Accident

Aircraft Type and Registration:	AW109SP, G-RAYN	
No & Type of Engines:	2 Pratt & Whitney Canada PW207C turboshaft engines	
Year of Manufacture:	2019 (Serial no: 22401)	
Date & Time (UTC):	1 November 2022 at 1726 hrs	
Location:	Nantclwyd Lodge, near Llanelidan, Denbighshire	
Type of Flight:	Non-commercial operation	
Persons on Board:	Crew - 1	Passengers - 5
Injuries:	Crew - None	Passengers - 1 (Serious) 4 (Minor)
Nature of Damage:	Helicopter destroyed	
Commander's Licence:	Commercial Pilot's Licence (Helicopters)	
Commander's Age:	47 years	
Commander's Flying Experience:	3,815 hours (of which 1,565 were on type) Last 90 days - 81 hours Last 28 days - 24 hours	
Information Source:	AAIB Field Investigation	

Synopsis

While climbing away from an unlit field landing site, at a height of approximately 40 ft agl, G-RAYN's main rotor blades struck trees and sustained catastrophic damage. The helicopter fell to the ground, coming to rest on its right side. The fuel tanks maintained their integrity and there was no fire. The pilot was able to shut down both engines and, with the assistance of onlookers, helped the passengers to escape from the cabin. One of the passengers was seriously injured in the accident. Of the five passengers, at least four had not fastened their seatbelts prior to departure.

No causal or contributory technical factors were identified with the helicopter during the investigation. The investigation found that the accident resulted from the unintended rearward transition of the helicopter into a stand of trees during a planned vertical departure at night from an unlit field landing site. The flight had been scheduled as a day departure but the takeoff became delayed until after nightfall.

The investigation found several operational barriers which might have prevented this accident but were either breached or not present. These included a misunderstanding of the applicable operator-level restrictions for the non-revenue flight being undertaken and opportunities missed during the planning process to anticipate and mitigate for flight delays.

Distraction and time pressure led to the pilot not completing auditable weight and balance (WB) calculations before leaving Biggin Hill, this potentially contributed to the helicopter being overweight when it took off on the accident flight. While the pilot had assessed the available lighting as sufficient for the intended takeoff profile, the visual cues available to him on the night proved inadequate for the detection of the subsequent unintentional rearward drift toward the trees behind the helicopter.

The passengers did not exert any pressure on the pilot to delay beyond the planned departure time, and the pilot did not consider that a night departure would pose an unacceptable risk.

The investigation thought it likely that, had all passengers been secured by their seat harnesses, the level of injuries sustained could have been less severe. For frequent flyer passengers, or those focused on time pressures, it might be tempting to see safety briefings and seatbelts as an unnecessary encumbrance. In helicopters with seating and cabin configurations like G-RAYN's, once pilots are in their seats, it is not possible for them to visually check the security of their passengers' seatbelts/harnesses. Nonetheless, it is important for all parties to understand that an aircraft commander is under a legal obligation to ensure passengers are appropriately briefed and have their harnesses secure for all takeoffs and landings.

While the pilot carried out a strategic pre-flight risk assessment, a more effective and targeted tactical Threat and Error Management (TEM) approach to each phase of the operation could have provided an additional safety barrier for the flights being undertaken.

Following the accident safety action has been taken by the operator to improve its night flying procedures, ground equipment and training.

History of the flight

The pilot flew G-RAYN from Biggin Hill on the morning of 1 November 2022 tasked with transporting five passengers to and from a field landing site in North Wales for a day's game shooting. The helicopter was owned by the lead passenger, but routinely maintained and operated by the third-party operating company who provided the pilot. For flights in support of the owner's requirements, G-RAYN was operated as a non-revenue flight under the regulations for '*non-commercial air operations with other-than complex motor-powered aircraft'* (NCO)[1]. It was being flown by one of the operator's '*company approved*' pilots contracted by the owner on a daily rate.

The pilot arrived at Biggin Hill at approximately 0645 hrs. His scheduled duty check-in time was 0700 hrs, 30 minutes before takeoff. While he had arrived early, much of that extra time was taken up with an unanticipated supportive conversation with a very recently bereaved colleague. The pilot self-briefed the weather, refuelled G-RAYN to approximately 600 kg of fuel and completed the prescribed pre-flight walk round check of the helicopter before taking off at 0727 hrs.

Footnote

[1] UK Regulation (EU) No 965/2012, Annex VII.

Having flown G-RAYN from Biggin Hill, the pilot landed at the helicopter owner's private landing site (Lisvane) north of Cardiff at 0830 hrs and embarked the five passengers and their luggage. The flight from Cardiff to North Wales was uneventful and the helicopter landed near Llanelidan at 0920 hrs. The field landing site was listed in the operator's company landing site directory (CLSD) with the reference code LEA2. The designated landing location was a flat area of grass adjacent to a stand of trees and a shooting lodge (Figure 1). To the northwest of the landing area the ground sloped down and away toward several isolated trees, as indicated by the chevrons in Figure 1.

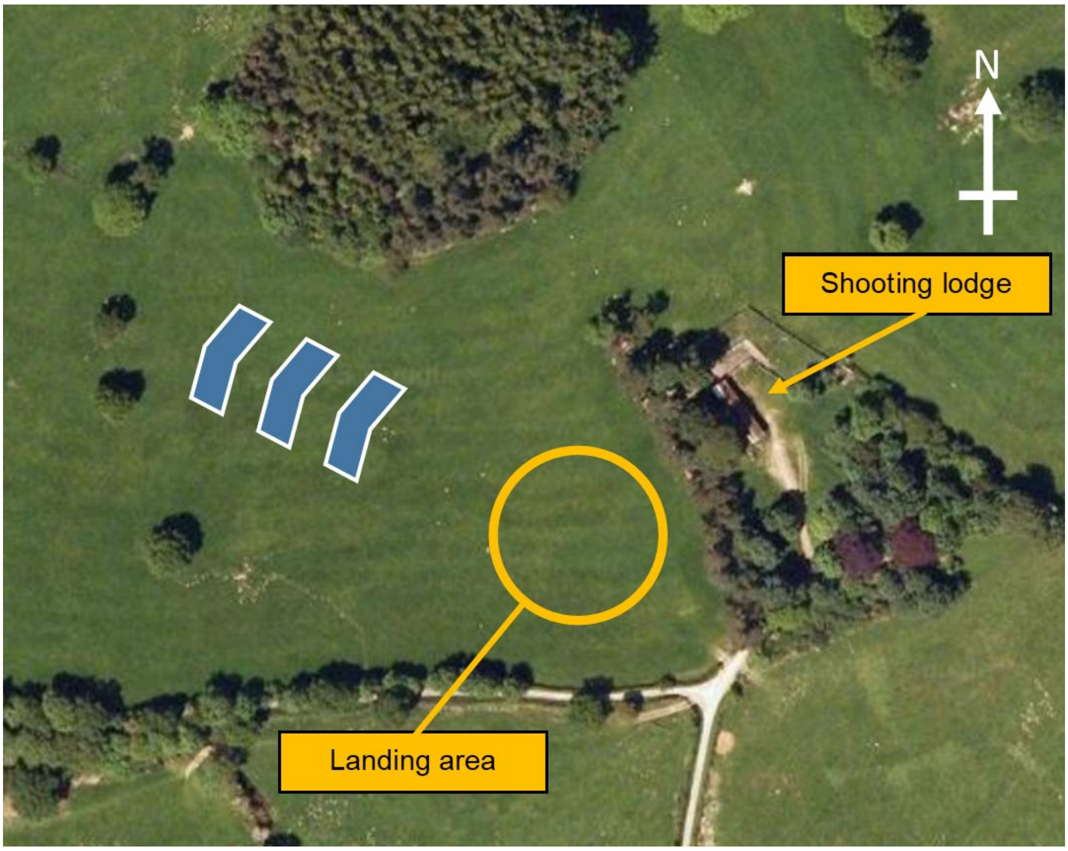

Figure 1

LEA2 field landing site near Llanelidan
(©2023 Bluesky, Infoterra Ltd & COWI A/S, CNES / Airbus, Getmapping plc, Maxar Technologies)

After disembarking his passengers, the pilot flew G-RAYN to Hawarden Airfield (Hawarden) to refuel. The pilot's firm recollection was that, after arriving at Hawarden, he refuelled the helicopter to 400 kg, calculating his required uplift of 250 kg[2] from the indicated fuel quantity he observed prior to shutdown. The total fuel quantities recorded by the helicopter's onboard systems were 206 kg on arrival at Hawarden and 456 kg when it departed for LEA2[3].

Footnote

[2] Receipted uplift of 320 litres of Jet A1 fuel with an assumed specific gravity of 0.78.

[3] See *Recorded data/Recorded fuel quantity* section.

The tasking for the return flight showed a scheduled departure time from LEA2 of 1630 hrs. Sunset was at 1645 hrs, with the end of official evening civil twilight, marking the transition from twilight to night, occurring at approximately 1718 hrs[4].

The passengers were not ready to depart on schedule and remained in the shooting lodge until approximately 1715 hrs before walking to the helicopter and taking their seats. The pilot remembered seeing the passengers rearranging their seatbelts after sitting down but did not visually confirm they had securely fastened them prior to the cabin door being closed.

The pilot's recollection was of having approximately 340 kg of fuel on board the helicopter before the flight and that he "took his time" after engine start to burn off additional fuel because he knew the helicopter would be close to its maximum takeoff weight (MTOW). The landing site was unlit but the pilot was satisfied there were sufficient visual references available for him to safely conduct a vertical departure. The helicopter's external lights were illuminating the area immediately around the helicopter and he could see what he described as a "vague horizon" ahead. The pilot judged that lights from the shooting lodge's windows to his right would be an adequate lateral marker for the departure climb.

The pilot reported that, after lifting into the hover, he translated G-RAYN forward and left to increase separation from the treeline and turned into wind. He used the beam from the helicopter's controllable search light to orientate himself in relation to the nearest trees. The pilot then directed the beam forward and down to illuminate the grass ahead of the helicopter before committing to the departure. The initial climb proceeded as the pilot expected but passing approximately 30-40 ft, he felt what he described as a "massive jolt" and immediately ascribed it to a significant rotor head imbalance. The helicopter began shaking violently and fell to the ground, ending up on its right side. Eyewitnesses, who were standing at the edge of the treeline behind G-RAYN and watching it take off, reported not hearing or seeing anything unusual with the helicopter prior to it striking the trees.

After the helicopter stopped moving, the pilot orientated himself in the cockpit, unstrapped and stood up to open the left cockpit door, which was by now above him. He reported hearing the engines still running and that he then turned the engine controls to OFF and closed the fuel valves. After doing this, the pilot could still hear a high-pitched whining noise which he determined was the rotor head spinning at high speed. He applied the rotor brake to try and stop it turning but this had no discernible effect.

The pilot climbed out onto the left, now top, side of the helicopter and opened the cabin door so the passengers could escape. Four of the passengers were able to vacate the helicopter with varying degrees of outside assistance but the fifth was lying unconscious at the bottom of the cabin. Through the combined effort of the pilot, the other passengers and some onlookers, the unconscious passenger was manually extracted from the helicopter. At this point he was in significant medical distress. The casualty was carried to the lodge and CPR was administered by the pilot under the guidance of the emergency services operator. After the application of CPR, the casualty regained a reportedly "more-normal" colour but did not fully regain consciousness. He sustained serious injuries in the accident and was subsequently hospitalised for several months.

Footnote

[4] See *Meteorology* section.

Accident site

The helicopter came to rest at the base of a tree approximately 30 m from the shooting lodge. The main fuselage of the helicopter was intact but the tail boom had separated and been thrown forward of the point of ground impact (Figure 2).

Figure 2

Overhead view of G-RAYN accident site

There was a large amount of debris spread around the surrounding area, mainly consisting of fragments from the rotor blades and branches from the trees. A detailed GNSS plot was taken of the main components of wreckage, impact marks and debris. There was no evidence of fuel leaks and there was no post-crash fire. There were clear impact marks near the top of the trunk of the tree adjacent to the helicopter wreckage and a significant swathe of branches had been cut from the top of this tree and landed adjacent to the main fuselage (Figure 3).

Figure 3

Ground view of main accident site

Helicopter description

General

The AW 109SP is a member of the Agusta family of twin engine, light class helicopters. The SP version features three main modifications: the introduction of a new composite fuselage structure material, a four-channel digital autopilot and a new cockpit layout with four Chelton display units (EFIS) and integrated COMM/NAV management system. The SP has a fuel system designed to be crashworthy such that in the event of an accident the amount of fuel that leaks from the tanks is kept to a minimum. The helicopter is powered by two Pratt and Whitney Canada PW207C turbine engines. The AW109SP was designed to meet the certification requirement[5] of providing '*reasonable protection*' to each occupant from the dynamic loads experienced in a crash landing if they are properly using the seats, safety belts, and shoulder harnesses.

Fuel system

The fuel storage system has two main forward independent tanks, one main rear tank and two auxiliary fuel tanks. Each main forward tank supplies fuel to its associated engine, the forward tanks are gravity fed by the rear tank. The total usable fuel capacity of the main tanks is 563 litres (450 kg)[6] with the auxiliary fuel tanks providing an additional 184 kg capacity. The fuel system is installed inside the helicopter and fuel vent lines are bonded to the airframe and are fitted with flame arrestors.

Fuel indication

The fuel indicating system (Figure 4) consists of the fuel monitoring and indicating systems to provide fuel system malfunctions and system indications. The fuel indicating system gives a continuous indication of the quantity of fuel contained in the fuel tanks and the pressure in the fuel system. Five variable-capacitance fuel probes are installed inside the tanks (two probes in the left bottom tank, two in the right bottom tank, one probe in the top tank). The tanks sense the difference in the dielectric constant of fuel and air. A change in the fuel level in the tank causes a change in the probe capacitance. Two independent electrical lines supply the Fuel Control Unit (FCU) with 28 V DC electrical power. When the quantity of fuel in the tank changes, the probes send an electrical signal to the FCU, which processes it and then sends proportional output currents to the Data Acquisition Unit (DAU). The latter sends the fuel quantity signals to the No 2 Electronic Display Unit (EDU) where the fuel quantity is continuously displayed. Another function of the FCU is to continuously monitor the system for faults. The FCU has two independent channels (left and right) and faults are monitored at channel level: when the analogue output signal of either FCU channel is less than 1.93 mA, the affected fuel quantity readout displays a white box with three red dashes.

