



Air Accident Investigation Unit Ireland

FORMAL REPORT

ACCIDENT

**Robinson R44 Raven II, N999RL
Kennycourt, Co. Kildare, Ireland**

11 December 2022



An Roinn Iompair
Department of Transport

FINAL REPORT

Foreword

This safety investigation is exclusively of a technical nature and the Final Report reflects the determination of the AAIU regarding the circumstances of this occurrence and its probable causes.

In accordance with the provisions of Annex 13¹ to the Convention on International Civil Aviation, Regulation (EU) No 996/2010² and Statutory Instrument No. 460 of 2009³, safety investigations are in no case concerned with apportioning blame or liability. They are independent of, separate from and without prejudice to any judicial or administrative proceedings to apportion blame or liability. The sole objective of this safety investigation and Final Report is the prevention of accidents and incidents.

Accordingly, it is inappropriate that AAIU Reports should be used to assign fault or blame or determine liability, since neither the safety investigation nor the reporting process has been undertaken for that purpose.

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¹ **Annex 13:** International Civil Aviation Organization (ICAO), Annex 13, Aircraft Accident and Incident Investigation.

² **Regulation (EU) No 996/2010** of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation.

³ **Statutory Instrument (SI) No. 460 of 2009:** Air Navigation (Notification and Investigation of Accidents, Serious Incidents and Incidents) Regulations 2009.



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In accordance with Annex 13 to the Convention on International Civil Aviation, Regulation (EU) No 996/2010 and the provisions of SI 460 of 2009, the Chief Inspector of Air Accidents, on 11 December 2022, appointed John Owens as the Investigator-in-Charge to carry out an Investigation into this Accident and prepare a Report.

Operator:	Private
Manufacturer:	Robinson
Model:	R44 Raven II
State of Registry:	United States of America
Registration:	N999RL
Serial Number:	10614
Pilot's Licence:	European Union (EU) Part-FCL Private Pilot Licence, Helicopter (H)
Pilot's Age:	71
Location:	Agricultural field near Kennycourt, Co. Kildare, Ireland
Date/Time (UTC) ⁴ :	11 December 2022 @ 15:45 hrs

SYNOPSIS

The Robinson R44 Raven II Helicopter departed from a private site at Ballygarrett, Co. Wexford at approximately 14:32 hrs on 11 December 2022 and flew to another private site at Tagoat, also in Co. Wexford. The Helicopter departed Tagoat at approximately 14:58 hrs for a flight to Kilrush Airfield (EIKH) and followed a north-westerly track towards EIKH. When the Helicopter was approximately 0.7 nautical miles (NM) to the south-west of EIKH and at an altitude of approximately 1,800 feet (ft), it turned right (north-east). It continued past EIKH and remained on a north-easterly track for a further 8.3 NM approximately, before turning back towards the south-west. Then, for a number of minutes, the Helicopter flew back-and-forth in the Kennycourt area, which is approximately 7 NM north-east of EIKH, before impacting with terrain near Kennycourt at approximately 15:45 hrs. The Helicopter was destroyed due to the impact and a post-crash fire. The Pilot, who was the sole occupant, was fatally injured.

The Investigation determined that the probable cause of the accident was a loss of control due to spatial disorientation following a loss of external visual references during an attempted or aborted descent in sub-optimal visibility conditions. The contributory causes were determined to be plan continuation bias when the flight was continued in meteorological conditions in which visual contact with the surface was deteriorating, and possible increasing pressure to land, or get to EIKH, due to a decreasing fuel quantity.

One Safety Recommendation is made as a result of this Safety Investigation.

⁴ UTC: Co-ordinated Universal Time. All times in this report are quoted in UTC unless otherwise stated; local time was the same as UTC on the date of the accident.

