Technical report
A-038/2022

Accident on 25 July 2022 involving a Eurocopter AS-350-B3 aircraft operated by Pegasus Aviación, registration EC-NTE, in the municipality of Cerezo de Mohernando, Guadalajara (Spain)

Please note that this report is not presented in its final layout and therefore it could include minor errors or need type corrections, but not related to its content. The final layout with its NIPO included (Identification Number for Official Publications) will substitute the present report when available.

GOBIERNO DE ESPAÑA
MINISTERIO DE TRANSPORTES Y MOVILIDAD SOSTENIBLE
SUBSECRETARÍA
COMISIÓN DE INVESTIGACIÓN DE ACCIDENTES E INCIDENTES DE AVIACIÓN CIVIL

Notice

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

In accordance with the provisions in Article 5.4.1 of Annexe 13 of the International Civil Aviation Convention; and with Articles 5.5 of Regulation (EU) No 996/2010 of the European Parliament and of the Council of 20 October 2010; Article 15 of Law 21/2003 on Air Safety; and Articles 1, 4 and 21.2 of RD 389/1998, this investigation is exclusively of a technical nature, and its objective is the prevention of future aviation accidents and incidents by issuing, if necessary, safety recommendations to prevent their recurrence. The investigation is not intended to attribute any blame or liability, nor to prejudge any decisions that may be taken by the judicial authorities. Therefore, and according to the laws specified above, the investigation was carried out using procedures not necessarily subject to the guarantees and rights by which evidence should be governed in a judicial process.

Consequently, the use of this report for any purpose other than the prevention of 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

° ‘ “	Sexagesimal degrees, minutes and seconds
“	Inches
°C	Degrees Celsius
ACT	Hours of flight experience in relevant activities
ACO	Coordination and observation aircraft for fire surveillance and observation
AEMET	State Meteorological Agency
AESA	Spain’s National Aviation Safety Agency
ALF	After the last flight of the day
ASC	Hours of flight experience in similar aircraft
BFF	Before the first flight of the day
SOE	Special Operator Certificate
CPL(H)	Commercial helicopter pilot license
CRFS	Crash resistant fuel system
CRFT	Crash resistant fuel tank
CRS	Certificate of release to service
CRSS	Crash-resistant seats and structures
EASA	European Union Aviation Safety Agency
ELT	Emergency location transmitter
FAA	Federal Aviation Administration
FADEC	Full Authority Digital Engine Control
FF	Firefighting operations
FH	Flight hours
FLI	First Limit Indicator
ft	Feet
h	Hours
IGN	National Geographic Institute
kg	Kilograms
km	Kilometres
km/h	Kilometres per hour
kt	Knots
kV	Kilovolts

kw	Kilowatts
l, l/h	Litres, Litres/hour
lb	Pounds
LAPL	Light aircraft pilot license
LT	Local time
m	Metres
mm	Millimetres
m/s	Metres/second
m^2	Metres squared
OM	Operations Manual
MSM	Master Service Manual
HFM	Helicopter flight manual
s/n	Serial number
N	North
Nf	Free power turbine speed
Ng	Engine gas generator speed
NOTAM	Notice distributed by means of telecommunications that contains information related to the establishment, condition or modification of any aeronautical facility, service, procedure or danger whose timely knowledge is essential for personnel in charge of flight operations.
NR	Rotation speed of the main rotor
PIC	Pilot-in-command
PICmin	Minimum previous experience in flight hours as pilot-in-command
PPL(H)	Private Helicopter Pilot License
SAR	Search and rescue service
SIB	Safety Information Bulletin
SOP	Standard operating procedures
SP	Single Pilot
TA	Visual inspection of the aircraft during turn-around
VEMD	Vehicle and Engine Multifunction Display
VFR	Visual flight rules
VHF	Very high frequency (30 to 300 MHz)
W	West
WSPS	Wire strike protection system

Technical report

A-038/2022

Owner:	Importaciones Carreira
Operator:	Pegasus Aviación
Aircraft:	Eurocopter AS-350-B3, registration EC-NTE, s/n: 9161
Date and time of accident:	Monday 25 July 2022, 20:45 local time
Site of the accident:	Municipality of Cerezo de Mohernando – Guadalajara (Spain)
Persons on board:	1 (pilot)
Type of operation:	Aerial works – Commercial – Firefighting
Phase of flight:	Manoeuvring - Helibucket water drop
Flight rules:	VFR
Date of approval:	29/11/2023

Synopsis

Summary:

On Monday, 25 July 2022, during a firefighting mission in the municipality of Cerezo de Mohernando in the province of Guadalajara, the AS-350-B3 helicopter with registration EC-NTE collided with high-voltage electrical cables during a firefighting manoeuvre and descended rapidly to the ground, causing a post-impact fire that destroyed the aircraft.

The pilot suffered minor injuries.

The investigation has established that the cause of the accident was the performance of a low-altitude flight during a firefighting operation in an environment with reduced operational safety conditions, which led to the main rotor blades striking a high-voltage power line.

The collision with the power line was caused by the pilot's inadvertent failure to comply with the safety rules set out in the water drop procedure.

The impact with the main rotor resulted in an unrecoverable loss of power to the helicopter, forcing the pilot to make an emergency landing on a steep slope. On impact with the ground, the aircraft overturned, trapping the pilot and causing a post-impact fire that completely destroyed the aircraft.

The difficulty in seeing the power line due to the smoke produced by the fire and the fact that it was camouflaged by the surroundings, which could have made it difficult for the pilot to judge his position in relation to the cables correctly, is thought to have been a contributing factor in the incident.

The report does not include any operational safety recommendations.

1. THE FACTS OF THE INCIDENT

1.1. Overview of the accident

On 25 July 2022, the pilot of the AS-350-B3 helicopter, registration EC-NTE, was mobilised at 17:27 local time from his base in Albendea (Cuenca) to assist in a firefighting mission at a forest fire in Humanes - Cerezo de Mohernando (Guadalajara). The fire had started at 15:34 local time with a total of 13 outbreaks distributed across 1600 hectares of woodland and agricultural pasture.

On arrival at the fire, the pilot surveyed the area, leaving the firefighters on the left flank and dropping water onto that same flank, from the tail to the head of the fire, by helibucket.

According to the pilot's statement, the firefighting team identified the main threats to the operation as the high virulence of the fire, the high speed of spread, the villages it threatened, the high number of resources working (6 helicopters and various ground resources), the large number of high, medium and low-voltage power lines in the area, the high mobility of tractors in the fields, the lack of ACOs[1] and, at the time of the reconnaissance, the presence of numerous large birds in the area.

Photograph 1: Aircraft EC-NTE at the incident site

[1]ACO: Coordination and observation aircraft for the surveillance and observation of fires, transmission of images and coordination of the aerial resources involved in a forest fire. Under state jurisdiction, they do not necessarily intervene in all fires.

The pilot was instructed by the firefighting commander to take rest periods (per Operational Circular 16B) and refuel at the base at Las Minas - Hiendelaencina (Guadalajara), as practically all the other air resources were using the other base closest to the fire, at El Serranillo (Guadalajara). He followed these instructions without incident during his first intervention in the area.

When the pilot departed the Las Minas base to resume activity, the instructions were to drop the brigade at the fire and return to the base in Cuenca in order to finish operations before sunset[2]. Initially, the pilot did not know whether he would have to pick up the brigade or not, but during the operation, the firefighting commander informed him by telephone that the brigade would remain in the area. After completing the water drops, he asked to return to the base with the helibucket deployed, but there was a change of plan, and he was instructed to continue working and spend the night at the El Serranillo base closest to the fire so that he could maximise his intervention and continue working until sunset.

Photograph 2. Helicopter EC-NTE involved in the accident

The pilot was working on the left flank of the fire, which was running parallel to the high-voltage line. According to the pilot's statement, he carried out 3 or 4 water drops in the area, and in the drop that led to the accident the plan was to exit the drop manoeuvre to the left as it required less power and there was less smoke. The sun was behind him and he would depart parallel to the power line with the pylon in sight.

During this exit manoeuvre, according to his testimony, he saw the reflection of an electric cable on the right side and tightened the turn to the left, lowering the collective. At that moment, he heard the whip of an electric cable striking the main rotor, and the revolutions began to drop. With the acoustic warning for low main rotor revolutions sounding, he levelled the aircraft and lowered the collective to recover revolutions, but they continued to drop, so he prepared for an emergency landing. According to his statement, the pilot, trying to control the helicopter at about 50 m above the ground, 40 kt speed and a descent rate of 50 to 100 ft/min and already very close to the ground, pulled the collective pitch control to maximum, practically putting the helicopter into a hover as it made initial contact with the ground. Unfortunately, however, the helicopter touched down on the side of a steep ravine with a considerable slope, and the second touch of the skid caused it to flip over and catch fire.

[2] According to information from the IGN (Spanish National Geographic Institute) - the National Astronomical Observatory, on 25/07/2022 in Guadalajara, sunset occurred at 21:35 local time.

The other flight crews and firefighters saw the accident and put out the mayday. The pilot, trapped under the aircraft, closed the fuel valve, disconnected the battery, and managed to free himself from the safety restraints and get out of the aircraft by his own means.

The helicopter was completely destroyed by the post-impact fire. Another factor was that the fire being targeted by the mission was very close to the accident site, on the opposite slope of the ravine.

The pilot was taken to Guadalajara University Hospital, where he was admitted with a mild diagnosis.

1.2. Injuries to persons

Injuries	Crew	Passengers	Total in the aircraft	Others
Fatal	-	-	-	-
Serious	-	-	-	-
Minor	1	-	1	-
Unharmed	-	-	-	-
TOTAL	1	-	1	-

1.3. Damage to the aircraft

The aircraft was completely destroyed by the post-impact fire.

1.4. Other damages

Damage was caused to the high-voltage power line between pylons 75 and 76 on the Iberdrola network, where the conductor cable was interrupted.

Also, at the site of the helicopter's impact with the ground, the undergrowth was burnt by the fire caused by the aircraft's fuel.

