067:45 flight hours, of which 340 had been on the type.

The following table summarizes the training the pilot had received on the type:

| TRAINING / CHECK | DATE | VALID FOR |
|---|---|---|
| Cockpit resource management training (CRM) | 21-01-2014 | 1 year |
| Hazardous cargo training | 20-01-2014 | 2 years |
| AVSEC (Aviation Security) training | 21-01-2014 | 2 years |
| Advancement training | 23-01-2014 | 1 year |
| Proficiency qualification | | |
| Refresher training | | |
| Training on emergency and safety equipment | | |
| Flight training | 26-02-2014 | 1 year |
| Training on the activity | | |
| Proficiency check | | |
| Check of the activity | | |

## 1.6. Aircraft information

### *1.6.1. General information*

The AGUSTA AW 119 helicopter, registration EC-KSD, was manufactured in 2004 with serial number 14050. It had an empty weight of 1,728 kg and a maximum takeoff weight of 2,720 kg.

It was 11.144 m long, 2.88 m wide and 3.598 m tall. The main rotor had a diameter of 10.83 m and four blades, and the tail rotor a diameter of 1.94 m and two blades.

The minimum crew was one pilot and it could carry a total of seven passengers.

It had a Pratt & Whitney PT6B-37A engine, manufactured in November 2004 with serial number RGB-PU0051.

It had a certificate of airworthiness, issued on 13 June 2008 by Spain's National Aviation Safety Agency (AESA), and since its manufacture it had had a total of 3,365:40 hours of operation until the day of the accident.

### *1.6.2. General maintenance information*

The aircraft was maintained by the operator of the helicopter, which was approved by the AESA as a maintenance organization, ES.145.057, and also as a CAMO[2], ES.MG.H06.

The last maintenance check had been a 50-h check on 18 August 2014, performed in accordance with the AG-119-REV.4 maintenance program of 30 May 2014, approved by the Continuing Airworthiness Manager and supervised by the Continuing Airworthiness Management Supervisor on 12 June 2014, with 3,365:05 h on the aircraft and 3,298:55 h on the engine.

The last overhaul had been on 15 November 2013 with 3,312:50 h on the aircraft and 3,246:05 h on the engine.

### *1.6.3. Information on the operation of the fuel system*

The helicopter's fuel system consists of three subsystems: storage, distribution and indication.

The storage subsystem has three tanks, two main tanks located at the bottom of the fuselage, one on each side, and one at the top. The left tank (no. 1) directly feeds the engine and the right tank (no. 2) transfers fuel to the left tank. The top tank supplies the other two via gravity drain. The system's maximum capacity is 605 l, 595 l of which is usable.

The distribution subsystem is what channels the fuel from the no. 1 tank to the engine. In addition to the associated fuel lines, it includes two fuel valves for tank no. 1, a transfer valve from tank no. 2, three pressure switches, one shutoff valve and a pressure transducer.

[2] Continuing Airworthiness Management Organization - CAMO.

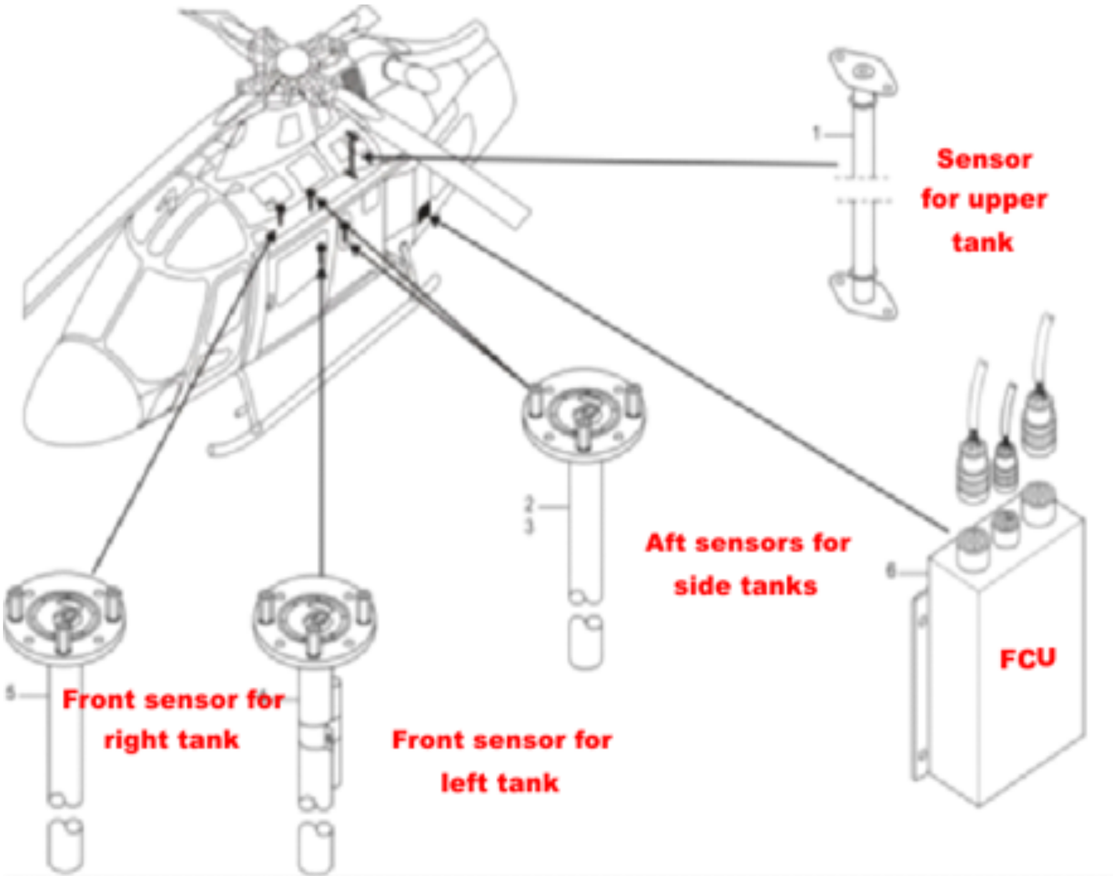


**Figure 3.** Diagram showing installation of the fuel quantity indicators

The indication subsystem consists of a pressure reading, a fuel quantity reading and a low fuel level warning.

All of the readings are routed to the Fuel Control Unit (FCU), which receives the indications from the various sensors and relays two independent signal types, the fuel level (FL) and a low-level system (LLS).

The FCU is electrically connected to two screens in the cockpit, EDU 1 and EDU 2 (Engine Display Units), which show the readings associated with the engine. The units are located one atop the other.

The top display (EDU 1) only shows warning lights, such as:

*FUEL LOW:* Indicates that the fuel quantity is low. If this light turns on, the pilot should verify the amount of fuel in tank 1. If this light turns on, the pilot has to land as soon as practicable, since there are only 10 minutes of flight time remaining at maximum continuous thrust. This warning message is shown in the messages area on the left of EDU 1 at least 5 s after the low fuel level is detected.

*F LOW FAIL:* Fault in the low fuel level sensor, meaning there is no indication for low fuel level. If this light turns on, the flight can continue, but the fuel level has to be monitored. The check that is done before engine start-up does not actually test the LLS sensor, but rather the FCU's ability to detect the low level signal sent by the LLS on the one hand, and to send the proper signal to the EDU on the other. If the LLS sensor is faulty (or the amount of fuel onboard is below 45 kg) and the FCU is in good condition, the FUEL LOW warning will appear on EDU 1 (and not the F LOW FAIL warning) as soon as the pilot turns on the power supply.

*FUEL DRAIN 1 (2):* Drain valve 1 or 2 (if installed) is open. They must be closed before refueling and taking off.

*FUEL PUMP 1 (2):* Fuel pump 1 or 2, in tank 1, has failed. Turn off the affected tank and land as soon as practicable.

*XFER PUMP:* Fuel tank 2 empty or, if the reading is not 0 kg, it indicates a fault with the fuel transfer pump. If this light turns on, the pump switch (PUM) must be placed in the OFF position.

If the fuel transfer pump is disconnected or fails, and the amount of fuel in the right tank is below 120 kg, the fuel level reading in the cockpit for the right tank will be crossed out to indicate that the fuel remaining in the tank is not usable. This is shown in the lower display, EDU 2 (see Figure 5).

This lower display (EDU 2) shows all of the parameters for the fuel, hydraulic, electrical, engine and transmission systems. The readings shown are oil pressure and temperature, transmission oil pressure and temperature, the fuel pressure and level in the main tanks, the pressure in the no. 1 and 2 hydraulic systems, electrical system load and DC voltage, the electrical system AC voltage, outside air temperature (OAT) and a clock.

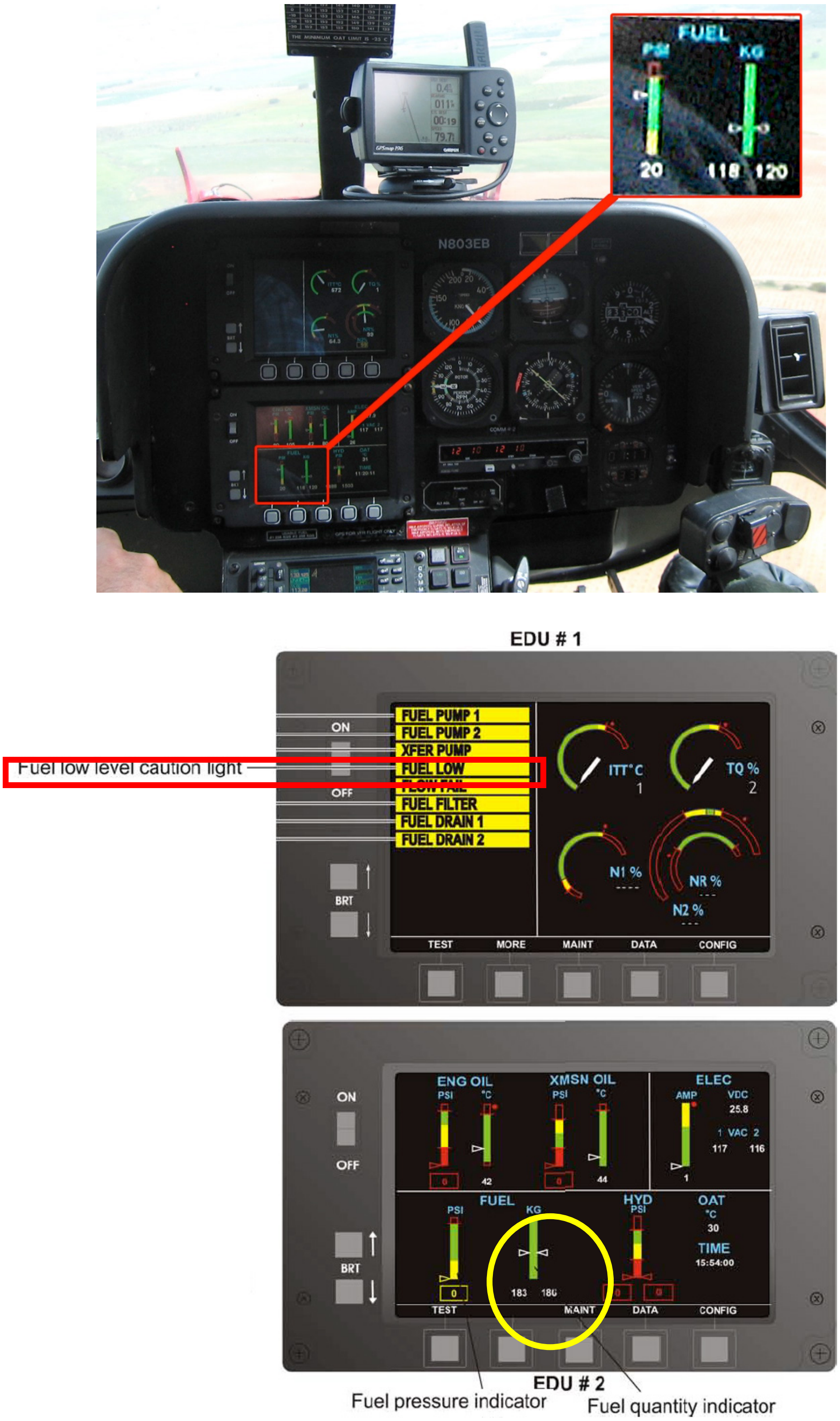


**Figure 4.** How the fuel information is displayed in the cockpit

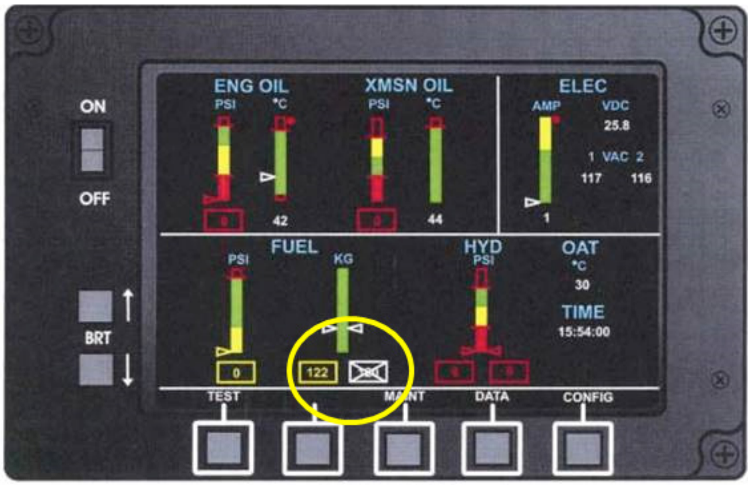


**Figure 5.** EDU 2 displaying the XFER PUMP warning

The LLS signal sent by the FCU to the EDU is discrete and involves an open or closed relay. When deenergized, the relay is closed (normal condition).

If the fuel level is higher than 45 kg and no fault is detected, the relay is energized and the circuit is open. If the fuel level is at or below 45 kg, if some fault in the LLS sensor is detected or if the FCU is deenergized, then the circuit is closed.

This FCU logic works such that the "Low Fuel" signal is activated not just when the fuel level reaches 45 kg, but also if there is a fault with the FCU (deenergized) or if the LLS sensor is defective. Since there is only one line (signal sent), the EDU cannot determine which of these three conditions has been triggered when the alarm is activated.