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NOTIFICATION AND RESPONSE

At 15:57 hrs on 11 December 2022, Shannon Air Traffic Control (ATC) telephoned Dublin ATC to advise that Shannon had been informed of a helicopter accident in Co. Kildare. Dublin ATC then informed the AAIU. Two Inspectors of Air Accidents deployed to the accident site to commence an Investigation. Following an initial examination of the site, it was secured overnight by An Garda Síochána. Four Inspectors of Air Accidents attended the site the following morning to continue the Investigation and recover the wreckage of the Helicopter for further examination.

1. FACTUAL INFORMATION

1.1 History of the Flight

The Pilot, who was the sole occupant of the Helicopter, contacted the Flight Information Service (FIS)⁵ at Shannon ATC at 14:32 hrs on the day of the accident to report that the Helicopter was departing from Ballygarrett, Co. Wexford, '*en route to Rosslare and then over to Kilrush Airfield [EIKH]*'. The Pilot confirmed to Shannon FIS that the communications were for '*information only*'. The Helicopter landed at approximately 14:42 hrs in Tagoat, Co. Wexford, which is 1.6 nautical miles (NM) south of Rosslare Town. At 14:58 hrs, the Pilot contacted Shannon FIS to advise that he was '*lifting out of Rosslare for Kilrush Airfield*', which is located approximately 52 NM to the north-west, in Co. Kildare. At 15:26 hrs, the Pilot reported to Shannon FIS that he was '*switching now to Kilrush frequency*'⁶. The Helicopter was first recorded by ATC radar at 15:28 hrs, when it was 5.5 NM south-east of EIKH and at an altitude of approximately 2,300 feet (ft) (**Figure No. 1**).

A review of ATC radar data for the flight indicates that at 15:32 hrs, when the Helicopter was approximately 0.7 NM to the south-west of EIKH and at an altitude of approximately 1,800 ft, it turned right (north-east). The radar data indicates that the Helicopter continued generally north-eastwards past EIKH and towards the Kennycourt area, which is located approximately 7 NM north-east of EIKH.

The Helicopter proceeded past Kennycourt in a north-easterly direction (dashed yellow line in lower image in **Figure No. 1**). The radar data indicates that when the Helicopter was approximately 1.5 NM north-east of Kennycourt and 8.3 NM from EIKH, at an altitude of approximately 2,400 ft, it turned around and flew in a south-westerly direction back towards the Kennycourt area (dashed blue line in lower image in **Figure No. 1**). The data indicates that the Helicopter then turned and flew generally eastwards on a zigzag path beyond Kennycourt (dashed green line in lower image in **Figure No. 1**), before flying in a generally westerly direction back towards the Kennycourt area (dashed magenta line in lower image in **Figure No. 1**). The last recorded radar position was approximately 0.38 NM (704 m) south-east of the accident site at 15:45 hrs. The data indicates that the Helicopter was at an altitude of approximately 1,500 ft at that time.

⁵ **Flight Information Service (FIS):** A service provided for the purpose of giving advice and information useful for the safe and efficient conduct of flights (Ref. Commission Implementing Regulation (EU) No 923/2012).

⁶ When arriving at an airfield, a pilot will normally broadcast his or her intentions on the airfield's frequency, which may or may not be manned.



Video footage provided to the Investigation showed the Helicopter travelling towards the ground on a steep trajectory in the final moments of the flight. The Helicopter impacted with terrain near Kennycourt at approximately 15:45 hrs. A fire occurred, which was subsequently extinguished by fire services that attended the scene. The Helicopter was destroyed due to the impact and the fire. The Pilot was fatally injured.