1.5. Information about the personnel

The 43-year-old pilot had a commercial helicopter pilot licence, CPL(H), issued by Spain's National Aviation Safety Agency (AESA) on 30/05/2011, and a private helicopter licence, PPL(H), issued on 17/02/2009 with the following ratings:

- Type rating AS-350/EC-130/SP single-pilot, valid until 30/04/2023,
- Type rating Bell 212/412/SP single-pilot, valid until 28/02/2023,
- Type rating W-3SOKOL/SP single-pilot, valid until 30/03/2023.

The pilot had a certificate of competency in firefighting operations with non-complex helicopters, valid until 14/06/2023, issued by the operator.

His medical certificate was valid until 30/11/2022 for Class 1 in commercial operations with a single pilot carrying passengers, until 30/05/2023 for Class 1 (general) and until 30/05/2024 for Class 2 and LAPL.

His total flight experience was 1295:47 hours, with 948:42 hours as pilot-in-command. His experience in the type of aircraft involved in the accident was 61:36 hours and he had 1019:14 hours in twin-engine helicopters such as the Sokol and BELL 412, and 276:33 hours in single-engine helicopters, including, in addition to the accident helicopter, helicopters such as the Robinson 22 and the Schweizer 300.

His experience as a pilot in firefighting operations was 940:52 h during 12 consecutive campaigns.

According to the operator's OM, his last ground training on the AS-350-B3 aircraft type was conducted on the 9th and 10th of May 2022. His last type-specific recurrent training on the AS-350-B3 2B1 & E aircraft type, which involved a 1-hour flight, and his most recent operator type-specific proficiency check, which lasted 1 hour, were conducted on 23/05/2022.

In regard to firefighting operations, the pilot's most recent training and proficiency check on the AS-350-B3 aircraft was conducted on 25/05/2022 during two flights with a total duration of 2:15 h.

1.6. Information about the aircraft

1.6.1. General information

The Airbus Helicopters AS-350-B3 E aircraft, registration EC-NTE and s/n: 9161 is a light, single-engine helicopter with a capacity of up to six people, equipped with a Turbomeca Arriel 2D turbine, s/n: 53704, whose avionics include an electronic VEMD[3] (with FLI[4]) and FADEC[5].

I. Main details

- Empty weight: 1,471 kg.
- Maximum take-off weight: 2,621 kg.
- Dimensions
  - Diameter of the main rotor: 10.69 m (3 blades)
  - Diameter of the tail rotor: 1.86 m (2 blades)
  - Total length: 12.94 m
  - Fuselage length: 10.93 m
  - Width: 1.87 m
  - Total height: 3.14 m

[3] VEMD: Vehicle and Engine Multifunction Display - A system consisting of two LCD multifunction displays used in flight mode to monitor the engine and helicopter, one on each display, optimising and calculating the mission parameters for the pilot.
[4] FLI: First Limit Indicator.
[5] FADEC: Full Authority Digital Engine Control.

- Performance:
  - Never-exceed speed: 155 kt
  - Cruise speed: 140 kt
- Main rotor: semi-rigid with a three-bladed *Starflex* rotor head.
- Main rotor blades made of composite materials.
- Single hydraulic system.
- Tail rotor: flexible see-saw type[6] made mainly from composite materials.
- Transmission system: transmits the power from the engine to the main rotor and the tail rotor drive shaft, with the peculiarity that, as it's a free turbine, there's no clutch, and the transmission is carried out through a freewheeling unit in the engine shaft module.

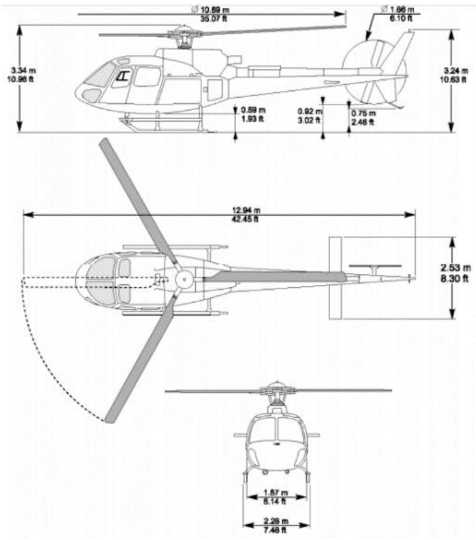

Figure 1: Aircraft AS-350-B3

- Landing gear: On the AS-350 variants, the undercarriage consists of two tubular steel crosstubes (front and rear) fastened to the side beams of the structure with rubber devices inside the attachment points and two light alloy skids. Two shock absorbers are mounted on the front crosstubes, one on each side of the cabin.
- The fuel tank had a capacity of 426 kg (540 l) and the optional auxiliary tank could hold 375 kg (475 l).

II. Load sheet

With regard to the aircraft load sheet, the weights on the accident flight were as follows:

- Pilot's weight: 80 kg
- Empty weight with equipment: 1471 kg
- Weight of the load on hook: 840 kg
- Total weight with 0 fuel: 2311 kg
- Fuel on take-off: 310 kg
- Maximum take-off weight: 2621 kg
- Fuel on landing 65 kg
- Total weight of the aircraft on landing: 2376 kg

III. Wire strike protection systems

The AS 350 B3 helicopter has two different crash-resistant fuel system options in compliance with the EASA recommendation under Safety Information Bulletin SIB No.: 2017-18R1 dated 15/05/2019. The system manufactured by Airbus Helicopters is called CRFS (Crash Resistant Fuel System). The other system, called CRFT (Crash Resistant Fuel Tank), is manufactured by Standard Aero. Only the CRFT system is certified for installation in the lower fuselage.

[6] Flexible See-saw-type tail rotor.

Figure 2. Position of anti-impact fuel tank

Several studies[7] have looked at the potential risk of a post-impact fire following a helicopter crash and its influence on occupant mortality. Among the main findings, the studies identified that post-impact fires were determining factors in occupant fatalities and that if aircraft were fitted with a crash-proof fuel tank, crew survival was improved because the risk of post-impact fires was reduced.

The helicopter involved in the incident was fitted with this type of crash-resistant fuel tank, specifically, the CRFS system.

The aircraft also had a wire strike protection system (WSPS) and improved crash-resistant seats and structures (CRSS).

The WSPS consists of an upper cutting blade, a lower cutting blade and a windshield deflector. The system is designed to guide the cables over the fuselage towards the heavy-duty steel cutting blades positioned to cut the cable in the event of a collision (cable cutter system).

For the system to work properly, the wires must be of limited diameter and strike the aircraft at a near perpendicular angle of approach from the front; even so, the aircraft must be travelling at a minimum speed to allow the wires to be routed through the structure and cut.

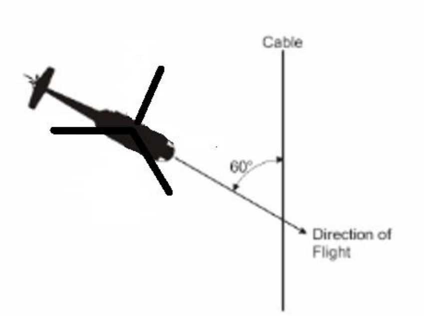

Figure 3. Maximum angle of impact with the cable

As such, for the cutting blades to be effective, the helicopter must be flying above 30 kt (in the event in question, the helicopter was flying at 40 kt). The blade manufacturer states that the system may be ineffective if the helicopter strikes the wire at an angle of less than 60° to the wire. In addition, to be effective, the maximum angle of inclination at which the blade must strike the cable is ±5°. In this event, as the collision happened during a left turn, the angle changed during the manoeuvre. The system is designed to cut a 3/8”(9.525 mm) steel wire with a tensile strength of 12,000 lbs. The cable cut in the event was made of 30 mm diameter aluminium with a steel core of about 9 mm diameter.

IV. Operational procedures

The following operating procedures are relevant to the investigation.

[7] Conducted by the FAA and EASA recommending to aircraft manufacturers the development and use of anti-impact fuel tanks.

Standard operating procedures for firefighting (FF) operations

- **Notice of departure**

Within the standard operating procedures for firefighting operations, section f.2. establishes that when a departure notification is received for an intervention, the following information must be collected from the emergency dispatch centre, the brigade or squad technician or the dispatcher themselves:

- Coordinates for the location of the fire.
- Closest base for refuelling and its coordinates.
- Frequencies to be used in the area – both air and terrestrial bands. Contact person in the area.
- Possible special conditions to bear in mind in terms of:
  - Meteorology
  - Location of cables
  - Restricted, prohibited or environmentally sensitive areas

- **Water drop procedure**

Within the standard operating procedures for firefighting operations, section f.6.3. establishes the following water drop procedure:

- The ability to perform an evasive manoeuvre in the event of unforeseen circumstances must be maintained at all times. These precautions should be heightened during the initial drop and whenever a different drop area is assigned.
- Particular attention should be paid to:
  - Any obstacles, cables... not previously observed
  - Terrain with a steeper-than-expected slope
  - Turbulence, shear, ...
- Aircraft must not enter the drop area without first planning a post-drop exit route, which must also take into account a possible failure of the helibucket water release system (always allow sufficient margin in terms of height clearance over obstacles, available power, etc., in case of a failure of the water release system)
- Similarly, aircraft must not enter the drop area without having obtained clearance and provided prior notification.
- In addition:
  - Aircraft must provide adequate advance notice of entry to drop
  - An instrument check to verify that all performance parameters are correct must be performed before lining up on course to the drop zone
  - If available, the drop warning siren must always be used, activating it before commencing the drop pass until the drop has been completed
  - The height and speed of the water drop must be carefully chosen so as not to compromise the effectiveness of the drop while at the same time ensuring the safety of ground personnel. The effects of a potential fire re-ignition must be taken into account. As a general rule, the height of the aircraft (including helibucket) above

the highest obstacle in the drop zone must not be less than 15 metres (45 feet), this being a good drop height, both for the effectiveness of the water dropped and to ensure safe operation with a Bambi bucket in terms of possible collisions with obstacles on the ground.

- The aircraft's speed must be between:
  - 35 to 40 kt over wooded areas
  - 40 to 50 kt over stubble fields
  - Never release water at a speed of less than 30 kt
- Water must not be dropped from a hover
- In the event of any unforeseen situation that could endanger the aircraft or its occupants, the pilot must jettison the water load.