In the cockpit, the information is presented to the pilot as shown in the photograph in Figure 4. On the left of the EDU 1 display is where the warning messages are given in yellow, and at the bottom of EDU 2 there is a vertical bar to the left that shows the fuel pressure, and to its right another vertical bar with the fuel level and a number on either side that shows the amount of fuel in kg in each of the two lateral tanks.

Section 8.3.3 of the FAASA Operations Manual specifies the policy and procedures for managing fuel while in flight. It states that to check the fuel in flight, captains have to ensure that the fuel amount is checked in flight at regular intervals to compare actual against planned consumption, to ensure that there is sufficient fuel remaining to complete the flight, and to determine the fuel remaining expected upon reaching the destination.

As concerns in-flight fuel management, it states that if as the result of an in-flight fuel check, the remaining fuel anticipated upon arriving at the destination is below the alternative fuel required plus the final reserve fuel, the captain must divert or replan the flight to the alternate, unless he thinks it is safer to continue to the destination.

Complementing the above is the information contained in Section 8.1.7, Determination of Fuel Amounts, in said manual, which says the following:

Given the special characteristics of helicopters, and the specific nature of some of the work done, the fuel policy shall be diverse based on the needs.

If the low fuel level light turns on, any type of sudden maneuver, and in particular tight turns, are prohibited.

Similarly, the maximum flight time permitted with the low fuel level light on shall be half that specified in the Flight Manual.

For work that requires travel, in addition to the aforementioned reserve fuel amounts, the pilot shall add the amount needed to reach the planned field plus 5% in a non-hostile environment and 10% in a hostile environment, increased by up to 30% when traveling over ocean.

At this company, most of the flights take place in visual conditions, and except for work in the ocean or over very specific areas, helicopters do not require an alternate airport.

In any event, the following points must be considered in order to calculate the fuel prior to the flight:

A flight shall not be commenced if, due to the weather conditions and any delay expected during the flight, the helicopter is not carrying sufficient fuel or oil to be able to complete the flight without danger. Moreover, a reserve amount shall be loaded in anticipation of contingencies and so that the helicopter can reach the alternate aerodrome when one is included in the flight plan.

When calculating the fuel and oil required, the following shall be considered, at a minimum:

a) the forecast weather conditions;

b) air traffic control routing and anticipated traffic delays;

c) an instrument approach, if required, at the destination aerodrome, including a missed approach;

d) the procedures described in the Operations Manual involving stopping one of the engines while en route; and

e) any other conditions that may delay landing the helicopter.

### *1.6.4. Information on maintenance performed on low fuel level sensor*

As concerns the maintenance tasks that are used to verify the correct operation of the low fuel level sensor, these are contained in the Maintenance Manual, in Section 28-41, in accordance with an extensive procedure that entails conducting a series of operational checks. These tasks must be performed every 600 h.

On 15 November 2013, the scheduled (600 h) maintenance was conducted on the low fuel level sensor, as per work order 33131100, when the aircraft had 3312:50 h.

On 3 January 2012, there was a faulty fuel reading and a maintenance task was performed three days later, as reflected in work order 376A, when the aircraft had 3024:40 h, which involved cleaning the connectors and the gauge.

In August 2008 the forward flow meter in the left tank was replaced. It is in this tank that the low fuel level sensor is located.

All of these tasks were carried out by the ES-145-057 maintenance center at FAASA AVIACIÓN S.A. There is no record that any maintenance task different from those listed above was performed, or that any deficiencies were detected during the performance of said tasks.

### *1.6.5. Information on the ELT*

The helicopter was equipped with a KANNAD 406 AF-H emergency locator transmitter (ELT) (S/N 2611568 – 0135), which is designed to be installed only on helicopters. This device broadcasts at a power of between 5 mW and 5 W with an A3X/A3N broadcast system on the 121.50, 243.99 and 406 MHz frequencies.

The specification for the minimum operational performance is regulated by the EUROCAE[3] ED.62 regulation, in keeping with which the ELT was set up to be activated when it experienced an impact of at least 6 g.

The ELT is installed under a minor modification certificate, as per D.O.A. A.P.A. Bulletin 0108003. The technical order for its installation provides a graph that shows where the different parts of the unit are to be installed, as follows:

- The ELT at the rear of the aircraft, located between the passenger compartment and the tailcone.
- The antenna at the top rear of the aircraft.
- The control remote for the ELT in the cockpit.

According to the manual, on the ELT itself there is a label that shows the position in which to install it, which can be with the lower part atop the floor of the aircraft or on the firewall, and always along the helicopter's longitudinal axis. It is important to note that the manual requires that the transmission line between the ELT and the antenna not cross any cutting components, such as a frame.

### *1.6.6. Information in the Helicopter Flight Manual*

EMERGENCIES.

In the Basics part of the Helicopter Flight Manual, Section 3, Emergencies, in the section on caution (yellow) lights, it states that there is a yellow light on the caution panel labeled FUEL LOW. If this light is energized, it means that the amount of fuel is low and that as a corrective action, the pilot must verify the amount of fuel in tank 1 and land as soon as practicable, since only 10 minutes of flight at maximum continuous power (MCP) remain.

In the same section on emergencies, in the part on Definitions, the concept of "LAND AS SOON AS PRACTICABLE" is explained to mean that "The duration of the flight and the chosen landing area are left to the pilot's discretion. Prolonging the flight beyond the nearest approved area is not recommended".

The above notwithstanding, and as indicated in Section 1.6.3 of the report, Section 8.3.3 of the FAASA Operations Manual states that captains shall monitor fuel levels in flight at regular intervals to compare the actual consumption against planned

[3] EUROCAE handles the standardization of electrical and electronic equipment for aircraft and land-based systems for aerial positioning and navigation. It also develops guidelines and documents in this area, which use the abbreviation ED. The members of EUROCAE are international aviation authorities, airplane manufacturers, air safety services providers, airlines, airport operators and other entities involved in aviation.

consumption, to ensure that there is enough fuel remaining to complete the flight, and to determine the fuel remaining upon arriving at the destination.

ENGINE FAILURE. AUTOROTATION.

An engine failure or malfunction is considered to occur when the N1 RPMs fall abnormally below 51% or when the engine stops. If this happens, the collective lever must be moved downward to lower the pitch of the blades. If the flight altitude allows it, the pilot must try to figure out the cause of the fault and try to start the engine; if not, the helicopter must be landed immediately by performing an autorotation.

If the engine failure occurs during cruise flight, inputs must be provided to the pedals to maintain the heading. The collective must be lowered immediately to keep the rotor RPMs (NR) in the 90 to 110% range, and the cyclic must be moved in order to achieve the desired flight speed in autorotation. The throttle will be closed to start the engine stop sequence.

To complete the maneuver, when at approximately 150 ft above ground level, the front of the helicopter will be flared by moving the cyclic aft to lower speed. The cyclic will then be moved forward to level the helicopter before landing by placing the skids parallel to the ground. Once the helicopter is level, the collective lever will continue to be moved to increase the pitch angle of the main rotor blades and dampen the landing. The heading must be maintained at all times using the pedals. If contact is made first with the rear part of the skids, the cyclic lever must not be moved forward.

The autorotation glide distance depends on the altitude and on the main rotor RPMs. Figure 6 shows this distance.

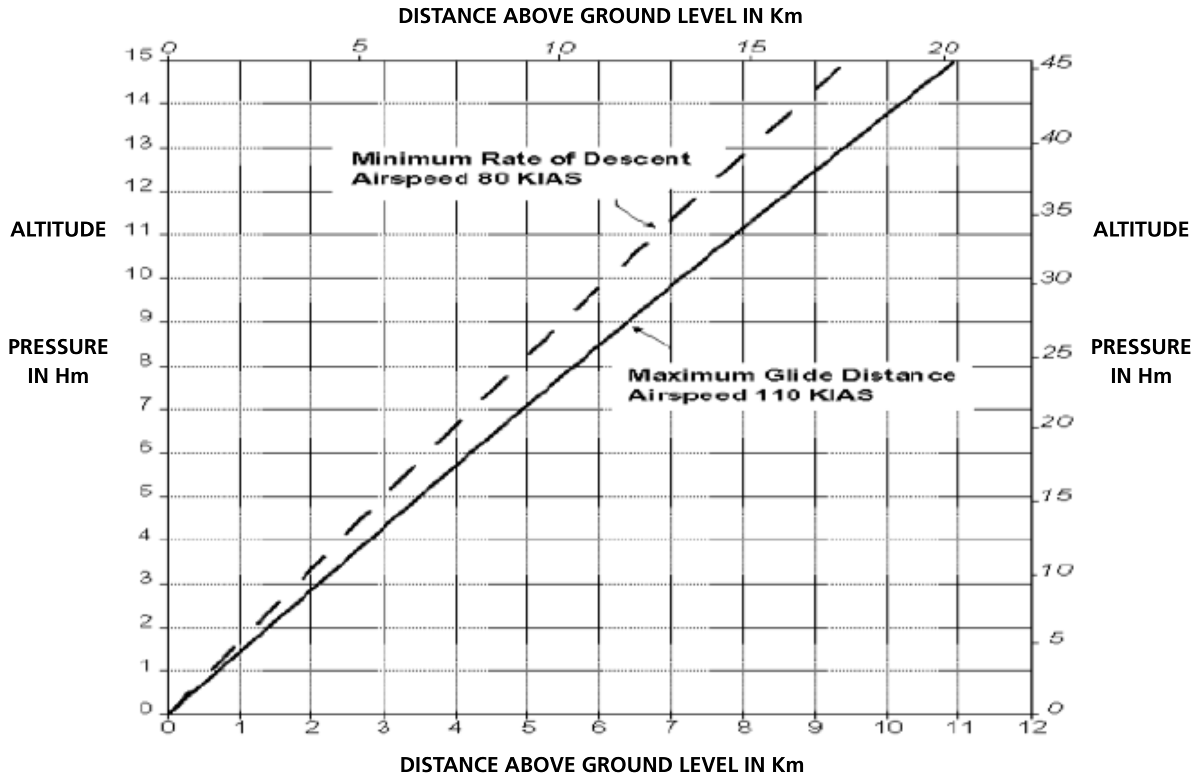


**Figure 6.** Autorotation distance

## MAXIMUM TAKEOFF WEIGHTS

The Helicopter Flight Manual provides the following maximum takeoff weights:

- **2550 kg.** This takeoff weight limit is given in Section 1, "Basic Limits".

- **2720 kg.** This takeoff weight limit appears in Appendix 6, "Increased internal gross weight", which contains the limitations and characteristics that apply when the helicopter is operated with an increased gross weight. Figure 4-2 in this Appendix, "Ceiling for hovering within ground effect at takeoff power with the heat off", includes the table used to calculate the maximum takeoff weight considering the altitude and ambient temperature. This weight limitation must be considered when transporting firefighting personnel.

- **3150 kg.** This takeoff weight limit is given in Appendix 11, "Load Hook", which contains the limits when operating with a load hook. This operation is also limited in the "Flight Crew" section, which states that when operating with a load on the hook, only personnel involved in the operation are allowed onboard. Figure 4-2 of this Appendix 11, "Ceiling for hovering outside the ground effect at takeoff power with the heat off", shows the table used to calculate the maximum takeoff weight considering the altitude and ambient temperature. This appendix is applicable when the helicopter takes off with water in the bucket.

## 1.7. Meteorological information

Spain's National Weather Agency (AEMET) reported that on the day of the accident, there were no surface winds in general in the area of Albacete. There was, however, a warm air current from Africa that was conducive to isolated convection flows that could be intense in strength. At 17:00[4], the wind in the accident area was from the southeast, specifically from 140º, at a speed of 10 km/h and gusting to 18 km/ from the same direction. The temperature was 28° C, the QNH 1012 hPa, the relative air humidity around 45% and there was good visibility on the surface. There were also storm cells in the area that caused occasional convection currents.

A study of the weather conditions in which these types of operations typically take place, during the hottest time of the year, and at the average elevation of the seven weather stations in the region of Castilla – La Mancha, which is 833 m, revealed that the maximum average temperature at these stations, as reported by AEMET, in the period between 14 July and 8 August was 32° C[5].

## 1.8. Aids to navigation

Not applicable in this case.

## 1.9. Communications

There is no record of the communications between the pilot and others involved in fighting the fire.

## 1.10. Aerodrome information

### *1.10.1. Base in Villahermosa (Ciudad Real)*

The base from which the helicopter took off is east of Villahermosa (Ciudad Real), at coordinates 38° 45′ 4.7″ N – 2° 50′ 33″ W and an elevation of 972 m (3,188 ft).

It has a concrete landing pad and three parking stands for helicopters. It also has well-equipped facilities to house helicopter and BIFOR crews.

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[4] The data are taken from the automated station in Zarra, located 10 km east-northeast of the accident site.

[5] These data are relevant to determining the conditions in which helicopters in the region of Castilla – La Mancha routinely fly, so that their performance can be calculated.

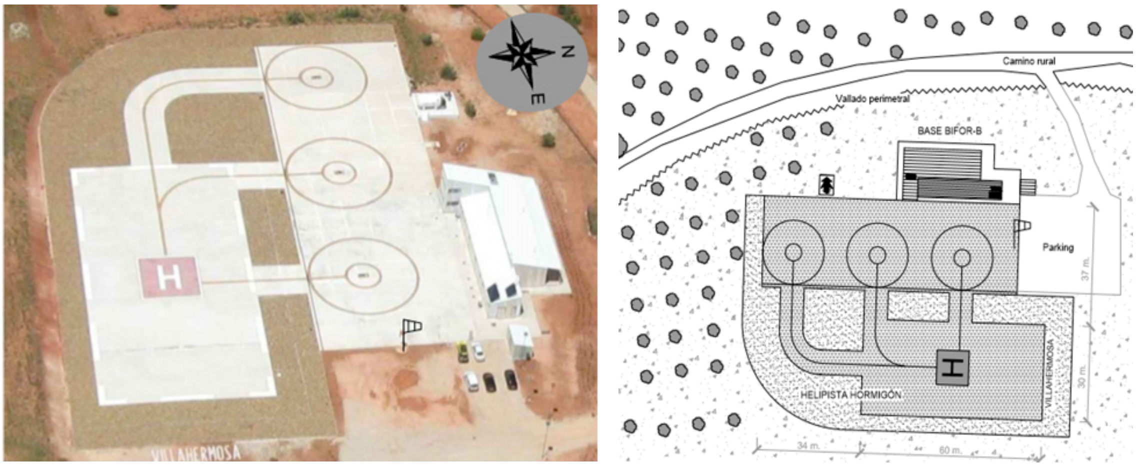


**Figure 7.** Villahermosa base

### *1.10.2. Base in Carcelén (Albacete)*

The base where the pilot was going to refuel is located in Carcelén (Albacete), from which both airplanes and helicopters can operate.