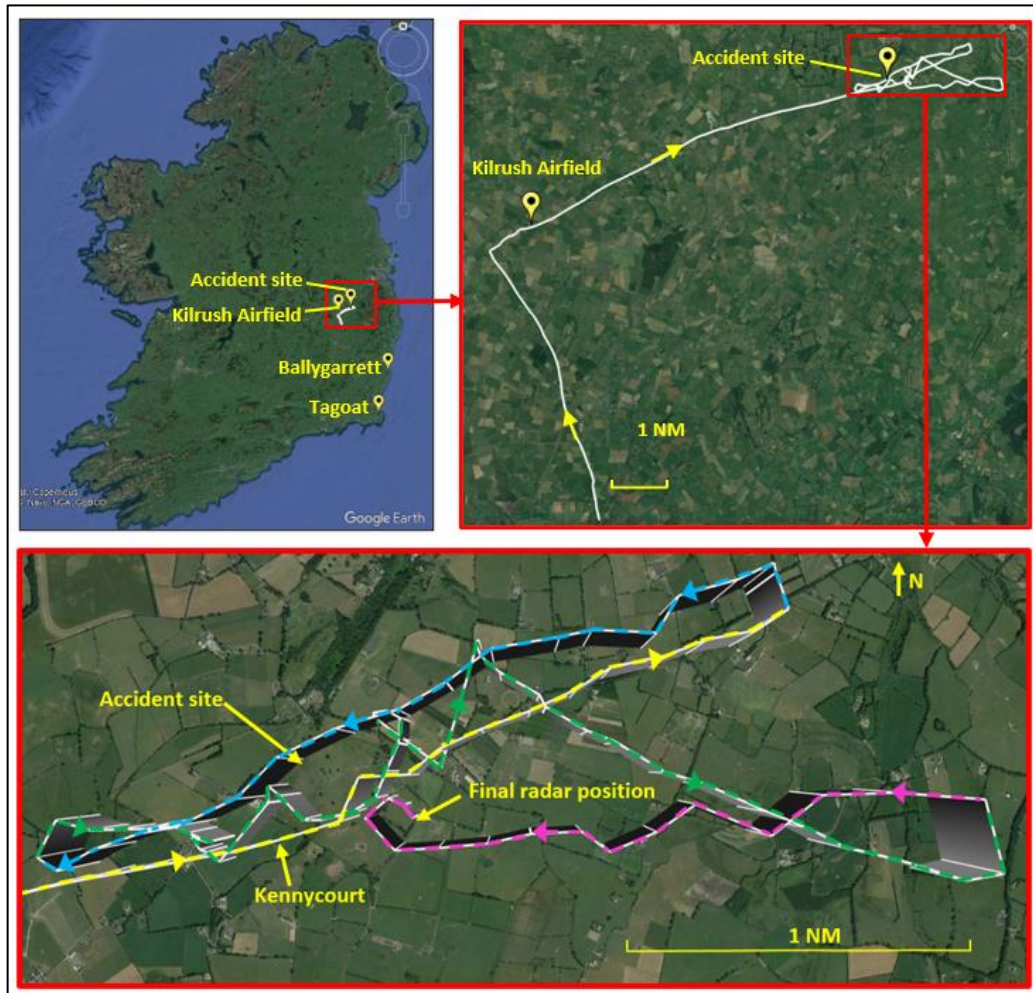


Figure No. 1: N999RL track from radar data (For clarity, coloured dashed lines divide the flight path into separate sections: yellow, followed by blue, then green, then magenta. **Note:** The terrain imagery is historic and does not represent the meteorological conditions prevailing on the day of the accident)

1.1.1 Witnesses

The Investigation spoke to a number of witnesses following the accident.

1.1.1.1 Witnesses Located in the Kennycourt and Surrounding Areas

Several witnesses were situated in the Kennycourt and surrounding areas. These witnesses heard the Helicopter *'going over and back'*, *'coming and going'*, *'circling'* and *'moving around'* for what one witness said *'seemed like five to ten minutes'*. Some of the witnesses reported being able to see a *'flashing light'*. One witness reported being able to hear the Helicopter but could not see it *'due to the clouds'*. This witness said that the Helicopter then became low enough to briefly see its underside, before it climbed and *'re-entered the clouds'* and then went *'nose-down into the field'*.