In relation to the drops, pilot's must consider the following:

- Deliberate entry into areas of high smoke density is not permitted due to the associated loss of visibility and the possible effect on engine performance (compressor stall, turbine shutdown).
- Drops on live high and medium-voltage lines are prohibited. Drops can only be made when the pilot is certain they are not live.
- Drops are not permitted in areas close to high and medium-voltage lines if they present a risk of impact at any point along the flight path.
- The wind direction and its effect on the water once released, such that:
  - Headwind drops may be associated with reduced visibility and increased turbulence.
  - Tailwind drops, while, in principle, associated with fewer visibility and turbulence issues, will require a higher pass speed to be maintained (a low tailwind-drop speed is very likely to result in some aircraft performance limits being exceeded).
- The slope of the terrain, such that:
  - When releasing from lower to higher altitudes, pilots must ensure that any failure to release water from the helibucket would not result in a collision with obstacles or the terrain due to a lack of power and/or space to turn. As a general rule, the approach to drops should be made at an angle of 45º to the ground. In this type of drop, the direction of exit must be taken into account in order to avoid flying into the sun, as this may momentarily blind the crew and compromise their judgement in regard to the helibucket's height above obstacles. Should the helibucket fail to open during the water drop manoeuvre over the fire, look for a suitable area to empty it on the ground. Prior to this, the aerial asset in charge of coordination must be notified of the departure of the traffic in order to proceed with the ground release manoeuvre. If there is no coordinating asset, the information must be passed on to the Firefighting Chief or Commander at the time. After selecting an area free from obstacles, proceed to make a straight approach with a gradual reduction in speed until the helibucket comes into contact with the ground. The manoeuvre must be extremely gentle so as not to disable the helibucket upon contact with the ground and to avoid exceeding the aircraft's power limits during the final moments of the manoeuvre. Once hovering with the helibucket on the ground, make lateral

movements towards the most convenient side until gravity releases the water from the helibucket. After the water has been emptied, carry out the necessary maintenance work to replace the device, either on-site or at the aircraft's base.

Emergency operating procedures

The operator states in its OM that the emergency operating procedures correspond to those provided in the HFM, adding that in the event of any emergency that necessitates the termination of work, either due to excess risk exposure time or a flight-related emergency, such as mechanical failure, pilots must carry out a forced landing.

- **System Failures**

According to section 3.2. of the helicopter flight manual on "System Failures", point 4 on "Abnormal NR readings" states that if there is a complete loss of the NR reading, the engine torque must be maintained above 10%, and the aircraft must be landed as soon as possible.

Furthermore, if the NR decreases to the extent that the reading is no longer within the green arc of the indicator, an audible warning will be activated, alerting the pilot to the abnormal NR value.

1.6.2. Maintenance information

An EASA-certified maintenance centre maintained the helicopter according to the approved maintenance programme ref: CVO-PM-AS350B3e-00, ed.1, rev.21 dated 14/07/2022.

According to this maintenance programme, periodic airframe inspections of varying scope and depth must be performed daily, every 10 FH or 7 days, 150 FH or 12 months, 600 FH or 24 months, and 1,200 FH or 48 months (whichever occurs first); and engine inspections are to be performed daily, every 15, 25, 30, 50, 150, 300, 600 FH and every 15 years.

The daily inspections include:
• BFF: Before the first flight of the day
• TA: Turn around
• ALF: After the last flight of the day

On 28/06/2022 the CRS[8] from the 2022 pre-campaign inspection was issued, installing some modifications when the aircraft had 10:28 FH.

The last three preventive maintenance overhauls performed on the helicopter were as follows:
- 15/07/2022: 30 FH inspection when the aircraft had 26:43 FH
- 18/07/2022: BFF, ALF and group tasks G01 to G09.
- 20/07/2022: inspection of onboard load release unit when aircraft had 41:48 FH
- 23/07/2022: BFF, ALF and the G04 group tasks when the aircraft had 41:48 FH

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[8] CRS: Certificate of release to service

- 24/07/2022: 50 FH inspection when the aircraft had 44:18 FH, carrying out group tasks G07 and G04.

And the last engine overhauls:

- 23/07/2022: BFF, TA and the 15 FH inspection when the engine had 42:00 FH.

With regard to corrective maintenance checks, the most recent was carried out on 15/07/2022 on the oil cooling fan and its motor.

The aircraft was compliant with the applicable manufacturer’s service bulletins and airworthiness directives, the most recent of which were implemented for the airframe on 23/07/22 and the engine on 25/05/2022.

At the time of the accident, the helicopter, airframe and engine, had a cumulative record of 41:65 flight hours and 239 cycles.

The incident flight commenced at 18:09 local time on 25/07/2022, and the accident occurred at 21:01 h, which meant the helicopter had flown for 2:52 h. It had previously flown between 15:39 and 17:57 h without incident. On 23/07/2022, the aircraft had completed two flights of 1:50 h and 0:40 h, also without incident.

1.6.3. Airworthiness status

According to AESA’s record of active registrations, the aircraft with serial number 9161 and registration EC-NTE was registered on the 27/06/2022, with a provisional registration certificate valid until 11/08/2022. The aircraft operator and lessor had the necessary authorisations to carry out aerial firefighting operations.

The aircraft had Airworthiness Certificate No. 8605, issued by AESA on 19/01/2022 with indefinite validity, in the “Small Helicopter” category with designation as a “Eurocopter AS-350-B3”. It also had an airworthiness review certificate with ref.: ES.ARC-NTE-001, valid until 19/01/2023 and issued when the aircraft had 5 flight hours.

1.7. Meteorological information

We consulted AEMET for the meteorological data at the time and place of the accident. Given the impossibility of having an observation station in the area of the incident, the observations recorded at the Guadalajara station (40.63028 N; -3.15 W; altitude: 721 m), which is sufficiently representative of the local meteorological environment in the area under investigation, were used as a reference. This station is located within a radius of no more than 27 kilometres from the location of the accident.

The records from both stations showed light winds of between 3.5 and 6.6 kt from variable directions between 266 and 339, with light gusts of at most 13 kt, temperatures around 35ºC, relative humidity of 11% and no record of any relevant meteorological phenomena.

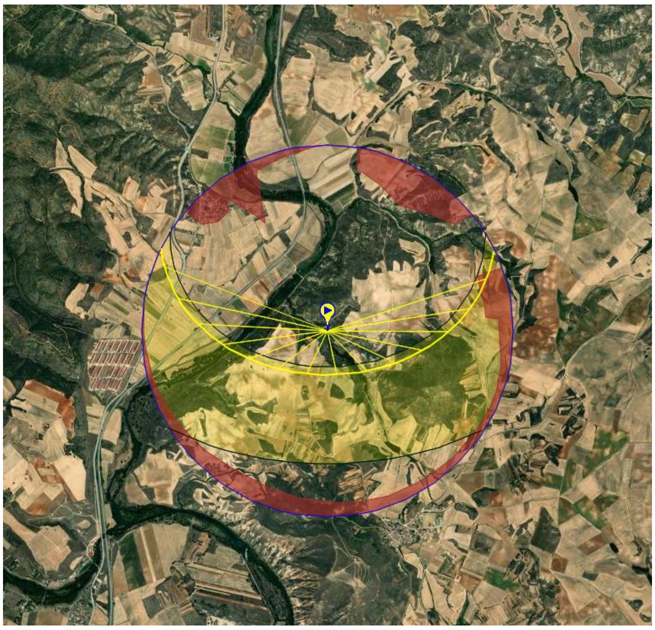


Figure 4. Graph illustrating sunlight at the time of the accident

The pilot checked the meteorological information and confirmed that no NOTAMs affecting the area of the flight had been issued. In his statement, he said that when he departed from the base to the fire, the temperature was 37ºC, noting that it was an extraordinary season in terms of temperatures, as there had been three consecutive heatwaves.

The natural light conditions at the time of the event were close to sunset at 20:45 local time: according to the IGN National Astronomical Observatory in Cerezo de Mohernando (Guadalajara), sunset occurred at 21:35 local time. Figure 4 contains a graph illustrating the sunlight conditions at the time of the accident.

1.8. Aids to navigation

The flight was operating under visual flight rules (VFR).

1.9. Communications

The aircraft was equipped with a Garmin GTN 650Xi VHF COMM 1 system, a Garmin GNC 255A VHF COMM 2 system, a Garmin GTX 335R transponder and a Kannad AP-H INTEGRA ELT. These systems were working correctly and are not relevant to the causes of the incident.

There are no communication recordings available, so the content of the communications has been provided by statements from the parties involved.

After activating the notice of departure to the fire, the pilot reported every 5 minutes and coordinated with the other resources once every minute, following the established communication protocols for initiating firefighting work. When close to the area of operation, the two deployed helicopters contacted the Torrejón tower to report their position and be able to work on the fire. Given that it was a large fire, they had two alternatives to their base in Albendea (Cuenca): the El Serranillo base (Guadalajara) and the Las Minas base in Villares de Jadraque (Guadalajara).

After several interventions on the fire, the pilot reported his work time to the firefighting commander, who changed the initial instructions and told them to spend the night at the El Serranillo base.

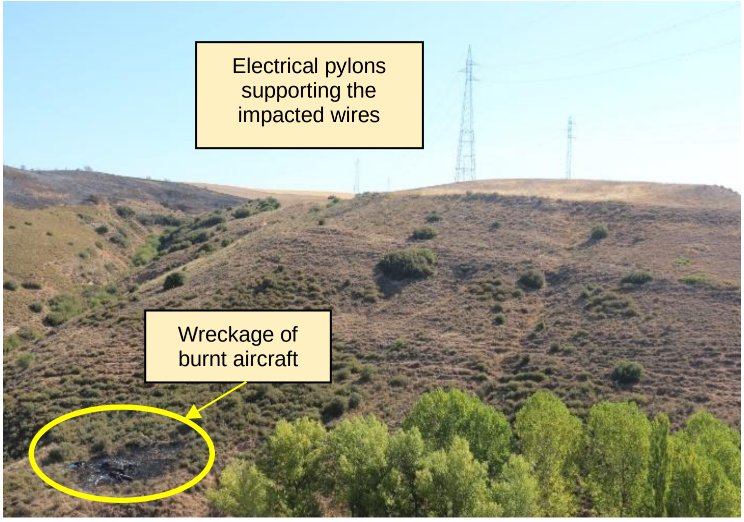
The pilot questioned the firefighting commander on up to 4 occasions about the possibility of resting at his base (in Cuenca), but this request was denied, and they continued working.

