Technical report

A-027/2019

Accident on 12 June 2019, involving AgustaWestland AW139 aircraft operated by Babcock Spain, registration EC-NEH, at the municipality of Albarracín (Teruel, 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.

MINISTRY OF TRANSPORT, MOBILITY AND URBAN AGENDA

UNDERSECRETARIAT

CIVIL AVIATION ACCIDENT AND INCIDENT INVESTIGATION COMMISSION

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 of Article 5.4.1 of Annexe 13 of the International Civil Aviation Convention, Article 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 detailed 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.

As a result, the use of this report for any purpose other than the prevention of future accidents may lead to erroneous conclusions or interpretations.

CONTENTS

ABBREVIATIONS

º.................................... Degree
ACC .... Air control centre
AP .... Autopilot
ATPL(H) .... Airline transport pilot license (helicopter)
CITAAM .... Commission for the Technical Investigation of Military Aircraft Accidents Military
CFD .... Computational Fluid Dynamics
COE .... Special Operator Certificate
DCU .... Data collection unit
ECL .... Engine control lever
EEC.............................. Electrical Engine Control
FEM .... Finite Element Model
FD .... Flight Director
FDR.............................. Flight data recorder
FIR .... Flight information region
FMM............................. Fuel Management Unit
fpm .... Feet per minute
ft................................... Feet
GS................................ Ground speed
h................................... Hours
IAS .... Indicated airspeed
kg .... Kilogrammes
km .... Kilometres
kt .... Knots
m.................................. Metres
MHz.............................. Mega Hertzs
min .... Minutes
N1 .... Compressor rotor speed (N1=Ng)
N2 .... Power turbine speed (N2=Nf=Npt)
NR................................ Rotor speed
PI .... Power Index
s .... Seconds
SAR.............................. Search and rescue
S/N .... Serial number

TACC ....Terminal Area Control Centre

TQ.................................Torque

UTC...............................Universal coordinated time

VFR...............................Visual flight rules

Technical report A-027/2019

Owner and operator:	Babcock Spain
Aircraft:	AgustaWestland AW139, registration number EC-NEH
Date and time of the accident:	Wednesday, 12 June 2019, 13:30 local time[1]
Site of the accident:	Municipality of Albarracín (Teruel)
Persons on board:	Crew: 1 (unharmed)
Type of flight:	General aviation - other - positioning flight
Phase of flight:	En route
Flight rules:	VFR
Date of approval:	1st March 2023

Synopsis

On Wednesday, June 12, 2019, the AW139 helicopter, registration EC-NEH, operated by Babcock, with flight code INR221A, made a positioning flight from Muchamiel airport (Alicante) to the El Musel base (Gijón).

At 53 minutes of flight, stabilised in the route phase over Serranía de Cuenca, the helicopter flew exceeding the certification limits in both yaw and balance, reaching in three seconds a roll angle of -140° while producing yaw oscillations with consecutive variations of +54°/s, -31°/s and +70°/s and variations in the pitch angles between -12° and 21°. This loss of control resulted in the following:

- the detachment of two emergency windows, and
- the change of the power control of the two engines to manual, due to an overspeed condition of the turbines which was not recognized by the pilot, which led him to make an emergency landing, thinking that the engines had failed.

The pilot managed to stabilise the helicopter 11 seconds after the event and, for 46 seconds, made a controlled descent, with power, to a clear area where he performed a run-on landing. The pilot and occupant were unharmed.

The investigation has concluded that the probable cause of the accident of the EC-NEH helicopter was a loss of control in flight following the disconnection of the automatic flight system through the FTR (Force Trim Release) switches and the assumption of manual control by the pilot. The loss of control was probably due to the pilot's misperception of the helicopter's actual attitude. No operational safety recommendations are issued.

[1] All times used in this report are local time, as extracted from the flight data recorder. In the seasonal period of the event, 13:30 local time was 11:30 UTC. Regarding time references with ATC, there is a 16-second lag.

1. FACTUAL INFORMATION

1.1. History of the flight

On Wednesday, June 12, 2019, the AW139 helicopter, registration EC-NEH, operated by Babcock, with flight code INR221A, made a positioning flight from Muchamiel airport (Alicante) to the El Musel base (Gijón)[2]. The commander, sitting to the right[3], was the only person on board. The flight had been postponed on two occasions: the previous day for meteorological reasons, and the same morning to update the onboard equipment[4] in the calculation of the weight and balance, which was carried out with an ATS flight plan with an expected duration of 3 hours 30 minutes. The pilot, who had already made the journey, had prepared the flight for that same day.

The lift-off occurred at 12:37:03 without incident. After 53 minutes of flight, the helicopter was flying over Serranía de Cuenca, stabilised in the route phase, with the Flight Director's IAS, LNAV and ALT modes coupled to autopilots[5] and the ATT stabilization system. At this point, there was what the pilot reported as a "*destabilization of the helicopter*".

The pilot's description of the event was as follows: *established en route, he noticed strong turbulence which destabilised the helicopter, placing it into a nose-up position, rolling to the right almost 90°, which he managed to recover. During this manoeuvre, he noticed air coming from his left. Later, when he could turn his head, he found that this was due to a rear window that had come off on that side. In addition, there was the failure of two engines that led him to initiate an autorotation and an emergency landing. During the event, the navigation charts he was carrying were placed on top of the instrument panels. When he landed, he became aware that the window on his side was also missing.*

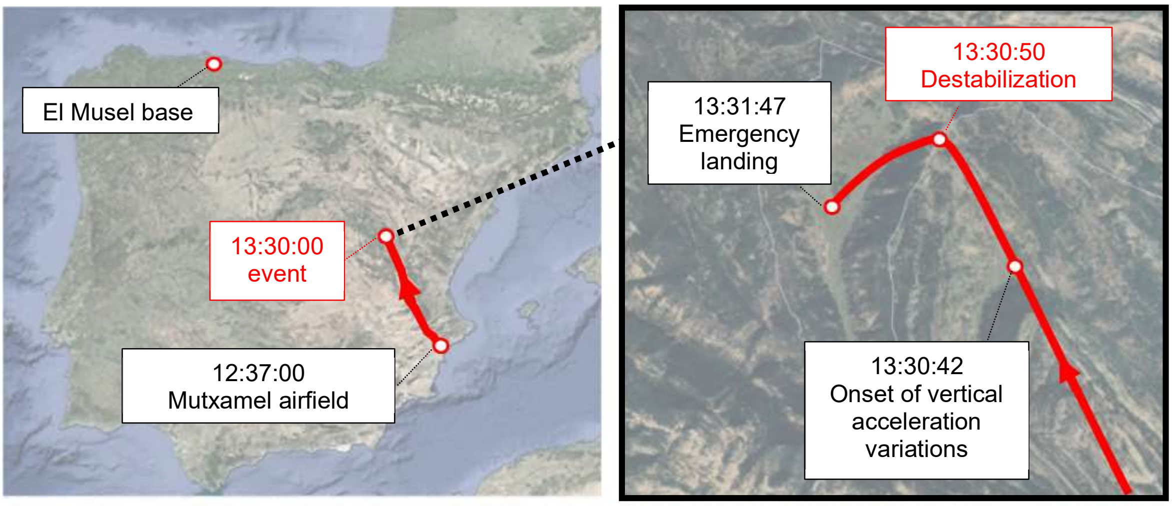

Figure 1. Full flight path and last 2 minutes in detail

The recorders confirmed that at 13:30:50, the helicopter was flying straight and level at a heading of 331°, at an altitude of 6,537 ft (1142 ft off the ground), 135 kt IAS and 152 kt GS, when the destabilization began, which reached its maximum development at 13:30:53:

[2] The El Musel base is one of the SAR Maritime Rescue bases. The helicopter, assigned to the SAR service of this agency, was to be positioned at this base.
[3] View of the helicopter from the pilot's position.
[4] The 31.66 kg searchlight was incorporated into the calculations.
[5] These modes are explained in section 1.6 Aircraft information.

- The roll angle[6] was increasing to the left until, at 3 seconds (13:30:53), it reached a maximum value of -140°.
- The yaw angle[7] underwent variations in both directions with maximum opposite rates of variation of +70°/s and -31°/s.
- The pitch angle[8] ranged from -12° to +22°.
- Within six seconds after the start of the event, the failure of the electronic controllers of the two engines (EEC) was recorded, which changed the mode of operation from automatic (AUTO) to manual (MAN).

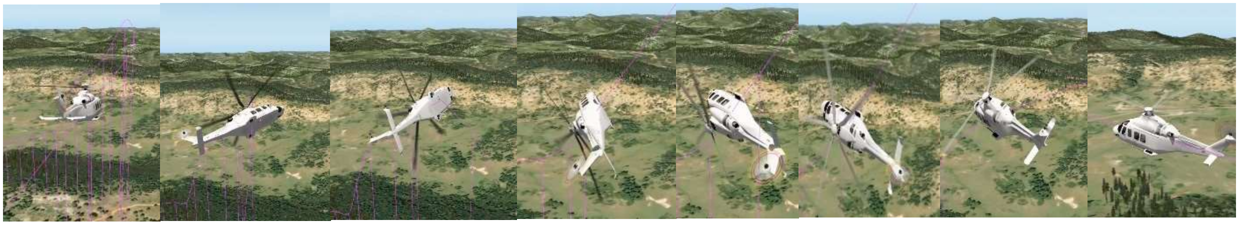

Figure 2. Event reconstruction: 13:30:50 to 13:31:01 (FDR data)

At 13:31:01, 11 seconds after the start of the event, the helicopter recovered its normal flight position, recording normal roll and pitch angles. The speed was 75 kt IAS. The helicopter had modified its course to the left at 239° and lost 473 ft in height, at this time being 669 ft above the ground. After the recovery, there was a descent that lasted 46 seconds until it landed in a controlled manner at 13:31:47. It was a run-on landing.

The helicopter was stopped at the coordinates 40.294567°N 1.718286°W, in a clear area in the interior of Serranía de Cuenca (Teruel), located 3 km southwest of the source of the Tagus river. The pilot was unharmed and left the aircraft by his own means using his door.

Figure 3. Status of the EC-NEH aircraft after emergency landing

[6] Positive roll angles indicate rolls to the right.
[7] Positive yaw angles indicate yaw to the right.
[8] Positive pitch indicates nose up.

1.2. Injuries to persons

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

1.3. Damage to the aircraft

The aircraft had damage to the left main landing gear, which had collapsed. The left raft was found deployed next to the helicopter. Two of the helicopter's eight windows, one on each side, had come off. The left-side window (of the passenger cabin) was located inside the helicopter with the curvature reversed. The right-side window (cockpit), on the captain´s side, was not found.