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One witness, who was located approximately 800 m east of the accident site, thought that the Helicopter was going to land, before it climbed *'nose straight up'* and into cloud. This witness then heard the Helicopter for a further *'three to four minutes'*. Several witnesses reported seeing the Helicopter descend steeply nose-first prior to impact. Some of the witnesses described hearing the sound of an engine running until an impact was heard. One thought the *'engine was coming under load a couple of times'*. Another heard a *'change in airflow through the propeller [main rotor]'* before the sound of an impact. Some of the witnesses went to the accident site and saw the Helicopter on fire.

A number of the witnesses used terms such as *'fine'* or *'okay'* to describe the visibility at ground level but that there was *'fog'* and the *'clouds were very low'*. One witness reported being able to see *'very little due to the fog'* but could see *'further along the ground than up into the sky'*. Another, who had aviation experience and was located close to the accident site, estimated the horizontal visibility to be 250-300 metres (m) and the vertical visibility to be approximately 150 ft (46 m).

1.1.1.2 Witnesses Located in Tagoat, Co. Wexford

The Investigation also spoke to witnesses who were at the site in Tagoat, Co. Wexford, from where the Helicopter departed on the flight towards EIKH. On arrival, the Pilot told them he was going to fly to Kilrush for fuel and that he intended to return to Ballygarrett before sunset. One of the witnesses told the Investigation that they thought that the Pilot mentioned getting back by 16:10 hrs (the time of sunset at Ballygarrett (**Section 1.7.8**)). The witnesses provided the Investigation with video recordings of the Helicopter arriving and departing from the landing site, and photographs of the Helicopter at the site (**Section 1.7.2.2**). It was reported that the Helicopter landed at Tagoat at 14:42 hrs. The videos showed the Helicopter to be operating normally. The sky appeared to be clear and blue in the videos and photographs.

1.1.1.3 Other Witness

Another person contacted the Investigation and advised that when out walking at a location approximately 5 NM south-east of EIKH, at approximately 14:55 hrs, the sound of what he thought was a helicopter could be heard. The person said the timing was based on the time of a call he made using his mobile phone. The noise was described to be like *'grating'* or *'metal-sharpening'*. The witness did not see a helicopter and estimated the cloud height to be 40 to 50 ft. This location would have been below the flight path of the subject Helicopter. However, radar data indicates that the Helicopter would not have been in the area until approximately 15:28 hrs (**Section 1.11.2**).

1.2 Injuries to Persons

The Pilot, who was the sole occupant of the Helicopter, sustained fatal injuries (**Table No. 1**).

Injuries	Crew	Passengers	Others
Fatal	1	0	0
Serious	0	0	0
Minor/None	0	0	

Table No. 1: Injuries to persons



1.3 Damage to Aircraft

The Helicopter was destroyed.

1.4 Other Damage

There was minor damage to the surface of the field at the accident site.

1.5 Personnel Information

1.5.1 Licence and Medical

The Pilot, aged 71 years, held a European Union (EU) Part-FCL⁷ PPL(H)⁸. This was issued by the Irish Aviation Authority (IAA) on 10 June 2021 to convert the Pilot's United States (US) Federal Aviation Administration (FAA) Airman Certificate (Private Pilot, Rotorcraft-Helicopter). This followed an application from the Pilot, the completion of theoretical and practical assessments, and the issuance of a European Union Aviation Safety Agency (EASA) medical certificate. The FAA Airman Certificate had been issued on 23 October 2006.

The EU PPL(H) contained a Robinson R44 Type-Rating, which was revalidated on 23 April 2022, following the completion of a successful proficiency check, and was valid until 30 April 2023. The proficiency check includes a mandatory requirement to perform '*Turns with 30° bank, 180° to 360° left and right, by sole reference to instruments*'. The licence did not contain an Instrument rating and therefore, generally, only flights in Visual Meteorological Conditions (VMC)⁹ were permitted. The Pilot's Class 2/LAPL¹⁰ Medical Certificate, required for a PPL(H), was valid until 10 December 2023. The associated medical examination, including an ECG¹¹, was conducted on 5 December 2022, six days before the accident.

⁷ **Part FCL** (Flight Crew Licensing): Commission Regulation 1178/2011, laying down technical requirements and administrative procedures related to civil aviation aircrew.