They established the appropriate communications to coordinate with the other aerial resources intervening in the operation, between all the aircraft, reporting and acknowledging their respective positions during all the flight phases, landings, and water collection and drop points.

At the time of the impact, one of the colleagues communicated with the pilot, declaring MAYDAY and indicating that he could drop water on him and the aircraft if necessary. Ultimately, this wasn't necessary, as the pilot managed to free himself from the restraints and climb out of the aircraft unaided.

1.10. Information about the accident site

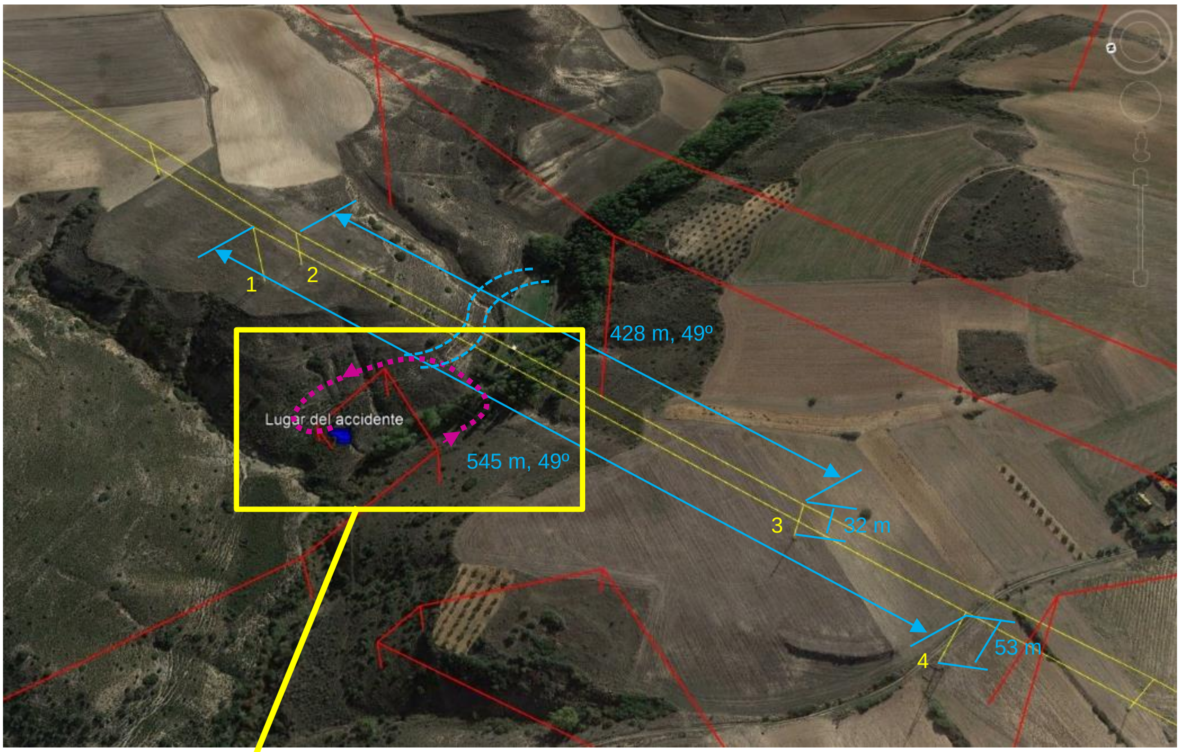
The firefighting operation was mobilised in response to a forest fire in the municipalities of Humanes and Cerezo de Mohernando in the province of Guadalajara (Spain).



Photograph 3. Accident site

The fire started at 15:34 local time in an area of forest and agricultural pasture. It affected a total of 1600 hectares with 13 active outbreaks. The extensive and virulent fire spread through several valleys, contributing to its expansion.

The accident site and extinction zone was an area of scrubland with pronounced slopes and steep descents into a ravine lined with large trees. The area was dotted with a large number of high, medium and low-voltage power lines. More specifically, the aircraft made contact with the ground on one of the sides of the ravine with a gradient of approximately 20%, between two plateaus connected by high-voltage pylons.



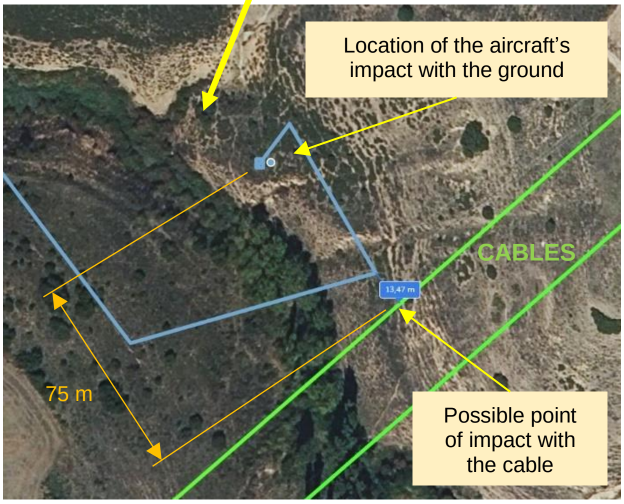


Figure 5. Trajectory of the accident aircraft and geometry of the impact.

Figure 5 shows the approximate path of the helicopter on the final leg of the flight before the accident, according to the records of the fleet tracking system. Also shown is the approximate geometry of distances and spacings of the high-voltage cables between the pylons, labelled 1, 2, 3 and 4 in the figure. The figure shows the heights of the pylons as approximately 32 and 53 m, and the lengths of cable between the pylons, which are approximately 545 and 428 m, with an orientation of 49º. Based on this information, we calculated the distance between the high-voltage cables in the area where the main rotor blade may have hit and where the aircraft's wreckage was found to be around 75 m, as shown in the detail extracted from the figure. We were also able to calculate that the point of least distance between the aircraft and the cable between pylons 1 and 4 m (pylons 75 and 76 of the Iberdrola network) occurred during its left turn at 86 m of height (vertical coordinate) and was approximately 13.47 m (horizontal coordinate), according to the fleet tracking records.

The GPS coordinates for the point where the aircraft hit the ground and subsequently caught fire are 40°51'51.96 N ; 3° 6'48.1"W.

Figure 6 contains photos of the severed cable after impact with the helicopter and its position at the accident site, marked in yellow for better visualisation, with views from both sides of the ravine.

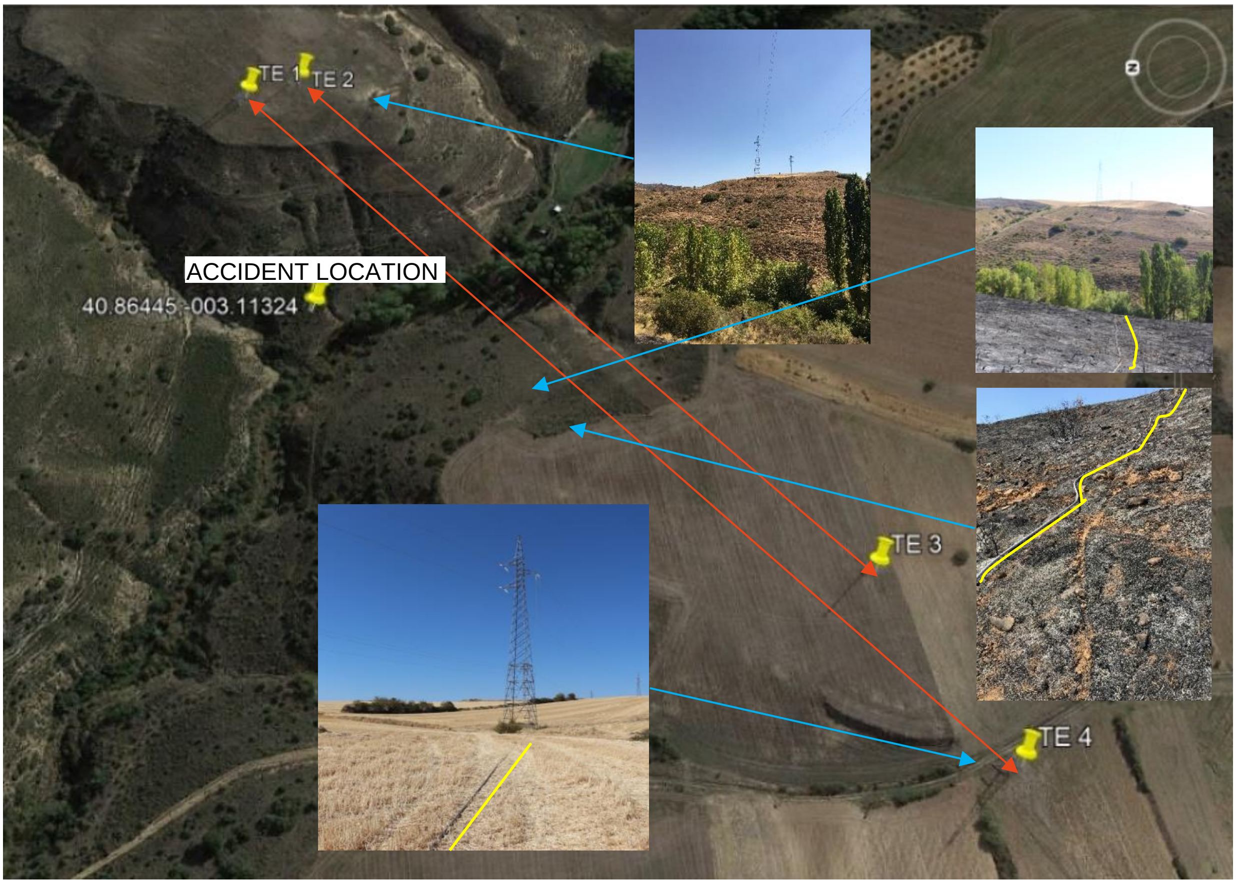


Figure 6. Severed cables at the accident site

1.11. Flight recorders

The aircraft was not equipped with a flight data recorder or a cockpit voice recorder, as the aeronautical regulations do not require them on these types of aircraft. Given the extent of the aircraft's destruction following the post-impact fire, it was impossible to obtain any information from the onboard instruments, and as a result, the only information available to the investigation was provided by the fleet tracking system.