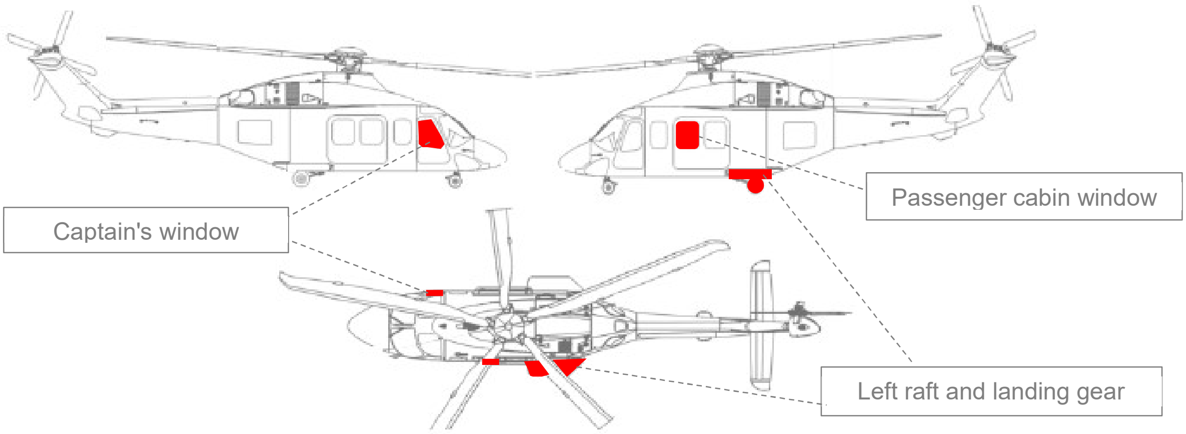

Figure 4. Damage to EC-NEH aircraft

1.4. Other damages

None.

1.5. Personnel information

The pilot, 47 years old, held a Helicopter Airline Transport Pilot License (ATPL (H)) and AW139 instrument flight and instructor ratings, all current at the time of the accident. He also held a valid medical certificate. He had accumulated a total of 6,407:45 h, of which 1,758:40 h were in AW139 and all with the operator.

He had been a military helicopter pilot for the Air Force. His activity with the operator began in 2003. Between 2003 and 2007, he combined his activity as a military pilot with civilian firefighting work with the operator. In October 2007, he joined the operator full-time, dedicating himself to SAR. Since 2013, he has been responsible for training. His base was Valencia.

Previous activity:

After 20 days of rest, he had resumed activity the day prior to the accident, on 11/06/2019. That day, he made two flights of 2 hours 5 minutes in total duration, the latter taking the EC-NEH helicopter from Valencia to Muchamiel. He had been resting since 14:20. On 12/06/2019, he had no prior activity. The accident flight was his first for the day.

1.6. Aircraft information

The helicopter was an AgustaWestland AW139 s/n 31579. It had recently been purchased by Babcock, so it had a provisional registration certificate issued by the AESA on 30/05/2019. It had a valid certificate of airworthiness. Since 30/05/2019, the helicopter had operated under the Babcock COE[9] and had made 4 flights. Both the aircraft and the two Pratt and Whitney PT6C-67C engines (engine 1 s/n KB1563, engine 2 s/n KB1600) had accumulated a total of 1,489:45 h total.

The only open deferred issue recorded on the list 06/01/2019, affected cartography. Because the helicopter had previously been operating in another geographical environment, mapping of the peninsula had not been incorporated. For this reason, the pilot carried paper maps and, as described, during the event, the maps were spread around the cockpit, covering the instruments. This issue had a correction deadline of 01/07/2019.

1.6.1 Weight and balance

Weight and balance calculations at the time of the event, considered a pilot weight of 85 kg and 1,152 kg of remaining fuel, with an aircraft weight of 6,112 kg, below the maximum certification (6,800 kg). The centre of gravity was within limits.

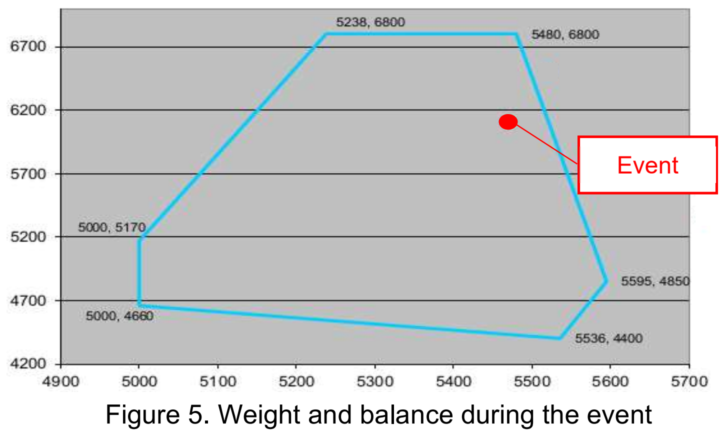

Figure 5. Weight and balance during the event

[9] Special Operator Certificate.

1.6.2 AW139 automatic flight system

The automatic flight system on the EC-NEH helicopter consists of two autopilots (AP) and two flight directors (FD), providing full control of the helicopter. When the AP is coupled to the FD, the helicopter performs the necessary actions on the flight control servo actuators to follow the instructions of the FD.

The automatic flight system can be turned off at any time by the pilot through the flight controls (cyclic, collective and pedals). Complete control over the helicopter by the pilot (hands on) is achieved in several ways. One method of interest to this investigation, is through switches FTR (Force Trim Release) located in the flight controls.

If the helicopter is flying with the FD and AP coupled, as it was at the time of the event, the pilot's actions can be two-fold:

- He can move the flight controls (cyclic, collective or pedal) without pressing the FTR and he will:
  - Keep the clutch closed (normal flight position).
  - Have complete control over the helicopter manually (hands-on).
  - Feel resistance in the controls (thanks to a spring).
  - The AP will switch from ATT mode to SAS mode.
  - When he releases the controller, the automatic flight (hands-off) will resume the flight references established before the pilot moved the controls.
  - This action will be recorded in the FDR with the DETENT parameter.
- He can move the flight controls (cyclic, collective or pedal) while pressing the FTR and he will:
  - Open the clutch.
  - Have complete control over the helicopter manually (hands-on).
  - Feel no resistance in the controls.
  - The AP will switch from ATT mode to SAS mode.
  - If any mode of the FD is activated, the AP will ignore it.
  - In the position in which the FTR is released, the automatic flight (hands-off) will resume, but with the new references associated with the position where the FTR was released.
  - This action will be recorded in the FDR with the FTR parameter.

In conclusion, the pilot's actions on the controls while holding down the FTR switch indicates the pilot's desire to assume manual control of the helicopter, cancelling any previous automation and establishing new references for the automatic pilots.

With regard to the stabilization functions of the automatic flight system (ATT and SAS), in addition to the switch on the cyclic, there are two switches on one of the panels (MISC) of the pedestal. The switches have two positions: OFF and ON. The inspection of the helicopter after the event confirmed that these switches were in the ON position, indicating that the AP was operating in ATT mode, which is the usual configuration. If these switches are turned OFF, the AP operates in SAS mode.

1.6.3 Flight Director (FD) modes for the AW139

The FD modes used during the flight, relevant to the event:

- IAS (Indicated Airspeed Mode): maintains speed selected by the pilot through actions on the pitch angle.
- ALT (altitude hold mode): maintains barometric altitude of reference selected by the pilot, through actions affecting the collective control.
- ALTA (altitude acquire mode): makes it possible to increase or decreased to the barometric altitude selected by the pilot, through actions affecting the collective control. With ALTA mode coupled, changes in altitude are performed at regimes between +1,000 fpm and -750 fpm, with IAS mode automatically coupled. Altitudes to be reached are set with the ALT SEL knob, located on the instrument panel to the left of the main screens. Then, the pilot must press the ALTA button located on the centre console.

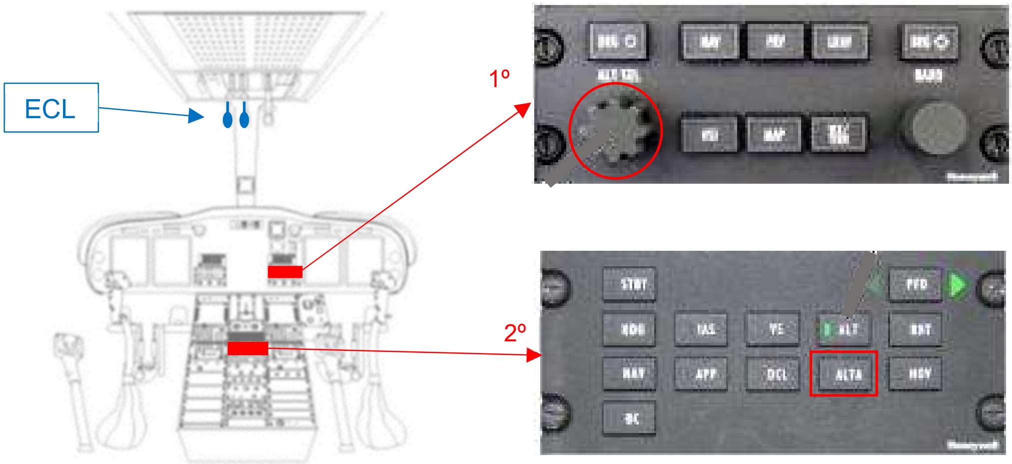

Figure 6. Cabin location of selectors for ALTA mode

- HDG (heading mode): captures and maintains heading selected by the pilot. Depending on the speed, this is performed by roll (at high speeds) or yaw (at low speeds and hover). In this mode, turns are enhanced at a rate of 3°/s.
- LNAV (lateral navigation mode): Captures and maintains the navigation set in the FMS through balance actions.

Both activation/deactivation of a mode (engaged/disengaged) and going from armed to captured issue an associated acoustic warning (a single chime) that can be heard in the flight CVR. The arming of modes does not have any acoustic chime.

All FD modes, with the exception of the ALT mode, are automatically deactivated when the speed is less than 55 kg IAS, which occurred in this event.

1.6.4 AW139 power control (EEC and FMM)

The PT6C-67C engine power is controlled through two main components working together: the FMM (fuel management module that delivers fuel to the engine via the metering valve) and the EEC (electronic engine control). For each engine, there is an FMM and an EEC, with communication between the two EECs. The main functions and operating modes related to the engine power controls involved during the event are explained briefly below:

Functions: control and protection

The fuel and power control system has two main functions:

- control fuel flow through the FMM torque motor to adjust the N1 according to the power demands to keep N2 constant within the limits of ITT, N1 and TQ.
- protect the engine from overspeed conditions in the N2 power turbine, through the FMM overspeed valve solenoid. This system, which was activated during the EC-NEH incident, receives independent information on N2 revolutions. This solenoid is activated when N2 exceeds 111%. What it does is reduce the fuel flow to the minimum so that the N2 can descend. When N2 falls below 109%, the solenoid is deactivated and the fuel flow is recovered, returning control of the metering valve either to the torque motor or to the ECL levers (figure 6), depending on whether the EEC is operating in AUTO or MANUAL mode, respectively. This protection system, therefore, is independent of the EEC mode (AUTO or MANUAL). This protection system was activated 6 times during the incident.

Indication to the pilot of the activation of the protection function

When the overspeed protection function of the EEC power turbine (N2) begins operation, two visual warnings appear for the pilot:

- the master caution light is illuminated.
- the letters “OVSP” appear in the warning panel.