⁸ **PPL(H)**: Private Pilot Licence (Helicopters).

⁹ **VMC**: Standardised European Rules of the Air (SERA) – Regulation (EU) 923/2012 states in Class G (uncontrolled) airspace at or below 900 m (3,000 ft) AMSL or 300 m (1,000 ft) above terrain, whichever is the higher, VMC flights must be operated with a flight visibility of 5 km, clear of cloud and with the surface in sight. When so prescribed by the Competent Authority (i.e. in Ireland, the IAA), Helicopters may be permitted to operate in less than 1,500 metres (m) but not less than 800 m flight visibility, if manoeuvred at a speed that will give adequate opportunity to observe other traffic or any obstacles in time to avoid collision. The IAA prescribes in Section ENR (en route) 1.4.1 of its Aeronautical Information Package (AIP) that, in Class G airspace, when operating under Visual Flight Rules (VFR), '*Helicopters may be flown below 300m (1,000ft) above terrain in flight visibility not less than 1,000 m [...]*'. **Note**: SERA does not define '*Surface in Sight*'. However, a definition is contained in the UK's Air Navigation Order (2016), which is included here for information only: "*with the surface in sight*" means '*with the flight crew being able to see sufficient surface features or surface illumination to enable the flight crew to maintain the aircraft in a desired attitude without reference to any flight instrument [...]*'.

¹⁰ **LAPL**: Light Aircraft Pilot Licence.

¹¹ **ECG**: Electrocardiogram.

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1.5.2 Licensing Legislative Requirements

S.I. No. 333 of 2000 *‘Irish Aviation Authority (Personnel Licensing) Order, 2000’*, Article 5 (2) (*‘Flight Crew Members to be Licensed’*) states:

‘A person shall not, within the territorial limits of the State, act as a flight crew member of an aircraft registered in any other state unless -

(a) [...]

(b) in the case of a private aircraft, that person is the holder of an appropriate licence, issued or validated by the competent licensing authority of the state in which the aircraft is registered or by the Authority [IAA], or a JAA licence’.

The IAA’s Personnel Licensing Advisory Memorandum (PLAM) 036 (Revision 1, dated 15 November 2022), regarding the *‘END OF DEROGATION PROVIDED UNDER AERONAUTICAL NOTICE P28¹²’* states the following:

[...]

From 20th June 2022, any pilot who resides in the EU must hold an EASA Part FCL licence [in accordance with the requirements of Commission Regulation (EU) 1178/2011] when flying any aircraft other than those defined in Annex I of the EU Basic Regulation (Regulation (EU) 2018/1139) e.g. gyroplanes, ex-military, homebuilt and certain historic aircraft, and microlight aeroplanes. The pilot shall also comply with the licensing requirements, as applicable, of the State of registry of the aircraft to be flown. [...].’

Regarding the requirements of the state of registry, the US Code of Federal Regulations (CFR), Title 14, Chapter I, Sub-chapter D, Part 61, Sub-part A, Section 61.3, Paragraph (a) (vii) (*‘Requirement for certificates, ratings, and authorizations’*) states: *‘When operating an aircraft within a foreign country, a pilot license issued by that country may be used’.*

The IAA and the FAA confirmed to the Investigation that the Pilot could operate a US-registered helicopter in Ireland with a valid EU licence and valid medical certificate.

1.5.3 Flying Experience

The Pilot’s logbook was found within the wreckage of the Helicopter. The logbook had sustained significant fire damage; however, most entries remained legible. The last entry was dated 3 December 2022. The Investigation obtained the following flight experience from the logbook (**Table No. 2**).