It has one 865-m long compacted dirt runway in a 09/27 orientation and its reference point is at an elevation of 830 m (2,723 ft) at coordinates 39° 07′ 57″ N – 1° 18′ 20″ W. The helicopter operations area is paved and is located west of the 09 threshold. It has a total length of 135 m.

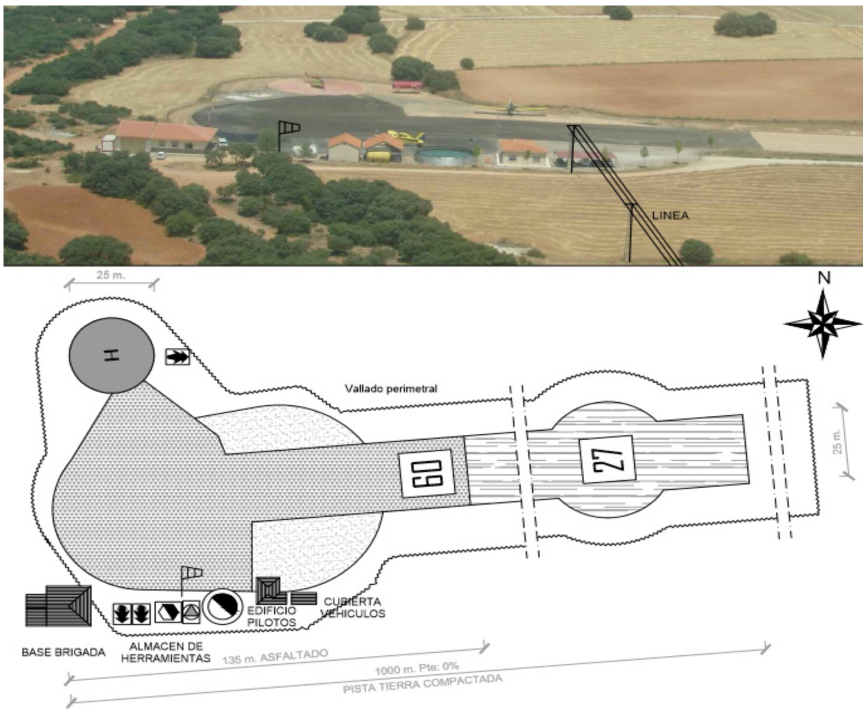


**Figure 8.** Carcelén base

### 1.11. Flight recorders

The helicopter was not equipped with any flight recorders, as they were not required by the applicable law.

The helicopter did have a fleet tracking system and a handheld global positioning system (GPS) receiver. These devices recorded and stored time, altitude, speed and position information on the flight.

During the flight, the helicopter's position was sent in real time to receivers located in the Provincial Operations Center (COP) in each of the provinces of the region of Castilla – La Mancha, and in the Regional Operations Center (COR) of this region, which is located in Toledo. The helicopter's movements were displayed in real time on digital maps at each receiver, on which users are able to see the coordinates and the flight path. The information was also sent to a unit located at the Operator's facilities.

The satellite fleet tracking system stopped recording consistent data at 17:02, and the portable positioning unit at 17:01. The helicopter is thus thought to have crashed moments later while in cruise flight. The graph in Figure 9 shows the helicopter's flight profile, with its altitude (m), the ground elevation (also in m, in orange) and speed (km/h). The data recorded are not exact but rather approximate, since in the two segments with constant altitude and speed, it was stopped on the ground (the times shown in the graph are in UTC).

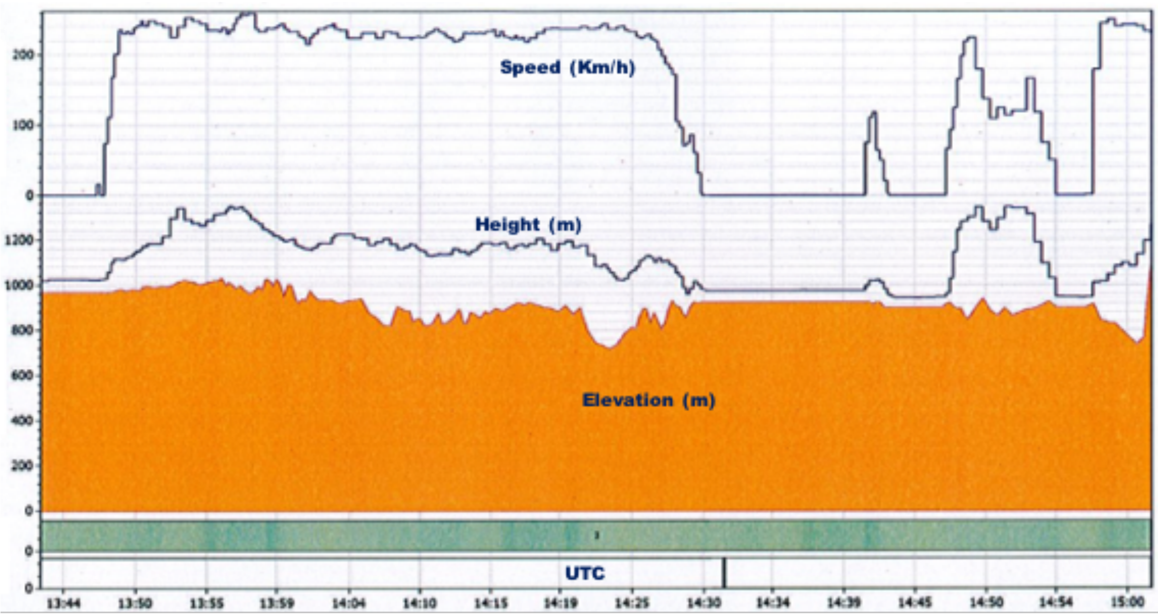


**Figure 9.** Flight profile

The two displays installed in the cockpit showed the engine parameters (EDU) and recorded some readings from the accident flight. When the memory card was installed on a similar EDU, it revealed a low fuel pressure warning at 16:51:17[6], which was the only evidence detected pertaining to the fuel.

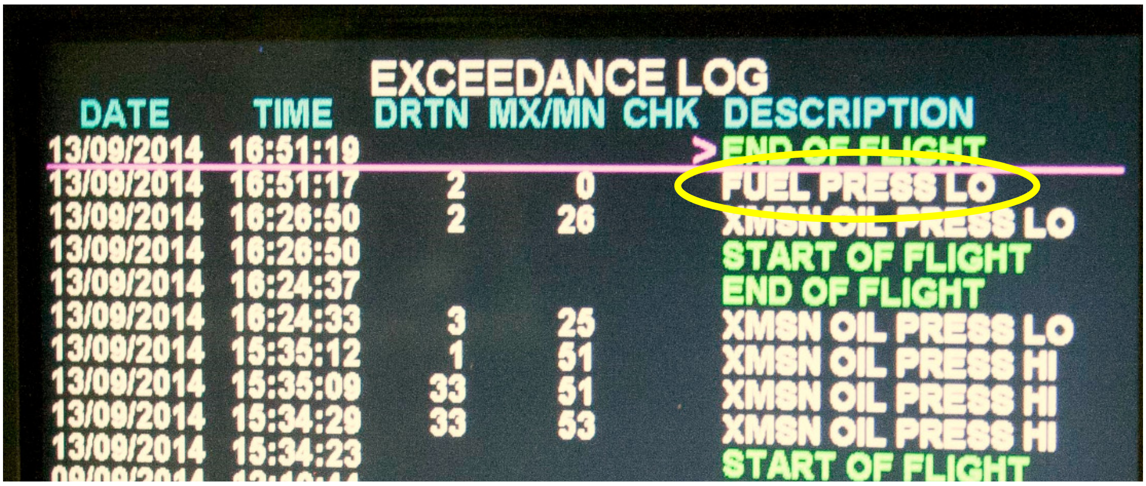


**Figure 10.** EDU 1 display reproduced on a workbench

There is no record of any low fuel level warnings.

## 1.12. Wreckage and impact information

### *1.12.1. Overall condition of the helicopter after impact*

The helicopter was found at coordinates 38° 56′ 17″ N – 1° 10′ 15″ W, with the fuselage pointing toward 025°. It was in a horizontal position. It showed signs of a strong vertical impact. The fuselage was flattened to a third of its height. The main rotor and the gearbox were leaning forward.

The marks on the ground indicated that after impact, it moved forward slightly. The battery was outside its housing, also shifted in the forward direction.

The damage exhibited by the main rotor blades was consistent with an impact at a very low rotational speed, and thus the damage was due exclusively to the vertical impact. The side edge was gone on one of the blades, but no impact marks were found on any of the leading edges of the blades. One was broken in half along the trailing edge and one of the parts had fallen vertically. All of the blades exhibited very light superficial scratches and stripes along their lower surface.

[6] The time stamps shown on the EDU are about 10 minutes out of sync with those recorded by the fleet tracking system.

The tail rotor blades did not exhibit any damage on the leading edge. One had slight scratches on the trailing edge that had been caused when the helicopter shifted slightly forward after impacting the ground.

There was no continuity in the rear rotor gearbox due to the damage sustained by the shaft, the supports and the shock absorbers.

The fuel reading on the fuel control unit (FCU) was checked, but the damage it had sustained did not yield any exact information.

The position of the throttle control located on the collective lever could also not be determined due to its condition after the impact.

The rotor brake lever was actuated and the brake set, but the cable was damaged and bent. Everything thus indicated that it had not been activated, but rather that it had shifted at the moment of impact. The damage to the pilot’s side of the cockpit had caused the entire seat assembly to shift forward, which could have moved the rotor brake activation lever from its position. The headrest was very close to the rotor brake lever unit after the impact.

The flight controls for the tail rotor did not exhibit significant damage.

The cockpit instruments were not heavily damaged, but there is no guarantee that their readings are reliable. The altimeter was set to 1013 mb and was showing approximately 2,900 ft, which is consistent with the elevation of the accident site. The variometer read 2,100 ft/min, consistent with the descent speed indicated by the last four readings obtained from the GPS. The heading on the horizontal situation indicator (HSI) read about 30º, practically the same as the orientation of the helicopter’s longitudinal axis.

Both the high- and low-pressure fuel filters were removed, and both contained a residual amount of fuel.

No evidence was found indicating that there were significant amounts of fuel in the tanks, in the lines or on the ground. There was barely any smell of fuel.

When the helicopter was lifted to be moved, only a small amount of residual fuel remaining in the broken fuel lines spilled out.

The servo actuators for both the cyclic and collective controls had been deformed, possibly due to the impact.

As for the hydraulic system, there was practically no fluid in the tanks. This is because the tank outlet line was broken. One of the hydraulic pumps had been moved from its housing by the impact, and the other was also warped.

### *1.12.2. Condition of the engine after impact*

The as-found condition of the engine at the accident site, and the checks made of the engine before the helicopter was moved, are described below.

First, the fuel line filter, the high-pressure fuel filter and the fuel inlet filter were removed. They were all clean. The first two had fuel in the retention cup, which was half full. The inlet fuel filter has a system to check for potential obstructions, which was working correctly.

The engine's oil pressure filter was removed. No metallic chips were found, it was not deformed and it was clean. There was a normal amount of oil in its housing.

The chip detector was also removed from the reduction gearbox. It had been moved from its housing by the impact. The part of the chip detector with the magnets was disassembled. No chips or dirt were found.

The chip detectors were also removed from the main (upper and lower) transmission and from the intermediate gearbox. All three were clean.

The control system for the fuel control unit (FCU) was checked to see if it was attached and in its position, i.e. in the grip of the collective lever (throttle). It was found to be broken just at the entrance to the actuator that transforms the linear motion of the control into a rotational motion of the shaft that controls the maximum compressor RPMs. The position in which both this shaft and its stop were found corresponds to an engine stopped position (top). The needle that indicates the percent at which the engine is running was also found in the zero position. The cable had broken under tension.

The turbine was dislodged from its attachment points, which had broken, and leaning to the left. Nothing out of the ordinary was found pertaining to the assembly of its components, the actuator control rods or the engine braking. There were no missing components or screws. There were no signs of corrosion. The absence of friction marks on the blades inside the housing indicated that the moment of impact, the engine was not supplying power. The front part of the driveshaft had been decoupled from the gearbox by the force of the impact. The inlet gearbox to the driveshaft was fractured. The screws that attached the main rotor were broken, leaving the rotor loose and resting on the helicopter under its own weight.

The external condition of the power turbine was also checked. It did not show any deformation. The blades were in good condition. Their leading edges were not damaged and there were no signs of excess temperature in the area. The turbine, however, did not rotate freely since the union of the thrust gear transfer case and the transmission main drive was jammed.

The fairing from the ignition-generator assembly was removed, and the compressor turbine was found not to rotate. Under normal conditions, if there had not been a strong impact it should have been turnable by hand, as is normally done when checking the first stage of the compressor during periodic inspections.

The part with the main transmission had fallen left and to the front, and the braces had detached from their anchor points. At first glance, nothing out of the ordinary was noticed with regard to its assembly. There were also no signs of corrosion.

The helicopter was subsequently moved to a hangar. The engine was removed from its housing in the aircraft and a more detailed inspection was conducted with the aid of a specialist sent by the manufacturer, who confirmed that there were no signs of leaks or oil, no residue, no signs of damage from overheating or signs of a fire. No particles or any type of component or parts foreign to the engine were found that might have been ingested.

The reduction gear, the input shaft and the casing were intact. The tail rotor shaft was decoupled, and the mesh pinion between the main and rear rotors did not exhibit any damage or deformation.

The engine’s inlet and outlet ducts were also undamaged.

The accessory drive and its components were in good condition.

Both the electronic and mechanical parts of the governor were in good condition, as was the pneumatic system. There was continuity between the fuel control unit and the electronic part of the governor. The levers on the fuel control unit were at their minimum position.

The firewall was bent forward.

### *1.12.3. Inspection of the transmission*

The transmission was checked during a subsequent inspection, once the helicopter was moved from the crash site.