Modes of operation: AUTO and MANUAL

The EEC can operate either automatically (AUTO), which is the normal operating mode, or manually (MANUAL), which is the emergency operating mode.

- In AUTO, the EEC calculates the necessary fuel flow and controls the position of the FMM metering valve electronically through the FMM torque motor.
- In MANUAL, the FMM torque motor is disabled and the ECL levers (the engine control levers located on the helicopter’s upper panel) control the positioning of the FMM metering valve mechanically. In addition to being able to control fuel flow with the ECL levers, there is a remote way to do so through the ENG TRIM switches on the collective control. The position of the ECL levers is not representative of the engine power, as the power range in MANUAL mode is conditioned by there being power during the transition from AUTO to MANUAL.

Transition from AUTO to MANUAL operating mode

The change from AUTO to MANUAL, in which the FMM torque motor is inhibited and ECL control of the metering valve is enabled, lasts 200 ms and assumes maximum variation in power of 10%. This transition, which can be initiated manually, also happens automatically when the EEC detects critical failures in the engines, which occurred during the event. When the change from AUTO to MANUAL happens due to a critical failure, the MANUAL mode will remain even if the critical failure disappears. That is, the EEC will not automatically return to AUTO mode.

Types of failures detected by the EEC

The EEC can detect two types of failures:

- 8 critical failures: these stop the normal operation of the EEC in AUTO and will force it to switch to MANUAL mode. These critical failures include the case where the N2 exceeds 127%. This assumes the inoperability of the probes, being outside the designed operating range.
- 27 non-critical failures: These do not stop the EEC AUTO operation but can undermine the EEC functionality.

Indication to the pilot of the EEC change from AUTO to MANUAL

The pilot is informed of the EEC change from AUTO to MANUAL operating mode in the following ways, depending on the origin of the change:

- The letters “MAN” will always appear visually, flashing for the first five seconds, and then static, lit in orange, to the left of the torque indicator (TQ) and PI dials for the engine where the EEC has failed.
- In the case where the change of mode is due to a critical failure, in addition to the above, there will be the following acoustic and visual warnings:
  - the EEC FAIL message will appear on the warning panel.
  - the master warning light is illuminated.
  - the acoustic warning associated is sounded.

  In this case, moreover, the critical fault is recorded in the DCU, which is a device that records the engine's health status.

1.6.5 Emergency windows

The helicopter has 8 total windows, of which, 6 are emergency exits. All windows have a small exterior curvature. The window is attached to the structure with a gasket. This gasket is attached through the application of an adhesive to the window itself (in the case of passenger cabin windows) or to the helicopter (in the case of pilot cabin windows).

In emergency situations, the window is opened by pulling a red ribbon and pushing it out by pressing with both hands. When this red ribbon is pulled, the gasket loses its rigidity, allowing the window to be removed. The pilot cabin windows, with respect to those in the passenger cabin, detach differently due to the area of application of the adhesive: in the pilot cabin windows, the gasket is attached to the helicopter, while in the passenger cabin, the gasket detaches with the window.

1.7. Meteorological information

Information has been obtained from four different sources: AEMET, the FDR, photographs taken after the incident and the pilot's statement. The AEMET analysis confirmed, based on remote sensing systems and the reports from the three stations closest to the accident site, that there were no significant phenomena in the accident area. The likely conditions were light winds of 10-15 km/h with maximums of 20-27 km/h, with a south-southeast component, temperatures of 15-18°C, humidity of 30%, rather high sparse clouds and no forecast of turbulence in the helicopter's flight levels. The FDR indicated a south-southwest wind of 22 km/h and temperature of 9°C. Photographs taken after the accident (figure 2) and data provided by the pilot confirm these conditions.

1.8. Aids to navigation

The flight was registered by the ENAIRE control system. The valid radar tracks[10] cover the period from lift-off to the start of the helicopter's destabilization. Taking into account the time lag between ATC and FDR, the last valid radar trace was at 13:30:56 (13:31:12 ATC time). The descent and emergency landing were not recorded.

The flight, under VFR rules, was carried out in G airspace, both in the VFR sectors of the Valencia TMA and in the Madrid FIR, where the last minutes of the flight took place. The service provided, therefore, is flight information. Flight altitudes maintained by the aircraft were within the maximum altitudes of the VFR sectors the helicopter was crossing.

Radar traces confirmed that after lift-off, the aircraft travelled in a northwest direction, avoiding three active LEDs at that time (138, 131 and 132), whose activation was alerted by the Valencia TACC Controllers. ATC communications confirmed that the pilot was aware of these areas and has already considered them in his flight planning.

The last six minutes of flight (from 13:25 to 13:31) took place within one of the reserved areas of the TLP (Tactical Leadership Programme), specifically TLP A4B, coinciding with LED104 in the airspace of the FIR Madrid. This programme had reserved areas for military aircraft training and had been included in AIP Supplement 164/18 and NOTAM D1503/19.

Information was collected through CITAAM on military activity in the TLP A4B area in the flight time slot in which the EC-NEH aircraft event occurred, in order to identify nearby flights that could have generated turbulent wakes, since these activities are not always carried out with a transponder. The following information was provided by the Air Force:

- Area TLP A4B was not used on the day of the accident and had been released the day prior at 19:00 (17:00 UTC).

[10] The last echoes corresponding to the period 13:31:12-13:31:31 (ATC time) are not valid since they are extrapolations of the system.

- TLP activity for the day of the accident occurred at a different time than when the accident occurred.

As far as civilian traffic is concerned, no echoes were identified nearby which could have caused a turbulent wake that would affect the EC-NEH.

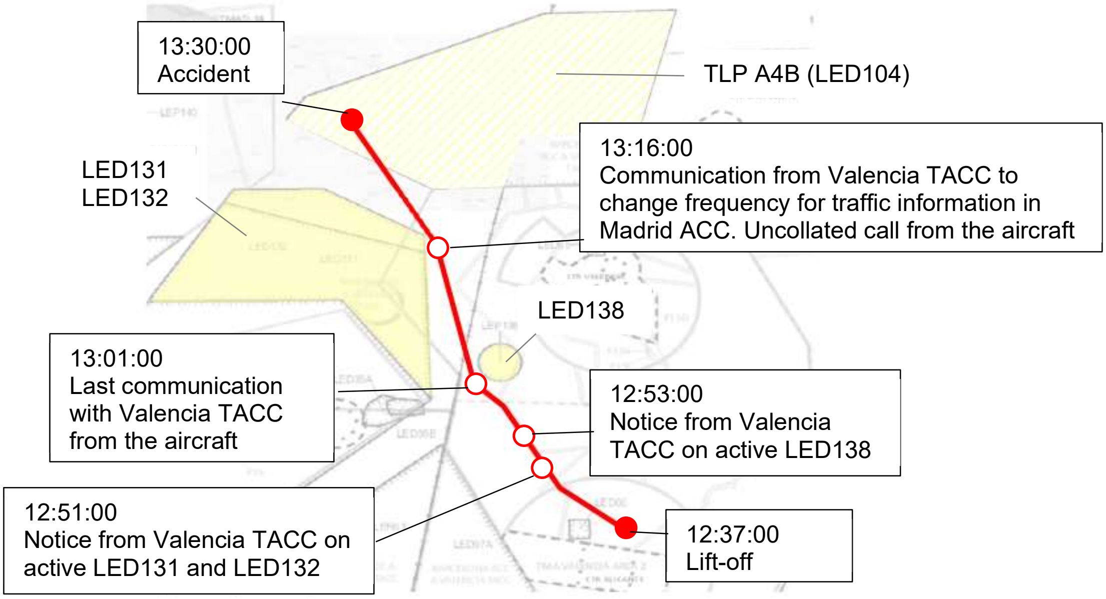

Figure 7. Reserved airspaces and communications with ATC in the flight path

1.9. Communications

Communications maintained during the flight (see figure 7) were reconstructed from the ATC communications recorded by ENAIRE control services, from the CVR records and PTT (push to talk) parameter of the FDR, which records the use in the cabin of the PTT button:

- ATC communications were covered from lift-off until 13:01, were properly read back by the pilot and standard phraseology was used. These communications showed that the pilot was aware of the active LED area and had a relaxed tone of voice.
- The last communication with ATC (Valencia TACC) occurred at 13:01 and during these last contacts, the pilot had to made several attempts because he was not able to manage contact, probably due to lack of coverage.
- At 13:16, Valencia TACC notified a new information frequency with Madrid ACC, but this call was not confirmed by the pilot, because it was not heard in the aircraft, probably due to lack of coverage. The aircraft inspection after the accident confirmed that the frequency selected on board had not been changed to that of Madrid ACC, but remained set to Valencia TACC (121,100 MHz).
- From 13:01 to 13:30, when the incident occurred, the pilot did not have any communications with ATC (the PTT parameter was not activated), and the pilot was not heard to say anything during the destabilization and emergency landing.
- The last CVR search occurred after the helicopter was grounded and stopped and corresponded to three-word interjections from the pilot.

1.10. Information about the aerodrome

The area where the emergency landing took place had an elevation of 1,537 m. It was elongated, clear of trees and relatively flat compared to all surrounding terrain, formed by mountains and hills of more than 1,700 m, completely covered with pine forests. The ground, grassy and wet, had undulations and sinkholes.

Due to the difficult accessibility of the site, the helicopter had to be recovered by a Boeing Ch-47 Chinook from FAMET, which carried it as external cargo to the Teruel airport on 18/06/2019.

Figure 8 shows the terrain covered by the helicopter over the last 27 metres, with two sinkholes which were crossed by the right main landing gear (see point 1.12).

Figure 8. Sinkholes and right footprint

1.11. Flight recorders

The information in this section is taken from two types of units: first, the helicopter FDR, and second, the two DCUs, one from each engine. The main feature of the DCU is that is only records certain types of events when they occur, but it is not a continuous recorded with a time scale, like the FDR. For this reason, the information taken from these two information sources is presented in two separate sections.

1.11.1 DCUs

The DCU is a unit that only receives and records information from the EEC when certain events occur in the engine. 28 parameters are stored for each event. The rate of recorded for the EEC parameters and the rate of transmission to the DCU for recording, is 20 ms, with a maximum delay of 83.2 ms upon recognition of the failure.

The download from the DCUs for both engines showed similar information, so they will be discussed together. From the outset, it could be ruled out that they were operating in training mode. There were two events recorded; one produced 21 hours prior, with no relation to the incident, and another corresponding to the incident.