Total all types:	316 hours
Total on type:	110 hours
Last 90 days:	18.2 hours
Last 28 days:	3.1 hours
Last 24 hours:	Nil

Table No. 2: Pilot’s flying experience (not including date of accident)

¹² **Aeronautical Notice P28:** *‘Derogation from certain requirements of the Aircrew Regulation with regard to recognition of 3rd country [Non-European Union/European Economic Area] licences’.*



1.6 Helicopter Information

1.6.1 General

The four-seater Helicopter was a Robinson R44 Raven II. The helicopter type is fitted with a Lycoming IO-540-AE1A5 fuel-injected, six-cylinder, reciprocating engine. The engine powers a counter-clockwise-rotating (viewed from above) semi-rigid, two-bladed main rotor, with a diameter of 10.06 (m), and a two-bladed tail rotor, with a diameter of 1.47 m. The helicopter's empennage consists of upper and lower vertical stabilisers and a horizontal stabiliser. The tail rotor, which is protected by a guard, is mounted on the left side of the empennage. Drive to the tail rotor is provided by a drive shaft located within a tailcone which connects the cabin to the empennage.

A red anti-collision light, which flashes when switched on, is located on the upper surface of the helicopter's tailcone, forward of the tail rotor. Navigation lights, which illuminate steadily when switched on, are located on each side of the cabin and on the tail. A cabin heater, with air outlets forward of the pedals and in the rear footwells, is installed. An outside air temperature gauge is also fitted.

The principal dimensions of the helicopter type, as outlined in the Pilot Operating Handbook (POH) for the Helicopter are shown in **Figure No. 2**.

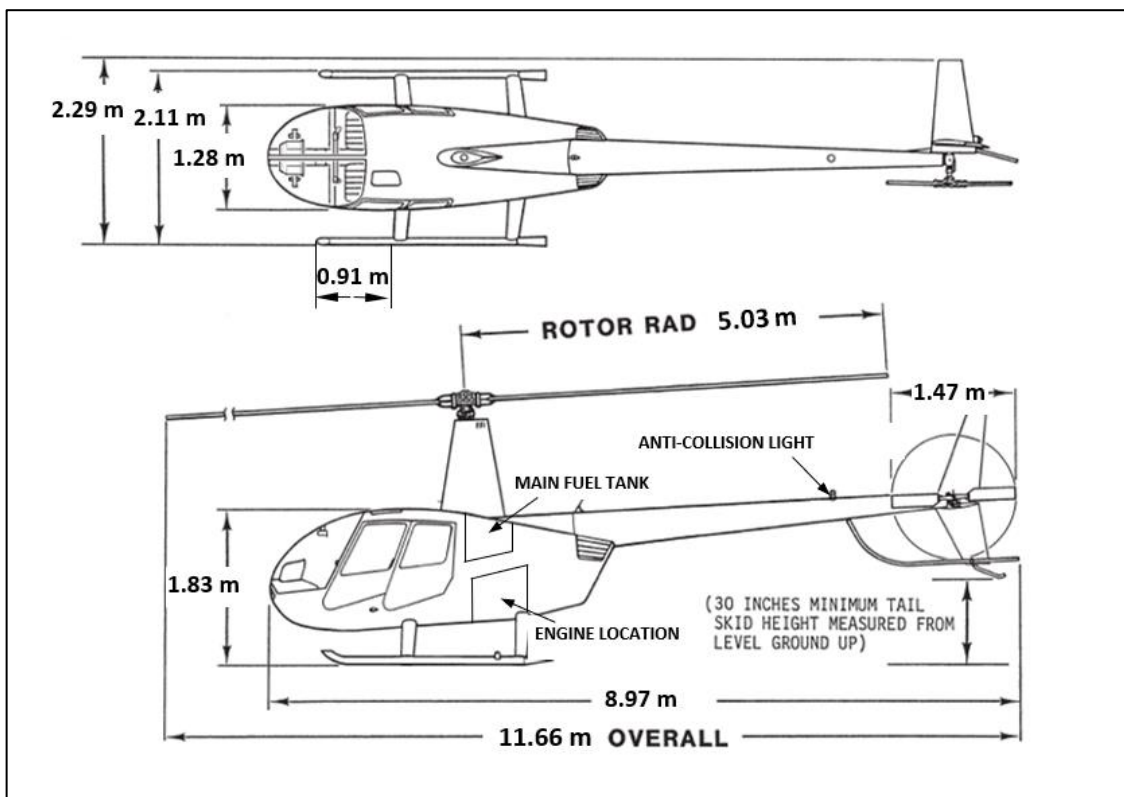


Figure No. 2: Robinson R44 principal dimensions (adapted from POH diagram)