1.11.1. Fleet tracking system

The helicopter was equipped with a fleet tracking system from which the flight data for the incident mission were retrieved.

The following parameters of interest to the investigation were recorded and extracted: Time - Latitude - Longitude - Altitude - Trace - Speed - Type of event.

The data was recorded at 15" intervals between 10:01:26 h (time of startup) and 10:40:03 h (time of shutdown) as per the trajectory shown in figure 7.

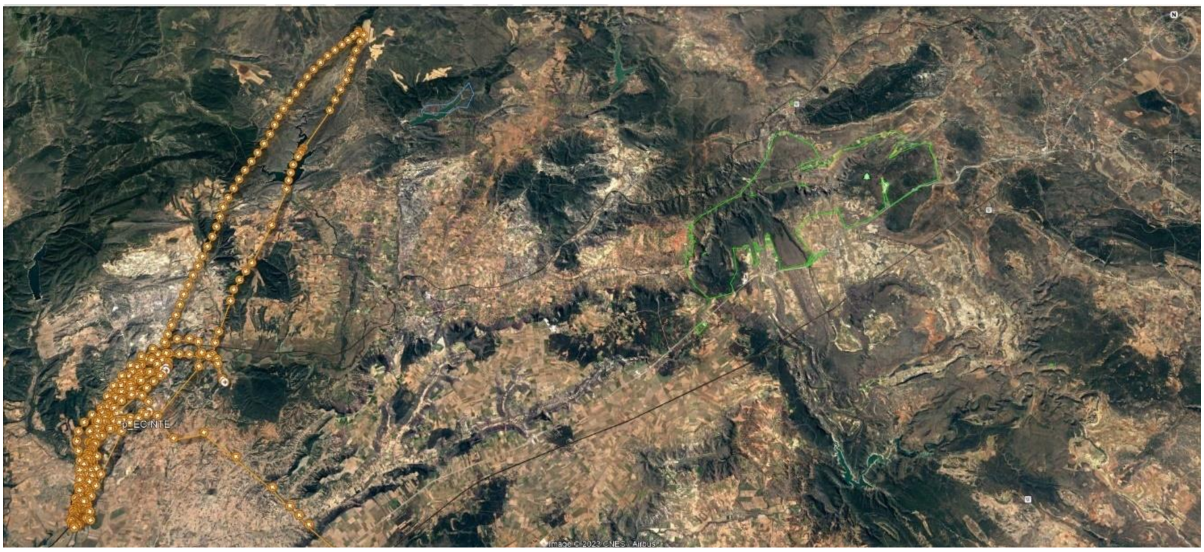


Figure 7. Trajectory of the incident flight

Figures 8 and 9 show the parameters at each recording point during the flight's final leg, in which the helicopter struck the high-voltage cable.

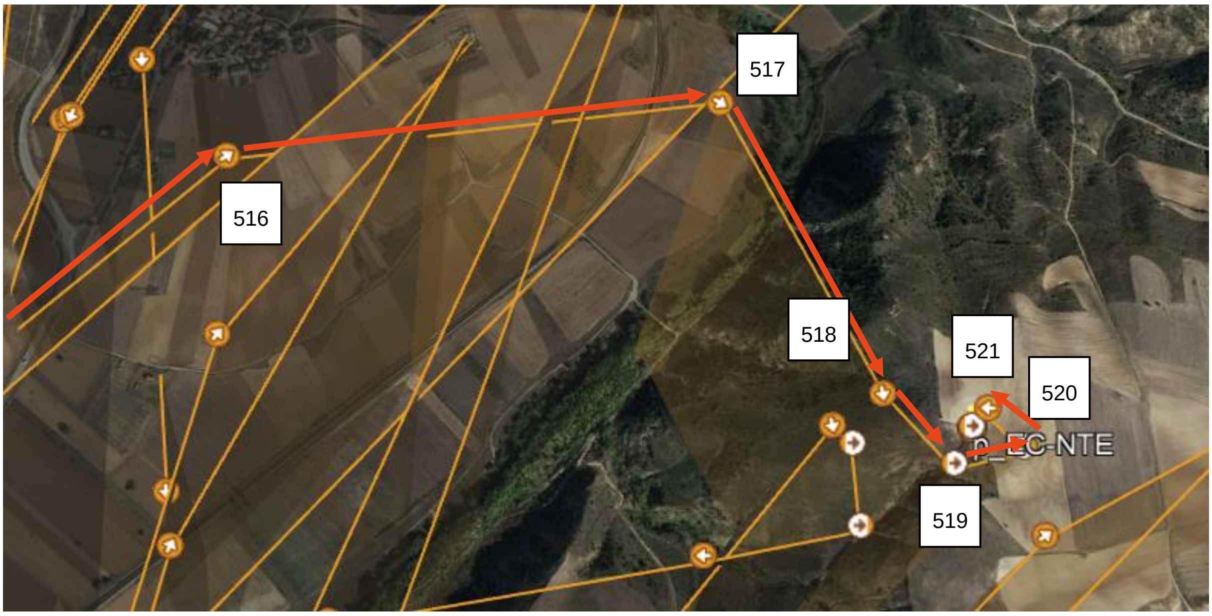


Figure 8. Flight path during the final leg of the incident flight section I

Sequence 516: 20:55:15 LT position: 40.8674º,-003.11386º; altitude: 823 m; track: 054º; speed: 166 km/h.
Sequence 517: 20:55:30 LT position: 40.8682º,-003.11654º; altitude: 814 m; track: 122º; speed: 133 km/h.
Sequence 518: 20:55:45 LT position: 40.8647º,-003.11463º; altitude: 797 m; track: 169º; speed: 83 km/h.
Sequence 519: 20:55:50 LT position: 40.8638º,-003.11380º; altitude: 793 m; track: 122º; speed: 94 km/h.
Sequence 520: 20:55:55 LT position: 40.8640º,-003.11278º; altitude: 787 m; track: 007º; speed: 68 km/h.
Sequence 521: 20:56:00 LT position: 40.8645º,-003.11313º; altitude: 770 m; track: 273º; speed: 35 km/h.

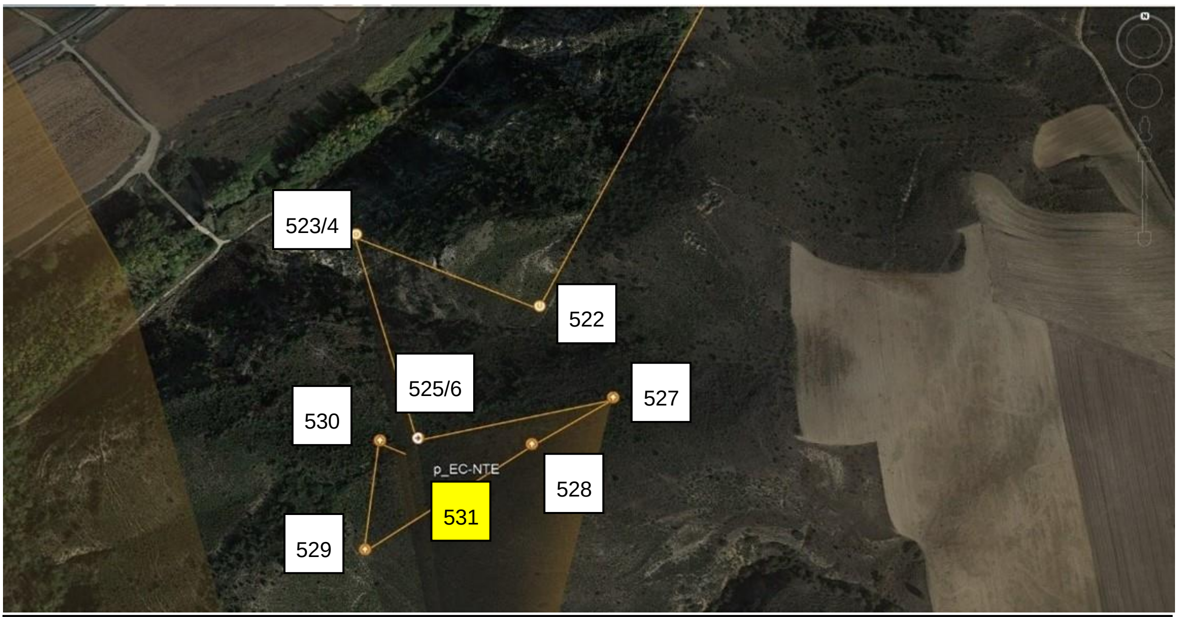


Figure 9. Flight path during the final leg of the incident flight section II

Sequence 522: 20:56:08 LT position: 40.8644º,-003.11326º; altitude: 743 m; track: 264º; speed: 16 km/h.
Sequence 523/4: 20:56:09 LT position: 40.8644º,-003.11329º; altitude: 745 m; track: 265º; speed: 7 km/h.
Sequence 525/6: 20:56:15 LT position: 40.8644º,-003.11328º; altitude: 743 m; track: 0º; speed: 0 km/h.
Sequence 527: 20:56:30 LT position: 40.8644º,-003.11324º; altitude: 737 m; track: 0º; speed: 0 km/h.
Sequence 528: 20:56:45 LT position: 40.8644º,-003.11326º; altitude: 740 m; track: 0º; speed: 0 km/h.
Sequence 529: 20:57:00 LT position: 40.8644º,-003.11329º; altitude: 741 m; track: 0º; speed: 0 km/h.
Sequence 530: 20:57:15 LT position: 40.8644º,-003.11329º; altitude: 740 m; track: 0º; speed: 0 km/h.
Sequence 531: 20:57:18 LT position: 40.8644º,-003.11328º; altitude: 739 m; track: 0º; speed: 0 km/h.