Regarding the event, the two DCUs had 7 inputs: the first 3 occurred at the same time and the latter 4 occurred 0.216 s later:

- 3 first inputs with non-critical faults. The faults were related to the N2/TQ values for both engines and NR. The parameters recorded indicated the following:

  - N2 for both engines above 111% (122% and 116%), a threshold that conditions the activation of the power turbine overspeed protection system.
  - The control system indicated 11 (*minimum torque stepper engine control),* indicating that the overspeed protection system was minimizing fuel flow to the engine to lower N2 below 109%.
  - The collective was at -3%.
  - N1 was at about 84-86%.
  - TQ was at about 21-34%.
- 4 inputs, 0.216 s after the previous three: two critical failures related to the N2/TQ values for both engines and two non-critical failures. The parameters recorded indicated the following:
  - Values of 0 in N2 for both engines. The value of 0 is set when the operating margins of the N2 probes are exceeded (N2 greater than 127% and N1 greater than 70%). This condition is what produced the critical failure and the switch to MANUAL EEC for both engines.
  - The control loop remained at 11, indicating that the overspeed protection system was still operating and fuel was still being restricted to the minimum.
  - The collective was at -3%.
  - N1 was at about 82-84%.
  - TQ was at about 14-19%.

1.11.2 FDR

The helicopter was equipped with a combined data and voice recorded in the cockpit, manufactured by Penny&Giles, model D51615-142, with capacity to record 600 parameters and four audio channels (pilot, co-pilot, cabin microphone and inter-cabin communications) for two hours. The information was downloaded two days after the accident with satisfactory results. After validating the parameters relevant to the investigation, it was confirmed that its use for the analysis of the event was reliable. In relation to the data, it is clarified that because the operating range of the TQ, N1, N2 and NR sensors was exceeded, the analogue backup data was used.

<u>Initial lift-off and climb up to 1,500 ft</u>

At 12:22:44, the FDR recording began with engine 2 in IDLE position. At 12:24:05, the complete starting sequence for both engines ended with both in FLIGHT mode and 100% NR. At 12:37:03, the helicopter began to rise. The pilot began the initial climb to 1,500 ft and 100 kt IAS was made in manual mode, coinciding with a communication reporting that he was leaving the airfield heading north.

Activation of FD modes and climb to 2,500 ft

At 12:38:55, the pilot coupled the FD to the AP, selecting the IAS, HDG and ALTA modes of the FD, with selected values of 110 kt, 313° and 2,500 ft, respectively.

At 12:39:36, the aircraft reached the selected altitude and changed from ALTA to ALT. A single chime was heard in the cockpit reporting this change. The speed was maintained at 110 kt, IAS. The GS was at 118 kt with a heading of 313°. The helicopter was level.

Climb to 3,500 ft

At 12:40:22, the pilot entered 3,500 ft as the new selected altitude and activated the ALTA mode (the process[11] lasted 6 seconds). The speed increased to 120 kt IAS and the helicopter reached 3,500 ft at 12:41:20. The FD mode switched back from ALTA to ALT with a single chime in the cockpit. The pilot increased the selected speed to 135 kt IAS. The flight was stabilised at 3,500 ft and the pilot made two calls to Valencia TACC but was unable to make contact.

Climb to 4,500 ft

At 12:43:44, the pilot commanded the new climb to 4,500 ft with the ALTA mode (this process lasted 8 seconds). In the cabin, a single chime was heard marking the change and the automatic flight system started the climb at the nominal speed of +700 fpm.

The helicopter reached 4,500 ft at 12:45:09, with the FD switching from ALTA to ALT and once again playing the chime. During the climb, the pilot reduced the speed to 120 kt and once established at 4,500 ft, he again increased the speed to 135 kt. After reaching 4,500 ft, the pilot again attempted to make two calls to Valencia TACC with no response.

At 12:47:13, the pilot changed the lateral mode of the FD from HDG to LNAV, changing course to 330° and shifting the helicopter with a drift to the right of 4-6°.

At 12:48, the pilot managed to make contact with Valencia TACC and indicated a change of transponder code (from 7000 to 7032) and was informed of the restricted areas, with the pilot confirming his knowledge of the activation status. The FDR confirmed that the code was changed.

Climb to 5,000 ft

At 12:53:53, the pilot commanded the new climb to 5,000 ft, per ATC instruction, with the ALTA mode (the process took 7 seconds). The speed was maintained at 135 kt with a heading of 330°. At this altitude, the pilot modified the FD lateral mode again by switching from LNAV to HDG. The new course selected was 315°. This change led to a single chime heard in the cockpit. Three minutes later, the pilot received instructions from Valencia TACC to change to a new frequency and he made contact with the new frequency at 13:01:20 after three calls.

[11] The term ‘process’ means the introduction of the new altitude in the ALT SEL Knob selector on the panel and once completed, the pressing of the ALTA button of the FD panel.

At 13:01:53, the HDG mode was switched back to LNAV, starting a turn towards 350° and seconds later, the pilot contacted Valencia TACC, which was the last communication made during the flight.

The flight maintained altitude of 5,000 ft for 20 minutes. During the last 16 minutes (starting at 12:58), there was a significant increase in the activity of the linear actuators of the automatic flight system in addition to fluctuations in the vertical speed of up to 1,000 fpm, which on one occasion achieved a deviation of 150 ft from the selected altitude. Despite everything, the pilot did not need to intervene on the flight controls, with the helicopter maintaining stability automatically. These parameters indicate that during this time, the helicopter passed through a zone of turbulence.

Climb to 5,500 ft

At 13:14:41, the pilot commanded a new climb to 5,500 ft with ALTA mode (the process took 5 seconds), development stable flight with very few moments of turbulence. A few seconds later, the helicopter turned towards 331°, a heading which it would maintain until the incident.

Climb to 6,500 ft

At 13:25:58, the pilot began a new clib to 6,500 ft in ALTA mode (the process took 9 seconds), which the helicopter would reach a minute and a half later, at 13:27:24, changing the mode once again to ALT.

During the final part of the climb and in the seconds following stabilization at 6,500 ft, there were fluctuations recorded in the indicated speed, with decreases of up to 15 kt with respect to the nominal 135 kt, and in vertical speed with variations of ±400 fpm with respect to speed of +1,000 fpm. These fluctuations indicate that the helicopter was traversing through a zone of turbulence.

At 13:30:25, in straight and level flight, with all parameters evolving steadily, there was a progressing increase in vertical speed which, for 15 seconds, increased to +540 fpm, probably generated by an ascending air current. This caused the automatic flight system to reduce the collective by 13% to compensate for this situation and maintain the helicopter's altitude at 6,500 ft (ALT mode as active with 6,500 ft set as the reference altitude).

Modification of reference altitude to 7,500 ft

At 13:30:35, for 7 seconds, the pilot started to modify the reference altitude from 6,500 ft to 7,500 ft. However, this modification was not accompanied by the pressing of the ALTA button, as the pilot had done on the five prior occasions during the flight, so the ALT mode associated with 6,500 ft remained active. The IAS with 135 kt reference speed and LNAV remained operational. The IAS was 138 kt, GS at 154 kt, altitude at 6,498 ft and heading 331°.

At 13:30:42, when the pilot was finalising the selection of the new reference altitude, which he was never able to activate, the helicopter recorded a change in vertical speed from 0 to -700 fpm in two seconds, which is believed to have been caused by the helicopter's exit from the rising air stream. This change in vertical velocity led to the following:

- the pitch angle, which had been at around +2° to that point, decreased to -5º (13:30:44), recording the performance of the linear actuators and longitudinal compensators in the automatic flight system reaching their design limits.
- the collective increased to maintain altitude of 6,500 ft, since the ALT mode was active.

The automatic flight system produced an increase in the pitch angle up to +10°, reached at 13:30:47. These compensations saturated the linear actuators and produced the maximum reaction in the autotrim (2.5°/s) of the automatic flight system. In the next two seconds, the pitch angle decreased to -7° and a maximum vertical acceleration of -1.2 g was recorded. On the transverse axis, the helicopter remained stable, with a roll angle value maintained at around -2°.

Up to that point, 13:30:49, the automatic flight system compensated for the external effects on the helicopter and the flight was developed with the lateral, vertical and collective FD modes coupled and activated. At 13:30:49, the helicopter was at 130 kt IAS, 144 kt GS, 6,598 ft, a heading of 332°, with a stable roll angle of -2°. The pitch angle was increasing from -2° to -7°, with maximum vertical accelerations of ±0.8 g, maximum lateral accelerations of ±0.3 g and maximum longitudinal accelerations of -0.2 g.

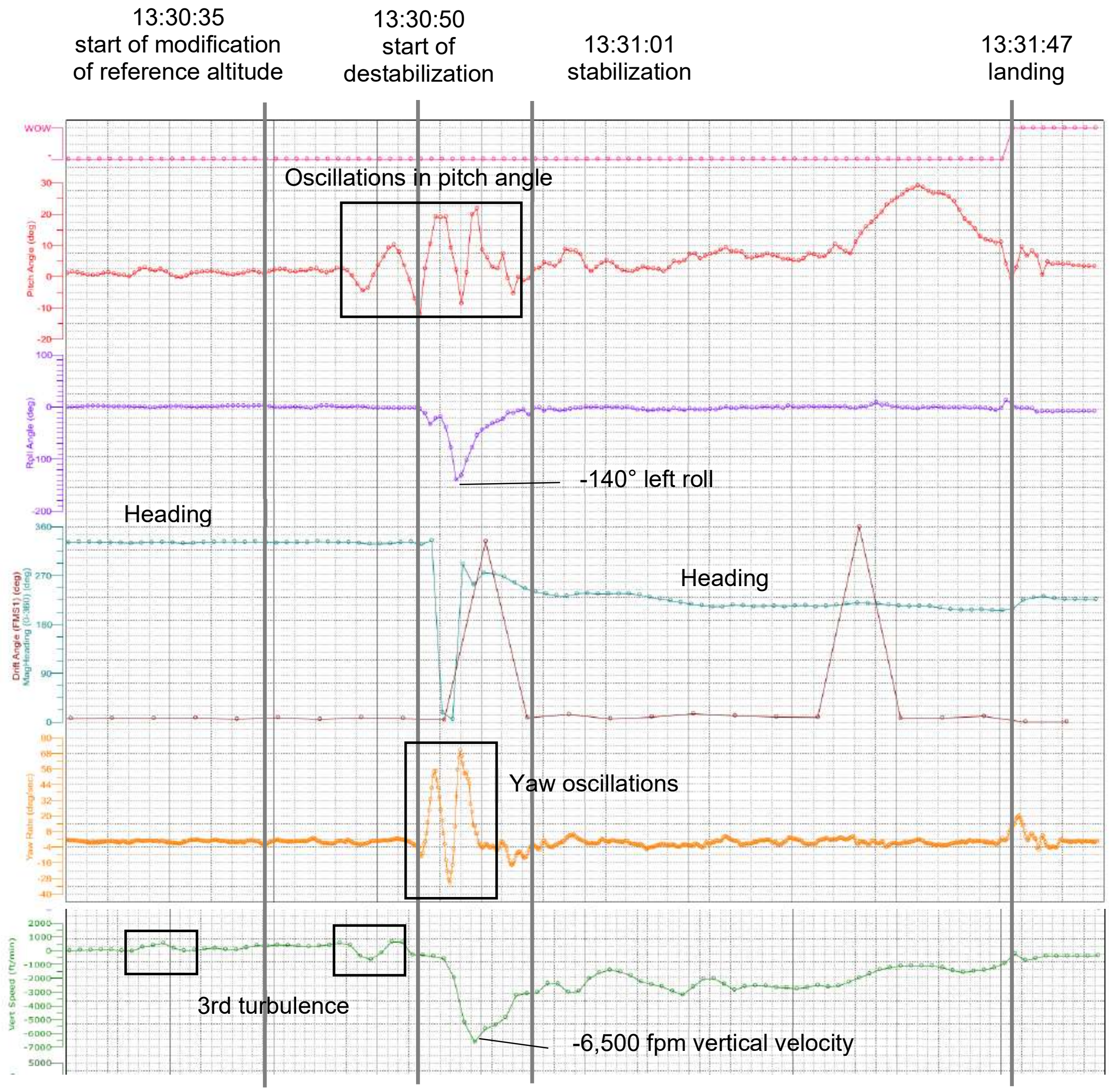

Figure 9. Altitude parameters from the event until landing

Pilot control of the helicopter (hands on)