Footnote

[5] As prescribed in CS 27.562 of Certification Specifications, Acceptable Means of Compliance and Guidance Material for Small Rotorcraft CS-27, dated 14 November 2003.

[6] Based on a specific gravity of 0.8 for Jet A1 Fuel.

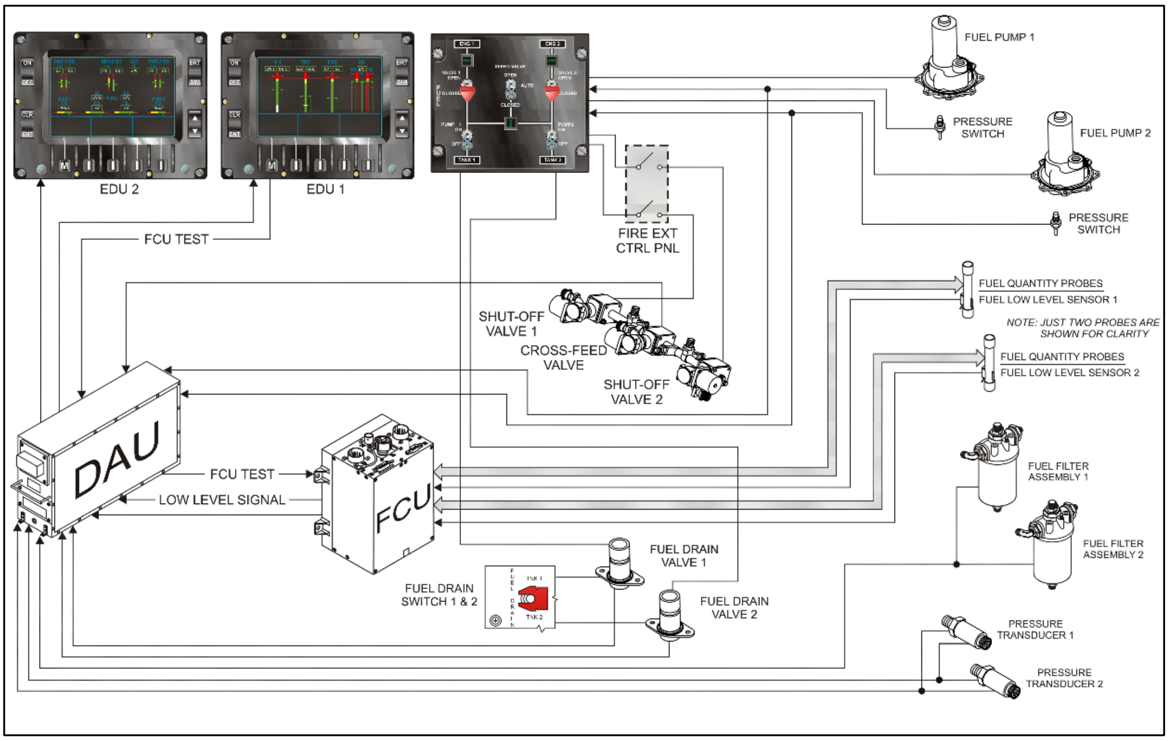

Figure 4

Fuel indication system schematic

Fuel quantity is displayed to pilots as separate totals for the left and right tanks rather than being presented as a single combined fuel total (Figure 5). Pilots are required to mentally sum the figures to calculate the total amount of fuel on board.

Figure 5

EDU fuel display

Helicopter cabin

Crashworthy seating and seatbelts are provided for the pilot and for the co-pilot. The seat structure consists of two lateral carriers milled from high tensile aluminium alloy. Between those carriers the seat bucket and the backrest are fixed. These two parts are made of an aramid and carbon fibre material. The seat is equipped with an approved four-point safety belt system: lap belts are fixed on the seat while shoulder belts are guided by an aluminium tube downward to the inertia reel fixed on the rear of the backrest. The front edge of the seat pan is hinged to the two carriers. Two links struts connect the rear edge of the seat bucket with two energy absorbers mounted in the carriers. Under severe vertical loads the seat pan rotates downward at its rear edge so that the load on the spinal column is reduced.

The passenger/cargo compartment occupies the rear portion of the cabin, access is provided by large sliding doors on each side of the helicopter. The passenger seats are provided with a fibre-reinforced structure to which the seat cushions attach by Velcro fasteners. The seats are also provided with a removable headrest. A four-point safety harness with a quick-release coupling holds the occupant to the seat. The four ends of the belts are fixed to the seat bucket. The shoulder-belt is guided over the upper edge of the seat bucket downward to the inertia reel. The inertia reel is fixed to the rear of the seat bucket and is equipped with a manual lock device for the shoulder belts. The seats are supported by two boomerang-shaped legs made of a high tensile aluminium alloy which carry the seat bucket and contain the energy absorbing device and act as rails for vertical stroking when severe vertical loads are applied to the seat assembly.

Helicopter maintenance

The Airworthiness Release Certificate was valid until June 2023. Responsibility for operation and maintenance of the helicopter had transferred to the operator in September 2022. After receipt and induction of the helicopter onto the operator's Continuous Airworthiness management system an annual maintenance was undertaken on the helicopter in October 2022. During this maintenance an issue with the fuel indication system was identified. After extensive fault diagnosis the cause was isolated to the FCU which was replaced. No further anomalies with the fuel control system were highlighted by crews in the technical logbook for the 26 sectors flown between the annual maintenance and the last recorded flight on 31 October. No technical logbook entry had been opened for the 1 November series of flights.

Recorded information

Introduction

The helicopter was not fitted with a flight data recorder or cockpit voice recorder, as neither was required by regulation. However, recorded data was available from the helicopters two Multi-Function Displays, two Primary Flight Displays, the DAU and two engine Data Collection Units (DCU). This provided time series data recorded at a rate of once per second, for the helicopter's most recent five hours of operation, which had been accrued between 30 October 2022 and 1 November 2022. Recorded parameters included the helicopter's indicated airspeed, groundspeed, altitude, normal acceleration, GNSS derived position, pitch and roll attitude, heading, total fuel quantity, rotor rpm (Nr) and engine collective position, torque, N_1 and N_2 speeds. The DAU and DCUs also provided snapshots of engine and system related faults and exceedances.

A tablet computer was fitted in the cockpit, which was operating a software navigation application[7]. This provided a recording of the helicopter's GNSS derived position, altitude, and groundspeed. The software application could also be used by the pilot to calculate the helicopter's WB.

Image footage and ambient sound of the helicopter during the accident takeoff was captured by a CCTV camera fitted to a private dwelling located 290 m south of the accident site. The helicopter's external lights were evident in the footage, which included its anti-collision lights fitted to the upper and lower fuselage, position lights fitted to the left horizontal stabiliser and end of the tail boom, and landing/taxi lights on the left sponson.

Accident flight

The recorded data showed the helicopter was parked on a heading of 315° and positioned (Figure 6) about 23 m from where it subsequently struck trees.

At 1722 hrs the No 1 engine was started, followed about 90 seconds later by the No 2 engine. The helicopter lifted into the hover (Figure 7 Point A) at 1726:06 hrs and made a left turn onto a heading of 305°; engine torque was 88% and the recorded fuel quantity was 405 kg. The helicopter's pitch attitude was about 6° nose-up and the collective was gradually raised, with engine torque increasing to 91%. This coincided with the start of the CCTV footage, which subsequently showed the helicopter moving slowly backwards towards the stand of trees. The engine torque continued to increase, and the helicopter climbed while also turning left onto a heading of 287°. The helicopter's pitch attitude had briefly reduced to about 3° nose-up during the turn, but then increased to nearly 8° nose-up (Figure 7 Point B and Figure 8). The pitch and roll attitude then stabilised at about 7° nose-up and -3° left roll, with the helicopter now having climbed to approximately 25 ft agl (Figure 7 Point C and Figure 9).

The collective was raised further, and engine torque increased through 106%. A few seconds later, at 1726:28 hrs, while travelling backwards at a groundspeed of about 7 kt and at a height of approximately 40 ft agl, the helicopter struck the stand of trees. The main rotor rpm (Nr) rapidly reduced from 100% and the helicopter pitched down to nearly 50° and rolled left to 83° as it then descended. Very shortly after, the helicopter struck the ground in a nose-down attitude before rolling onto its right side, where it came to rest. A few seconds later the No 2 engine was shut down, followed about one minute later by the No 1 engine. The main rotor head stopped rotating about 30 seconds later.

The audio from the CCTV camera contained sounds consistent with the rotation of the helicopter's Nr and tail rotor. The derived rotational speeds were consistent with the data recorded by the helicopter. There was no evidence of unusual sounds prior to the helicopter striking the trees.

Footnote

[7] SkyDemon, VFR Flight Planning Software and GNSS Navigation [accessed 14 November 2023].

The WB function of the software navigation application was reviewed with the assistance of its manufacturer. This showed that for the flights flown on 1 November 2022, the pilot's weight was set at 85 kg, co-pilot, passengers and luggage were set at 0 kg and the total fuel was set to 640 kg. An additional 108 kg was also set for "floats"; although these were not fitted to G-RAYN. Based on these settings, the application would have provided a visual alert because the helicopter's WB were outside of the limitations entered into the software.