The cover was opened to access the inside, where the planetary gear is housed. It was not deformed, but it did not turn because it was blocked. Some retaining screws were bent. The planetary gear itself did rotate freely once it was removed from its housing. The heads of the screws that held it in place were not damaged, but the studs on some of the screws had been bent.

The shaft bearings of the planetary gears were outside their housing and shifted along the longitudinal axis by the vertical impact.

One of the hydraulic pumps between the transmission and the engine rotated correctly and was not deformed. The bottom bearing and the ball bearings were in good condition.

The other hydraulic pump had seized because some of the cogs had been driven into the bottom of the casing.

All of the deformations noted were along the vertical axis of the transmission, i.e. in the direction of the impact.

The rotor head rotated freely on the connection that goes to the transmission. The internal screws were broken longitudinally.

The assembly was well greased and clean and appeared to be in good condition overall. All of the linkages were in good condition.

#### *1.12.4. ELT*

The ELT was on the floor of the helicopter, immediately behind the first tailcone frame. It was in its housing but the velcro strip around it was broken, and thus the ELT was loose.

The remote control was in the cockpit and undamaged.

During the inspection of the wreckage, the antenna to which the ELT was connected was found to be located at the front of the fuselage, outside the cockpit, atop the transparent plastic panels that are located in the overhead of the pilots’ positions. The connecting cable had been broken as a result of the structural deformations that had been caused by the impact. The Spanish Air Force’s Rescue Coordination Center (RCC) did not receive a signal from the ELT, which indicates that it was not activated. During the onsite investigation, however, it was found armed and the battery that powered it held a charge. It was verified to be transmitting normally.

### 1.13. Medical and pathological information

The autopsy revealed that the pilot was killed immediately by multiple traumatic injuries all over his body.

### 1.14. Fire

There was no fire.

### 1.15. Survival aspects

The aircraft was found by chance by someone who was passing by the accident site and who notified the Civil Guard, which dispatched a unit to the location of the helicopter. The officers verified that the pilot inside was dead and that he was wearing his flight helmet and his seat belt.

The Regional Operations Center (COR) of the Board of Communities of Castilla – La Mancha was then contacted to see if they were aware of the accident. They replied that they were not, and that they would look into it. The COR later reported that the callsign of the accident aircraft was H23.

During the almost two and a half hours that elapsed between the time the helicopter left the fire site and when it was found, there is no record that any attempts were made by the Operator, or by anyone from the Agriculture Office of the Board of Castilla - La Mancha involved in the firefighting efforts, to communicate with the pilot either via radio or telephone.

At the start of the investigation, it was noticed that neither the operator nor the firefighter supervisors who worked for the Agriculture Office of the Board of Communities of Castilla - La Mancha (JCCLM) had a specific procedure for constantly and effectively tracking the aircraft that were fighting a fire.

During the meetings held with JCCLM officials, investigators also noticed that the procedures that were in place involving the emergencies and the professionals hired to combat them considered all of the aspects involved in fighting forest fires and managing natural spaces, meaning they did not have personnel who specialized in managing aspects related to preventing air accidents. The use of air resources to fight fires was given the same consideration as any other means that was used to fight fires.

Given the possibility that other regional governments in Spain were in the same situation, and in an effort to prevent a similar situation from occurring once more, investigators looked into the conditions under which firefighting operations involving aerial resources were being handled.

To this end, and with assistance from the Ministry of Agriculture, Fishing, Food and the Environment (MAPAMA), every regional government was sent a questionnaire with twelve simple questions, the answers to which could be used to assess the situation.

The questions posed, and the findings associated with them, are provided below:

| | QUESTION | FINDINGS FROM ANSWERS |
|---|---|---|
| 1. | What types of aerial services are conducted by the region (or MAPAMA)? | Every region provides firefighting services, and many of them also offer emergency and surveillance services. |
| 2. | Are all of the services provided for the same department or is more than one involved? | The various services are usually provided to more than one department. |
| 3. | Is there a person who coordinates all of the aerial resources that work for the region (or MAPAMA)? | In general there is no single person trained in aviation to whom all of the aerial resources report. |
| 4. | Are the various aerial resources contracted from more than one operator? | The services are provided by more than one operator in most cases. |
| 5. | Does the region (or MAPAMA) have an Air Safety Plan or Program? | None of the regions has an Operational Safety Plan. |
| 6. | In the bidding conditions, are the operators required to have a Safety Plan or Program? | In most cases, operators are not required to present an Operational Safety Plan when bidding on a contract. |
| 7. | Does the region (or MAPAMA) have a system in place that provides an early warning if contact is lost with an aircraft during an operation? | Almost every region has a fleet tracking system, contracted through an operator, but there is no guarantee that an aircraft's disappearance will be detected immediately. |
| 8. | Is the above required in the bidding conditions? | In some cases, the bidding conditions require operators to have fleet tracking systems[7]. |
| 9. | Beyond conventional tracking systems, how are aircraft monitored at all times? | Aircraft are monitored in different ways in each case. |
| 10. | What process triggers an alert that an aircraft is potentially missing? How is the search commenced and who is notified? Who has to give the order? And how is the search conducted? | If an aircraft is missing, the search and rescue process is specified by different protocols. IN MANY CASES THERE ARE NO PROTOCOLS. |

continues >

[7] In most cases, the tracking is carried out by the same specialized company in several regions.

| | | |
|---|---|---|
| 11. | What system do you think is best suited to ensuring that an aircraft that has been involved in an accident is detected? | In most cases, the ELT is regarded as the best method for detecting the disappearance of an aircraft. |
| 12. | Do you think it is necessary for a system to be implemented in your organization to prevent the above situation from occurring? | Not every region deems it necessary to implement new systems. |

## 1.16. Tests and research

### *1.16.1. Analysis of the engine*

The engine was sent to the manufacturer for analysis. All of the tests conducted were done in the presence of a certified representative of Canada's Transportation Safety Board (TSB), which was acting as part of the CIAIAC investigation team as part of an existing partnership program. The most relevant aspects found and the conclusions reached are presented below.

The deformations it exhibited were such that it could not be set up on a test bench and started.

The first external inspection revealed that the top of the turbine exhaust duct, the bottom of the gas generator casing and the fuel drain valves had been jammed and deformed by the impact.

The majority of the lubrication system's components had also been deformed and broken by the impact, and the pneumatic system components also exhibited significant warping.

The electronic speed control was detached and dented, and its electrical connector had also detached during the impact with the ground. The fuel injectors, along with the lines and the flow and outlet valves, were in their proper place, but several of the lines were bent and warped.

The fuel control unit, the fuel pump, the oil in the fuel heater, the compressor purge valve, the governor and the ignition wires were all intact.

The air supply lines to the controls did not have any leaks, as demonstrated by the pressure test that was carried out. The nuts were found to be tight and secure.

When an attempt was made to turn the compressor rotor by hand, it was found to be seized, but there was no damage or foreign objects in the first stage or in the inlet blades.

The chip detector was removed from the accessory drive and it was clean. The oil that was removed after draining the oil from the sump tank and the filter was also clean and its color was good. Looking at the tips of the power turbine blades from the exhaust duct revealed that none of them was fractured and that the turbine was able to rotate freely.

The engine accessories and controls, meaning the fuel control unit, the fuel pump, the governor, the oil heater and the speed sensor, were disassembled and tested on a bench. They were all verified to be operational.

The engine was opened by removing the flange that separated the gas generator casing and the turbine exhaust duct in order to reveal the disc assembly. Everything was in its place, although the compressor rotor was difficult to rotate. The assembly was removed from the accessory drive, and the coupling unit was verified to be properly attached to the compressor rotor assembly, which made it possible for it to rotate freely, without resistance and with no abnormal noises. The segments of the cover and the blades were in good condition, with no friction marks.

The oil pressure pump was removed from the accessory drive. The gear assembly was difficult to mesh and turn, although the pump did rotate freely. The compressor rotor balancing assembly was also disassembled and its components were verified to be in good condition.

The damage found in the engine's power section was directly related to the impact.

In conclusion, it is safe to say that the engine analysis showed that it was stopped when it impacted the ground, that no external or internal anomalies were found in the engine that would have impeded its normal operation prior to the impact with the ground, and that all of the damage identified in the engine components resulted from the aircraft's impact with the ground.

### *1.16.2. Laboratory analysis of the ELT*

The ELT did not exhibit any problems that would prevent it from transmitting normally. That was the conclusion reached after analyzing the ELT at an avionics laboratory in Spain.

The external inspection conducted revealed that the antenna was not connected, as its cable had been severed during the impact when the accident occurred. The remote control and data recorder were also not connected since those cables too had been severed during the impact.

The ELT's code matched that on the external label. The expiration date was January 2020, and thus it was within its operating range.

The switch was in the ON position and slightly bent, also as a result of the impact. The status light flashed a faint red color when it was turned on, indicating that it was transmitting but that the battery was low, as was later verified during the laboratory tests.

After the external inspection, a detailed analysis was conducted in the laboratory. This required using an external power source since the internal battery was only supplying 6.6 V, which was insufficient to conduct any type of testing given that the battery's nominal voltage is 9 V.

The first tests were done at a slightly lower voltage (8.6 V) to simulate a battery with a lower charge than normal and to study its response, i.e. the transmission quality. Tests were performed at different frequencies, which yielded the following results:

<u>Frequency of 121.5 MHz</u>

Transmission frequency 121.4945 MHz. (± 0.006 MHz); Tones correct; Modulation > 99%; Power 0.13 W, which is correct, since the minimum required is 0.1 W. The parameters analyzed were within normal ranges for this frequency.

<u>Frequency of 243.0 MHz. (± 0.012 MHz)</u>

Transmission frequency 242.8204 MHz, which was shifted, that is, below the manufacturer's specifications; Power 0.14 W, which was within margins, since the minimum was 0.1 W.

<u>Frequency of 406.0256 MHz. (± 0.002MHz)</u>

This code was correct and matched that on the unit's external label; Power 3.7 W, which was good since the minimum was 3.1 W.

### *1.16.3. Laboratory analysis of the low fuel level sensor (LLS)*

No fuel level warnings were recorded on the two displays installed in the cockpit that showed the engine parameters (Engine Display Unit – EDU). Thus, in order to see if the sensor had failed, it was first analyzed in the same specialized avionics laboratory in Spain where the ELT was inspected. This analysis was completed in late January 2016.

The analysis concluded that because of the condition of the contacts, it was not possible to confirm whether or not the low level sensor (LLS) had worked correctly.

The LLS is housed inside the flow meter that is at the front of the left-side fuel tank, and which is used to determine if the fuel amount is below 45 kg.

One possible fault in the sensor can only be detected when a test is done on the EDU screen, which can only be performed with the helicopter in ground mode, that is, when the rotor RPMs are below 75% (NR>75%). The test checks if the ENG FIRE and FUEL LOW messages appear on the EDU 1 screen for 4 s and then go out. If there is a fault in the low fuel level detection chain, the message shown on EDU 1 is F LOW FAIL.

In the event of a fault in the jet pump sensor (the jet pump is located at the rear of the left tank) during flight, that is, with rotor RPMs above 75% (NR>75%), no warning will be shown on the EDU displays, nor will this fault be recorded in the FAULT LOG or in the EXCEEDANCE LOG.

In flight (NR>75%), only the FUEL LOW warning (fuel below 45 kg) is recorded in the FAULT LOG. This happened on two specific dates, 5 July 2014 and 21 July 2014, as was verified on the EDU logs.

If the sensor fails in flight, either of the following two situations may apply:

a.- The amount of fuel is higher than 45 kg and a **FUEL LOW** warning appears, which will be registered in the **FAULT LOG**.

b.- The amount of fuel is below 45 kg and no **FUEL LOW** warning is given, which will **NOT** be recorded in the **FAULT LOG**, although the fuel level indication system would indicate the amount on EDU 2. This is the result of a fault of the low fuel level sensor.

No functional tests cold be run due to the bad condition of the sensor.

A fault in the detection chain in which no information is transmitted from the FCU to the EDU would also not be recorded in the FAULT LOG.

The probe has an induction sensor, which was divided into two parts for analysis. One contained the float and the coil, and the other the oscillating circuit and its associated components. These two parts are joined by tin soldered pins.

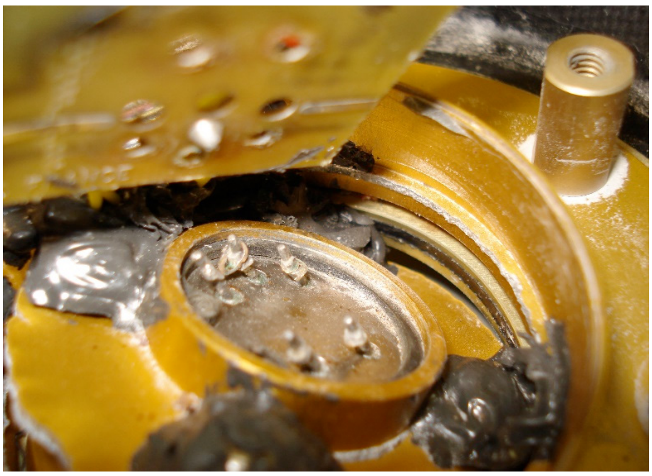

**Figure 11.** Parts of LLS probe

The float system was broken (probably by the impact), but it was still able to move, and thus it was operating correctly.

The resistance of the coil from the pins that attach to the printed circuit board on the sensor was 4.8 ohms, which is also correct for this sensor type.

The analysis of the board revealed poor, or very soft, welds, which could have produced false contacts and thus intermittent faults in both the sensor board and in the specimens, giving rise to erroneous fuel level readings.

The analysis showed that the pin welds on the sensor board exhibited clear signs of having been welded atop previous welds.

The printed circuit board also revealed that the contacts from several components had detached. In the opinion of the laboratory personnel who conducted the test, this could have been due to soft welds, which could have caused intermittent faults.