Photograph 4. Video images of the last water drop, the helicopter drifting (1) and descending to the ground (2).

In addition, the investigation was provided with a video recording filmed by firefighting personnel showing the last water drop, the helicopter's impact with the high-voltage cable and the subsequent impact with the ground. Photograph set 4, although at very low resolution, shows that after dropping the water, the helicopter turned towards the hillside in front of the fire (1), showing the low visibility in the area around the power line due to the smoke, and then turned and made an emergency landing on the hillside (2).

1.12. Information about the damage to the aircraft

After the last water drop, the aircraft hit a high-voltage cable, and according to the pilot's statement, failed to recover NR and descended towards the hillside opposite the power line. There, one of the skids hit the ground and bounced off before impacting for a second time on a steep slope, which caused the helicopter to overturn and burst into flames.

The aircraft trapped the pilot, who closed the fuel valve, disconnected the battery, and managed to free himself from the restraints and get out of the aircraft unaided. The fire then spread to the entire aircraft, completely destroying the helicopter.

Markings on the ground (photograph 5) show that the aircraft's wreckage was concentrated in the area where it caught fire.

Photograph 5. Overhead view of the accident site

No traces of impacts were visible in the surrounding areas. Small traces of material from the blades, skid, etc., were identified within 2 to 3 m of the helicopter.

Photograph 6. Relief view of the accident site

Identifiable among the wreckage were the empennage (vertical and horizontal stabilisers) and the end of the tail boom, which had not been burnt (marked with the number 1 in photograph 5); one of the skids (2), the three main rotor blades retracted to the same side and burnt (3) and the melted engine with the helibucket carrier on top which still retained its identifiable structure (4).

One of the two tail rotor blades had detached and was located about 3 m from the skid, separated from the aircraft, with no signs of charring.

Photograph 7. Empennage and tail boom section

Photograph 8. Detached skid

Photograph 9. Melted engine, helibucket carrier and main rotor blades

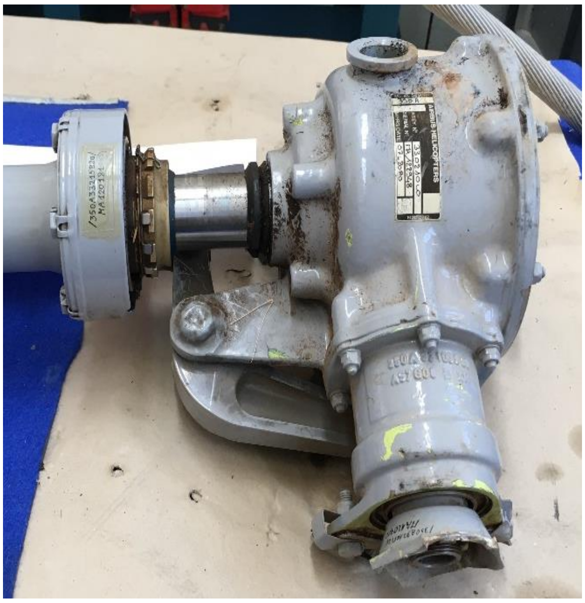
Photograph 10. Detached tail rotor blade

Photograph 11. Tail rotor at the accident site

Photograph 12. Tail rotor

Photograph 13 left. Breakage of tail rotor attachment to tail boom.

Photograph 14 right. Breakage of tail rotor



1.13. Medical and pathological information

There is no evidence that physiological factors or incapacities affected the pilot's actions.

The pilot was taken to Guadalajara University Hospital, where he was admitted with chest pain and intercostal bruising with a mild diagnosis.

1.14. Fire

The helicopter was destroyed by a post-impact fire, which allowed the pilot enough time to free himself from his restraints and exit the aircraft unaided.

1.15. Survival aspects

The pilot was pinned under the helicopter after it overturned when one of the skids hit the ground. It then caught fire.
The helicopter's cabin retained its structure, keeping the pilot safe, and the seat restraint systems worked effectively.

The pilot, still trapped in the cockpit and aware that the helicopter had started to burn and that the target fire was on the hillside in front of him, cut the fuel valve, disconnected the battery, and was able to free himself from his restraints and climb out of the aircraft by himself. The helicopter was then completely destroyed by the post-impact fire.

1.16. Tests and research

N/A.

1.17. Organisational and management information

The operator had a valid Special Operator Certificate (SOC[9]), issued on 27/08/2021 by EASA, authorising aerial operations for commercial firefighting and search and rescue purposes. In addition, it had EASA Part-145 approval as a maintenance organisation for the accident aircraft, both for base and line maintenance.

The activity undertaken during the accident flight was firefighting, which is regulated by Royal Decree 750/2014 of 5 September, which also approves the rules applicable to said aerial activities, incorporated as Annexes I to IV.

Part A of the current operations manual for FF and SAR (OM-A), ed.3 rev.8, details the requirements of the royal decree, particularly those relating to the experience of the pilot-in-command, as set out in TAE.ORO.FC.LCI.212 for FF operations[10]:

	PIC	ACT	ASC	PICmin
Helicopter				
Observation and patrolling	200	-	-	-
Coordination	300	30	-	200
Deployment of water and transfer of additional specialist personnel	500	50	100	400

Table 1: Firefighting experience requirements

With regard to recent experience, the operator's OM-A states that pilots may not operate an aircraft:

- as pilot-in-command, unless they have carried out, within the preceding 90 days, at least 3 take-offs, approaches and landings in an aircraft of the same type or class or in a simulator representing that type or class. The 3 take-offs and landings must be performed in multi-pilot or single-pilot operations, depending on the pilot's ratings, and

[9] SOC: Special Operator Certificate
[10] ACT: hours of flight experience in relevant activities
ASC: hours of flight experience in similar aircraft
PICmin: minimum previous experience in flight hours as pilot-in-command

- as pilot-in-command in FF operations requiring water deployment, unless they have conducted at least 3 water loading and unloading operations with an aircraft of the same type or class or simulator representing that type or class within the preceding 90 days.

For firefighting operations, the operator's OM states that a pilot may only be designated as highly experienced if they hold the type rating for the aircraft they use to carry out their duties and that they must have a minimum of 600 hours as PIC, of which 100 hours must have been accrued in firefighting activity, and 50 hours in the relevant aircraft type. In addition, they must be able to demonstrate one of the following forms of experience:

- more than 5 forest fire campaigns;
- more than 3 forest fire campaigns, including the two most recent ones;
- experience as an agro-forestry instructor.

With regard to flight time limitations and the rest breaks that ensure safe operation, the OM establishes that helicopter flights in firefighting operations shall not last longer than 2 h, with intermediate stops of at least 40' for every 2 h of flight, and for flights of less than 2 h, a 20' intermediate stop for every hour of flight or 10', whichever is greater.

Any period of physical presence must be preceded by a rest period of at least 10.5 h.

The pilot-in-command during the incident flight complied with the experience requirements established for firefighting operations, as well as the required rest periods and flight limitations. Furthermore, the operation was conducted in compliance with the limitations included in paragraph 1.2 of the OM Part B for the AS350-B3 helicopter type and in accordance with standard operating procedures.

In regard to the specific training provided to the PIC on the aircraft and operation type involved in the incident, as per Part D of the OM, the organisation had additional approvals allowing it to conduct recurrent type training and proficiency checks for firefighting operations. Specifically, the pilot involved in the event had received both two months before the incident, so the OM requirements had been met.

The organisation also had standard, non-standard and emergency procedures for firefighting operations in place, in line with OM-B 12.3 and SOP-LCI-H Ed.: 03; Rev.: 02 dated 20/08/2021, which covers the following aspects relevant to the investigation:

- The criteria for selecting set-down points for operations in unprepared and/or mountainous landing sites.
- The complexity of these types of operations requires that special consideration be given to the unique conditions that the flights may entail, such as:
  - low altitude
  - low speed
  - flying close to the operational limits of the helicopter
  - hostile areas with medium-high air traffic density, as several aerial resources of different categories may converge in small spaces
  - the need to land nearby to unload crews

- o the need for a water collection point in the vicinity
- o low visibility in some areas due to smoke
- o turbulence caused by the fire itself

Furthermore, if the pilot-in-command of an aircraft is aware that they are not the first aircraft to arrive at the fire, they must act bearing in mind that a Fire Flight Area of a radius proportional to the magnitude of the fire will have been established around the fire, which will change depending on how it evolves. This will include the establishment of initial contact rings with the incoming aerial resources, the approach to the area, the fire operations zone, the manoeuvring zone for unloading, notifications between the various resources, surveillance and identification of the fire area to find the most suitable landing zone for the firefighters to disembark, standby circuits, risks and dangers due to the presence of cables or low or high voltage pylons, etc.

During the operation, the role of the Firefighting Chief or Commander[11] is restricted exclusively to requesting the drops and authorising them, i.e. designating the water deployment area. The aerial resources (the pilots) must then assess the suitability or otherwise of the requested area and are responsible for deciding whether it is safe to operate there or not.

If an air resources coordinator is involved in the operation, they are responsible for informing the pilots whether or not the area is free to enter, but the pilots still bear sole responsibility for assessing the suitability of executing the drops. In this event, the firefighting commander identified the drop zone to the pilot.

1.17.1. Minimum crew

Part A, paragraph H.4.1.4. of the OM for FF and SAR operations establishes the minimum crew and flight period for this type of operation and for the AS350-B3 helicopter type.

In addition, based on the conditions applicable to the operation (VFR or IFR), the Flight Operations Manager may establish the minimum crew onboard requirements as indicated in Table 2.

Type of aircraft	FF OBSERVATION AND PATROL - COORDINATION	FF WATER DEPLOYMENT (LA) & TRANSFER (TPE)	SAR GROUND	SAR SEA	VFR	VFR NOCTURNAL	IFR
AS350-B3	1	1	1	N/A	1	2	N/A

Table 2: Minimum crew according to the operation type and conditions

[11] The firefighting chief is not employed by the operator but by the public body responsible for the Forest Fire Extinguishing Plan. In the event in question the public body was INFOCAM (Forest Fires in the autonomous community of Castilla-La Mancha)

As indicated in the OM in regard to control and supervision of the operation, the operator may provide for additional onboard crew if required by the type of operation and provided that their number is not less than that specified in that manual or supplements thereto. Similarly, depending on the duration of the service, it may also be necessary to increase the number of flight crew, at the operator's discretion.