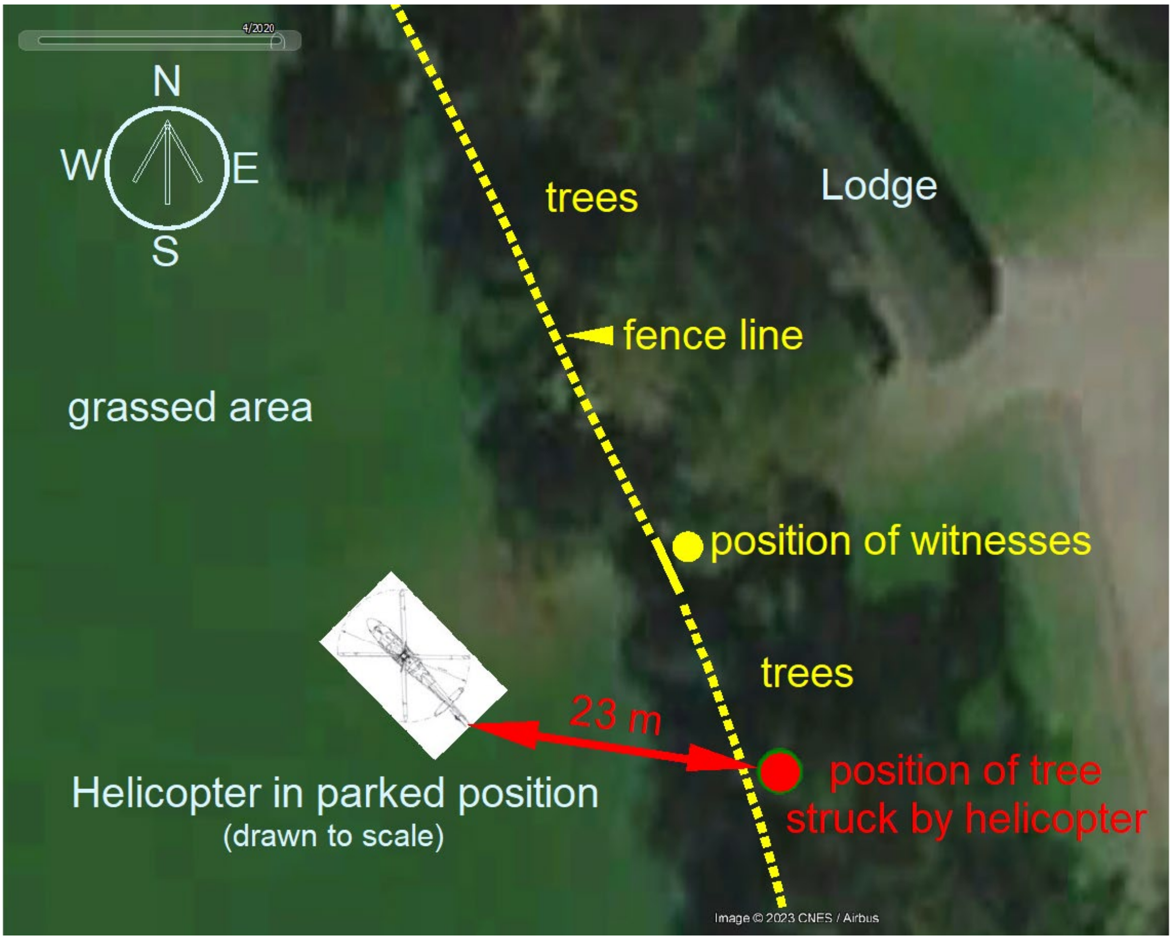

Figure 6

Position of helicopter prior to takeoff
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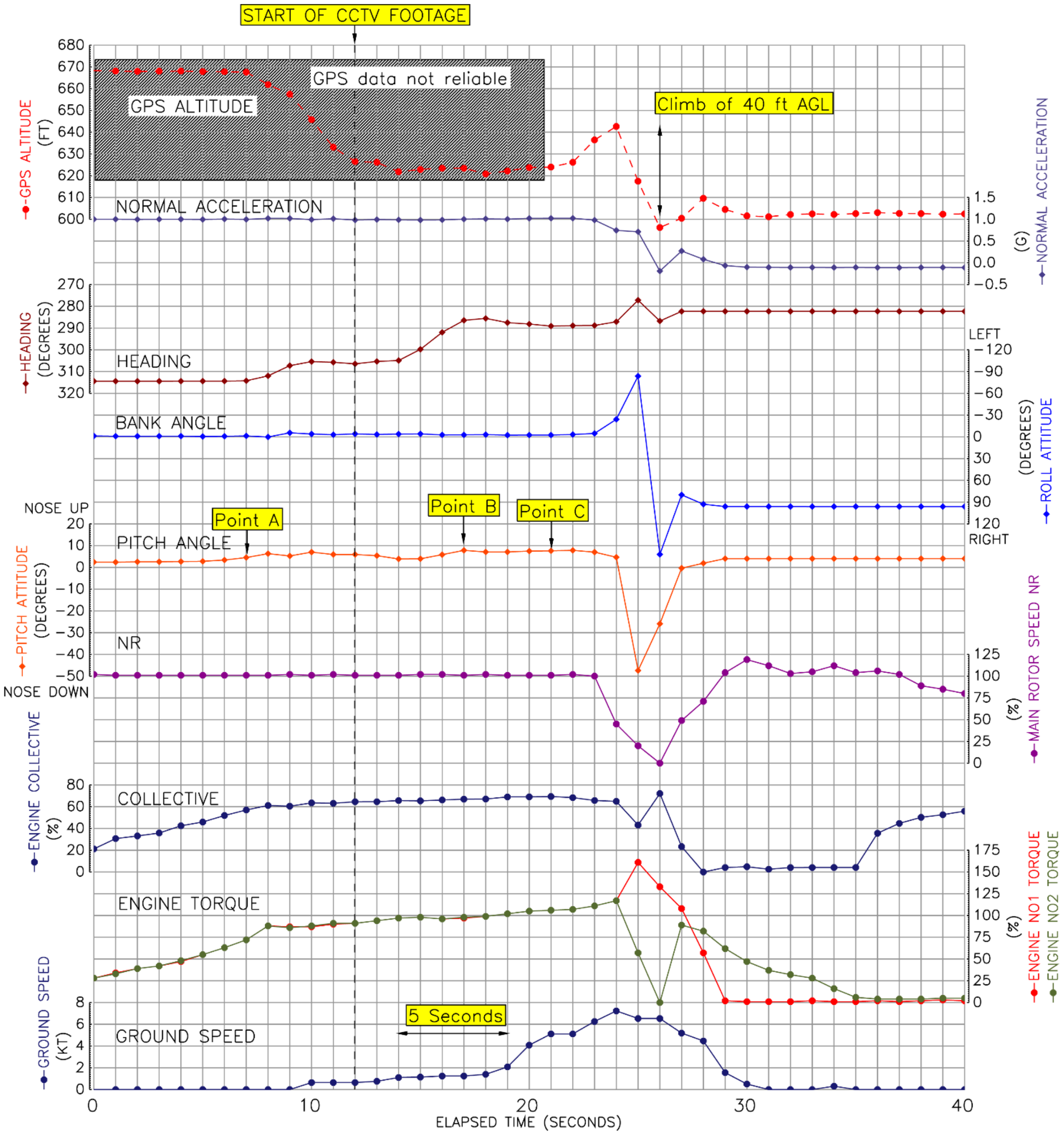

Figure 7

Flight data during the accident

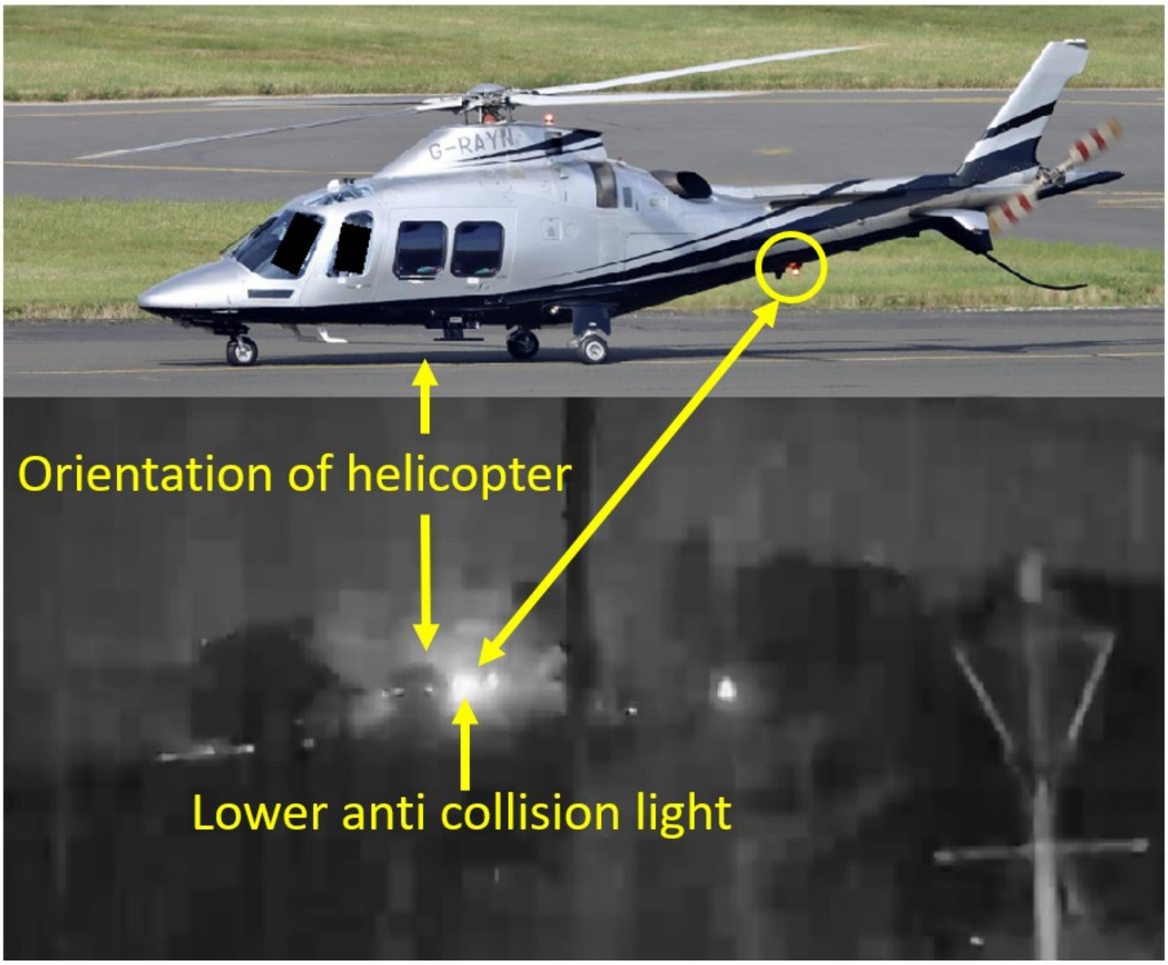

Figure 8

CCTV image as the helicopter started to climb

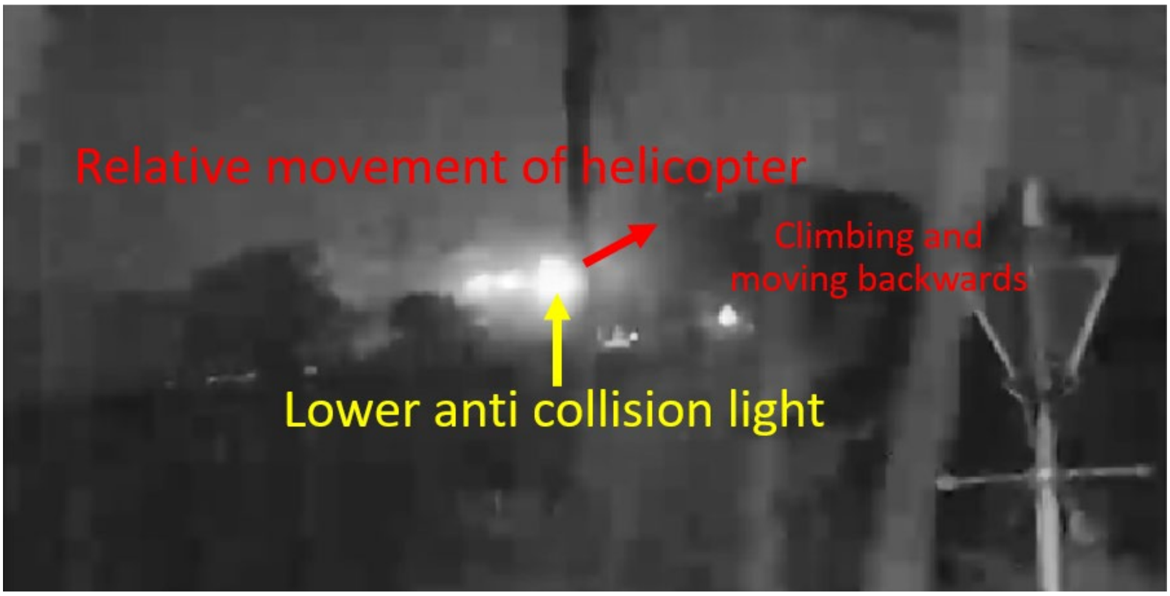

Figure 9

Image of helicopter shortly before striking trees

Recorded fuel quantity

Table 1 shows, in sequential order, the helicopter's total fuel quantity recorded at takeoff for each of the flights flown on 1 November 2022. Upon landing at Hawarden, the sensed fuel quantity was 206 kg and upon recommencement of the recording, when the helicopter was on the ground, the total fuel quantity had increased to 456 kg. This was consistent with the receipted uplift of 320 litres of Jet A1 fuel with an assumed specific gravity of 0.78 which equates to just less than 250 kg.

Takeoff location	Fuel quantity (kg)
Biggin Hill Airport	592
Lisvane	380
Lodge (LEA2)	245
Hawarden	448
Lodge (LEA2)	405

Table 1

Recorded fuel quantity during takeoffs on1 November 2022

Aircraft examination

A general visual inspection of the wreckage was conducted. While the main fuselage body was intact the nose was damaged and the tail boom had detached from the fuselage. The main rotor blades had all detached from the rotor head and were severely damaged.

A detailed inspection of the upper deck including the Main Gearbox (MGB) and Rotor Head was performed. All the main rotor pitch links and rotating scissor were severed. The fracture surfaces of these damaged components exhibited the characteristics of overload failures.

The No 1 hydraulic system filters were intact, but the No 2 system filters had both 'popped.' These filters sense a differential pressure of 70 psi between inlet and return. They are spring loaded and magnetic and can be set off by impact forces.

Several locking nuts on the bolts on the case connecting the MGB with the rotor head were found not properly in contact with the joint surface of the MGB upper case. These were all on the right side of the casing. However, it was determined that this happened during the lifting operation to recover the aircraft which caused the bolts to stretch; the vector of force during the lifting operation would have initially been at 90° to the rotor head which would have placed a bending moment on the rotor head and placed these bolts under tension.

Flying controls

The flying control system was examined. A visual check of the system did not reveal any damage to the flying control rods or linkages up to the damaged section of the rotor head.

The upper deck panels were removed and flight controls disconnected from the servo actuators to check the free movement of the mechanical link and continuity of movement.

From the co-pilot position the cyclic and collective full range of movement was achieved with the mixer unit reaching its backstops. However pedal movement was limited by nose deformation and the control run could only be checked up to the yaw actuators, due to the tail detachment at this section.

From the pilot position the cyclic and collective operation resulted in full and free range of movement of the mechanical flying controls. To fully examine the system in yaw the co-pilot controls were disconnected from the connecting bar to see if full and free range of movement could be achieved using the pilot's pedals. The range of movement on the pedals was different with greater movement on the right pedal than the left. The control mechanism would hit the forward backstops on the servo but not the rear backstop. There remained a clearance of approximately 4 mm.

Examination of the fuselage showed impact damage that corresponds with the location of the control run for yaw channel. Borescope inspections in this area revealed some impact damage and a foreign object that had likely entered the structure during ground impact. It was not possible to assess if the control rod was distorted, but examination of the routing of the control run showed it contacting some of the surrounding structure. The extreme forces needed to separate the tail rotor boom from the fuselage would have resulted in high bending moments being applied to the fuselage and yaw control run which would have distorted its alignment.

Tail boom and tail rotor

Inspection of the detached tail boom and the tail rotor showed impact marks on the left side of the tail. One of the tail rotor blades was cut at the root and the other one damaged. The tail rotor blade that detached had impact damage on its leading edge. The tail rotor drive shaft was twisted at its broken section confirming rotation at the moment of impact. The tail rotor output shaft was distorted as a result of the high bending moments applied during the impact with the trees.

Cockpit survey

The following observations were made from a survey of the cockpit:

- Fuel Control Panel: both shutoff valve switches were found in the CLOSED position, the XFEED valve switch was in the AUTO position.
- Rotor Brake lever in ON position.
- Engine Control Panel: ENG 1 knob found in IDLE, ENG 2 knob in OFF position.
- Landing lever in DOWN position.
- Overhead panel: Engine levers in flight position (the Engine Control Panel overrides this throttle position).

- NO 1 and 2 GEN BUS switches in OFF position (as expected being a magnetic retaining type).
- Two circuit breakers had tripped: WRX and Anti-collision light breakers. No other circuit breakers had tripped.

Avionic units

The Flight Control Computer and FCU were inspected and found to be physically intact. These were removed for further testing. Similarly, both engines' Digital Control Units (DCU) were inspected and removed so that data from these could be extracted.

Organisational information

Basic regulation

Regulations for air operations with aeroplanes and helicopters within the UK are detailed in UK Regulation (EU) No 965/2012[8] (965/2012). These regulations include detailed rules for operators of aircraft engaged in both commercial and non-commercial air activities. The regulations are intended to be proportionate, with the most stringent criteria being applied to commercial air transport (CAT) operations. Aircraft operators may further limit the scope of their activities by publishing more restrictive guidance for their own operations. Requirements for '*non-commercial operations of an AOC holder with aircraft listed on its AOC*' are detailed in 965/2012 at ORO.AOC.125.

Company operations manual

G-RAYN's operator published an operations manual (OM) containing instructions to be followed by its personnel. Compliance with the OM was required to ensure that all CAT flights were planned and executed in accordance with applicable policies and requirements. The OM contained a statement that it had been '*issued in accordance with the EASA Implementing Rules*' and that it complied with the acceptable means of compliance and guidance material contained within Annex III to 965/2012, '*Organisation Requirements for Air Operations*' (Part-ORO), and with the terms and conditions of the company's Air Operator's Certificate.

The OM consisted of four parts, published as separate manuals:

- **Part A (OMA) General**: non-type-related operational policies, instructions, and procedures.
- **Part B (OMB) Type-Related Helicopter Operating Matters**: type-related instructions and procedures, including differences between types, variants, and individual helicopters.