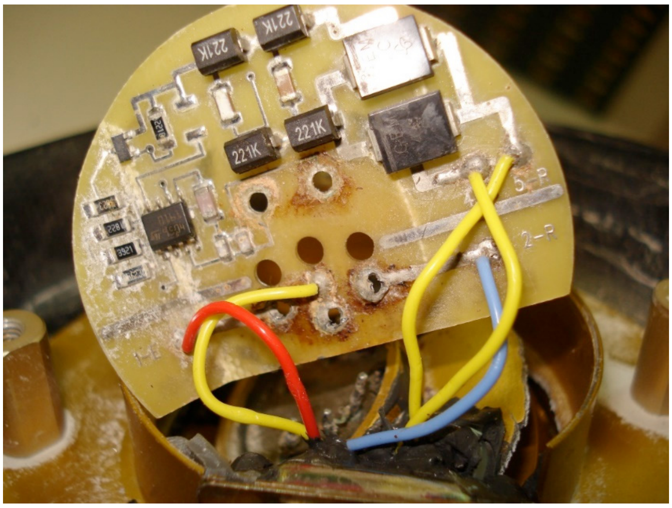


**Figure 12.** LLS probe plate

### *1.16.4. Laboratory analysis of all the fuel level sensors*

In light of the results, and considering that the assembly where the sensor that measures the low fuel level was replaced in August 2008 by the operator, and that there is no record that it was repaired, said assembly was sent in July 2016 to the French investigation authority (Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile - BEA) for a more detailed study, since the manufacturer of the sensor is French.

Along with the sensor, the other three flow meters that were installed in the left tank (one, at the rear) and in the right tank (two) were also sent to France. These three components, as mentioned previously, only provide a reading of the fuel level.

These analyses revealed that the condition of the front sensor in the left tank did not appear to impede it from sending a correct low fuel level signal (LLS), but that the three remaining sensors (without LLS) had points with soft welds that could have resulted in false contacts, and that they could thus have transmitted faulty indications to the fuel control unit. These tests, therefore, could not confirm or rule out a fault in the components analyzed.

An initial test was conducted in late July 2016, a second test in September 2016 and a third and final test in late October 2016.

Each sensor has a printed circuit board (PCB), an integrated circuit (IC), an insulation plate (IP), a surface-mounted device (SMD), a small-outline integrated circuit (SOIC), a low-level sensor (LLS) and a DB9 D-sub 9-pin connector.

The initial visual inspection intended to ascertain if the front left sensor exhibited any abnormalities that could indicate why it did not provide a low fuel level indication. This initial inspection showed that the board housing the integrated circuit and the associated integrated circuit had been broken by the impact.

The second inspection was done at the facilities of the sensor manufacturer under the BEA's supervision. This analysis revealed that the four sensors were severely damaged. As a result, no functional tests could be performed on any of them.

There were traces of a whitish dust on the surface of the aluminum body, the source of which could not be determined. Several continuity and resistance measurements were taken for some of the passive components, the values of which were normal. No short circuits were found in any of the components analyzed.

The welds on the five wires that run from the board to the DB9 connector were in good condition.

During the inspection, the sensor manufacturer reported that the manufacture of the printed circuit boards, both those containing the LLS and non-LLS circuitry, is subcontracted to another supplier, and that the board is connected to the sensors, which are submerged, using a manual welding process. It also reported that it had not made any repairs to the sensor.

What the sensor manufacturer does do is check the quality of the welds before assembling the different components. The sensors then undergo quality controls and are calibrated.

The final inspection was again performed at the BEA's facilities, and was intended to check the connection between the PCB and the float sensor, and between the PCB and the connector (DB9).

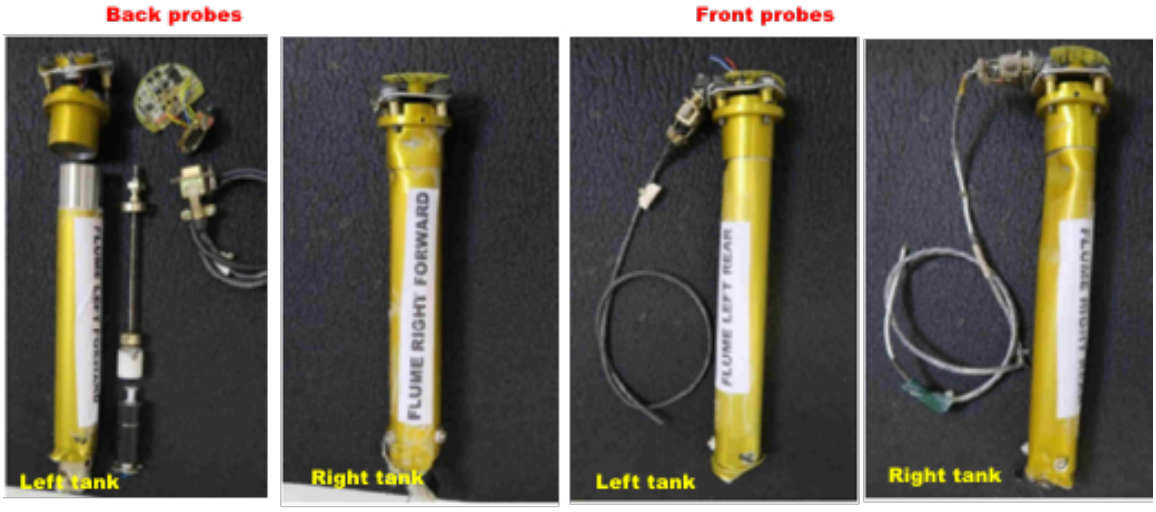


**Figure 13.** Probes of the inferior tanks, object of study

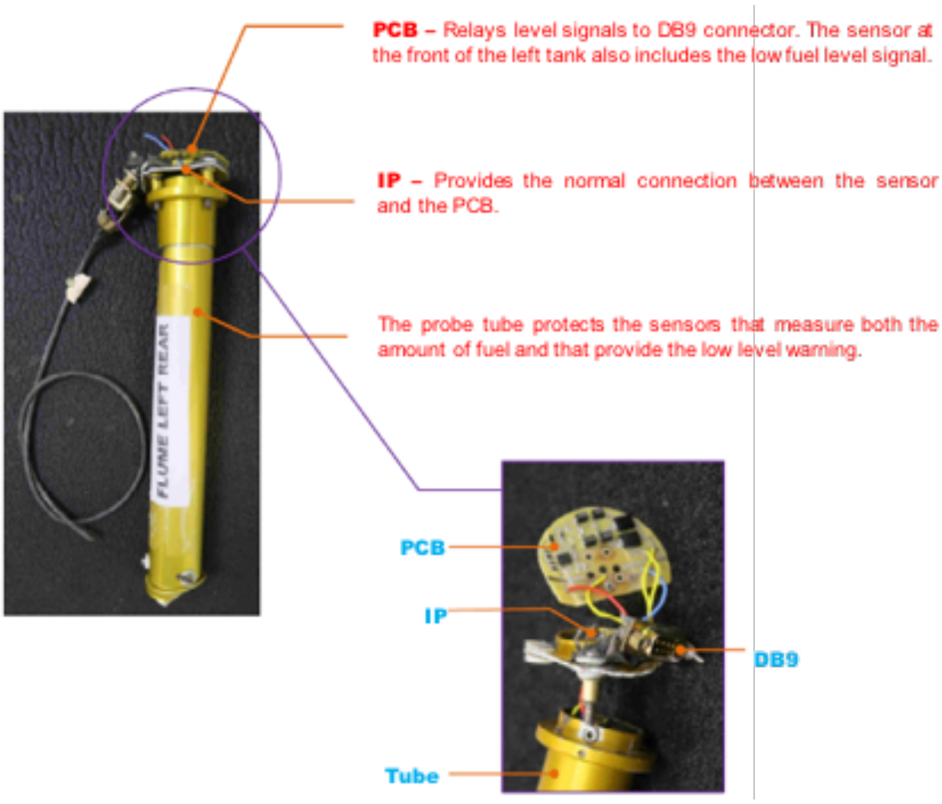


**Figure 14.** Sketch of the probe elements

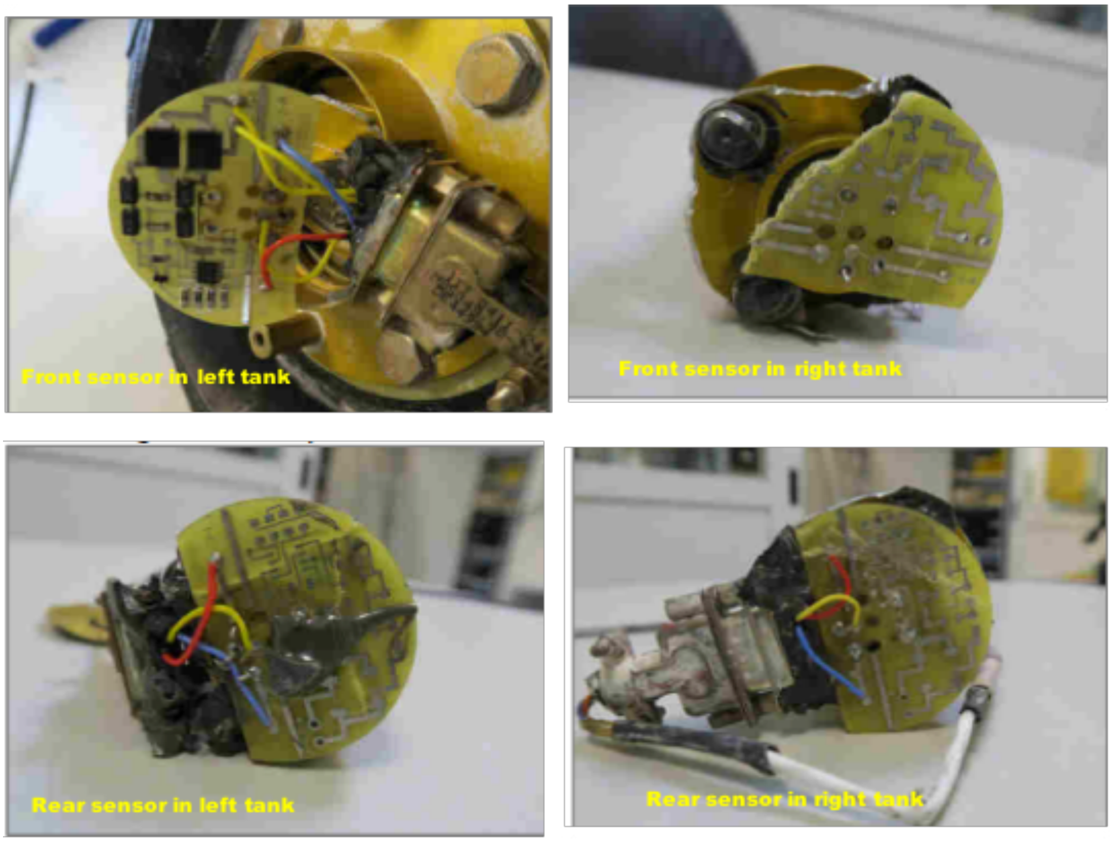


**Figure 15.** Condition of the sensor circuit boards

The components in the left tank front sensor did not show any signs that a functional failure could have occurred prior to the impact, since the welds on the PCB and the SMD were in good condition, as were the contact elements between the PCB and the IP. This indicates that both the fuel level and low fuel level sensors (LLS) were in condition to send a good signal to the DB9 connector prior to the impact. There were indications, however, of what seemed to have been a repair made to the PCB.

The condition of the front sensor in the right tank was also such that the signal transmitted to the DB9 connector should have been good. However, the analysis also showed broken welds in some of the IP pins, similar to the cracks that appear in soft welds.

The pins on the DB9 connector in the two rear sensors also showed signs of soft welds.

### *1.16.5. Estimation of the flight variables during the final moments*

The aircraft manufacturer was asked to simulate the helicopter's dynamic behavior during a high-energy impact, as happened in this accident, based on the damage that was caused.

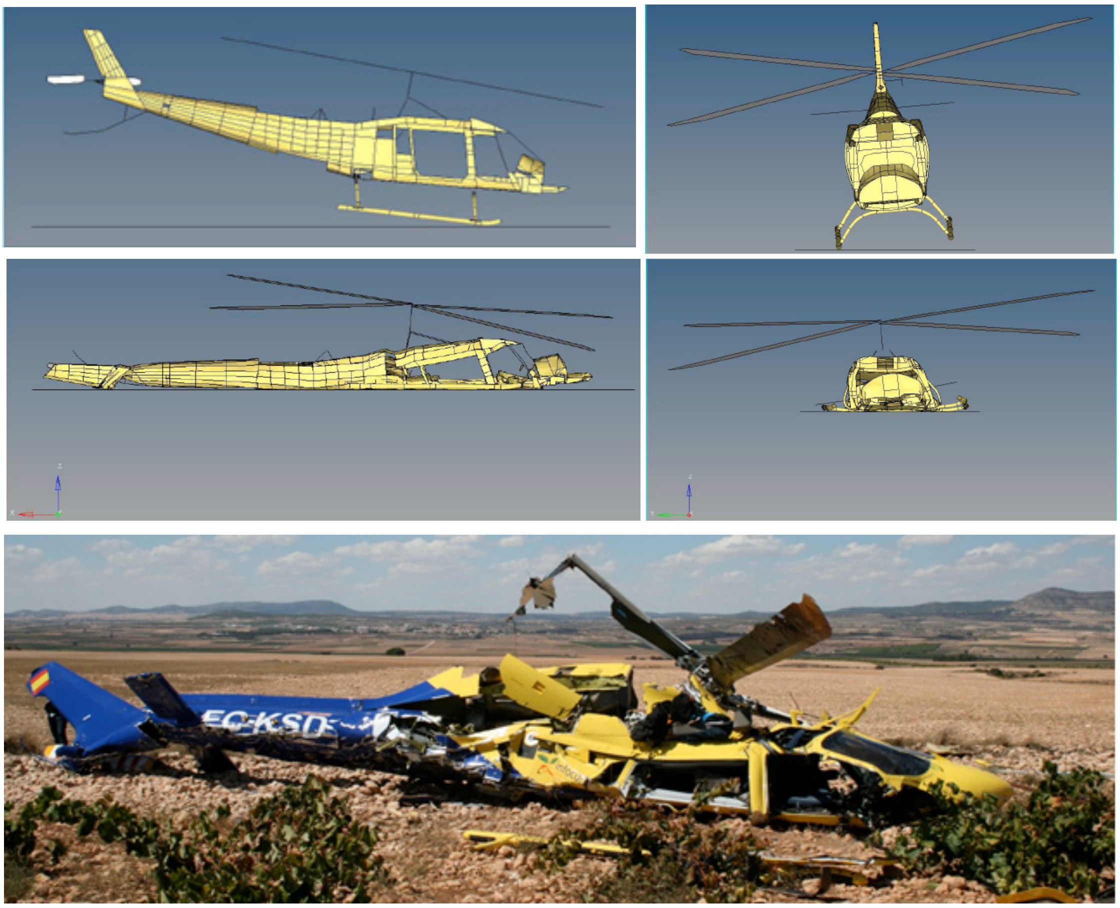


**Figure 16.** Model of the dynamic simulation conducted by the manufacturer

Although no initial data were available, several models were created that simulated damage that was similar to that actually caused to the helicopter. The goal was to determine the approximate energy at which the impact took place in order to estimate the vertical speed the helicopter had upon reaching the ground, and thus estimate the altitude from which it fell after the autorotation maneuver was terminated.