At 13:30:50, the pilot took complete authority of the helicopter by pressing the FTR buttons on the flight controls, first on the cyclic, then one second later on the collective and then on the pedals. This action on the FTR was maintained until landing. This action overruled the FD modes and the stabilization system that had been active to this point. The sequence of actions on the controls and the helicopter's movements were as follows:

- 13:30:50: The cyclic was shifted backward (from 81% to 22%) and rightward (from 55% to 59% in the first half-second and forward (from 23% to 90%) and leftward (from 48% to 8%) in the next half-second, while applying the right pedal. The collective remained in position (68%). The speed of the helicopter was 135 kt IAS. The helicopter began to roll to the left from -2° to -12°, increasing the pitch angle from -12° to +2° and the yaw rate, which had previously been maintained between 0-5°/s, increased to +24°/s.

- 13:30:51: The cyclic remained forward, moving toward the centre and then completely to the left. The right pedal was completely pressed down, and the collective control began its upward movement (from 69% to 74%). The helicopter's speed was 128 kt IAS. The roll to the left had increased to -33° and the nose-up position increased to -19°. The yaw rate continued to increase to +54°/s to the right.
- 13:30:52: The cyclic remained completely to the left and then moved backwards to the middle of the longitudinal path of the lever, with the right pedal fully applied. As a result, the helicopter continued to increase the roll angle to the left to -40°, maintained the nose-up position at +19° and the yaw rate changed direction from +54°/s to the right to -31°/s to the left, for one second before increasing again to the right. The speed decreased to 113 kt IAS. At this moment, the CVR recorded the appearance in the cabin of a very strong aerodynamic noise, probably produced by the detachment of one of the windows.

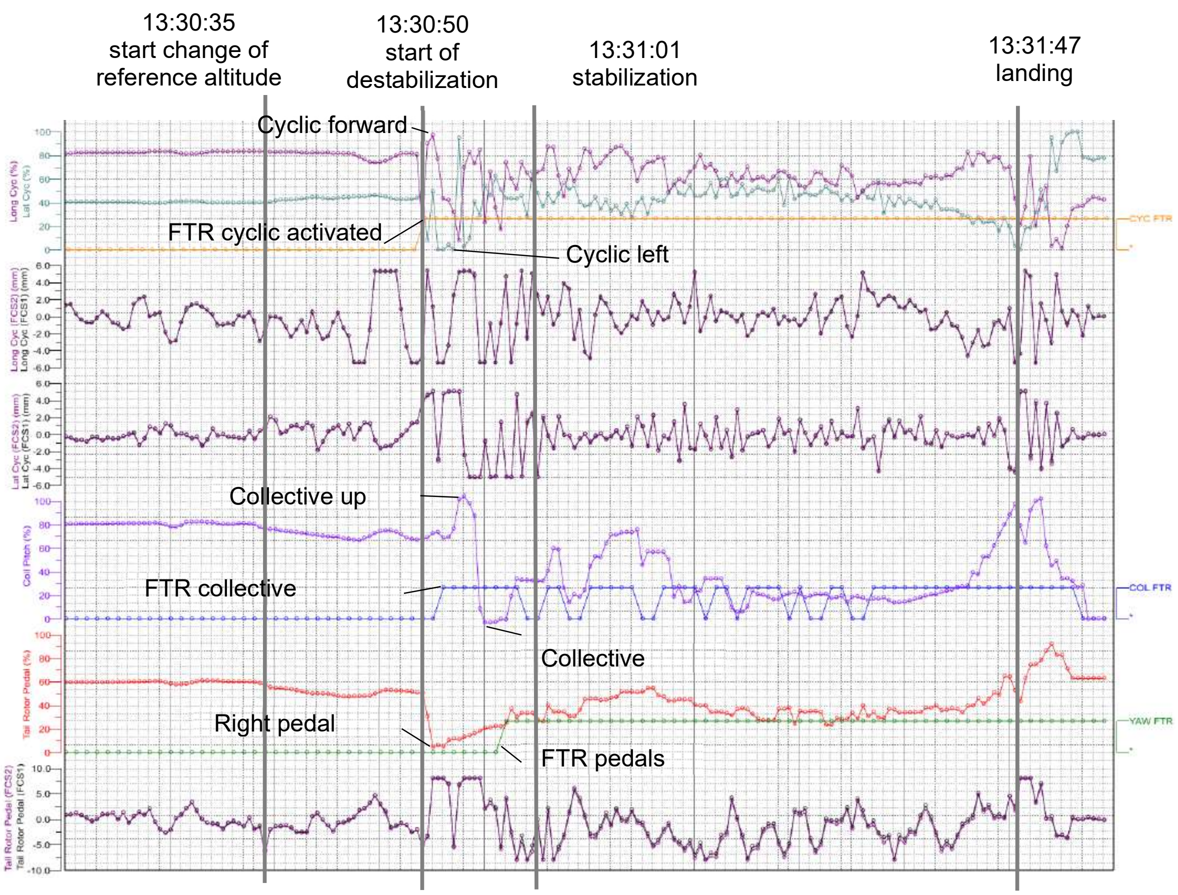

Figure 10. Flight control parameters from the incident until landing

Maximum destabilization

At 13:30:53, the pilot moved the cyclic completely back and to the left, keeping the right pedal pressed, while pulling the collective to its highest point. At this moment, the helicopter suffered its greatest destabilization, with a balance of -140°, which generated the BANK ANGLE acoustic warning in the cockpit (generated when the roll past ±55°). The speed dropped below 55 kt (the FDR recorded 3 kt), which deactivated all FD modes simultaneously. The yaw rate went from -31°/s to its maximum value during the incident of +70°/s. The pitch angle was reduced, going from +9° to +2° in one second and then the helicopter began to descend to a regime close to -2,000 fpm. The main rotor recorded deceleration up to 94%, which caused the LOW ROTOR aural warning (activated when the NR is lower than 98%).

From this moment, until practically the end of the flight, the CVR confirmed the appearance and overlap in the cabin of aural warnings that were appearing according to the order of priority of the failures: BANK ANGLE, ROTOR LOW, SINK RATE, ROTOR HIGH, LOW SPEED, WARNING, TERRAIN and PULL UP.

Recovery of the balance and overspeed of the turbines

After the maximum destabilization of the helicopter at 13:30:53, with roll to the left of -140°, the pilot tried to regain control of the helicopter.

- 13:30:54: The collective remained completely up and, in the last half of this second, began to drop abruptly to its lower limit. The cyclic was moved completely forward longitudinally while being held to the left. The right pedal was depressed. The revolutions of the main rotor remained below 97%. The FDR recorded the activation of the ROTOR LOW, FUEL PUMP and ENG OIL PRESS warnings for the two engines, produced by the helicopter's inverted position (roll angle was at -131°). The helicopter reached a nose-down position of -8° and the yaw rate decreased from +66°/s to +29°/s. The helicopter continued to descent at a rate higher than -5,000 fpm.
- 13:30:55: The collective remained in the lowest position for 3 seconds. Consequently, torque decreased to 0%. The cyclic relaxed its position to the left, shifting slightly towards the centre, while remaining completely forward while pressure on the right pedal was slightly reduced. The roll decreased to -79° and -55° in one second. The pitch angle reached its positive maximum of +22° and the helicopter recorded its maximum descent of almost -6,500 fpm. Consequently, the engines began to accelerate, exceeding the 111% value of N2 and finishing at 13:30:55, which conditioned the activation of the engine overspeed protection system, which reduced fuel flow to the minimum in an attempt to reduce N2 below 109%. This protection system would remain active for almost 6 seconds. For two seconds, the MGB OIL PRESS warning was activated.

In the cabin, the BANK ANGLE and LOW ROTOR acoustic warnings were superimposed. One second later, the SINK RATE alerted, which would repeat until landing.