Footnote

[8] Available at Commission Regulation (EU) No 965/2012 of 5 October 2012 laying down technical requirements and administrative procedures related to air operations pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council (Retained EU Legislation) (caa.co.uk) [accessed 16 January 2023].

- **Part C (OMC) Route & Aerodrome Instructions**: instructions and information needed for the area of operation.
- **Part D (OMD) Training**: training instructions for personnel.

The OMA required that '*every flight undertaken by the Company for whatever reason shall be conducted in accordance with the provisions of* [the] *Operations Manual*.' While the OMA was written primarily to support CAT operations it did allow for differences when conducting non-revenue flights. The scope of non-revenue flights listed in the OMA included '*flights for a private owner using their aircraft with company approved pilots.*' The accident occurred on a non-revenue, NCO flight, flown by one of the operator's pilots.

The OMA[9] listed specific differences from the CAT requirements for non-revenue and non-CAT flights. These included:

- fuel requirements,
- IFR destination alternate requirements,
- helicopter performance criteria,
- pilot age limitations,
- helicopter flights over water, and
- pilot licensing requirements for IFR flights.

The OMA also gave guidance regarding the degree of flexibility that could be used in the following areas for non-revenue flights:

- flight time limitations,
- long term CAA permissions and exemptions,
- carriage and use of an electronic flight bag, and
- night helicopter landing site (HLS) operations.

Specifically, the OM contained no derogation for night HLS operations, stating[10], '*all Categories of flight, (CAT/SPO/NCC/NCO) shall without exception, shall* [sic] *be flown IAW the Company Operations Manual.*'

The investigation heard that, culturally within the industry, NCO operations for helicopter owners in their own aircraft were often referred to as 'private' flights; a description used before the category NCO was adopted by regulators to encompass such activity. This legacy terminology contributed to the pilot's misunderstanding that, being a 'private' flight, he could choose to apply commander's discretion regarding all additional limitations contained within the OMA, provided he complied with the higher-level regulations of 965/2012.

Footnote

[9] OMA 8.7 '*Non-revenue / Non-CAT Flights*.'

[10] OMA 8.7.9 '*Night HLS*.'

Training and checking

Part-ORO specifies the requirements to be followed by an air operator conducting CAT and non-commercial operations with complex motor-powered aircraft (NCC) operations. Part-ORO subpart FC (Flight Crew) establishes requirements to be met by an operator in relation to flight crew training, experience, and qualification. ORO.FC.230 details the requirements for recurrent training and checking, including the requirement for operator proficiency checks (OPC) ORO.FC.202(b) '*Single-pilot operations under IFR or at night'* stipulates that '*the recurrent checks required by ORO.FC.230 shall be performed in the single-pilot role on the relevant type or class of aircraft in an environment representative of the operation*.' Due to the diverse range and scope of operations covered by these regulations, the UK Regulator does not explicitly specify more detailed requirements for proficiency checks, instead delegating that to individual operators. The investigation found that the UK Regulator's interpretation was that, for an operator that conducts night operations, '*an environment representative of the operation*' would include an element of night flying.

The OMD required any of the operator's pilots without a valid Instrument Rating (IR) to undergo a night proficiency check before operating VMC at night. Thereafter, each second proficiency check was to be conducted at night. This requirement did not apply to the accident pilot because he held a valid IR. In the preceding five years, none of the accident pilot's licence proficiency checks or OPCs flown on the AW109 had involved any night flying. The pilot completed his AW139 helicopter type course in early 2022, the two OPCs he had undertaken on that type were conducted in a flight simulator and did include night elements. The pilot recalled previously receiving training on night operations using a NATO-T lighting system[11] and being accompanied by a senior company pilot on "many of [his] first night flights in and out of sites." He also thought it likely that he had departed from unlit HLSs at some point in his career but could not recall specific occurrences.

In having flown three takeoffs and landings at night on the aircraft type and three instrument approaches in the previous 90 days, the pilot met the OMD criteria for night recency.

Safety management system

Through their safety management system (SMS), the operator had identified five top risks to their organisation. These included the heightened risk associated with '*off-airfield night landings*.' While potentially implicit, the SMS did not specifically extend the scope of that risk acknowledgement to off-airfield night departures.

At the operator's '*Flight Operations Safety Action Group'* meeting held in September 2022 it was reported that a new contractor for deployable lighting provision for off-airfield operations had been found but the new system would benefit from '*further integration and practise before being used operationally*.' A training event for pilots and ground crews to practise the associated procedures under controlled conditions on a '*dusk running into dark exercise*' had been booked for 25 October 2022 but was postponed due to a key participant's illness.

Footnote

[11] See *Airfield Information, HLS Lighting provision* section.

Operational oversight and commercial pressure

The OMA contains a policy statement that no commercial pressure from the company, or its employees should be placed on individual aircraft commanders to undertake a particular flight.

Given the nature of the company's business, its pilots are often conducting single-pilot operations at remote locations and needing to manage customer expectations in a dynamic and pressurised, commercially competitive environment. Expectation from clients to deliver an anticipated level of service irrespective of unforeseen complications can, on occasion, be at odds with the flight safety imperative. To limit such pressure on pilots, the OMA directs that company ground operations staff should act as the primary customer interface. This responsibility starts from when tasking is first proposed. To further separate the commander from commercial pressure, '*whenever practical*,' go/no-go decisions by pilots on live operations are communicated to customers by ground operations staff or 'a *pilot not involved in the flight*.' The OMA says that, where there is '*the likelihood of a divert or delay*,' customers should be made aware of contingency plan options in advance to help manage their expectations during a flight.

The pilot reported that delayed departures were not uncommon when undertaking corporate tasking. Pilots were often required to adopt a flexible and proactive approach to emerging problems to achieve their assigned tasking.

The shooting party had not been given a latest-possible departure time and did not exert any pressure on the pilot in relation to the day's flying schedule.

Tasking and flight planning processes

The OMA lists operational factors[12] that should be considered during the quotation process. These areas include:

- *'day/night considerations,'*
- *'the suitability of any unlicensed landing sites,' and*
- *'times of sunrise/sunset if applicable*.'

On receipt of a task enquiry, the operator's ground operations department use a commercially available software planning tool (planning tool) to validate the viability of the proposed flight schedule. The intended flight routing and timings, as well as crew, passenger, and luggage weights, are input to the planning tool for it to evaluate task feasibility. The system uses detailed weight, centre of gravity (CG) and performance data for the assigned helicopter to determine limiting conditions for the tasking on a sector-by-sector basis. For each sector, the planning tool calculates a range of acceptable fuel levels for departure that would keep the helicopter within MTOW, CG and Final Reserve fuel limits. Potential exceedances, such as CG out of limits or insufficient fuel on board to complete any proposed sector, are flagged to the planner. All such exceedances require an alteration of flight parameters in the draft

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Footnote

[12] OMA 2.3.3 Operational considerations for acceptance of a task.

plan to resolve the issue before a workable flight plan can be generated. If, for example, the revenue payload meant MTOW considerations limited the maximum fuel on board at departure to less than was required to fly the proposed sector, a reduction in payload or the addition of an intermediate refuelling stop would be required to clear the warning. Similarly, sunrise and sunset times are automatically calculated for each landing and takeoff site. Greyscale shading for each sector is used to indicate to the planner if it would be day, night, or twilight at the planned arrival/departure time. This shading is not carried over into the operator's pilot tasking documents. Detailed lighting and fuel data could potentially be included on the pilot tasking paperwork but the operator's version of the planning tool was not configured to do this.

Planned for 15 minutes before sunset, the flight from LEA2 to Lisvane was shown as a day departure in the planning tool. Although both sites were listed as Estimated HLSs in the CLSD, and therefore day-only under OMA rules[13], contingency options had not been developed to mitigate the effect of potential delays precluding a daytime departure from LEA2. From the outset, the planned arrival time at Lisvane was after nightfall[14].

The operator's pilots routinely received their tasking through documentation generated by the planning tool. This typically included printed route and payload data for the assigned duty. The pilots then used third-party software on their company-issued tablet computers for detailed flight and fuel planning. Route and waypoint data could be uploaded from the planning tool directly into pilots' tablets using a weblink. The planning tool was not configured to export WB data to the third-party software applications used by the pilots. The operator's standard duty check-in time for pilots ahead of a flight was 30 minutes prior to departure and allowed time for final planning and pre-flight preparation of the aircraft. To give pilots more time for detailed planning, the ground operations staff would aim to send tasking documentation no later than the day prior, although this was not always possible for short-notice tasks.

The pilot received the flight paperwork for the 1 November task the day beforehand and uploaded the route waypoints to his tablet computer navigation application. He reported that using this application, he calculated fuel requirements for each sector on a 'fuel-to-fuel'[15] basis. The pilot also reported being aware that sunset would be approximately 15 minutes after the scheduled departure time from LEA2. At the time, it was his understanding that the OMA alleviations for non-revenue flights could be applied to night HLS operations, thus allowing him to depart the unlit site after dark. Accordingly, he was unconcerned about a delayed departure and did not pass a last possible day takeoff time to the passengers.

TEM

For multi-pilot operations the acceptable means of compliance (AMC) for the inclusion of TEM[16] in Crew Resource Management (CRM) training are outlined in AMC1 ORO.FC.115

Footnote

[13] See *Airfield information* section.
[14] Using the OMA definition of nightfall being 30 minutes after sunset.
[15] Planning refuelling levels to ensure compliance with Final Reserve requirements for each sector.
[16] The practice of planning and thinking ahead to predict/identify potential errors and threats and consider strategies to manage or mitigate those that do occur.

of 965/2012 (AMC1). A corresponding AMC for single-pilot operations is specified at AMC2 ORO.FC.115 and directs that training should focus on the elements specified in Table 1 of AMC1. TEM is included as a required topic in the '*General principles*' section of the referenced table. The investigation noted that TEM training is a core element of the current pilot training syllabi for LAPL onwards and widely referenced in Part FCL.

The operator established risk management and mitigation activities through its SMS and TEM was included in the operator's syllabus for initial and recurrent CRM training[17]. The operator reported that CRM, "including TEM," would be assessed during OPC and Line Check flights.

The pilot reported that he would be expected to manage and mitigate on-the-day risks using his own judgement. For the flight from LEA2 to Lisvane he assessed the most significant threats to be the weather, and any lengthy delay that might result in an extended flight duty period or an unscheduled night stop in Cardiff. He completed a written risk assessment, as detailed in the OM Part A2[18], before leaving Biggin Hill. The OM risk assessment format was derived from the European Helicopter Safety Team (EHEST) Excel Tool[19]. The EHEST tool is intended to be completed before flight and aims to help inform pilots as to whether their planned flight is '*safe enough to be undertaken*.' Not all the operator's personnel fully appreciated the principle of TEM being a complimentary and proactive, flight phase-by-flight phase, tactical strategy focused on anticipating potential immediate threats to safe operation.

Following TEM principles helps pilots focus on and mitigate conceivable human, technical, and environmental threats engendered by the actual conditions prevailing during the immediate phase of flight. Threats identified may be less generic or different to those identified during a pre-flight risk assessment.

Survivability

Crashworthiness

Despite the helicopter being subject to dynamic and complex loads during the impact sequence no fuel had leaked and there was no post-impact fire. The main fuselage retained its integrity during the accident sequence and protected the occupants from external hazards.

Regulatory requirement

NCO.OP.150 of 965/2012[20] places a requirement on the pilot in command of an aircraft to ensure that '*prior to and during taxiing, takeoff and landing…each passenger on board occupies a seat or berth and has his/her safety belt or restraint device properly secured.*'

Footnote

[17] OMD 5.1: 'Flight crew CRM training: General Principles.'

[18] OMA A2 2.4.19: 'Helicopter Commanders Pre-Flight Checklist and Risk Assessment.'

[19] EHEST pre-departure checklist. Available at https://www.easa.europa.eu/en/downloads/23352/en [accessed 7 February 2023].

[20] Available at NCO.OP.150 Carriage of passengers (caa.co.uk) [accessed 11 January 2024].

Passenger briefing

The OM[21] stipulates a requirement for passengers to be appropriately briefed before flight, including on the operation of '*normal and emergency exits*' as well as '*the use of safety belts/ harnesses.*' Because the flight was in support of the helicopter owner, who was a frequent flyer, the pilot did not consider that a refresher pre-flight safety briefing was required. He was not aware that some of the passengers had not flown in that model of helicopter before.

Use of restraint devices

As well as placing a responsibility on commanders to ensure that each passenger is briefed on seatbelt/harness operation before takeoff, the OM[22] also requires them to ensure that each passenger has their safety belt/harness properly secured before takeoff and landing.

Of the five passengers on board, four remembered not fastening their seatbelts prior to departure, it was not conclusively determined whether the fifth passenger had fastened theirs. One passenger ascribed the reason for not wearing their seatbelt to the dim lighting in the rear cabin making it difficult to locate '*the correct belts with the necessary attachments*.' Another passenger did not fasten their seatbelt because others had not been wearing theirs on the morning flight so he chose not to for the return journey.

The most seriously injured passenger had been sitting in the right rear cabin seat. The other passengers had been thrown from their seats during the accident sequence and some, if not all, had ended up on top of him. The investigation did not have supporting data to enable a determination of the dynamics of the passengers' trajectories within the cabin from the time when the helicopter struck the trees until it came to rest on the ground.

While not requested by the passengers on the accident flight, the pilot reported that, in his experience, it was not unheard of for frequent flyer corporate passengers, in the interests of expediency, to encourage flight crews to close the cabin doors and begin their pre-flight procedures as soon as the passengers were on board, rather than waiting to visually check that all seatbelts were fastened. The previous experience of one of the lead passengers was that the operator's "pilots would always carry out a safety briefing, and included in those briefings would be the importance of wearing a seatbelt."

Weight and Balance

G-RAYN had a certified MTOW of 3,175 kg. The helicopter's empty weight was recorded as 2,269 kg when it was last weighed on 8 September 2022. The operator uses a mix of standard and actual weights for passengers, baggage and crew. For the 1 November series of flights, the weights being used were as follows:

- Crew: standard weight of pilot and personal effects, 85 kg.
- Passengers: actual weights listed on tasking sheet, total 467 kg.

Footnote

[21] OMA 8.2.2.2.4 Passenger Brief and OMA 8.3.16 Passenger Briefing.
[22] OMA 8.3.11.2 Passenger Restraint Devices.