For example, the AS350-B3 helicopter must have a minimum crew of 2 pilots for nighttime VFR operations.

1.18. Additional information

1.18.1. Safety in firefighting operations

Firefighting operations are highly complex activities conducted in challenging and changing environments that can make operability difficult. Helicopters operate in a wide range of flight conditions, including marginal visual flight in low visibility, as was the case in the accident, due to the smoke produced by the fire, which can also affect the aircraft's performance.

Some of the most important safety aspects to consider in helicopter firefighting operations include the following:

1. Situational perception and awareness
2. The presence of obstacles: identify and avoid them
3. Managing the flight route
4. Applying rules and procedures
5. Adverse weather conditions
6. The experience, training and competence of the people involved
7. Dealing with technical failures
8. Operating in poor visual conditions
9. Decision-making and planning

In relation to the above aspects, it should be noted that at the time of the accident, there were a series of conditions that objectively and significantly reduced the pilot's reaction time, including the turbulence generated by the flame front, the reduced visibility due to smoke dispersion and the proximity to the power lines and the terrain (aspects 1, 2 and 8).

Furthermore, the presence of a high concentration of power lines in the area implied a significant increase in the pilot's workload, as in order to carry out the water drops, he had to make turns very close to one of the power lines, specifically the one running perpendicular to the valley over which the fire was progressing uphill, with the added pressure of the risk of the fire spreading towards the nearby population (aspects 1, 2, 3 and 9).

The pilot chose a flight path that did not allow him to maintain adequate separation from the power line. In addition, the object's immobility and the lack of contrast with the background prevented him from correctly perceiving his depth with respect to the overhead power line. Moreover, when turning to the left to avoid it, the pilot's peripheral vision towards the side with the power line catenary was partially restricted by the design of the helicopter itself, together with the reduced visibility caused by the smoke from the fire (aspects 1, 2, 3, 8 and 9).

The pilot's ability to correctly understand and assess the helicopter's position was reduced, which limited his ability to make effective real-time decisions (aspects 1 and 9).

1.18.2. Effective detection of objects in the air

The effective detection of objects in the air from aircraft depends basically on six conditions, which are discussed below in relation to the specific event in question:

1. The size of the image or part of the field of view occupied by the object. In this event, although the power line was very long, its relatively smaller diameter compared to the surrounding area occupied a small field of view, which was further reduced during the turn.
2. The object's luminance or degree of shine: non-existent in the case of the power line as it was not a new cable. However, during the exit from the last drop, the pilot reported that he saw the reflection of a cable on the right side and tightened the turn to the left, lowering the pitch. At that moment, he heard the whip of the cable as it struck the main rotor.
3. The contrast between the object and the background due to the difference in the brightness, colour and shape of the object and of the background: the contrast was significantly reduced by the lack of shine, by the shape of the cable and because its colour blended in with the background and the sky.
4. The adaptation of the human eye or the time needed to adjust to the surrounding lighting: the lighting at the time was that of the hours around sunset. During the left turn to exit from the water drop, the sun was behind the pilot and did not impede his view of the cable. He had planned the departure parallel to the power line with the high-voltage pylon in sight.
5. The relative movement or speed of the object, the aircraft, or both: in the event in question, it was the movement of the aircraft only.
6. The exposure time or duration of time that the object is exposed to view: the exposure time was reduced by the dispersed smoke in the area and by the design of the helicopter itself during the left turn, which decreased the visibility of the power line catenary.

1.18.3. Power lines

In firefighting operations, power lines are a risk that is frequently responsible for accidents involving both ground personnel and airborne resources. One of the first measures undertaken when analysing a fire scene is identifying and locating them and then informing all resources of their position. This information must also be transmitted to the operations centre so that it can arrange for the power supply to be cut for the duration of the extinguishing tasks.

They represent a hazard for aerial resources due to the risk of collision, especially for helicopters.

Photograph 15. Impacted section of the cable

In this incident, the electricity company supplying the affected line did not provide its specifications to the investigation, so the only information available was that gathered during the field investigation at the site of the accident with the company’s technicians.

The power line was a high-voltage line with no flagging or markings of any kind, either on the support pylons or along the cable. The type of pylon involved tells us that the line voltage was 132 kV. The pylons were approximately 53 m tall, and the cable was a 30 mm diameter concentric layer braided cable made up of 54 aluminium conductor wires with a core of 7 reinforced steel wires.

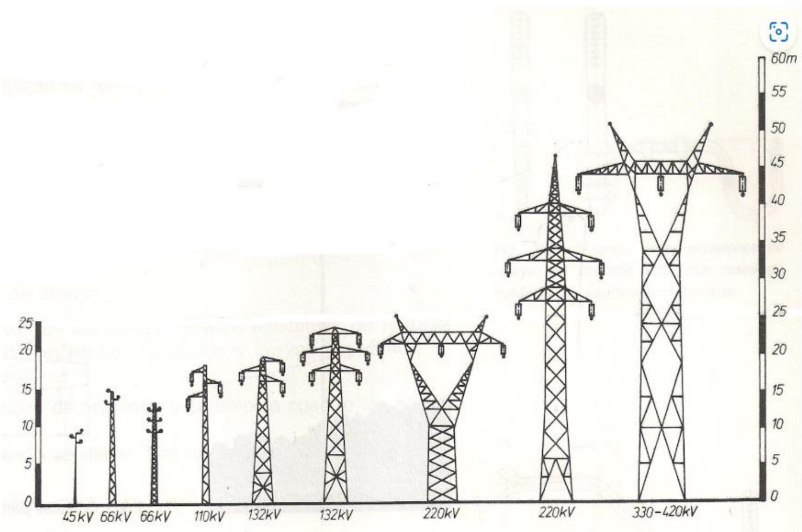


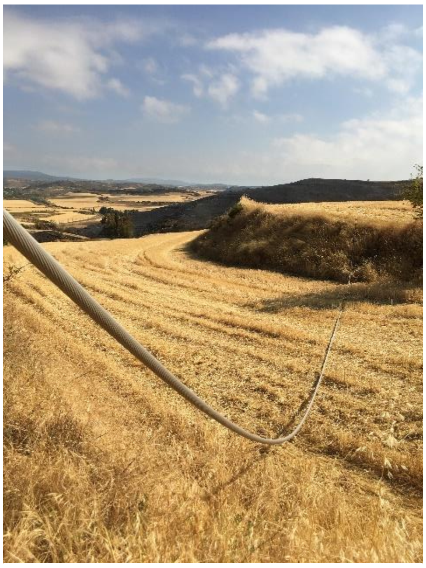
Figure 10. Types of electricity pylons

Photograph 16. Pylon and severed cable from the incident

Photograph 17. Colour transferred to the cable by the impact

Photograph 18. End of the severed cable from the southern slope

The severed cables did not exhibit any melted areas (photograph 15), which would typically be found if a short circuit takes place during contact with the wiring. We, therefore, believe that the line was not live at the time of the impact with the aircraft. The cable displayed colour transfer from the helicopter, confirming its contact with the fuselage (photograph 17) in an approximate 1 m section close to one of the severed ends (photograph 18).


Photograph 19. Severed cable from the northern slope


Photograph 20. Severed cable from the southern slope

Photograph 19 shows the end of the cable hanging from the pylon located on the north slope. It was on this slope that the helicopter hit the ground and caught fire.

Photograph 20 shows the other loose end of the severed cable from the pylon located on the southern slope, which was where the fire was spreading and was completely burnt.

After the final water drop, on exiting the manoeuvre and making a left turn with the power line catenary on the right and the sun behind the pilot, he claims to have seen the reflection of a cable on his right side just before the impact with the main rotor. The concentration of power lines in the area and the position of the cables can be seen in Photograph 21.



Photograph 21. Pylon and overhead cables at the incident site, with the cable severed by the impact

1.18.4. Human factors: cable strikes

Most cable strikes occur during the day, with good visibility and experienced pilots. In 40% of these accidents the pilots were aware of the presence of obstacles.

Cables are difficult to see, partly because of the way the human eye works and partly because of the way they blend into the background. The movement of cables in sunlight and the changing patterns of solar light can obscure the cables. Older cables are also more difficult to see than new ones because they tend to change colour and shine less brightly due to oxidation or passivation, depending on their construction material.

The pilot’s exterior view can be affected by the condition of the helicopter’s fairing, which can contribute to reduced visibility, and prolonged exposure to the vibrating environment of the cockpit, which can impair the pilot’s performance by affecting their perception of obstacles such as wires.

Pilots should be trained to recognise different types of cables and determine their direction from the location of the insulating connectors and pylons in order to anticipate their position.

To reduce the risk of cable strikes, pilots must be specifically trained to develop an understanding of cable identification and avoidance. In addition, cable proximity warning devices can be useful in approximately 75% of helicopters, as well as mechanical cable cutters that can be installed on the helicopter structure or specific markings and beacons that can be fixed onto cables.

In firefighting, it is also recommended that pilots check aeronautical charts and conduct a reconnaissance flight at higher altitudes before conducting low-altitude firefighting operations.

1.19. Special investigation techniques

N/A.

2. ANALYSIS

2.1. Analysis of the meteorological conditions

The weather conditions in the area and around the time of the event were suitable for the flight; the wind was not significant, the gusts were light and no relevant meteorological phenomena were observed.

However, it is important to note that the smoke generated by the fire limited visibility and that the aircraft was subjected to high temperatures due to the heatwave the area was experiencing at the time, in addition to the increase in temperature brought about by the fire itself.

The operation was also affected by the turbulence produced by the terrain and by the high temperatures from the fire.