Several conditions for the helicopter's speed and attitude at the moment of impact were considered. The one that best modeled the position in which the aircraft was found involved a vertical fall with a slight 5° forward pitch angle and a minor 5° right bank angle.

As for the vertical speed at the moment of impact, four speeds were considered: 20 m/s, 30 m/s, 35 m/s and 40 m/s[8]. Of these, the most feasible was 20 m/s. The calculations made are provided in Annex 1, and revealed that the helicopter fell from an altitude of around 23 m, with no horizontal speed.

## 1.17. Organizational and management information

### *1.17.1. Board of Castilla – La Mancha*

The contract between the JCCLM and the operator to provide the services of fourteen helicopters and seven aircraft under the INFOCAM plan describes the technical requirements that the aerial assets involved in the 2014 and 2015 firefighting campaigns of the Board of Castilla - La Mancha had to meet.

Point 4.1, Aircraft types and characteristics, specifies the conditions for the accident helicopter, which was a TYPE A.

A total of eight TYPE A helicopters (they are divided into categories based on the contract length) shall be contracted. They shall meet the following minimum requirements:

- Turbine helicopter with a minimum of 4 main rotor blades.
- Capacity to transport a minimum of 7 people, excluding the crew, seated, and carrying their work equipment and support equipment.
- Minimum takeoff power of 1002 SHP.
- Minimum maximum continuous power of 872 SHP.
- Minimum cruise speed of 257 km/h.
- Minimum maximum load hook capacity of 1400 kg.
- Equipped with a Bambi bucket with a capacity between 910 l and 1,000 l. This volume includes the device to inject the foam-producing agent.
- Unit to inject foam-producing agent with a minimum capacity of 45 l.
- Skid-type landing gear.
- Minimum flight time of 2 h.

[8] 20 m/s is 72 Km/h or 3,937.2 ft/min - 30 m/s is 108 Km/h or 5,905.8 ft/min - 35 m/s is 126 Km/h or 6,889.8 ft/min and 40 m/s is 144 Km/h or 7,873.8 ft/min.

It shall have operational sliding doors on both sides of the fuselage to facilitate personnel loading and unloading operations.

The helicopter model shall have a Type Certificate that meets the specifications of the European Aviation Safety Agency (EASA) or FAR 29 of the Federal Aviation Administration (FAA) of the United States.

The capabilities required shall be understood to mean both the technical or theoretical abilities of the aircraft, and its legal abilities. In other words, the aircraft shall be rated and authorized in Spain to be able to provide this performance by the Civil Aviation General Directorate (DGAC), the National Aviation Safety Agency (EASA) and other competent authorities.

The contract also required that it have an operational ELT.

It likewise required that it have another transmitter for fleet tracking.

These specifications were drafted by the regional governments and by MAPAMA, but during the award phase, AESA did not carry out any checks to ensure that the specifications were met, as this is not required by the applicable law.

### *1.17.2. FAASA. Flight logs. Refueling information*

The flight and maintenance logs are included in the Flight Log and Maintenance Book, which is part of the maintenance program approved by AESA.

The flight and maintenance logs feature the following classification:

| *READING / REFUELING | | | |
|---|---|---|---|
| 4D *FUEL | | | |
| REP | INI | FIN | Ud |

These boxes are filled out as described in the instructions, which include the following:

"**4D *FUEL** is a box for writing in the fuel reading before the flight (INI), the reading at the end of the flight (**FIN**) and the pre-flight refueling (there is an option for 2 prior refuelings **REP**) as well as their units..."

As noted in the final flight and maintenance log, before the accident flight there were 150 kg, and 90 kg of additional fuel were added.

### *1.17.3. Regulation*

On the day of the accident, Civil Aviation Directorate General Operating Circular 16 B of 31 July 1995, on flight time limitation, flight duty periods and minimum rest periods for crews, was in effect. Annex 1, Section 4. FLIGHT TIME LIMITATIONS AND PHYSICAL PRESENCE, Point 4.2.4 of this Circular specifies that in firefighting aircraft, the pilot shall rest every 2 flight hours, with intermediate breaks of at least 40 minutes for every 2 flight hours.

A few days after the accident, on Thursday, 18 September 2014, Royal Decree 750/2014 of 5 September was published in the Official State Journal (BOE). This Decree regulates aerial firefighting and search and rescue activities and lays out the airworthiness and licensing requirements for other aviation activities. It also approves the regulations that govern aviation firefighting and search and rescue activities, and those applicable to customs, police, coast guard and similar activities as these pertain to airworthiness and flight crews.

According to the stipulations in the sixth final provision of the aforementioned Royal Decree, since 1 June 2015 any air operator that wishes to engage in this type of operation must conform to the requirements specified in the Royal Decree and have a special Air Operator Certificate (COE). The AESA Resolution of 26 December 2014 defines how to evaluate the Operations Manual written as per the requirements laid out in the Royal Decree by means of a four-step process defined in the Annex to this Resolution. Also, pursuant to the contents of the third final provision in the Royal Decree, AESA also published seven guidelines for implementing this process and provisions for applying it, the first of them on 17 December 2014 and the remaining six between 2 February and 25 May 2015.

The Royal Decree, however, does not change the rest times specified in the previous Operating Circular.

Article 11.2 of Law 1/2011 of 4 March, which lays out the National Operational Safety Program for Civil Aviation and amends Law 21/2003 of 7 July on Air Safety, specifies that the bodies, public organizations, and public and private entities and subjects required by the National Operational Safety Program for Civil Aviation shall be implemented as required by law. It also defines the scope of their obligations.

This program is an integrated set of regulations and activities intended to improve the management of operational safety in Spain. That is, it provides a management system for the State to administer operational safety. This programs facilitates decision making in the area of aviation safety through the constant analysis of the information provided by the main actors in Spain’s aviation sector through an integrated management system.

Subsequently, Royal Decree 995/2013 of 13 December was published, which implements the regulation of the National Operational Safety Program for Civil Aviation. This Royal Decree did not identify the General Directorate for Rural Development and Forestry Policy as one of the public agencies to be integrated into the program.

On the day of the accident, Royal Decree 401/2012 of 17 February was also in effect, which implements the basic organizational structure for the Ministry of Agriculture, Food and the Environment. Article 10 of this Decree specifies the powers of the General Directorate for Rural Development and Forestry Policy, which include taking part in preparing plans to protect forests and, in particular, to defend against forest fires.

The department is currently called the Ministry of Agriculture, Fishing, Food and the Environment (pursuant to Royal Decree 415/2016 of 3 November, which restructured ministerial departments (BOE 04-11-2017)), but the General Directorate for Rural Development and Forestry Policy still exists and it has the same responsibilities (Royal Decree 424/2016 of 11 November, which lays out the basic organizational structure of ministerial departments).

The Ministry of Agriculture, Fishing, Food and the Environment has high-capacity aircraft for fighting forest fires that are available year-round to cover requests for assistance from Spain's regions.

During the summer campaign, as well as during the winter months with the highest risk of forest fires, the existing forces are supplemented by contracting additional aircraft and heliborne reinforcement brigades (BRIF), as well as Mobile Meteorology and Broadcasting Units (UMMT) and Communications and Observation Aircraft (ACO), which are located throughout Spain.

The Ministry of Agriculture, Food and the Environment created the Forest Firefighting Committee (CLIF) to coordinate and plan aspects related to forest fires. This technical committee is made up of representatives from every agency involved in fighting forest fires and is presided over by the Assistant Director General of Forestry Affairs, who reports to the MAPAMA's General Directorate for Rural Development and Forestry Policy. It meets twice a year, before and after the summer campaign, to coordinate national firefighting efforts.

The CLIF presents to Spain's various regions an annual plan for deploying the national resources assigned to MAPAMA. This plan is subsequently approved by the corresponding General Directors during a Sectorial Conference on the Environment, and finally by the Council of Ministers.

## 1.18. Additional information

### *1.18.1. Background. Preliminary recommendations*

In light of the risk of a repeat occurrence taking place during the 2015 firefighting campaign involving a protracted delay in casually locating an accident aircraft, two recommendations were issued, to the Region of Castilla – La Mancha and to FAASA, intended to improve the chances of survival in the event that one of the aircraft under their command was involved in an accident.

**REC. 4/15.** It is recommended that the Agriculture Office of the Board of Communities of Castilla - La Mancha establish a procedure to ensure the periodic monitoring of aircraft that render services for it so that an early warning can be provided in the event that an aircraft is involved in an accident.

**REC. 5/15.** It is recommended that FAASA Aviación, in concert with the clients for which it provides its services, establish the necessary mechanisms to ensure that all of its aircraft are locatable and that an early warning is provided in the event of an accident.

The two recommendations were published on 25 March 2015.

<u>Follow-up on recommendations</u>

As concerns REC. 4/15, on 9 April 2015 the General Directorate of Forests and Natural Spaces of the Board of Communities of Castilla - La Mancha was informed that preliminary safety recommendation REC 04/15 had been issued, and a response was requested within the legally stipulated 90-day period. On 15 September 2015, a response was again requested.

On 29 September 2015, a reply was received from the General Directorate of Forests and Natural Spaces of the JCCLM's Board of Agriculture, the Environment and Rural Development, which detailed the measures adopted in response to said recommendation:

"The first technical and tested measure to ensure that all aircraft that provide services to the Board of agriculture are monitored was to implement an alert module in the "Platform Monitor" fleet tracking application that is installed at each of the five provincial operations centers (COP) and at the regional operations center (COR). This module can be used to quickly alert system users to the loss of signal from any of the aerial resources that are airborne. The new alert module implemented in the fleet tracking system is capable of generating visual and aural alerts on every screen in the control center when updated positions are not received from any aerial asset whose status is "in flight". The features of this new alert module, which can be customized as necessary, are:

- Adjustable alert warning time. Currently set to alert 5 minutes following receipt of the last position. Adjustable from 1 second to 15 minutes.
- Custom alert time for each aircraft. The alert time for loss of signal can be adjusted separately for each aircraft, depending on the aircraft type and on the work it will be doing. Adjustable as required.
- Record of alert every 6 hours. If the operator did not have the "Platform Monitor" program open, it would receive any alerts generated while the program was closed that were up to 6 hours old.
- Alarm resolution verification check. Every alert generated by the system must be reset using a specific command once they are cleared as part of verifying their resolution. Any alarm that is not reset will result in the system issuing new reminder warnings every 10 minutes.

Another measure adopted to monitor the alert module described above was to designate specific personnel to operate and control said platform at both the Provincial Operations Center (COP) and the Regional Operations Center (COR), such that any alert generated by the system can be detected early. If the signal is lost from any aerial asset, a work procedure was created for the COR and COP to be used by the personnel on duty when the signal loss is detected. It is currently in the draft stage as it is being checked during actual fires to identify potential deficiencies and thus improve it. The draft of this procedure is presented below.

<u>1st alarm on the Monitor (5 min)</u>

COR Fidias Operator: Inform technician and monitor incident.

COP Fidias Operator: Inform technician and monitor frequency to see if the aircraft is simply out of range.

<u>2nd alarm on the Monitor (15 min)</u>

COR Fidias Operator: Call the COP Fidias Operator to confirm they are aware of the problem and contact the BIFOR via Telegram message and the air coordinator, if any.

COP Fidias Operator: Inform broadcaster so he can try to contact the aerial asset or, if not possible, the aerial coordinator, if any.

<u>3rd alarm (25 min)</u>

COR: Organize an aerial search for the asset, contact Civil Aviation[9], call 112 and inform the company via telephone of the missing aerial asset.

[9] This refers to the Civil Aviation Accident and Incident Investigation Commission.

Another measure to adopt in the next tender for aerial assets will be to require operators to have dual-band (GPRS/satellite) position locator beacons on their aircraft, meaning beacons that broadcast on GPRS when that type of signal is available and that automatically transfer to satellite communications when beyond the range of a GPRS signal. This will guarantee the constant and uninterrupted broadcast of data from the aircraft to the "Platform Monitor" alarm system. If the signal from an aircraft with this type of ELT were lost, it would trigger an alert in the system that would be guaranteed not to be due from the aircraft being outside the range of the network."

The CIAIAC regarded the reply from the Board of Agriculture of Castilla - La Mancha as satisfactory, and deemed that the measures taken adequately addressed the recommendation, especially the implementation of the alert module in the aircraft tracking platform, which allows identifying the loss of signal from airborne aerial assets. As a result, the recommendation was closed out.

As concerns **REC. 5/15**, on 9 April 2015 FAASA Aviación was informed that preliminary safety recommendation REC 05/15 had been issued, and a response was requested within the legally stipulated 90-day period. On 15 September 2015, a response was again requested. On 17 September 2015, FAASA replied by informing that it had changed Chapter 2, Section 2.3, Part A of its FF-SAR Operations Manual to implement the recommendation, a change that the AESA had approved on 31 May 2015. The paragraph in the Operations Manual that contains the mitigative measure of implementing a mechanism to ensure that all aircraft are locatable and that early warning of accident can be provided is copied below. It should also be noted that all FAASA Aviación aircraft have a tracking ELT, and that this complements what has been applied in the FF-SAR OM since 1 June 2015.

"The purpose of operational control is to promote the safety, regularity and efficiency of operations by monitoring flights of FAASA Aviación aircraft from start to end. This operational control is provided from the main activity center and encompasses all flights under COE. It also includes operations conducted by aircraft operated under dry-lease agreements and in remote bases.

Coordination of the operational area is overseen from the Coordination and Emergency Centers of the various government agencies that monitor, control, supervise and direct all FF/SAR operations and are in permanent radio contact with the aircraft. However, FAASA Aviación also has a procedure for more efficiently exercising operational control, as described below:

1. Fleet tracking by personnel authorized to conduct this activity using computers during working hours at FAASA facilities.