- Baggage: the weight listed on tasking sheet was 25 kg but the pilot assessed the weight of loaded luggage to be 20 kg.

Using the figures above, with crew, passengers and baggage, but minus fuel, the weight of G-RAYN would have been 2,841 kg. In that configuration, MTOW would have been reached with 334 kg of fuel on board.

The morning flight from Lisvane took off with an indicated 380 kg of fuel, giving a TOW of 3,221 kg.

At the accident site the AAIB recovered 520 litres of fuel from the helicopter's tanks, which equated to 405.6 kg using an assumed specific gravity of 0.78. Allowing for 10 kg of unusable fuel being present in its systems when the helicopter was weighed, G-RAYN's all-up weight at the time of the accident was an estimated 3,237 kg. The corresponding longitudinal CG position would have been 3,403 mm aft of datum (Figure 12).

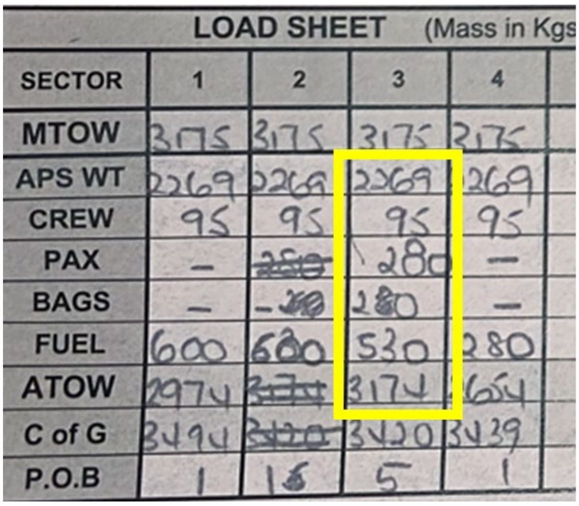
The pilot stated that 340 kg was his calculated startup fuel at LEA2 to remain within MTOW limits once the shooting party was on board. He was not able to provide the investigation with auditable WB calculations for the day's flying. He had not completed a manual loadsheet load, either standalone or as part of a technical log entry for the day's flying, and the WB function on the pilot's software navigation application had not been changed from its default parameters[23]. While 965/2012 does not require it for NCO flights, OMA directs that WB documentation for all categories of flight should be retained by the company for a minimum period of three months.

A review conducted by the operator, of actual vs assumed fuel consumption rates for the AW109SP, revealed that the assumed figure of 240 kg/hr for planning purposes was overly pessimistic and that 220 kg/hr was more representative. They considered that this pessimistic planning consumption rate would have contributed, in part, to the helicopter arriving at destinations with more fuel than anticipated.

The OMA[24] also required final WB data for all flights to be recorded on the relevant sector record page in the aircraft's technical log. A review of G-RAYN's technical log showed that this requirement was not always complied with for NCO flights. Additionally, during a review of technical log pages on board the helicopter at the time of the accident, it was noted the loadsheet data for sector three of G-RAYN's flying on 2 October 2022 was incorrect. While the actual takeoff weight (ATOW) was recorded on the sector record page as 3,174 kg, the total of the masses listed for helicopter on that sector ('*APS WT, CREW, PAX, BAGS'* and '*FUEL*') was 3,194 kg (Figure 10)[25].

Footnote

[23] See '*Recorded information'* section.
[24] OMA 8.1.8.11.1 Mass and Balance Data and Documentation/Records.
[25] 2,269 + 95 + 280 + 20 + 530 = 3,194 kg.



LOAD SHEET (Mass in Kgs

SECTOR	1	2	3	4
MTOW	3175	3175	3175	3175
APS WT	2269	2269	2269	2269
CREW	95	95	95	95
PAX	–	~~280~~	280	–
BAGS	–	– ~~[illegible]~~	280	–
FUEL	600	600	530	280
ATOW	2974	~~[illegible]~~	3174	2654
C of G	3494	~~3420~~	3420	3439
P.O.B	1	15	5	1

Figure 10

Extract from G-RAYN's technical log sector record page for 2 October 2022

Helicopter performance

Hover attitude

The helicopter manufacturer performed a simulation based on the accident takeoff weight, CG, and wind conditions, to establish the pitch and roll attitude, and engine torque necessary to have maintained a stationary hover. This showed the required pitch attitude was 4.0° nose-up and, depending upon being in or out of ground effect, the required roll attitudes and power settings were 3.3° and 3.8° left bank and 81% and 95% torque, respectively.

The manufacturer also performed simulations to establish if the helicopter could maintain a stationary hover when the pitch attitude was at 7° nose-up, as recorded during the accident takeoff. This showed that at the MTOW of 3,175 kg it was possible, but the CG would need to be set at 3,583 mm which would be outside the certified longitudinal envelope (Figure 11). With CG set at 3,430 mm, the maximum longitudinal aft position for the helicopter at MTOW, it was not possible to maintain a stationary hover with a pitch attitude of 7° nose-up.

Another simulation using the recorded pitch and roll attitude, heading and collective position was performed for the weight and CG calculated for the accident takeoff. The manufacturer concluded that, based on the accident data, the helicopter would not have maintained a steady hover position, but would have moved rearwards while also climbing.

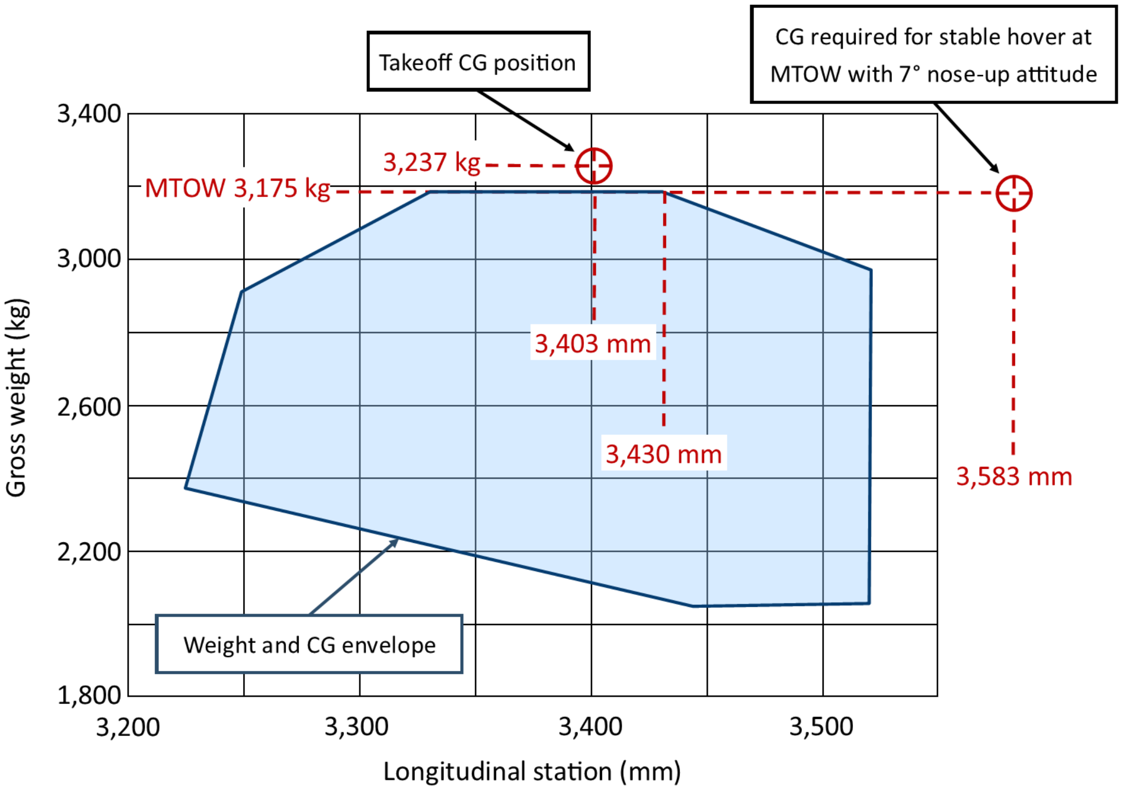


Figure 11

Weight and longitudinal CG envelope for G-RAYN

Performance Classes

Under the aviation regulatory framework, operational regulations are specified according to the single engine failure capability of a helicopter in a defined area of operations. These are designated as Performance Classes.

- In areas where Performance Class 1 (PC1) operations are planned the helicopter must be able to safely continue the flight or land within the rejected takeoff or landing area.
- Performance Class 2 (PC2) requires that the helicopter should be capable of either being safely flown away or executing a forced landing during takeoff and landing.
- Performance Class 3 operations are those where, should an engine fail, a forced landing will be required.

Performance class compliance for routine operations

Notwithstanding the OMA day-only restriction on LEA2, the physical characteristics of the site would, under the OMB criteria[26], have allowed the commander to depart using helicopter PC2 criteria. Nonetheless, the pilot elected to conduct a Category A vertical

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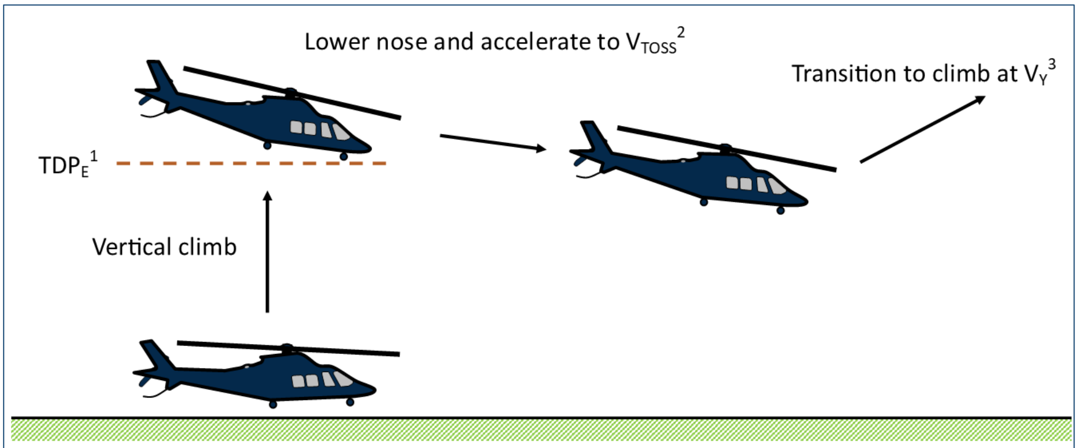
Footnote

[26] OMB Part B2 Section 4.2 *Performance Applicability – General Operating Restrictions*.

takeoff profile (Figure 12) which was compliant with PC1 operations and described in the RFM[27]. This was in line with the OMB direction[28] that *'the Commander shall endeavour to operate the helicopter in* [PC1] *whenever possible thereby maximising the safety margin for the passengers at all times.*' Due to the presence of trees behind the helicopter, the pilot elected to fly a vertical rather than '*back-up*' procedure which would have required an initial rearward climbing flightpath (Figure 14).



Notes:

1. TDP_E = Extended takeoff decision point height. For engine failure below TDP_E height reject the takeoff, otherwise continue. TDP_E height to be in the range 35-75 ft above the takeoff surface.
2. V_{TOSS} = Takeoff safety speed (35 kt).
3. V_Y = Best rate of climb speed (80 kt below 10,000 ft AMSL).

Figure 12

Overview of Category A ground level vertical departure profile

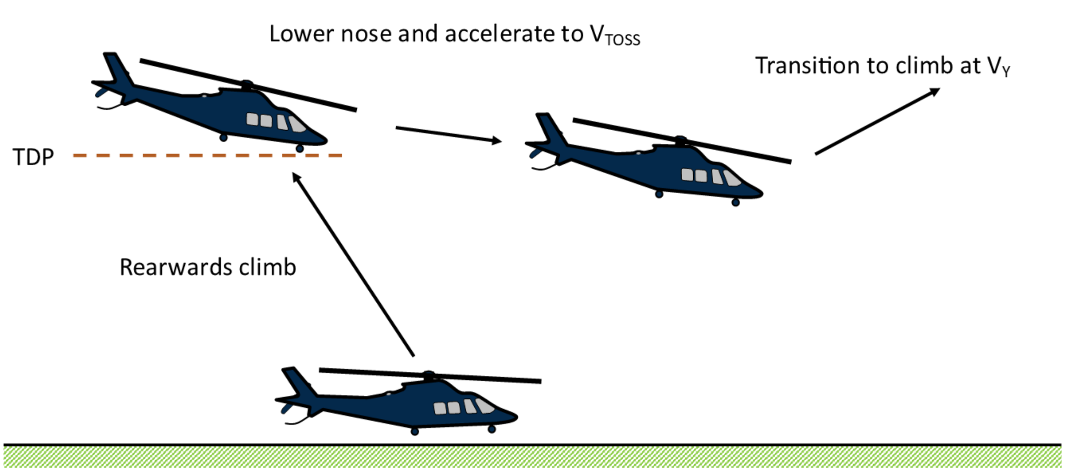


Figure 13

Overview of Category A ground level back-up takeoff procedure

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Footnote

[27] AW109SP RFM Supplement 4 Part E *CAT A Operations, Ground Level Heliport*.

[28] OMB Part B2 paragraph 4.2.3.

The pilot's experience was that, after power was applied to commence the climb for a vertical departure, the AW109 type was very stable and would invariably climb vertically with little longitudinal drift. For Category A 'back-up' procedures, the pilot reported needing to apply a conscious and positive pitch up to initiate the necessary rearwards movement. He did not recall making a positive pitch up of that nature during the accident flight takeoff. Based on previous experience, he estimated that he would have needed to hold approximately 5° nose-up to maintain his longitudinal position in the hover.

A comparison between the recorded pitch attitudes and groundspeeds during the Category A back-up departure flown from Lisvane that morning and the attempted vertical departure on the accident flight is shown below (Figure 14). Other than the temporary reduction in pitch attitude as the pilot turned into wind at LEA2[29] the pitch attitude profiles are broadly similar. The takeoff from Lisvane was a crosswind departure, whereas the helicopter was experiencing a headwind as it climbed from LEA2, this could explain the difference in rearward ground speed acceleration rates observed beyond the 20 second point on the Figure 15 chart.