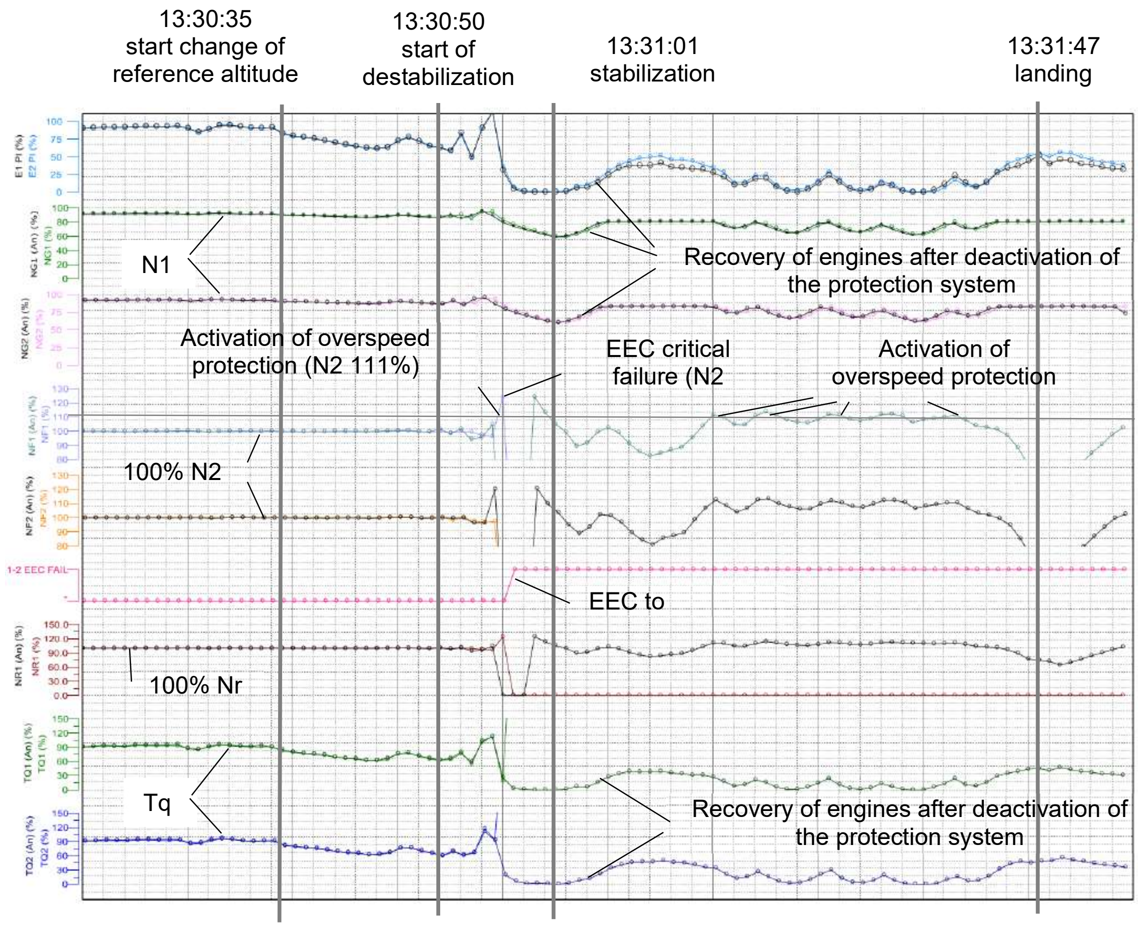

Figure 11. Engine parameters from the event until landing

EEC Failure: transition from AUTO to MANUAL

At 13:30:56, the roll angle and pitch angle continued to decrease (-37° roll and +6° nose-up) and the speed recorded was 57 kt IAS. From this moment, the descent began to reduce (-5,500 fpm). The pilot kept the collective fully down. The engines and main rotor maintained the tendency to accelerate initiated in the previous second, despite the reduction in fuel, with the power turbine exceeding 127% N2 (with N1 above 70%), producing the critical failure of the two EEC and recording the complete failure of the EEC in the FDR. For its part, the main rotor exceeded 115% NR, activating the ROTOR HIGH warning (activated when the NR is greater than 104%).

These parameters (activation of the engine overspeed protection system, EEC failure, the position of the collective, torques, turbine revolutions) coincide with the data extracted from the DCUs (part 1.11.1) and therefore, it is considered that the time reference of 13:30:56 is valid as the reference time for the EEC passage from AUTO to MANUAL. This change in the EEC from AUTO to MANUAL occurred when the fuel was already being limited to the minimum by the protection system, which explains the reduction of N1 in both engines to the minimum. Since this fuel restriction was active until 13:31:00, the pilot pulling on the collective at 13:30:58 to increase power had no effect on the engines, but the N1 continued to be reduced due to the operation of the engine protection systems. Once this system was deactivated, the N1 increased to the value it had been when the EEC made the transition from AUTO to MANUAL, which was also being reduced as a result of the protection system.

With regard to information in the cabin, after the transition from AUTO to MANUAL, the information presented was not changed to analogue, so the pilot continued the rest of the flight without any indication from the engines, with the exception of the PI (Power Index) in the PFD (Primary Flight Display) of the pilot's position.

At the end of this period, the ROTOR HIGH warnings stopped, turning to ROTOR LOW warnings.

<u>Stabilization</u>

The loss of control ended at 13:31:01, coinciding with the deactivation of the engine protection system. The speed was set between 75-85 kt IAS. The roll angle was maintained between 0º and -8°. The pitch angle was between +2 and +8°. The rate of descent ranged from -3,000 fpm to -1,500 fpm. The helicopter was 669 feet above the ground and had turned to the left during the event, currently at 239°. The engine parameters showed that they were active, ruling out malfunctions providing the power associated with the N1 value set during the transition of the EEC from AUTO to MANUAL.

During the descent, there were evident problems maintaining N2 and NR, which generated alternating low and high rotor warnings. Specifically, between 13:31:01 and 13:31:14, there were ROTOR LOW warnings recorded.

From 13:31:16 to 13:31:41, ROTOR HIGH and SINK RATE warnings were activated, and up to a total of five times, the engine overspeed protection system was activated due to the N2 for both engines exceeding 111%. During the descent, which was happening at a rate of -3,000 fpm, the TERRAIN and PULL UP warnings were activated, reporting the proximity to the ground.

At 13:31:32, the 150 FEET cabin warning was heard, together with PULL UP. The flare was identified, increasing the pitch angle to almost 30°. Throughout the process, the ROTOR HIGH, SINK RATE and PULL UP alerts were active.

At 13:31:45, two seconds prior to landing, the ROTOR LOW warning was activated again. At 13:31:47, the helicopter made contact with the ground, at just under -700 fpm and with a translational velocity of 12 kt IAS. It rolled on the ground, as confirmed by the footprints found, and eventually stopped.

Data recorded was complete at 13:31:55. At 13:32:14 and 13:32:22, the pilot's first words could be heard from the start of the event.

1.12. Aircraft wreckage and impact information

<u>Debris:</u>

The helicopter was found resting on the left side of the lower fuselage, the right main landing gear and the nose landing gear. The entire area of the left structure and raft housing above it has been displaced upwards. As a result of this displacement, the raft was ejected, landing next to where the helicopter was stopped and where the left skid had collapsed. The searchlight support had fractures and was supported on the ground. In the left area of the main rotor fairing, vertical traces of oil from the dumper were identified, indicating that they had occurred during contact with the ground, not while in flight. The rest of the structure was not damaged. The rotors were intact and had no impact marks.

The two detached windows, one on each side, were emergency exists designed to be detached by pulling a red ribbon. The left-side window was recovered inside the helicopter with the curvature reversed. The window still had the red ribbon installed which would be used to eject the window and gasket. The captain's window was not recovered. In examining this window, it was discovered that the gasket has also peeled off and there were discontinuities in the adhesive.

Marks on the ground:

Landing gear markings were identified on the ground along a stretch of 57 m. The terrain, seen in the forward direction, had numerous undulations and a slight downward slope to the right, with two large sinkholes of earth at the end of the path. There were two sections of marks: the first of 30 metres and the later of 27 metres, before arriving at the helicopter:

- In the first 30 metres, there were identified two continuous tracks of the wheels from the main landing gear, separated by the width of the AW139 lading gear. In this section, although uneven, there were no sinkholes.
- In the last 27 metres:
  - The footprint of the left landing gear continued another 27 m to the helicopter.
  - The footprint of the right landing gear was found to be divided into three sections, since it crossed two large sinkholes of earth of 15 and 10 m^2 (see figure 8).
  - The double footprint of the nose landing gear had been marked in two sections: the first was 70 cm from the left landing gear and the latter, close behind the helicopter, was 40 cm from the footprint of the right landing gear, indicative of a skid first to the left, then to the right.
  - The separation between the tracks of the main landing gear in this section decreased from an initial 3 metres to 2 metres near the helicopter, consistent with the lateral displacement evidenced by the tracks of the nose gear with respect to those of the main landing gear.

1.13. Medical and pathological information

The pilot did not sustain any damage during the event. A SESCAM helicopter arrived at the accident site and took the pilot to a hospital where was examined with satisfactory results.

1.14. Fire

There was no evidence of fire during the flight or after the impact.

1.15. Survival aspects

The restraint systems performed their function properly and the cabin maintained its structural integrity. Thus, the pilot was not injured and was able to leave the helicopter without any problems.

After stopping the helicopter, the pilot checked that there was no coverage and activated the emergency beacon, which was detected by the Air Rescue Service (SAR) at 13:35. After an hour of walking in search of coverage, he managed to find an area where he was able to make two telephone calls. He then returned to the helicopter. A SESCAM helicopter, an ambulance and two patrols from the Cuenca Civil Guard arrived in the area.

1.16. Tests and research

1.16.1 Testing at the CIMA Biodynamics Laboratory

Data obtained from the FDR showed that the helicopter was subjected to vertical accelerations and oscillations in the pitch angle before the destabilization began. In order to assess the possible effect of these oscillations, as well as the light conditions and their effect on the pilot's capabilities, tests were carried out in the Space Disorientation Unit simulator at the CIMA Biodynamics Laboratory.

The tests were carried out with two helicopter pilots with over 5,000 hours of flight experience, who were not provided with any information about the accident. They were placed in the same geographical area, at the same time and with the same weather and visibility conditions. The following scenarios were used:

- Scenario 1: Established in straight and level flight, with the same altitude and speed values, the vertical accelerations recorded in the FDR were induced externally.
- Scenario 2: Established in straight and level flight, with the same altitude and speed values, and in conditions of flicker vertigo[12], the vertical accelerations recorded in the FDR prior to destabilization were induced.

The conclusions were as follows:

- Scenario 1: The oscillation prior to the event had no effect on the pilots. They did not generate feelings of physical discomfort and the pilots were aware of their position with respect to the environment. Recovery of the helicopter was rapid (on the order of 3 seconds). His personal assessment was that the simulated scenario was normal in mountain areas.
- Scenario 2: The flashing light effect of the flicker vertigo was reported as "annoying", but had no additional effect. The pilot's reactions and recovery were similar to those of scenario 1.

In addition, a third scenario was simulated, putting the helicopter in the abnormal flight position with a roll angle of 140° to assess the capacity for recovery. Although the pilots managed to regain control of the helicopter in a relatively short time, it was not possible to obtain relevant conclusions because the accident involved highly unsteady and changing scenarios in three axes, which could not be reproduced in the simulator.

[12] Flicker vertigo is a spatial disorientation phenomenon that produces erroneous perceptions of the position, speed, and height of the aircraft. It can give the pilot the sensation of turning, as well as other effects such as nausea, dizziness or confusion. It originates from intermittent exposure to bright low-frequency light, such as zenith sunlight through the main rotor of a helicopter, afternoon sunlight through the propeller of a fixed-wing aircraft, or strobe lights in foggy environments. During the EC-NEH event, the position of the sun and sky conditions favoured this effect.

1.16.2 Functional tests of the windows

Functional emergency opening tests were carried out on two windows of the EC-NEH helicopter: on the co-pilot window, which is installed identically to the pilot window, and another passenger cabin window on the side as the window that had detached. The results were satisfactory: the windows were opened by exerting a normal force and the joints were attached to the door and window, respectively. It was confirmed that the adhesive used on both windows peeled off during the event and those tested during the inspection were the same.

1.16.3 Tests of the window installation materials

Samples were taken of the gaskets, filler wedges and glue adhesives that were part of the window installation. These samples were taken to a laboratory and subjected to hardness, creep, thermal and crystallization tests[13]. The same tests were also carried out with new gaskets, filler wedges and adhesives, to compare with those installed on the helicopter. The results were conclusive: the materials complied with the required specifications and showed no chemical or physical changes with respect to new materials.

1.16.4 Design loads on detached windows

The design specifications were consulted in order to determine the maximum loads to which the windows may be subjected, by certification. The CS29 certification standard with which the AW139 was certified establishes 16 case studies (Figure 12), defined by combinations of speed, angles of attack, yaw angles and load application areas, for which load calculations must be performed. Results of interest to the accident indicate that:

- The pilot's window is designed to withstand a maximum[14] suction load of 197 kg (obtained in a defined scenario with the helicopter flying at 185 kt, -5° pitch angle, and -8° yaw).
- The passenger cabin window is designed to withstand a maximum compression load of 144 kg (obtained in a defined scenario with the helicopter flying at 130 kt, 0° pitch angle, and -60° yaw).