2. Since there is no individual assigned to track the fleet 24 hours a day, there is a procedure to be used by aircraft captains, mechanics, base assistants, area coordinators and the ROV, which consists of the following:

a. Duties and responsibilities of the aircraft's captain (automatic dispatch area or same province):

   i. The aircraft captain shall inform the mechanic or assistant upon arrival whenever a flight has been dispatched via telephone or message, so as to be certain that the aircraft did not have any problems.

   ii. An "uncertainty phase" starts 2h 30 min after an aircraft is dispatched if the mechanic or assistant has not been notified of the aircraft's arrival by its captain or any other person or entity within the organization, in which case the mechanic shall attempt to contact the captain of the aircraft.

   iii. If no reply is received from the captain of the aircraft, the mechanic or assistant shall call the area coordinator pilot to explain the situation, and the pilot shall, in turn, call the ROV so that the Company can take any measures deemed appropriate.

b. Duties and responsibilities of the aircraft's captain (dispatch outside the province where the aircraft is located):

   i. Everything specified above applies and the captain shall call the pilot coordinator for his area on every landing and takeoff such that the aircraft is constantly tracked and such that the logistical support required can be provided, if need be, so that the crew can work normally."

The CIAIAC accepted the response of FAASA Aviación, following the operator's implementation of the operational control procedure, as contained in its FF/SAR OM, and with the additional measure of outfitting its aircraft with a tracking beacon, and closed out the recommendation.

### *1.18.2. Eyewitness interviews*

During the investigation, several pilots and mechanics who worked for the operator were interviewed. They reported that although the flight and maintenance log noted that the aircraft normally took off with 240 kg of fuel, in reality, according to their statements, it was common practice for many pilots to load 290 kg of fuel. This 50 kg of fuel in excess of that specified in the log represents 20% more.

Another issue that was noted and that is worth mentioning is that the fuel tank is drained every day, removing approximately 0.5 l of fuel to check it for water and other impurities.

Interview of Maintenance Technician who refueled the helicopter

He was an Aircraft Maintenance Technician (AMT) with no ratings, license E0044989, who on the day of the accident was assigned as part of the support staff for the AGUSTA AW 119 Koala helicopter, and who usually refueled that aircraft.

The only inspection he is qualified to do on that helicopter model is the 25-h CMR. According to his statement, EC-KSD had last been refueled on 9 September 2014 with 146 l. During a refueling, he records the company, registration and the reading on the tank pump counter.

He stated that on the day of the accident, he thought the helicopter had taken off with 280 kg or perhaps 290 kg. He also reported that the sequence used at the Villahermosa Base, and which was used on the day of the accident, is as follows:

1) The base is notified.

2) The pilot dons his flight suit if not already wearing it.

3) The pilot does the pre-flight check for the second time (the first time being first thing in the morning).

4) The helicopter left the Villahermosa Base at 15:45.

5) The pilot signed the flight dispatch sheet.

6) He lifted the right engine cover and checked the shaft connecting the turbine to the transmission.

On the day of the accident, at about 19:30 or maybe a little later, the radio operator, who was the only person remaining at the base beside the AMT, informed him that the helicopter was going to the base in Carcelén to refuel.

At about 20:00 (or maybe even earlier), the radio operator told him that there had been an accident. He then spoke with the certifying AMT, who is responsible for all the helicopters and who was the coordinator, who told him he did not know anything about the accident.

The Flight Safety Manager also did not know anything. He was supposed to relieve the pilot. They have 22-day duty periods and the accident pilot had started his period on 9 September.

## 1.19. Useful or effective investigation techniques

### *1.19.1. Test flight and associated findings*

On 15 May 2015, a test flight was conducted under conditions as close as possible to those present on the day of the accident, both in terms of the weight the aircraft was carrying and of the weather conditions, the goal being to determine the helicopter's average fuel consumption.

The test flight yielded an average consumption of 2.3 kg/min. Interviews of several pilots of this helicopter type concluded that, in general, the average consumption rate for this helicopter type is 2.4 kg/min.

### *1.19.2. Relationship between mass and flight time on the day of the accident*

The table below shows the various weights that were considered to calculate the total empty weight of the helicopter, that is, without fuel, when it took off on the day of the accident:

| COMPONENT | WEIGHT |
|---|---|
| Basic helicopter weight (empty weight) | 1.728 kg |
| Persons onboard (8 persons weighing an average of 80 kg each) | 640 kg |
| Water bucket | 62 kg |
| 2 backpacks with water | 34 kg |
| 1 tool box | 20 kg |
| **SUMA** | **2.484 kg** |

Based on the empty fuel weight in the above table (2,484 kg), the table below shows the relationship between the weight and the fuel range of the helicopter under the different flight conditions that could have existed on the day of the accident:

| TAKEOFF CONDITIONS | WEIGHT | | FLIGHT TIME |
|---|---|---|---|
| | FUEL | TOTAL | |
| Without refueling after previous flight | 150 kg[10] | 2634 kg | 1 h 06 min |
| Without refueling after previous flight plus 20% of fuel 150 Kg + 30 Kg = 180 Kg | 180 kg | 2664 kg | **1 h 18 min** |
| Fuel onboard as listed in the flight and maintenance log | 240 kg | 2724 kg | 1 h 45 min |
| Fuel normally onboard at takeoff, as stated by several pilots | 290 kg | 2774 kg | 2 h 06 min |

The maximum authorized weight on the day of the accident, as per the tables in the Flight Manual, was 2,650 kg, which would have meant there were 166 kg of fuel, yielding a flight time of 1:12 h.

To comply with the flight time requirement, which was 2:00 h plus reserve fuel, which was 10 minutes (2:10 h total), it should have taken off with 299 kg of fuel, or a total weight of 2,733 kg.

[10] Listed in flight log.

# 2. ANALYSIS

## 2.1. Introduction

The investigation into this accident took into account numerous circumstances that will be discussed in the sections that follow.

We will attempt to explain why the engine stopped, why the helicopter fell to the ground and how the impact occurred.

We will also go into detail on the survival aspects and try to underscore some of the systematic and organizational deficiencies that were detected in the various regional agencies and in the MAPAMA.

Finally, we will present a series of circumstances and latent risks that were detected after the accident.

## 2.2. Analysis of fuel consumption during accident flight

In this case we know that the duration of the helicopter's flight between takeoff until it crashed to the ground was 1:18 h, which means that during the flight, it must have consumed **179.4 kg** (based on the calculated consumption rate of 2.3 kg/min).

According to the contents of the last flight log, the helicopter had 150 kg of fuel remaining and was refueled with 90 kg, meaning it theoretically took off with 240 kg of fuel, in which case it would have been able to fly for 1:45 h, which is longer than it actually flew.

According to pilots and mechanics, it was usual practice to take off with 50 kg (20%) more, even if the flight and maintenance log specified that a helicopter took off with 240 kg. In other words, that in this case it would actually have taken off with 290 kg, more than in the previous case and which have allowed for an even longer flight time.

Assuming the pilot did not refuel and that the aircraft took off with the fuel remaining from the previous flight (150 kg according to the flight log), its flight time would have been 1:06 h, meaning it would not have been able to reach the accident site.

Finally, accepting the hypothesis that it did not in fact refuel after the last flight and that it had the 150 kg of fuel remaining shown in the flight log, if we consider that there could in fact have been 20% more fuel onboard, assuming that practice discussed earlier as factual, then it would have taken off with 180 kg (20% more than the 150 kg remaining).

This 180 kg represents practically the amount that the helicopter is calculated to have consumed during its actual flight time, which was 1:18 h.

Another factor to consider is that the helicopter had not been flown for four days, during which, in keeping with the standard practice, some 2 l of fuel would have been drained from the tank.

Therefore, all of the data tend to indicate that the helicopter was not refueled after the last flight and that it took off with about **180 kg** of fuel onboard.

### 2.3. Analysis of the wreckage

The layout of the wreckage at the crash site was consistent with a practically vertical, high-energy impact, since the damage and warping sustained by the helicopter were associated with the vertical inertial forces, with only a minor component of motion forward and to the right.

The condition of the main rotor blades and the tail rotor blades clearly indicated that the impact occurred with the engine stopped.

The analyses of both the engine and the transmission were conclusive in the determination that the damage observed in their components had taken place after the impact.

In the case of the engine, the analysis also confirmed that it was stopped before the impact.

The accident scenario corresponded to what would be expected if the engine had run out of fuel. This is because there was no fire despite the high-energy involved in the crash, there was no smell of fuel or any fuel leaks that were visible to the naked eye, or any indication that any fuel had been absorbed by the ground, even though the tanks fractured during the impact, allowing investigators to see directly inside. In fact, investigators dug into the ground underneath the helicopter and found no fuel with the exception of a superficial stain caused by the remaining non-usable fuel.

A small amount of residual fuel was found in the fuel system filters, which means that the engine stoppage was not the result of a blockage, but because the little amount left in the lines was not sufficient for the pumps to supply the pressure needed for the fuel to reach the engine. In this regard, it should be noted that the pilot received a low fuel pressure warning in the cockpit.

The sensor that not only measures the amount of fuel, but that also detects a potential low fuel level and sends a corresponding signal to the cockpit, was analyzed in two different laboratories, and even though their findings were not exactly identical, both studies do lead to the conclusion that it is not possible to confirm whether or not the fuel reading in the cockpit was erroneous or inaccurate.

### 2.4. Final moments of the flight prior to impact

In the final moments of the flight, there is no doubt that the pilot performed an autorotation, because otherwise it would have been impossible for the helicopter to reach the ground with only vertical speed and stabilized about the pitch and roll axes.

Based on the foregoing, the calculations done indicate that the helicopter descended while in autorotation and that the flare maneuver to brake the helicopter by raising the nose to bleed off the speed in order to land was performed much higher than it should have been (for a given speed), at around 6-10 m, meaning that it would have started falling from an altitude of 18-21 m. This would explain the damage to the helicopter consistent with a strong vertical impact, which flattened the helicopter's total height by practically a third.

### 2.5. Survival

The ELT was located on the floor immediately aft of the first tailcone frame, attached to the floor of the helicopter in accordance with the instructions provided by the manufacturer in its user manual; that is, it was fastened using a Velcro strip which broke on impact. The antenna, however, was not connected as per the same instructions in the manual, as it crossed several structural sections of the helicopter with sharp edges.

Even though it was armed and sufficiently charged, it did not activate. Investigators were unable to determine exactly why. What is certain is that if it had activated, it would only have been able to broadcast a signal within a limited radius around the helicopter, and not a broader signal through the antenna, and that would have been received by the Air Force's Rescue Coordination Center (RCC). This is because the cable that connected the antenna was cut after the impact by a sharp object, probably the frame across which it was laid, since it was not installed in accordance with the manufacturer's specifications.

Upon realizing that a recurrence was possible anywhere in Spain, two safety recommendations were issued, to the Operator and to the JCCLM, and both were published for the information of every Spanish regional government and the MAPAMA.

The reply from the JCCLM to the recommendation that a tracking system be set up for aircraft fighting a fire was deemed to be sufficient to prevent a similar case from happening again. It would be advisable for a similar system, designed to eliminate this risk, to be adopted by all the other regional governments and by the MAPAMA, which does not have any effective protocols.

Similarly, the measures implemented by the aircraft's Operator, which made a change to its FF-SAR Operations Manual to implement a procedure requiring the aircraft captain, the mechanic or the assistant at the base, the area coordinators and the Flight Operations Manager to make a series of calls to ensure that all of the helicopters are accounted for at all times, could be an adequate solution to avoid a situation similar to the one described in this report.

There is no regulation in place that is intended to prevent a case similar to the one described above from happening again and that applies to both the agencies that are tasked with fighting fires and to the operators. As a result, it would be advisable for both the AESA and DGAC to take the steps needed to create the necessary regulation that will prevent a similar situation from occurring in the future.

### 2.6. Circumstances and latent risks prior to the accident

The investigation attempted to determine what circumstances prior to the accident could have contributed to creating a scenario with certain latent risks that were not detected or eliminated in time, as well as what direct actions were taken.

The calculations done indicate that the helicopter was not refueled prior to its flight for unknown reasons. The immediate nature of a takeoff when there is an alert is a latent risk factor that is known and controlled and cannot be eliminated, but it can be mitigated by leaving the helicopter ready and in operational condition immediately after each flight.

Once a helicopter is airborne and en route to the fire site, circumstances can arise that alter the flight time planned by the pilot, as happened in this case. As a result, it would be very helpful, when planning the flight time, for the pilot to contact the coordination aircraft as soon as possible. In this case, according to reports from the various eyewitnesses, the pilot made contact upon reaching the fire site, and the plan he had made, which was to drop off the BIFOR, take on water, make a water drop and go refuel, had to be changed on the go in order to carry out a different task he was requested to perform.

A change of plans on the go, such as the reconnaissance flight with the Firefighting Director onboard, without prior planning always introduces an element of risk, however small. In this case, it forced the pilot to alter his planned flight time, and given that he did not have enough fuel, it resulted in the engine stopping before the helicopter could be refueled.

If the practice were in place to contact as quickly as possible the resource that is coordinating the firefighting efforts from the air, the flight time could be planned better, thus eliminating another risk factor.

During the autorotation maneuver, the pilot managed to stabilize the helicopter, since the fall was practically vertical and stabilized about both the pitch and roll angles. However, despite being highly experienced as a helicopter pilot, he did not execute the final phase of the autorotation maneuver correctly.

# 3. CONCLUSIONS

## 3.1. Findings

- The helicopter left from the base at Villahermosa.

- The engine was started at 15:43 and it took off four minutes later with seven BIFOR specialists onboard. It flew to the municipality of Almansa (Albacate) to take part in firefighting efforts.

- Upon reaching the fire site, the pilot contacted the Aerial Resources Coordinator (CMA), who told the pilot where to offload the BIFOR, which he did at 16:30.

- Between 16:46 and 16:54, he took the firefighting director on a reconnaissance flight.

- At 16:57, he left the fire area and headed to the base of Carcelén (Albacate), informing the CMA that he was going to refuel and take his break.

- The helicopter had a fleet tracking system and a portable GPS unit onboard, which stopped recording at 17:02 and 17:01 respectively.