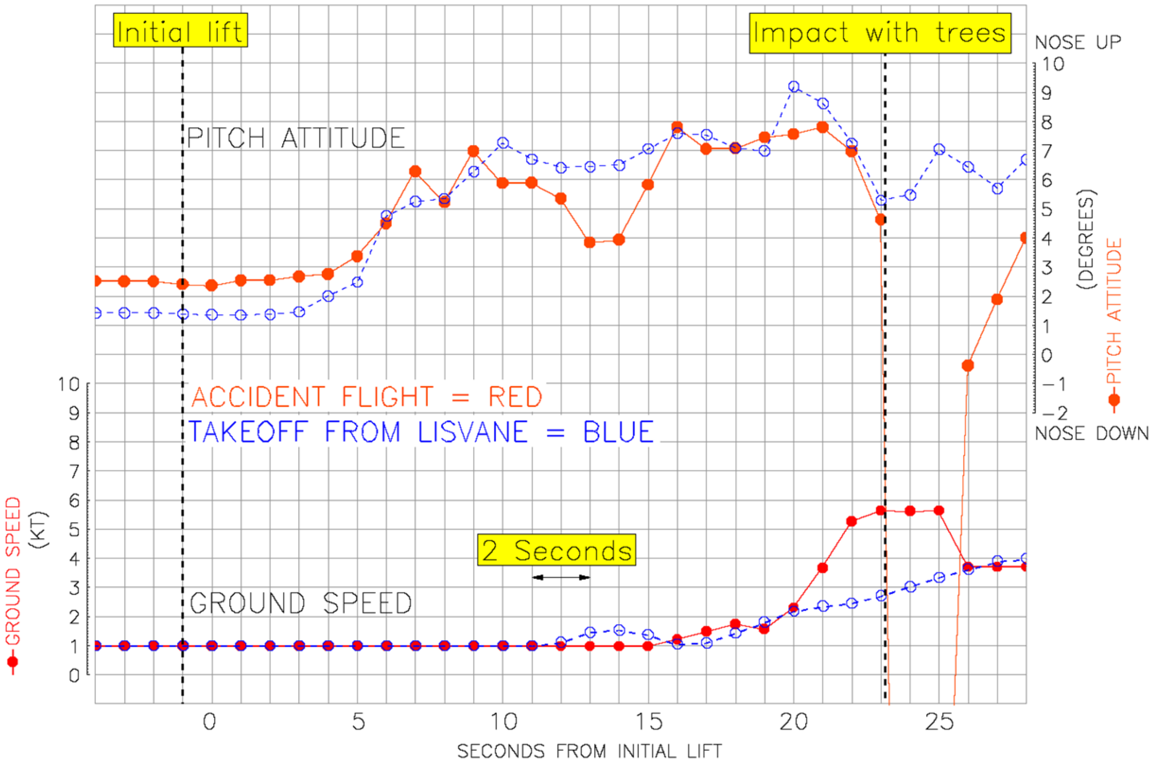

Figure 14

Comparison of Lisvane (blue) and accident flight (red) Category A departures

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Footnote

[29] Between 10 and 15 seconds on the chart and described fully in the *Recorded information, Data interpretation* section.

Meteorology

The conditions in the vicinity of Llanelidan during the period of 0700-1900 UTC on the day of the accident were generally fine with good visibility, however, occasional showers throughout the period reduced reported visibility to between 8,000 and 9,000 m. Surface winds were recorded as being generally west-south-westerly at 5-11 kt. At the approximate time of the accident RAF Shawbury, 28 nm east-south-east of LEA2, was reporting 1-2 oktas of cloud at 2,200 ft with complete cloud cover at 4,000 ft. At the same time, Hawarden, 15 nm east-northeast of LEA2, was reporting light rain with 3-4 oktas of cloud at 2,400 ft and 5-7 oktas of cloud at 3,700 ft. Visibility in that light rain had reduced to 8,000 m, previously it had been reported as ≥10 km.

The reported weather was above the OMA minimum requirement for night VFR flights by pilots holding a valid IR, of 3,000 m visibility and cloudbase 1,200 ft above nearby terrain.

The pilot recalled that when he walked to the helicopter for the accident flight, “the rain had all but stopped and the wind had died off to a gentle westerly breeze.”

Met Office data indicated that on 1 November 2022, local sunset at LEA2 was 1645 hrs. The end of official evening civil twilight would have been approximately 1718 hrs.

Airfield information

The operator’s OMA refers to an unlicensed heliport as an HLS. HLSs could be heliports intended for regular use, with a Final Approach and Takeoff area (FATO) in place, or ad hoc ones using an area of ground that has been assessed or surveyed as suitable for the purpose. Pre-approved HLSs are listed in the CLSD. A standard CLSD entry would include site details, such as contact and navigational information, as well as mapping and imagery of the landing area. The final page of a CLSD entry is titled ‘*Area Survey (If Applicable)*’ and includes a table on which the nature, location and height of relevant surveyed obstacles can be listed.

Depending on the degree of prior surveying that has taken place, a site is assessed as falling into in one of the operator’s three HLS categories: Surveyed, Measured or Estimated. The three categories allow a degree of operational flexibility to use unlicensed and ad hoc HLSs, balancing operational imperative against the time available for pre-survey of a site. The OMA directs that, where ‘*time permits and an existing acceptable site survey report is not available the site should be surveyed in accordance with the procedures described at* [OMA] *paragraph 8.10.5*.’ The OMA also highlights that *‘the Company has a duty of care to both the crew and the passengers to pre-survey sites prior to use whenever operationally possible*.’ Only once the appropriate procedure, as described at OMA 8.10.5 has been carried out, can an HLS be considered for categorisation as a Surveyed site.

The HLS categories have different operating restrictions. For example, Surveyed sites can be used at night subject to certain caveats, but Measured and Estimated HLS '*may be used by Day only.*'

The overall length (D) of the AW109SP type including the rotor is 12.96 m. The OMA requires that for day operations, the touchdown and lift off (TLOF) area of an HLS must be at least the larger of twice the helicopter length, (ie 2D) or the minimum heliport/helipad size detailed in the approved helicopter flight manual. For night operations the TLOF must be at least four times the helicopter length (ie 4D) or 110 m x 60 m, whichever is the greater. For the AW109SP, 4D is approximately 52 m so for night HLS operations the minimum acceptable TLOF area of 110 m x 60 m applies. The Limitations section of the AW109SP RFM[30] did not detail a minimum heliport/helipad size.

CLSD entries for Lisvane and LEA2

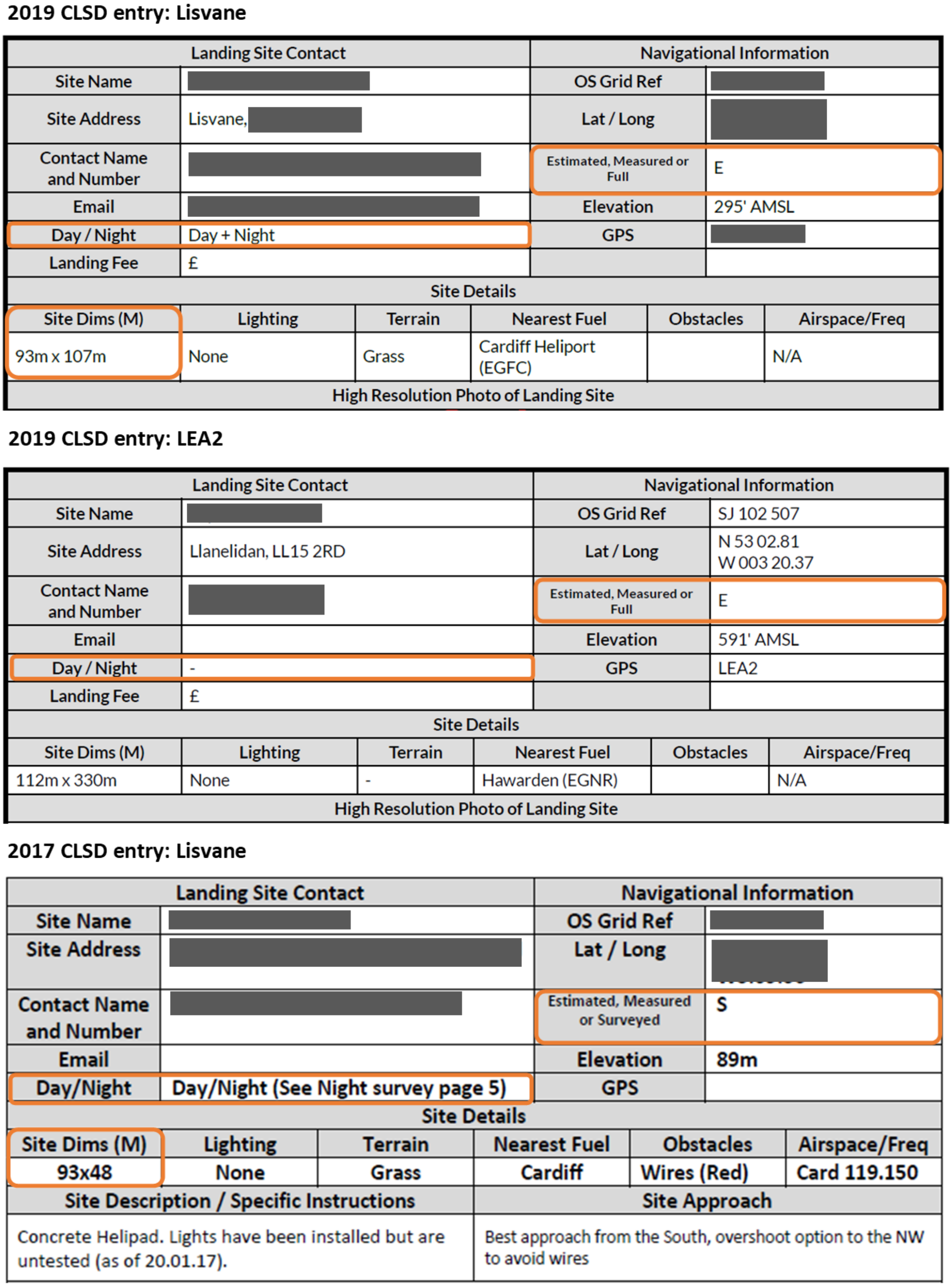
On the flight paperwork provided to the pilot, the Lisvane and LEA2 CLSD entries were both depicted as having been created on 25 March 2019. Comparing the entries for Lisvane and LEA2 revealed discrepancies in presentation and approval status (Figure 16). While Lisvane was listed as an Estimated HLS, the CLSD appeared to give approval for both day and night operations. This was in contradiction with the generic '*use by day only*' OMA restriction for other than Surveyed sites. Additionally, at 107 m x 93 m, the longest dimension quoted in the CLSD for Lisvane was below the OMA requirement of 110 m x 60 m for a night HLS. LEA2 was listed as an Estimated HLS and the '*Day/Night*' box only contained a dash symbol rather than an explicit 'day' or 'day and night' annotation. The investigation also noted the CLSD categorised sites as Estimated, Measured and Full rather than Estimated, Measured and Surveyed.

Neither CLSD entry contained detailed obstacle or obstruction data, although adjacent power lines were depicted on satellite imagery of the Lisvane site. Nonetheless, the pilot was aware of the presence of trees at the LEA2 site and was familiar with the Lisvane HLS.

Information later provided by the operator revealed that Lisvane had been surveyed for night operations on 28 January 2017. The relevant details were recorded in their legacy CLSD which was superseded in 2019 (Figure 15). The Lisvane survey details not been transposed to the new format CLSD. On the 2017 CLSD entry, the site dimensions for Lisvane were recorded as 93 m x 48 m.

Footnote

[30] AW109SP RFM (Document N°109G0040A018) Section 1.



2019 CLSD entry: Lisvane

Landing Site Contact		Navigational Information	
Site Name	[redacted]	OS Grid Ref	[redacted]
Site Address	Lisvane, [redacted]	Lat / Long	[redacted]
Contact Name and Number	[redacted]	Estimated, Measured or Full	E
Email	[redacted]	Elevation	295' AMSL
Day / Night	Day + Night	GPS	[redacted]
Landing Fee	£		

Site Details

Site Dims (M)	Lighting	Terrain	Nearest Fuel	Obstacles	Airspace/Freq
93m x 107m	None	Grass	Cardiff Heliport (EGFC)		N/A

High Resolution Photo of Landing Site

2019 CLSD entry: LEA2

Landing Site Contact		Navigational Information	
Site Name	[redacted]	OS Grid Ref	SJ 102 507
Site Address	Llanelidan, LL15 2RD	Lat / Long	N 53 02.81 W 003 20.37
Contact Name and Number	[redacted]	Estimated, Measured or Full	E
Email		Elevation	591' AMSL
Day / Night	-	GPS	LEA2
Landing Fee	£		

Site Details

Site Dims (M)	Lighting	Terrain	Nearest Fuel	Obstacles	Airspace/Freq
112m x 330m	None	-	Hawarden (EGNR)		N/A

High Resolution Photo of Landing Site

2017 CLSD entry: Lisvane

Landing Site Contact		Navigational Information	
Site Name	[redacted]	OS Grid Ref	[redacted]
Site Address	[redacted]	Lat / Long	[redacted]
Contact Name and Number	[redacted]	Estimated, Measured or Surveyed	S
Email		Elevation	89m
Day/Night	Day/Night (See Night survey page 5)	GPS	

Site Details

Site Dims (M)	Lighting	Terrain	Nearest Fuel	Obstacles	Airspace/Freq
93x48	None	Grass	Cardiff	Wires (Red)	Card 119.150

Site Description / Specific Instructions	Site Approach
Concrete Helipad. Lights have been installed but are untested (as of 20.01.17).	Best approach from the South, overshoot option to the NW to avoid wires

Figure 15

Extract from CLSD entries for Lisvane and LEA2

HLS lighting provision

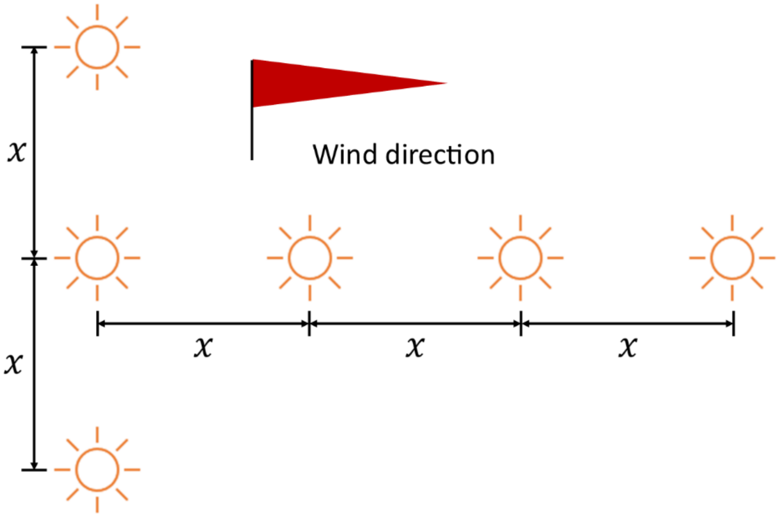
Given the restriction on use by day only, no minimum lighting standard was specified for an Estimated HLS.