Case Study	V_{EAS} (kt)	α_F (º)	β_F (º)
1	100.2 (0,6 V_{NE})	0	-90
2	130	0	-60
3	167 (V_{NE})	0	-20
4	185 (V_D)	0	-10
5	185 (V_D)	-5	-8
6	185 (V_D)	+18	-8
7	130	-17	0
8	150	-13	0
9	167 (V_{NE})	-10	0
10	185 (V_D)	-5	0
11	202.8 (V_D + 30ft/sec)	+2	0
12	202.8 (V_D + 30ft/sec)	+5	0
13	185 (V_D)	+18	0
14	167 (V_{NE})	+20	0
15	150	+22	0
16	130	+24	0

Figure 12. Case studies for design loads

[13] Hardness SHORE A ref. ASTM D2240, creep tests in compression at 50°C and 70°C, thermal analysis, DSC and crystallization.
[14] The maximum load is the limit load increased by a multiplication factor of 1.5.

1.16.5 Aerodynamic loads during the event

Based on the FDR data, a simulation was performed using CFD (Computational Fluid Dynamics) to calculate the loads to which the helicopter was subjected during the event. The objective of the simulation was to determine the most critical loads on the windows. The whole flight was not simulated, but only the most critical conditions towards the beginning of the event. The simulation included 17 conditions with various combinations of speed, pitch angle (0-20°) and roll (0-90°).

In general, the calculations have a limitation because the CFD model assumes steady conditions while the event was characterized as being non-steady. In this sense, all results obtained must be considered inferior, by far, to those that took place during the real event.

<u>Areas with the greatest loads:</u>

The study results confirmed that the windows subjected to the greatest pressures were precisely those affected during the event:

- The right side of the helicopter was subjected to suction, with the pilot's window coming under the most pressure.
- The left side of the helicopter was subjected to overpressure, with the central window of the passenger cabin receiving the most pressure.

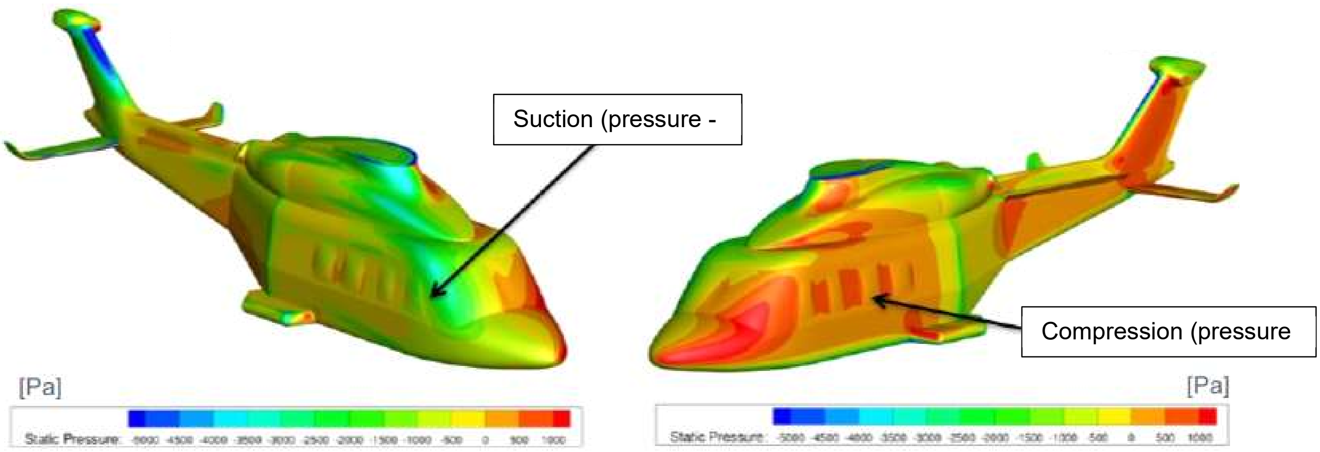

Figure 13. Pressure diagram for case study (0° pitch angle, 30° roll angle)

<u>Release sequence</u>

The aerodynamic study of the event made it possible to determine that the sequence of events in the detachment of the windows was as follows: first, the pilot window, and then the passenger cabin window.

1.16.6 Study of the windows under the aerodynamic loads of the event

A Finite Element Model (FEM) was built to study the behaviour of the detached windows. This model considered the displacement in three axes, the aerodynamic loads identified during the event, the thickness of 3.2 mm, a speed of 140 kt and 17 different combinations between pitch and roll angles. As in the CFD model used to analyse the aerodynamic loads, the study did not reflect reality due to limitations associated with steady states. The study did not include boundary conditions, such as the rigidity of the attachment of the windows to the frame, or the effect of the decrease in cabin pressure after the detachment of the first window.

Passenger cabin window:

The results obtained indicate that the passenger cabin window would be deformed in the shape of an “s” (second order), when the reality is that the window suffered deformations of the first order (inverting the curvature). The numerical values obtained using this model show a maximum load of 129 kg, less than the 144 kg the window is certified for. Thus, according to this value, the window should not have come off, although it did. To reverse the curvature of the window, the model indicated a required value of 161 kg. This last value is much higher than the 144 kg of maximum compression load certified. That is, before reversing the curvature, the window would have come off, which did not happen. These discrepancies between reality and the model results confirm the extreme complexity of the dynamics during the event, the instability of the loads, the existence of load peaks and the presence of loads much higher than what the window was certified for.

In an attempt to calculate the load needed to detach the window without previously weakening the frame by pulling on the red ribbon, the FEM model was not able to reproduce the boundary conditions related to the installation. Considering that the window was glued to the frame, the reversal of curvature must have weakened the union between the joint and the window frame, making the complete separation possible. In relation to the loads, the conclusions are similar to previous tests: the helicopter was subjected to aerodynamic loads much higher than those it was designed for and very complex dynamics.

Pilot cabin windows:

The simulation results show a value of 113 kg as the total resulting load acting on the cabin window, a value significantly lower than the certification value (197 kg). As in the previous case, the limitations of the model used in these calculations mean that these results should not be granted much weight in relation to the reality of the event.

1.16.7 Yaw certification envelope

The AW139 certification requirements (CS 29.351) establish a slippery flight envelope defined by two points: for 167 kt (V_{NE}) a slip of 15°; for a speed of 100 kt ($0.6V_{NE}$) a slip of 90°. Thus, for a speed of around 140 kt, the speed during the event, a maximum skip of 45° is possible. This value was exceeded by far during the event, in which the helicopter reached angles of 60°-70°.

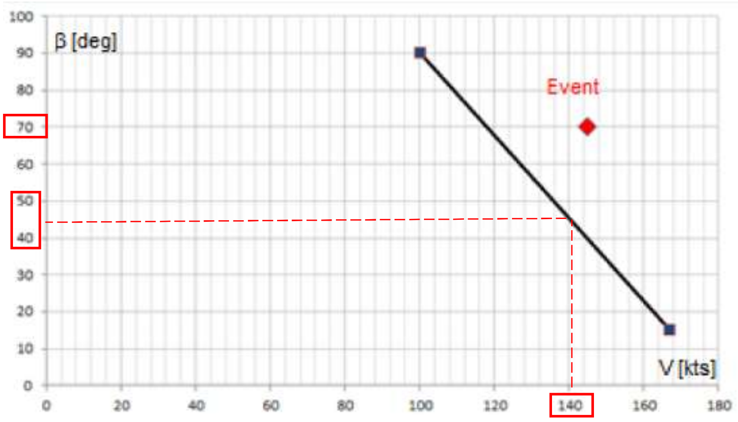

Figure 14. Event with regard to the slip certification envelope

1.17. Organisational and management information

N/A.

1.18. Additional information

N/A.

1.19. Special investigation techniques

N/A.

2. ANALYSIS

The event that occurred on June 12, 2019, with the AW139 EC-NEH helicopter involved a loss of flight control, which developed outside the certification margins, especially in regard to roll and yaw. The investigation has concluded that this loss of flight control led to the following:

- The detachment of two emergency windows, and
- The change to manual control over the control power of the two engines, which was not recognized by the pilot, and which led him to make an emergency landing.

2.1. On the loss of control

Loss of control

The first relevant aspect regarding the loss of control was the pilot's decision to assume full manual control of the helicopter by activating the FTR on the cyclic, collective and pedal controls at 13:30:50. With this action, the pilot cancelled the helicopter's automatic flight system and stabilization system, which had been active until then, and which (as confirmed by the FDR data) had managed to compensate for disturbances produced by the turbulence to keep the helicopter stable.

When the pilot assumed control of the helicopter, the automatic flight system was compensating for the turbulence that had appeared 25 seconds earlier, affecting the pitch angle. In roll, specifically, the helicopter had seen no variations and was stable at around -2°. From this starting situation, the pilot induced abrupt and extreme actions on the controls (cyclic to the left, right pedal down and pulling up on the collective) which evolved into a loss of control which would reach its maximum three seconds later.

The main conclusion of the analysis of the pilot's actions is that they were not related to the actual position of the helicopter and were not coordinated. At this point, the pilot's description of the event becomes relevant, when he states that the helicopter was suddenly in a nose-up position with roll of +90°. This description indicates that the pilot was misperceiving his position in space. This is considered to be the most likely cause of the loss of control.

In order to identify the origin of this misperception, the flight was analysed from the point of view of the helicopter's movements, accelerations and changes in position, the geographical and visual environment of the event, and the tasks, activities and movements the pilot performed prior to the event.

Prior flight

The loss of control occurred in a properly planned flight, with weather conditions suitable for visual flight, with no pressure, and carried out by a qualified pilot with extensive experience who, in addition, was not fatigued due to activity.

During the 53 minutes prior to the event, the flight (except for some difficulties making contact with ATC due to lack of coverage) had passed without incident. The flight was not in a congested area that could have increased the pilot's workload, nor were there previous events that could have affected the pilot's cognitive and attention abilities.

With regard to the pilot's state of activation or alert, of the total 53 minutes of flight, 52 minutes were flown with the Flight Director coupled with the autopilots, decreasing the pilot's number of "active" tasks. The term "active" here means those tasks that, in view of the analysis, show that the pilot carried out conscious actions on controls or switches. During the flight at hand, the changes in FD mode, modifications of the reference parameters in the FD and communications with ATC are evidences of the pilot's "active" state. The FDR and CVR review showed that during the first 20 minutes of flight, the pilot's interventions were much more frequent (every 1-4 minutes) than during the rest of the flight (every 5-13 minutes). With regard to the timing of the event, the last evidence of the pilot's activity occurred 5 minutes earlier. 15 seconds prior to the start of destabilization, the pilot started to modify the reference altitude, which he did not complete. Therefore, it is considered that there are indications of a possible low activation state due to the flight phase, the area where the event took place, the lack of external stimuli and a low workload required for the flight at that time.