Consequently, although no adverse meteorological phenomena were recorded, the specific conditions created by the fire involved in the event were as follows:

1.- low visibility due to smoke,

2.- turbulence on the slopes of the ravine, and,

3.- high temperatures,

Which may have contributed to:

1.- the failure to correctly identify the distance between the aircraft and the cables when conducting the water drop and turn,

2. the fact that after the main rotor struck the cable, the helicopter's performance diminished even more, making it difficult to control the aircraft,

3.- the fact that a post-impact fire broke out, destroying the helicopter in its entirety.

2.2. Analysis of the aircraft wreckage

According to the records provided by the operator and maintainer of the aircraft, it was a new helicopter with only a few hours of flight time, and it was up to date with its scheduled maintenance and the implementation of service bulletins and manufacturer's directives. According to the pilot, he had not noticed any previous anomalies in the helicopter's performance during the incident flight, and as a result, we have concluded that the aircraft was not affected by any mechanical failures that could have contributed to the accident.

The aircraft was completely destroyed by the post-impact fire that broke out as a result of the hard landing on the hillside. According to the pilot's testimony, the fire started as soon as the aircraft hit the ground. The high air temperatures were conducive to the fire, although the fact that the aircraft was fitted with an anti-impact fuel tank slowed the spread of the fire, minimising personal injury by affording the pilot more time than he would have had with a conventional fuel tank to release himself from his restraints and extricate himself from the aircraft before the fire spread to the cockpit.

The identification of the wreckage and the marks on the ground were consistent with the pilot's statement and the available records.

The inspection of the aircraft wreckage at the accident site found that it was concentrated in a small area, suggesting that the impact with the ground occurred at low speed, with insufficient energy to disperse the wreckage further and, therefore, with a low translational and vertical speed. In line with the pilot's statement, one of the skids was found a few metres from the aircraft. This must have been the skid that impacted the terrain and was ejected, which, due to the slope, then caused the helicopter to overturn, trapping the pilot.

The main rotor blades were completely burnt and ended up on top of each other due to the rollover of the aircraft, which meant we were unable to identify the point of impact with the power line. Presumably, one of the blades struck one of the power lines, which caused the aircraft to lose NR and lift. The electrical cable was severed transversely through all its conductors. Given the clean and irregular cut identified on the cable section, probably by the upper cable cutter installed on the fuselage. Therefore, the WSPS cutting and protection system was effective, both because of the size of the cables involved in the accident, the angle of incidence of the cable cutter in relation to the cable, and because the helicopter was travelling above the minimum speed necessary for it to work (40 kt).

The severed power cable remained attached to the pylons and exhibited colour transfer from the helicopter in the form of blue and yellow scratches. There was no evidence of arcing, such as burnt ends, melted ends or material loss, which confirms that the power line was not live and had been switched off by the utility company following the declaration of a forest fire in the area.

As for the other remnants of the aircraft, the engine and the structure had been melted by the high temperatures reached during combustion; some elements, such as the helibucket basket and the skid under the helicopter, although charred, were identifiable; the tail empennage had been severed, probably when the helicopter hit the ground and overturned, and was separated from the main wreckage, which initially prevented it from burning, unlike the tail boom; given the rupture of its supporting structure, the tail rotor possibly detached after the impact with the ground and also escaped the fire. One of its blades remained in good condition in its mounting, and the other was practically detached from the root of the hub but remained intact, so, presumably, it didn't come into contact with the severed electrical cable that caused the accident.

2.3. Operational analysis

On the day of the incident, the firefighting operation was particularly complex due to the extreme virulence of the fire, the number of aerial resources in the area, the high temperatures, the fact that the area was covered with power lines, the complicated orography of ravines and the presence of birds.

The pilot involved in the incident was at the end of the day's operations after a complicated mission. This may have led to reduced situational awareness when he performed his final water drop in an area close to a high-voltage power line.

The pilot was highly skilled and experienced in FF operations. For this reason, we do not believe that the pilot's impaired perception of the location of the power line was due to a lack of skill or experience. The environment was highly affected by the high temperatures and low visibility, in addition to the sunlight conditions being near sunset, which eliminated glare and reduced the line's visibility due to the lack of contrast.

The video footage of the incident, albeit with very low resolution, shows that the helicopter began to descend towards the northern slope of the ravine after the water drop and during the left-turning exit manoeuvre. During the descent, the aircraft was stable, not out of control at any time and remained intact until it hit the ground. We have, therefore, concluded that neither the tail rotor nor the helibucket were involved in the cable strike. Based on the available records, the geometry of the trajectory is consistent with this assumption.

Communications with the other aerial resources and the firefighting commander were appropriate. The departure notification for the intervention complied with the requirements in terms of information and coordination between the resources. A first pass was conducted to identify the target and possible obstacles, including power lines, verifying that neither the high-voltage lines nor the pylons were marked and, as a result, blended into the terrain and the sky when flying over them.

With regard to the water drop procedure, the pilot complied with the requirements in terms of recognising obstacles (the cables), the orography and the presence of possible turbulence in the area. He also made the appropriate communications and requested the necessary clearances before entering the drop zones, complying with the established parameters for carrying them out: a minimum height of 15 m and speeds between 40 and 50 kt. He ensured the power lines weren't live and ran above (around 86 m) the flight level, which meant his action was permissible.

The pilot had already carried out several water drops in the area and was aware of the presence of power lines in the extinction zone. In all the drops before the incident, he avoided them adequately, as did the other aerial resources working in the area, suggesting that the zone had been assessed as suitable for carrying out the drops.

It's likely that the proximity to the source of the fire, as well as the fatigue accumulated during a difficult and strenuous day, caused the pilot, who was at the end of the intervention and eager to finish the extinguishing mission, to focus his attention on the location of the water drop, lose visual references and misjudge the distance between his aircraft the power line, which had clearly decreased compared to previous drops. In doing so, he inadvertently failed to comply with the water drop operating procedure, which states that "drops are not permitted in areas close to high and medium-voltage lines if they present a risk of impact at any point along the flight path".

This misjudgement was probably compounded by the fact that it was a single pilot taking on the workload, mental pressure and demands of the operation in a smoke-impaired, low-visibility environment; by the near-sunset lighting —although the pilot stated that he was not dazzled by the sun because it was behind him, he was nevertheless surprised by a close reflection of the power line on his right side just as he made the final turn— all of which corroborates the assumption that his perception of the line during this last drop was compromised.

In an effort to control the aircraft, the pilot lowered the collective, provoking a rapid descent due to the loss of lift and activating the acoustic alarm for low NR without any possibility of recovery. Stabilising the aircraft, the pilot carried out an emergency landing, setting the aircraft down at low speed on the slope. Unfortunately, the incline of the terrain (approximately 20%) caused the aircraft to touch down on one skid. This unbalanced the helicopter and caused it to overturn, trapping the pilot and producing a post-impact fire that destroyed the aircraft. A combination of the impact, the fuel onboard the aircraft and the high temperatures in the area created favourable conditions for the outbreak of the post-impact fire.

The pilot remained conscious despite the impact and being trapped under the helicopter when it ignited. Fortunately, the fire took sufficiently long enough to spread, probably due to the anti-impact fuel tank, to allow the pilot time to shut off the fuel valve and battery, free himself from the restraints in the pilot's seat and escape from the aircraft without assistance.

The pilot-in-command complied with the experience requirements established for firefighting operations. The operation was conducted respecting the established rest periods and the required flight and helicopter type limitations, following the operating procedures specified in the aircraft's flight manual.

In terms of the pilot's training specifically, the requirements of the organisation's OM had been met as he had received the required recurrent type training and proficiency checks for firefighting operations in recent months.

In addition, the aircraft was compliant with operational weight limits and there was no evidence of malfunctions in any of its systems. As a result, it has been concluded that the aircraft functioned as expected and mechanical failures did not contribute to the accident.

As a consequence of the preceding, it is thought that the accident occurred due to the pilot's loss of situational awareness at the end of a highly demanding mission in an extremely challenging environment with the presence of multiple power lines, which added to the pilot's regular firefighting workload.

Due to the nature of the operation, low-level flying close to the fire is unavoidable if efficient extinguishing is to be achieved, and therefore, in an area with power lines, the risk of wire strikes is inevitably increased, even if the aircraft is equipped with detection equipment and the power lines have been flagged.

3. CONCLUSION

3.1. Findings

- The meteorological conditions at the time of the accident were suitable for the flight, and no relevant meteorological phenomena were observed.
- The accident flight took place during a special firefighting operation in an orographically complex area with the presence of several airborne resources, in a highly degraded environment with reduced visibility, high temperatures and an extremely virulent fire that was spreading towards populated areas.
- The main rotor blades struck a high-voltage power line during a manoeuvre to drop water on the fire.
- The power line was severed across all its conductors with no signs of voltage on the network at the time of the cut.
- The helicopter had an operational fleet tracking system which recorded the flight involved in the event.
- The aircraft was up to date with the scheduled inspections required by the maintenance programme and updates issued by applicable service bulletins and directives.
- The aircraft was within its operating weight limits, and there was no evidence of malfunction in any of its systems.
- The operator had the appropriate authorisations to conduct the operation in which the incident occurred.
- The pilot had the experience and training required for the special firefighting operation, and the rest times and limitations set out in the operations manual had been respected.

- The pilot became trapped when the helicopter overturned on impact with the uneven terrain but managed to free himself and get out of the helicopter without assistance.
- The aircraft was completely destroyed by the post-impact fire.

3.2. Causes / Contributing factors

The investigation has established that the cause of the accident was the performance of a low-altitude flight during a firefighting operation in an environment with reduced operational safety conditions, which led to the main rotor blades striking a high-voltage power line.

The collision with the power line was caused by the pilot’s inadvertent failure to comply with the safety rules set out in the water drop procedure.

The impact with the main rotor resulted in an unrecoverable loss of power to the helicopter, forcing the pilot to make an emergency landing on a steep slope. On impact with the ground, the aircraft overturned, trapping the pilot and causing a post-impact fire that completely destroyed the aircraft.

The difficulty in seeing the power line due to the smoke produced by the fire and the fact that it was camouflaged by the surroundings, which could have made it difficult for the pilot to judge his position in relation to the cables correctly, is thought to have been a contributing factor.

4. RECOMMENDATIONS

No operational safety recommendations are proposed.