The operator's minimum lighting standard[31] for night flights at Surveyed HLSs was:

> *'(i) A dedicated lighting system that clearly defines the TLOF and all obstacles in the approach/departure paths. [or]*
>
> *(ii) Secondary lighting from surrounding buildings and structures such that the TLOF/FATO is easily defined and surrounding critical obstacles in the approach/departure paths can be easily seen. [or]*
>
> *(iii) Mobile lighting or mobile floodlights.'*

The lighting at LEA2 on the evening of the accident flight did not meet the above criteria.

For pre-planned night operations at an HLS without an established lighting system, the operator had engaged a third-party contractor to deploy suitable lighting. The preferred solution was a set of portable lights laid out in the NATO-T lighting configuration as shown below in Figure 16. Deployable lighting had not been requested to support the accident flight.



Omni-directional white lights, with dimension x being approximately 10 m.

Ideally visible from 4 nm away and orientated for helicopter to approach into wind.

Figure 16
Depiction of NATO-T lighting layout

A note in the Site Description section of the Lisvane CLSD entry stated that helipad lights had been installed at the HLS but remained '*untested*.' The date of that observation was

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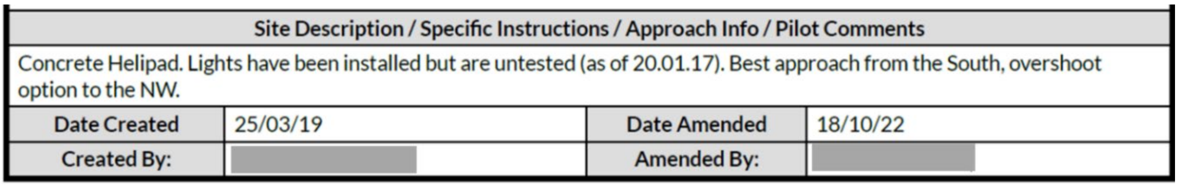
Footnote

[31] OMA 8.10.5.5.2 Lighting.

20 January 2017 (Figure 17). The arrival at Lisvane had been planned for 1715 hrs, a night arrival based on the OM definition of night starting 30 minutes after sunset. Prior to boarding the helicopter, its owner informed the pilot that he had turned the Lisvane helipad lights on using an application on his mobile phone.



Site Description / Specific Instructions / Approach Info / Pilot Comments

Concrete Helipad. Lights have been installed but are untested (as of 20.01.17). Best approach from the South, overshoot option to the NW.

Date Created	25/03/19	**Date Amended**	18/10/22
Created By:	[redacted]	**Amended By:**	[redacted]

Figure 17

Note referring to lighting installation at Lisvane

While on the ground at LEA2, the pilot had visually assessed the site as being suitable for the intended flight but had not completed the full site survey process as described in the OMA.

Personnel

The pilot began his flying career in 2000 and had been employed by the operating company for more than five years at the time of the accident. He had over 1,500 hours flying time on the AW109 type although only a small proportion of which were on the AW109SP variant.

The pilot's licence and medical were valid for the flight and he held a current IR. He completed his AW109 OPC the day before the accident and reported being in good health and sufficiently rested when he attended for duty on 1 November.

Tests and research

Fuel system

Due to the necessary disruption of the aircraft and fuel system during the recovery process it was not possible to perform an end-to-end test of the fuel system to prove it's serviceability. However, a key component of the system, the FCU, was removed and tested at the manufacturer's facilities in France. Testing of the FCU showed it to be serviceable and in good condition. The data from the DAU download was also examined for evidence of fuel system faults present prior to the estimated time of impact with the trees. No fault codes relating to the fuel system could be identified in the data. Examination of the aircraft logbooks revealed no indications of anomalies or faults with the fuel system reported by crews on the flights prior to the accident.

Flight Control Computer

The Flight Control Computer (FCC) was removed from the helicopter and taken to the manufacturer in France for testing. The FCC was subjected to visual inspections, automatic bench testing and supplementary manual testing. All but one test point was passed, the failed test point related to the Channel 1 Coupling light CPL indication. There was no evidence that this indication light fault was present at the time of the accident. But as the output was indication only and did not influence command of the autopilot modes this was considered to not have been relevant to the accident sequence.

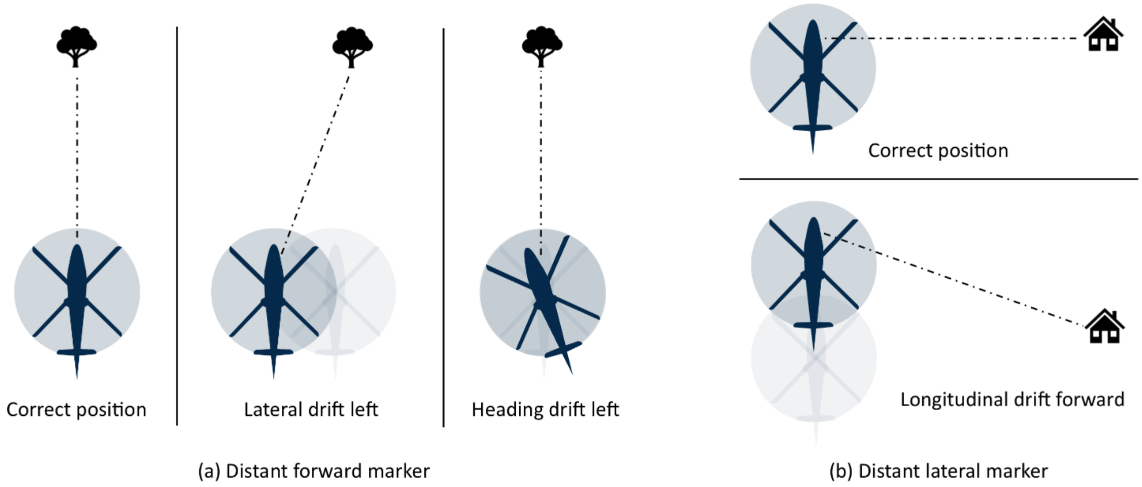
Engine DCUs

Data was successfully extracted from the engine DCUs. From this information it was established that both the engines were serviceable and performing normally prior to the accident. Fault codes were seen on the system but these were attributable to the high resistance forces exerted on the rotor drive system during the impact with the trees.

Other information

Hover references

Helicopter pilots use visual references, referred to as ‘markers,’ to maintain a stable position over the ground. By picking suitably visible objects when the helicopter is established in the desired location, pilots can detect, and correct, any drift away from the target position by reference to the alignment of their markers with other objects or the cockpit structure. Normally, a distant forward marker would be used to assess heading and lateral drift, while a distant lateral marker is used to detect longitudinal drift (Figure 18). Pilots would also generally choose a close-in lateral marker for height assessment and fine position keeping.



(a) Distant forward marker

(b) Distant lateral marker

Figure 18

Distant forward and lateral markers

Heading changes affect the angular orientation of markers relative to the helicopter’s longitudinal and lateral axes (Figure 19). In a degraded visual environment without two usable distant markers, it is more challenging to correctly determine if the change in marker orientation results from positional rather than heading drift.

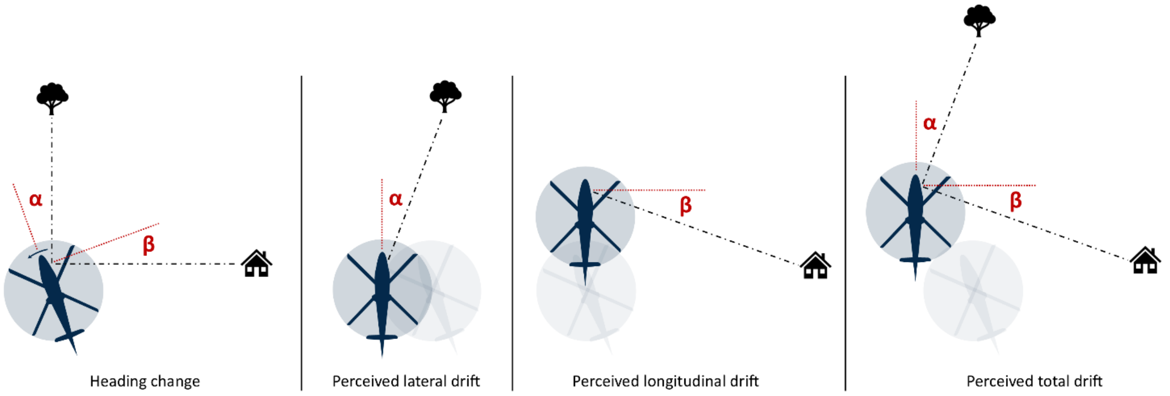


Figure 19

Heading change perceived as positional drift

Visually acquiring suitable markers at night is challenging unless they are lit, there is sufficient cultural or environmental lighting (eg moonlight on a clear night) for objects to be easily seen with the naked eye or the pilot is using a night vision device. In conditions of limited visibility, such as when relying on illumination from a helicopter's external lights, pilots are more likely to pick a single identifiable ground feature close to the cockpit to use as their primary hover reference. The downward sightline from the pilot's eyes to the feature means that, if it is maintained in the same relative position when lifting, the helicopter will naturally move up and rearwards as the pilot maintains that fixed sightline (Figure 20). Without an adequate distant lateral marker any consequential rearward movement is more difficult to detect visually. The investigation heard that, at night on an unlit site, a searchlight beam directed to a close-in reference 30-60° either side of the helicopter's nose offers greater opportunity to detect rearward drift than one directed straight ahead.

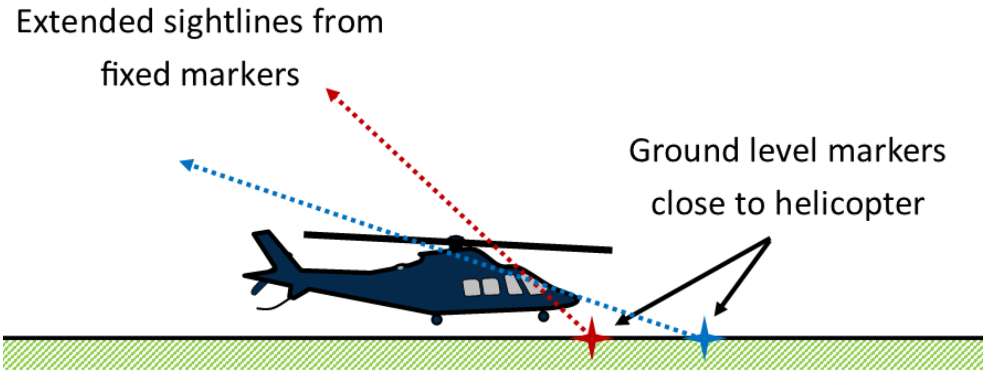


Figure 20

Extended sightline from close-in ground level markers

At the time of departure on the accident flight, it was dark with overcast cloud and little cultural lighting other than that from the lodge's windows. The pilot was not using a night vision device and the portable HLS lighting system had not been deployed.

Analysis

Aircraft serviceability

Extensive inspection and examination of the helicopter, component level testing and examination of maintenance records was undertaken to determine if there were any technical factors that were causal or contributory to the accident. The extensive damage to the helicopter was determined to be due the impacts during the accident sequence. While end-to-end testing of systems such as the fuel system was not possible, the manufacturer analysis of key components such as the FCC, FCU and DAU showed that the aircraft systems were functioning correctly prior to the accident. The maintenance records showed that the helicopter had been correctly maintained. The investigation concluded that the helicopter was serviceable at the time of the accident.

NCO and OM compliance

The reported cultural misunderstanding regarding the status of ‘private’ flights, those conducted on behalf of owners flying in their own aircraft, led to the helicopter being flown outwith the OM restrictions for Estimated HLSs. The legacy term ‘private flights’ is no longer used by the regulator; such flights now fall under the remit of Part NCO. For those elements of the accident flight which took advantage of the less-restrictive Part NCO regulations, the associated enhanced protections established in the OM were not in place, negating safety barriers that might have prevented the accident.

To reduce the opportunity for future confusion amongst its pilots over the applicability of OM restrictions for any flight being undertaken, as a safety action:

> The operator had amended their OM, flight documentation, and aircraft technical log sector record pages, to provide greater clarity on who, operator or owner, holds the duty of care and regulatory compliance oversight responsibility for the flight, or series of flights, being undertaken.

Flight tasking and planning

G-RAYN’s tasking for the 1 November series of flights was generated in response to the helicopter owner’s request for return flights for five passengers between Lisvane and LEA2. The operator’s ground operations staff followed their normal processes, using their planning tool to validate task feasibility before accepting the request. The OMA required planners to consider day/night implications and the suitability of landing sites ‘*during the quotation process*.’ Both LEA2 and Lisvane were listed as Estimated HLSs in the CLSD and, therefore, night operations at them were not permitted by the OMA. The departure from LEA2 was scheduled for 1630 hrs, 15 minutes before sunset. The evening arrival and departure at Lisvane were planned to occur at night.

A departure from LEA2 before 1715 hrs would have been classed as a daytime takeoff, and thereby compliant with the OMA day-only restriction on Estimated HLSs. The tasking documentation generated for the pilot did not include sunset times, neither did it outline any contingency planning considerations for a delayed departure from LEA2.