Geographically, the event occurred over a mountainous area. The pilot, who had performed fire-fighting work, was familiar with flying in low-altitude mountain environments. The possible effects of instability in the atmosphere were not new to him. Flying in this environment should not have been a novel situation. The FDR confirmed that, as indicated, the pilot in his narration of the event, the flight suffered from three phenomena of turbulence during the flight over Serranía de Cuenca. These phenomena occurred 29 minutes, 2 minutes and 25 second prior to the event, and can be classified[15] as light turbulence phenomena when considering their effect on the flight parameters.

8 seconds prior

Within the context of the flight described above, the only circumstance that could be identified prior to its destabilization is related to the third turbulence event. Identified as an upstream, it started 25 seconds prior to the event and continued until 8 seconds before the helicopter appeared to exit this airstream. This exit occurred just when the pilot had selected 7,500 ft on the ALT SEL knob, and this is the only explanation for the pilot not pressing the FD ALTA button to complete the process, as he had done 5 times previously during this flight. Considering that this is a common and frequent process as part of the normal flight routine, failure to complete this task is considered an indication that the turbulence may have affected the pilot in some way.

The analysis of the effects of this turbulence shows that it did not create abnormal variations or positions in the helicopter. The changes mainly affected the pitch angle, which underwent oscillations between -5° and +10°, and the vertical acceleration which recorded a maximum of 1.2 g. These values are not considered exceptional. The helicopter's yaw and roll angles were stable and did not undergo changes with regard to the state prior to the turbulence. These values, both in magnitude and in directionality, should have had no effect on the pilot's steering ability. On the other hand, the flight prior to the accident had taken place in a straight and level path, with no sustained turns. Accelerations had been practically negligible and there had been no changes in visibility that could have contributed to some type of spatial disorientation in the pilot. Tests conducted at the Biodynamics laboratory confirmed these conclusions. With regard to the

[15] According to the UK Met Office Handbook of Aviation Meteorology.

disturbance, the possibility of turbulent wake produced by the TLP program exercises could also be ruled out.

The movement that required the pilot’s actions were reviewed, from the point of view of their contribution to the spatial disorientation. The change of reference altitude in the ALT SEL knob, which is the task he was performing, required the pilot to contact an instrument located in the central position in front of the pilot and did not require any lateral rotation or inclination. The second step, consisting of pressing the ALTA button, did require a turn of his head to the left and down, and although this step was not completed, it is unknown if the pilot did manage to modify the position of his head and body to some degree. In conclusion, with regard to the tasks that the pilot was performing, the first step should not have affected his orientation capacity and the second, which involved a twist and rotation, is the only movement which could have affected him.

Finally, a study completed with CIMA personnel examining the environmental conditions of the flight considered the possibility of a flicker vertigo, given the position and incidence of the sun on the main rotor, as well as the absence of clouds for a maintained period of time. This phenomenon has generated optical illusions in pilots who have suffered from it, and although the tests carried out during the investigation did not provide conclusive results, it is included in this analysis as one of the factors which could have affected the pilot.

Conclusion

The study of the loads and movements, in terms of intensity, frequency and directionality, generated by the turbulence prior to flight are not associated, from a physiological point of view, with the most known and common causes of disorientation. However, the pilot performed actions on the controls compatible with a state of misperception of his position in space. The only explanation involves a possible combination of the following conditions:

- A low activation state conditioned by the flight phase, the area where it was located, the lack of external stimuli and the low workload required by the flight at that time.
- Conditions with the light and the rotor consistent with a flicker vertigo.
- The changes in the pilot’s posture during the change of altitude process performed during turbulence.

2.2. On the detachment of the emergency windows

The event was characterized by being highly unsteady. The helicopter underwent complex and extreme dynamics that exceeded the helicopter's certification limits: In just three seconds, the helicopter reached a roll angle of -140° while producing yaw oscillations with consecutive variations of +54°/s, -31°/s and +70°/s, and variations in pitch angle with alternating maximum values of -12° and 21°.

The investigation into the detachment of the two emergency windows focused on assessing whether this was expected in an event with these characteristics or, on the contrary, the windows should have remained in position. The study examined the loads that the windows should have supported by design, performing studies with CFD and FEM to determine the conditions of the event. These studies, despite presenting limitations due to the inability to reproduce the specific dynamics of the event, have indeed confirmed that the event was highly unsteady and the calculated load values must be considered lower that the actual values that must have occurred during the event. Even with these limitations, the conclusions are clear.

The windows that underwent the most force where precisely those that were detached during the event and the sequence of detachment was as follows: first, the pilot's cockpit window, followed by the left central window in the passenger cabin.

The CVR made it possible to place this moment in time at about 13:50:52, with the appearance of aerodynamic noise in the cabin produced by the intake of air. This noise coincided with the most extreme moments of the event, where the helicopter, traveling at 135 kt indicated airspeed, developed wide opposing variations in yaw while descending and rolled in an inverted position. As a result, the helicopter was subjected for loads which were the cause of the detachment of the two windows.

The pilot's cockpit window, which was not recovered, was the first to detach. While this window showed discontinuities in the gasket adhesive, this did not influence the event or its functionality under both normal and emergency conditions.

In the case of the passenger cabin window, the fact that it came off with the red gasket installed confirms that the loads were much higher than it was designed for. The inversion of the window curvature occurred prior to detachment, confirming that it was subjected to loads even greater than those required for instability, which further increased with the decreased in cabin pressure after the detachment of the pilot cockpit window. Once the curvature was reversed, the window's retention capacity was reduced. And since no adhesive is applied fixing this window to the helicopter, the entire assembly was detached. Calculations indicate that before its curvature reversed, the window should have come off, which it did not. These discrepancies between reality and the model results confirm the extreme complexity of the dynamics during the event, the instability of the loads, the existence of load peaks and the presence of loads much higher than what the window was designed for.

In addition to the theoretical studies, a functional check of the windows was carried out, confirming that the window emergency ejection function was operating correctly in both normal and emergency conditions. Finally, with regard to the analysis of the materials used in the installation of the emergency window, the tests and analyses confirmed that the materials complied with the required specifications and did not show any chemical or physical changes with respect to the new materials.

In conclusion, the investigation confirmed that the detachment of the windows originated in the structural loads produced during the event, detaching at about 13:30:52.

2.3. On switching to manual engine power control

During the flight prior to the event, the parameters N1, N2, TQ (for both engines) and NR, in relation to the position of the collective control, confirmed that the two engines were operating within limits, coupled to the main rotor and following the movements of the collective.

With regard to the event, the investigation was able to confirm, in both engines, an overspeed condition with the power turbines that created values typified as a critical failure of the EEC, which were detected by the two EECs, which caused the automatic change of the operating mode for both EECs. This process, therefore, had two phases which explain why the pilot interpreted that the engines had stopped. The first phase has to do with the overspeed condition and the second with the critical failure.

The turbine overspeed condition, initiated when the N2 exceeded 111% at 13:30:55, caused the engine protection system to enter into operation, minimizing the flow of fuel supplied to the engine in an attempt to lower the N2 below 109%. Even though the protection system was working, as confirmed by the descent of the N1 and the fuel flow, the N2 continued to increase. It is believed that the reason why the protection system could not prevent the two turbines from accelerating further was a combination of the actions on the collective (which was lowered sharply from top to bottom in less than one second), together with the helicopter's evolution (roll angle at about -79°, descending at a speed of -6,500 fpm, and a pitch angle of +22°).

The two turbines continued accelerating up to 13:30:56, exceeding values of 127%, while the N1 was at 80% and fuel flow was at a minimum in both engines. This condition (N2 above 127% and N1 above 70%) started the second phase at 13:30:56, which changed the EEC operating mode from AUTOMATIC to MANUAL in both engines at the same time. This change was not commanded by the pilot, but was automatic. When this occurred, the overspeed protection system was operational. This system would hold for several more seconds and brought down the N1 to about 60% and N2 to below 109%.

This active state of the protection system was the reason that the pilot did not notice an effect on power when he pulled the collective at two seconds, because the fuel was being restricted to the minimum.

Later, the pilot’s use of the collective did not have a response in the power because, at this time, the EEC being set to MANUAL disabled the control of the fuel through the collective. This double condition was what led the pilot to misidentify that the engines had failed.

Because the pilot had not identified the switch to MANUAL, he was unable to perform fuel management through the ECL levers, which remained set in the FLIGHT position for the remainder of the flight. When the overspeed protection system was disabled, the engines accelerated to where they had been set when the system changed from AUTO to MANUAL, which corresponded to an N1 value of about 80% and a TQ close to 60%.

In conclusion, the operation of the engines before, during and after the event was as expected, ruling out operational problems or any contribution to the accident.

2.4. On the descent and landing

The rest of the flight, after the EEC change, because no action was taken on the ECL levers to take control of engine power, consisted of a descent with the active engines developing power up to the levels prior to the change from AUTO to MANUAL.

The descent, which was carried out in a controlled manner, had a rather unstable profile with a multitude of warnings generated mainly due to the difficulties in controlling the revolutions of the rotor and turbine and the excessive speed of descent which caused ground proximity system warnings. Despite everything, the landing was satisfactory, with limited damage to the helicopter and the pilot.

The main conclusions regarding the landing indicate that the helicopter made contact with the ground in a level, aligned manner, with velocity (700 fpm and 12 kt IAS) as it advanced, rolling on the landing gear for 57 metres.

Damage to the helicopter undercarriage, lower fuselage, main rotor and left raft occurred during touchdown and ground taxiing, and did not contribute to the accident, occurring only moments prior to the stopping of the helicopter.

3. CONCLUSION

3.1. Findings

General:

- The flight went smoothly prior to the event.
- The flight passed through three zones of light turbulence, the last of which was immediately before the destabilization and loss of control.
- The automatic flight system was active and functioning properly until the beginning of the helicopter’s destabilization.
- The automatic flight system had compensated for disturbances in the turbulence zones, keeping the helicopter stable and level prior to the event.

Event:

- The event began with the pilot assumed full manual control of the helicopter through the FTR of the cyclic, collective and pedal controls.
- The loss of control resulted in a maximum roll angle of -140° over three seconds, coupled with alternative variations in yaw rate of +54°/s, -31°/s and +70°/s and variations in the pitch angle with alternating maximum values of -12° and 21°.
- The loss of control was caused by the commanded actions of the pilot through controls. These actions were unrelated to the helicopter’s actual position.
- The loss of control created load forces on the helicopter that caused the detachment of the two emergency windows.
- During the loss of control, the engines suffered from overspeed conditions which exceeded 127% N2. This condition was detected by the EECs, which automatically switched to MANUAL operation mode.
- The EECs change to MANUAL was not detected by the pilot.
- At 11 seconds, the pilot had recovered control of the helicopter.
- The descent was performed with the engines functioning.
- Touchdown and taxiing cased the damage to the undercarriage, lower fuselage, left raft and main rotor.

3.2. Causes/contributing factors

The probable cause of the accident of the EC-NEH helicopter was a loss of control in flight following the disconnection of the automatic flight system through the FTR (Force Trim Release) switches and the assumption of manual control by the pilot. The loss of control was probably due to the pilot's misperception of the helicopter’s actual attitude.

4. RECOMMENDATIONS

None.