- The aircraft was located in the municipality of Alpera (Albacete) by chance by an individual who passed by the accident site and who called the Civil Guard's emergency number (062) at 19:20. The Civil Guard dispatched a unit to the accident site.

- The Civil Guard officers called the Castilla – La Mancha 112 coordination room to report the event and confirm that the pilot had been killed.

- The COR (Regional Operations Center) of the JCCLM was unaware of the event.

- There is no record of any communications with the helicopter during the almost two and a half hours that elapsed between the time it left the fire area until it was found.

- The ELT was armed and the battery charged, but it did not activate. The cable that connects the antenna had been severed by the impact. The installation between the ELT and the antenna was not in accordance with the manual.

- The Operator's Operations Manual specified that captains must check the fuel at regular intervals during a flight to make sure, among other things, that there is enough fuel remaining to complete the flight.

- The engine stopped during the flight due to fuel starvation.

- The engine display units, which monitor engine parameters, did not record any low fuel level warnings.

- The time shown on the EDUs did not match that recorded by the fleet tracking system.

- The condition of the low fuel level sensor (LLS) could not be used to confirm or rule out the correct operation of the system.

- The condition of the remaining sensors that are used to measure the fuel level could not be used to confirm or rule out the correct operation of the system.

- The engine was running for 1:18 h between startup until it stopped, which indicates that it would have had approximately 180 kg of fuel when it took off.

- The flight log, which was not signed, indicated that it took off with 240 kg of fuel, which was in excess of the actual amount it was carrying.

- The helicopter crashed almost vertically to the ground from an altitude of between 18 and 21 m. It was a very high energy impact.

- At 16:51:17, just 2 s before the impact, EDU 1 recorded a low fuel pressure warning.

- The CIAIAC issued two preliminary recommendations to the JCCLM and to the operator to have them take measures that would allow them to effectively track their aircraft at all times. These measures were satisfactorily implemented and the recommendations closed out.

- There are no similar measures implemented in most regions of Spain, or in the MAPAMA, to effectively track aircraft at all times.

## 3.2. Causes/Contributing factors

The accident was caused by the deficient execution of an autorotation maneuver after the helicopter's engine stopped due to fuel starvation.

Contributing to the accident was the improper management of the fuel onboard by the pilot.

## 4. SAFETY RECOMMENDATIONS

The emergency locator transmitter did not activate despite being armed, but even if it had, it would have been unable to transmit via the antenna because the cable that connected it to the antenna was cut after the impact by a sharp component. This is because the cable between the ELT and the antenna had not been installed as per the manufacturer's specifications.

**REC. 09/17.** It is recommended that FAASA AVIACIÓN take the measures needed to ensure that the emergency locator transmitters are properly installed and fastened.

As was already noted in the report, if specific measures are not taken by the operators of the various government agencies that are responsible for fighting forest fires, there could be a repeat occurrence of this case, in which an aircraft is involved in an accident after leaving the site of the fire and its absence is not detected either by the operator or by the agency to which is was providing its services.

The replies to the preliminary recommendations by the JCCLM and the operator in terms of establishing an effective tracking system for aircraft operating at a fire site were regarded as satisfactory and have been closed, since they are deemed to be sufficient to prevent a similar case from occurring once more. As a result, it would be convenient for the aforementioned government agencies that still do not have an effective protocol to adopt a method that achieves a similar result.

**REC. 10/17.** It is recommended that Spain's National Aviation Safety Agency (AESA) take the regulatory initiative to include a requirement for operators to have them adopt effective tracking measures to ensure that aircraft taking part in aerial work are accounted for at all times.

**REC. 11/17.** It is recommended that Spain's Civil Aviation General Directorate (DGAC) adopt the necessary changes with respect to the regulation, as proposed by Spain's National Aviation Safety Agency (AESA), to include the requirement for operators to have them adopt effective tracking measures to ensure that aircraft taking part in aerial work are accounted for at all times.

## ANNEX 1. CALCULATIONS FOR ESTIMATING THE FLIGHT VARIABLES IN THE FINAL SECONDS

Given the records in the fleet tracking system and in the pilot's portable GPS device, the investigation attempted to reconstruct the final seconds of the flight with the portable GPS data, which were deemed to be more accurate.

The recorded data indicate that the last phase of the flight, that is, from the time it took off to head to the base at Carcelén until the data end, lasted 309 s (5 min 9 s).

There is a final data set at second 311 that was not used because the speed and altitude data are not consistent with the final movement the aircraft must have made to reach the impact site.

There are six separate phases of flight during this time:

| PHASE | TIME [S] | DURATION [S] | DESCRIPTION |
|---|---|---|---|
| 1 | 0 ÷ 52 | 52 | Takeoff and climb to cruise speed and altitude (130 kt and 3,200 ft respectively) |
| 2 | 52 ÷ 179 | 127 | Constant cruise speed of 130 kt and altitude between 3,200 and 3,400 ft |
| 3 | 179 ÷ 292 | 113 | Climb to 4,000 ft to clear a rise in the ground at 3,500 ft. Speed reduced from 130 kt to 125 kt |
| 4 | 292 ÷ 299 | 7 | Slight descent while keeping speed at 125 kt |
| 5 | 299 ÷ 309 | 10 | Engine stoppage and significant loss of altitude. Moderate drop in speed |
| 6 | >309 | - | No further data |

The coordinates of the last valid point recorded by the GPS were approximately 80 m away (ground distance) from the impact site, at an altitude of 400 ft (121.92 m). Starting with the possible flight path taken from the last known point recorded by the fleet tracking system, and assuming an impact speed into the ground of 20 m/s, the investigation attempted to figure out the altitude from which the helicopter fell vertically, taking into account the resistance offered by both the fuselage and the rotor, as well as the loads on each part of the helicopter, in order to achieve this speed.

We considered the generic free-fall problem of a body in the atmosphere subject to its own weight and frictional forces, taking as the coordinates of the origin the point where it started its free fall. A second initial condition considered is that the initial speed was zero. The problem was adjusted to the atmospheric conditions present on the day of the accident, and to the helicopter's geometry and its load.

| | Position r (t) | Speed dr/dt | | | | Acceleration $d^2r/dt^2$ | |
|---|---|---|---|---|---|---|---|
| t (s) | m | m/s | Vz/Vio | ft/min | % on $V_{lim}$ | m/s² | % on g |
| 0,00 | 0,0 | 0,0 | 0,00 | 0 | 0,0% | 9,8 | 100,0% |
| 0,50 | 1,2 | 4,9 | -0,49 | 960 | 12,8% | 9,7 | 98,7% |
| 1,00 | 4,9 | 9,6 | -0,96 | 1896 | 25,3% | 9,3 | 95,0% |
| 1,50 | 10,8 | 14,2 | -1,41 | 2786 | 37,2% | 8,7 | 89,2% |
| 2,00 | 19,0 | 18,3 | -1,83 | 3612 | 48,2% | 8,0 | 81,8% |
| 2,10 | 20,83 | 19,14 | -1,91 | 3768 | 50,3% | 7,86 | 80,2% |
| 2,20 | 22,79 | 19,92 | -1,99 | 3922 | 52,3% | 7,70 | 78,6% |
| 2,22 | 23,19 | 20,08 | -2,00 | 3952 | 52,7% | 7,67 | 78,3% |
| 2,30 | 24,81 | 20,50 | -2,04 | 4035 | 53,8% | 5,45 | 55,6% |
| 2,50 | 29,02 | 21,57 | -2,15 | 4245 | 56,6% | 5,21 | 53,2% |
| 3,00 | 40,4 | 24,0 | -2,40 | 4729 | 63,1% | 4,6 | 47,1% |
| 3,50 | 53,0 | 26,2 | -2,61 | 5156 | 68,8% | 4,0 | 41,3% |
| 4,00 | 66,6 | 28,1 | -2,80 | 5527 | 73,7% | 3,5 | 35,8% |
| 4,50 | 81,0 | 29,7 | -2,96 | 5847 | 78,0% | 3,0 | 30,7% |
| 5,00 | 96,2 | 31,1 | -3,10 | 6121 | 81,6% | 2,6 | 26,1% |
| 5,50 | 112,1 | 32,3 | -3,22 | 6353 | 84,7% | 2,2 | 22,1% |
| 6,00 | 128,5 | 33,3 | -3,32 | 6549 | 87,3% | 1,8 | 18,6% |
| 6,50 | 145,3 | 34,1 | -3,40 | 6713 | 89,5% | 1,5 | 15,6% |
| 7,00 | 162,6 | 34,8 | -3,47 | 6850 | 91,3% | 1,3 | 13,0% |
| 7,50 | 180,1 | 35,4 | -3,53 | 6964 | 92,9% | 1,1 | 10,8% |
| 8,00 | 197,9 | 35,9 | -3,58 | 7059 | 94,1% | 0,9 | 8,9% |
| 8,50 | 215,9 | 36,3 | -3,61 | 7137 | 95,2% | 0,7 | 7,4% |
| 9,00 | 234,2 | 36,6 | -3,65 | 7202 | 96,0% | 0,6 | 6,1% |
| 9,50 | 252,5 | 36,9 | -3,67 | 7255 | 96,8% | 0,5 | 5,0% |
| 10,00 | 271,0 | 37,1 | -3,70 | 7299 | 97,3% | 0,4 | 4,1% |

The necessary simplifications were made to the dynamic equation along the vertical axis.

A separate study of the vertical descent of the helicopter's main rotor was then conducted in order to calculate the descent speed from which this helicopter's rotor, in the atmospheric conditions present on the day of the accident, enters the windmill brake state, and also the contribution of said state to the vertical force balance. Finally, the two results were combined to solve the overall problem. Once all of the calculations were completed, the output was the table below, which shows that in order to reach the ground at a speed near 20 m/s, it would have had to fall from an altitude of around 23 m.

The experiment demonstrates that before its final maneuver, the helicopter had to have a certain vertical speed. As a result, the previous calculations were performed again to start with an initial fall speed different from zero. Based on this, different scenarios were considered, assuming initial speeds from 1 m/s (197 ft/min) to 10 m/s (1,979 ft/min), the results of which are provided in the table.

| INITIAL SPEED – $V_0$ (m/s) | (ft/min) | TIME (s) | ALTITUDE (m) |
|---|---|---|---|
| 1 | 197 | 2,12 | 23,2 |
| 2 | 394 | 2,01 | 22,9 |
| 3 | 591 | 1,91 | 22,7 |
| 4 | 787 | 1,81 | 22,4 |
| 5 | 984 | 1,7 | 21,8 |
| 6 | 1.181 | 1,6 | 21,3 |
| 7 | 1.378 | 1,5 | 20,7 |
| 8 | 1.575 | 1,39 | 19,8 |
| 9 | 1.772 | 1,28 | 18,8 |
| 10 | 1.969 | 1,18 | 17,9 |

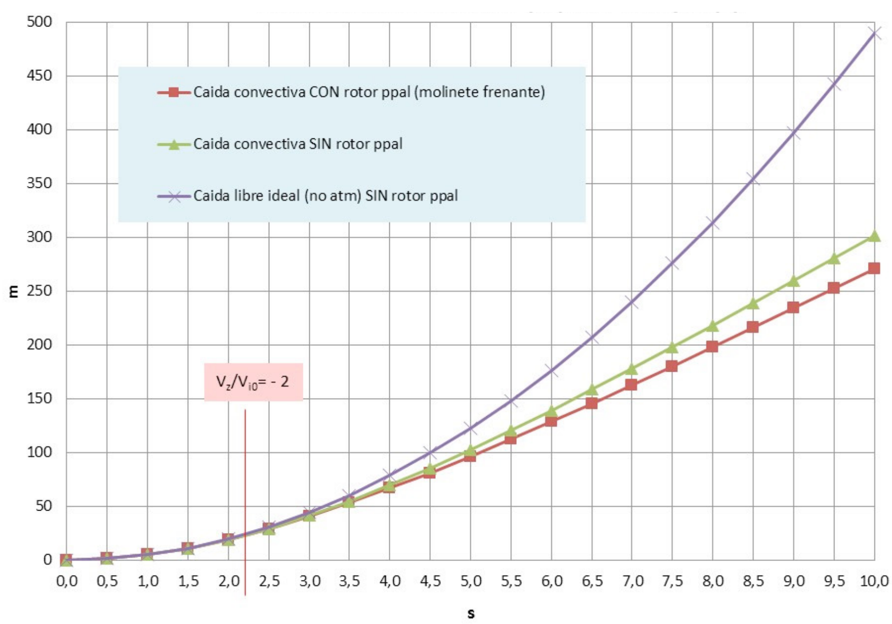


**Figure 17.** Free fall distance versus time

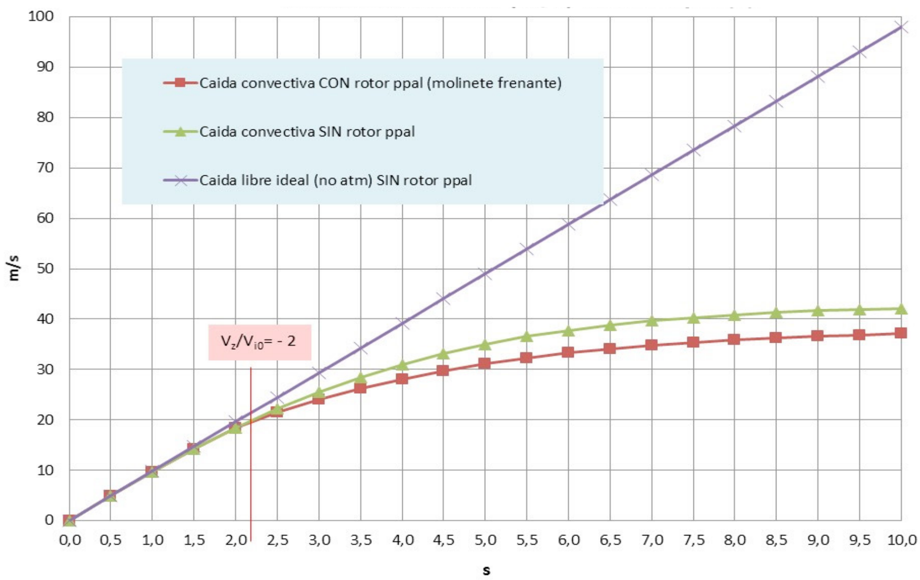


**Figure 18.** Graphic of the vertical speed versus time