While Lisvane had been surveyed in 2017 and approved for day and night flights, incomplete transfer of data to the extant (2019) version of the CLSD meant the survey details were not included in the accident pilot's tasking documentation. The discrepancy between the 2019 CLSD's Estimated HLS categorisation for Lisvane and its '*Day + Night*' status had not been resolved in the intervening period leading up to 1 November 2022. On both versions of the CLSD, the reported dimensions of the landing site were less than the OMA-specified minima of 110 m x 60 m for a night HLS.

The CLSD entry for LEA2 was potentially ambiguous regarding day/night status.

While the pilot was aware of the sunset time at LEA2, he was under the misapprehension that the OMA allowed him to depart from LEA2 at night because he was operating a non-revenue, private flight. The OMA specifically stated that no deviation from CAT criteria could be applied to night HLS operations, regardless of flight category.

The operator has since undertaken to work with the developer of the planning tool to explore the possibilities for further exploiting the tool's capabilities for increasing operational oversight and providing additional information to pilots through enhanced tasking documentation.

> As a safety action, the operator had issued additional instructions to their pilots regarding the process for updating site entries and were working with the planning tool's developer to align the CLSD management protocols and templates to their requirements.

Decision making and commercial pressure

The existence of the OMA derogations for certain aspects of non-revenue operations and contradictory entries in the CLSD contributed to the pilot's misinterpretation of company regulations. Believing he could waive the day-only restriction, as the scheduled 1630 hrs departure time approached, the pilot saw no need to hurry the passengers. They did not apply pressure on him to delay the flight. While not an explicit factor in this accident, commercial and customer pressure is an unavoidable element of corporate helicopter operations. The operator had established procedures to alleviate pressures on individual pilots, whereby difficult conversations with customers would be the responsibility of duty managers. The judgement of when to refer to a duty manager was subjective, rather than objective. Inevitably, successful operations delivering client satisfaction require a flexible and proactive approach by pilots in command who are directly responsible for delivery of an expected level of service. Continually exposed to this operational environment, the danger is that pilots become acclimatised into an excessively 'can do' mindset where the balance of what is possible versus what is appropriate becomes tilted toward a more risk-tolerant approach.

The operator declared an intent to review the scope and suitability of training for handling commercial and customer pressure currently provided as part of its recurrent CRM syllabus.

TEM

The investigation found that, while TEM was included in the CRM training syllabus for the operator's flight crew, the level of understanding of how it could be used to best effect was not fully appreciated across the organisation.

While the pilot identified weather and delays as holistic threats for the flight from LEA2 to Lisvane, a more effective TEM strategy would have focused on the specific threats for each phase of the flight. For the accident flight takeoff, significant threats were the degraded visual environment coupled with a lack of HLS lighting, the presence of trees behind and relatively close to the helicopter, and the westerly wind blowing toward the trees. These combined threats gave rise to the potential error of an inaccurate hover leading to reduced separation from the treeline. The investigation considered that had the pilot been habituated to employing TEM in a more focused way he might have been more effective in identifying and proactively mitigating the takeoff threats.

The operator declared an intention to issue enhanced guidance to their personnel on the implementation of TEM, from initial planning by ground operations staff through to sector-level considerations for pilots. The intent would be to include guidance for both single and multi-pilot operations as well as suggested mitigations for known general threats. Once codified within the OM and the SMS, the policy would be referenced during training, checking and auditing activities.

Accident flight departure

Having flown into the site during the day, the pilot was aware of the presence of trees to the east of the landing site. To meet the OMA intent of operating to PC1 standards whenever possible, he planned for a vertical Category A departure as a precaution against engine failure. While night had fallen when he took off, the pilot assessed that he had sufficient visual references to safely conduct the intended departure manoeuvre. He described using light from the lodge's windows as his lateral marker and establishing a forward visual reference with the aid of the controllable searchlight.

As the helicopter lifted into the hover, the lodge's windows would have been in the helicopter's approximate 3 o'clock position, in line with the pilot's shoulders. Having turned into wind, the chosen lateral markers would have become more difficult to see, the pilot needing to look back over his shoulder to see the lights, approximately 30° behind his shoulder line (Figure 21). The lights' change in relative position would have made it harder to discriminate between real and apparent drift, degrading their usefulness as markers. As the helicopter translated rearwards the lights would have appeared to move closer to their original orientation in the pilot's 3 o'clock position.

Figure 21

Representation of pilot's sightline to lodge windows during departure
(image © 2023 Getmapping plc)

During the time from lift off until the pilot committed to the climb the helicopter's attitude rose to 6° nose-up and G-RAYN was already moving rearward toward the trees before the attitude stabilised at approximately 7° nose-up. While the pilot reported having a "vague, but usable, horizon" ahead, he had not intended to use, nor appreciated, the amount of nose-up attitude selected. That the attitudes flown were similar to those used to generate the rearward trajectory for the earlier departure from Lisvane, indicates the external references available to the pilot were insufficient for accurate visual assessment of the helicopter's pitch attitude. G-RAYN's rearward drift was consistent with that predicted by the manufacturer's performance modelling based on the helicopter's recorded nose-up attitude and CG[32]. The investigation considered that, in twisting to look at the lodge lights, the pilot may have inadvertently applied increased rearward pressure on the control column, contributing to the higher than intended nose attitude.

The investigation also considered it likely that, having the searchlight beam directed ahead of the helicopter made it more difficult to assess rearward movement by reference to sightline shift from a close-in marker. Having the searchlight beam directed 30-60° right, rather than straight ahead, could have aided detection of longitudinal drift. Training to depart from an unlit HLS might have helped the pilot avoid these pitfalls, nonetheless, the operator's chosen mitigations were to prohibit night operations at Estimated HLSs and to stipulate a minimum lighting standard for Surveyed sites. Following this accident, the operator intended to investigate the potential for pilots to practise night takeoffs, with environmental lighting conditions "near to official dark" in a flight simulator where one is "available and capable of this training."

Footnote

[32] Albeit modelling weight set to MTOW limit of 3,175 kg.

Survivability

The specific crashworthiness features introduced on the AW109SP appeared to function well. There was no fuel leak and no post-crash fire and the structural integrity of the main crew and passenger compartments were not breached. This reduced the severity of risk and protected crew and passengers against more severe or even lethal post-accident consequences in what was considered a survivable accident.

The pilot had not delivered a passenger safety brief for either flight and had not confirmed that all passengers had fastened their seatbelts prior to the departure from Lisvane or on the accident flight. Most, if not all, of the passengers were unrestrained on the accident flight. The investigation did not have data to support a detailed analysis of how the wearing of seatbelts would have affected the injuries sustained by the passengers during the accident sequence.

Ensuring that passengers are appropriately briefed and seated with harnesses secure is a regulatory obligation placed on aircraft commanders. Following this accident, the operator undertook to review different methods of delivering passenger briefings and any training that might be required to support a change in methodology.

The operator had taken specific safety action to remind pilots that, irrespective of a passenger's previous flying experience or status, safety briefings and a check of seatbelt/ harness security must be carried out for every flight, as per the OM.

Weight and balance

Although not a causal factor, G-RAYN was above the RFM MTOW limitation of 3,175 kg when it took off on the accident flight. It had also been above the MTOW limit when it departed Lisvane that morning. While he reported for duty ahead of his nominated check-in time, the pilot was distracted by the unanticipated conversation with his bereaved colleague and had not opened a tech log entry for the day's flying.

No auditable WB calculations for the day's flying were provided to the investigation. Data from the software navigation application on the tablet device the pilot was using for the flight showed that the WB function had not been accessed on any of the sectors. The application remained set at its default parameters, which would have generated a CG warning if checked.

Using the tablet-based software navigation application's WB function or completing the tech log SRP loadsheet prior to each sector could have been a barrier to the aircraft taking off above MTOW.

While the OMA required the SRP loadsheet to be completed for all flights, this requirement was not always complied with for NCO flights. One instance of the SRP loadsheet being incorrectly calculated was found in the tech log recovered from the aircraft.

Exporting acceptable sector fuel ranges, as automatically calculated in the planning tool, to the pilots' tasking paperwork could have been another barrier against MTOW exceedances resulting from excess fuel on board. The investigation was not able to resolve the discrepancy between the pilot's recollection of the weight of fuel on board at takeoff and the physical quantity recovered from G-RAYN at the accident site. Data recovered from the helicopter indicated that its fuel displays would have been showing a combined total of just above 400 kg as G-RAYN lifted from LEA2.

In December 2022, the operator issued an internal Flying Staff Instruction to remind all pilots that the load sheet section of the technical log sector record page must be completed for every sector on all flights, including NCO. They also amended the default WB configuration in the pilot's software planning application and undertook a review of representative fuel burn rates to be used for flight planning purposes.

SMS

The risk of night off-airfield landings had been identified as one of the operator's top risks in their SMS. There was no explicit mention of the risks associated with night off-airfield takeoffs but in many regards the risks could be directly read across. The operator commented that they had been unable to find an authoritative guide to the specifications for, and procedures for using, a NATO-T lighting array.

Safety actions taken by the operator to further manage the risk of night off-airfield night operations were as follows:

- A new Integrated Management System was developed to improve operator processes for the management of hazards. This included a new generic risk assessment for off-airfield night operations that explicitly covered both night landings and night takeoffs.
- In November 2022 an FSI was issued to re-iterate the requirements for night off-airfield operations. This was subsequently incorporated into the OM.
- Deployable lighting sets were procured for use on flights where there was an identifiable risk of an unscheduled night takeoff resulting from a delay to the planned programme.
- Landing site risk was added as an additional criterion in the OM pre-flight risk assessment tool, with night off-airfield operations attracting the highest risk factor loading.

Training

ORO.FC.202(b) did not explicitly mandate that pilot recurrent checks should contain an element of night flying but did require such checks to be conducted '*in an environment representative of the operation*.' The regulator's interpretation was that for operators undertaking night flying operations, '*an environment representative of the operation*' would include night flying elements.

The operator had not inferred from ORO.FC.202(b) that their instrument rated pilots were required to undergo any form of recurrent night proficiency training or checking. The accident pilot held a valid IR and none of his recurrent proficiency checks on the AW109 type included an element of night flying. The pilot could not recall having been trained or checked as proficient to operate from an unlit HLS at night during his employment with the operator.

The operator's Safety Action Group had identified a training need for operations utilising its contracted portable HLS lighting system but an illness-related delay meant the planned training had not been completed before the accident occurred.

> The operator took safety action to instigate an annual night flying training programme for all its onshore charter pilots (employees and contractors). The programme's syllabus specified theoretical training on night procedures and site surveys as well as a flying element to include night takeoffs and landings using a NATO-T lighting array. The first iteration of this training programme was conducted in November 2022.

Conclusion

The accident resulted from the undetected rearward transition of the helicopter into a stand of trees during a planned vertical departure at night from an unlit HLS. No causal or contributory technical factors with the helicopter were discovered.

The investigation identified several barriers that were either breached or not present which might have prevented this accident. Contradictory and potentially confusing CLSD entries and differing requirements for CAT and non-revenue flights, combined with colloquial legacy terminology, offered an opportunity for misinterpretation over the applicability of the OMA restrictions at the HLSs being used on the day.

Opportunities were also missed during the planning process to anticipate and develop proactive mitigation strategies for delays to the published flight schedule. There was an air gap of information where data such as sunset time and acceptable sector fuel loads were available in the operator's planning tool but not presented to the pilot. Distraction and time pressure contributed to the pilot not completing auditable WB calculations which could have alerted him to the potential for MTOW exceedances. Offloading planning tasks from pilots to the planning tool could have reduced their pre-flight workload, thereby releasing capacity in a time-pressured operation.

The pilot could not recall having been trained to takeoff from an unlit HLS but judged there to be sufficient lighting for his intended departure. Even with the helicopter's external lights to aid vision, the "vague horizon" and lights from the lodge windows proved inadequate visual reference for the pilot to detect unintentional rearward drift during the climb. The pilot's focus on delivering the expected service to the clients, despite the challenges posed by a night departure from an unlit site, was indicative of an insidious acclimatisation to risk engendered by long term exposure to the nature of commercial and corporate charter operations.

Acclimatisation to risk is not the sole purview of pilots. For owners and frequent flyer passengers, or those focused on time pressures, it is tempting to see safety briefings and seatbelts as an unnecessary encumbrance. Nonetheless, it is important that all parties realise an aircraft commander is under a legal obligation to ensure passengers are appropriately briefed and have their harnesses secure for all takeoffs and landings. A shared understanding of this obligation is key to expectation management in this regard.

Effective TEM could have provided an additional safety barrier for the accident flight.

Safety Actions

Following the accident, the operator took the following safety actions. They:

- Amended their Operations Manual, flight documentation, and aircraft technical log sector record pages, to provide greater clarity on who, operator or owner, holds the duty of care and regulatory compliance oversight responsibility for the flight, or series of flights, being undertaken.
- Issued additional instructions to their pilots regarding the process for updating company landing site directory entries and are working with the planning tool developer to align the directory management protocols and templates to their requirements.
- Reminded pilots that, irrespective of a passenger's previous flying experience or status, safety briefings and a check of seatbelt/harness security must be carried out for every flight.
- Issued an internal Flying Staff Instruction to remind all pilots that the load sheet section of the technical log sector record page must be completed for every sector on all flights.
- They also amended the default weight and balance configuration in the pilot's software planning application and undertook a review of representative fuel burn rates to be used for flight planning purposes.
- Developed a new Integrated Management System to improve operator processes for the management of hazards. This included a new risk assessment for off-airfield night operations that explicitly covered both night landings and night takeoffs.
- Issued a Flying Staff Instruction in November 2022 to re-iterate the requirements for night off-airfield operations.
- Procured deployable lighting sets for use on flights where there was an identifiable risk of an unscheduled night takeoff resulting from a delay to the planned programme.

- Instigated an annual night flying training programme for all its onshore charter pilots (employees and contractors). The programme's syllabus specifies theoretical training on night procedures and site surveys as well as a flying element to include night takeoffs and landings using a NATO-T lighting array. The first iteration of this training programme was conducted in November 2022.
- Added landing site risk as an additional criterion in the OM pre-flight risk assessment tool, with night off-airfield operations attracting the highest risk factor loading.

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