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The approved fuel is aviation gasoline (Avgas). Two fuel tanks – a main and an auxiliary – are fitted above the engine in a separate section behind the cabin area. According to the POH, the main tank has a total capacity of 30.5 US gallons (29.5 usable), the auxiliary tank has a total capacity of 17.2 US gallons (17 usable), and the resulting overall usable capacity is 46.5 US gallons¹³ (176 L). The fuel from the auxiliary tank flows into the main tank through an interconnect hose fitted to the bottom of the auxiliary tank. The fuel used by the engine is drawn from the main tank only. The bottom of the main tank is positioned lower than the bottom of the auxiliary tank, so that when the auxiliary tank is empty, the main tank still has fuel remaining. According to the Helicopter Manufacturer, the fuel gauge indication needles (one for each tank) will initially drop simultaneously during flight, but the auxiliary tank gauge will drop slightly faster and will read empty while the main tank gauge will show the fuel remaining in the main tank. A *LOW FUEL* quantity warning light will illuminate when the remaining usable fuel reaches approximately 2.9 US gallons (11 L). A two-second delay is incorporated into the electrical circuit to prevent sloshing fuel from giving a false indication.

A cyclic control stick¹⁴ is located between the front seats and is operated via a control grip in front of the pilot. The control grip is fitted to a cross tube, which is connected to the cyclic control stick. A collective control lever¹⁵ is located to the left of each front seat; a twist-grip throttle control is located on each collective lever. Cyclic and collective control of the main rotor is assisted by three hydraulic servos. An rpm¹⁶ governor assists in controlling the engine rpm under normal conditions; it can be over-ridden by the pilot using the throttle twist-grip. In normal flight, a throttle correlator opens the throttle as the collective lever is raised. Anti-torque/yaw pedals in the cockpit are connected to a tail rotor pitch-change mechanism by a control rod located within the tailcone.

When operating at normal rotational speed, the main rotor rotates at 408 rpm and the tail rotor rotates at 2,426 rpm. If the main rotor speed drops below 97% (approximately 388 rpm), a low rotor rpm warning horn sounds, and a *LOW RPM* warning light illuminates. The horn is muted when the collective lever is fully down. The helicopter's normal (*'green arc'*) operating speed range is 0 to 110 knots indicated airspeed (KIAS). The maximum take-off weight of the helicopter type is 2,500 pounds (1,134 kilograms). The POH for the helicopter type notes that *'flights in known icing conditions'¹⁷ [are] prohibited'*.

The subject Helicopter, registration N999RL (**Photo No. 1**), was manufactured in 2005. A weighing report, dated February 2005, noted that its empty weight was 1,522.86 pounds (691 kilograms). The Helicopter was fitted with a *'Mode S'* transponder which identifies the Helicopter and transmits its pressure altitude (altitude referenced to 1013.2 hectopascals) to ATC and other aircraft. The Helicopter's seats were fitted with three-point restraints comprising a lap and shoulder strap.

¹³ **US Gallon:** 1 US Gallon is equal to 0.833 Imperial gallons or 3.785 litres.

¹⁴ **Cyclic control stick:** This control stick changes the pitch of the main rotor blades during each cycle of rotation, resulting in the rotor disc tilting in a particular direction and causing the helicopter to move in that direction.

¹⁵ **Collective control lever:** The control lever in a helicopter which increases or decreases the total lift derived from the rotor by changing the pitch angle of all the main rotor blades collectively.

¹⁶ **rpm:** revolutions per minute.

¹⁷ **Icing Conditions:** When a liquid such as water is below its freezing point without it becoming a solid, it is known as *'supercooled'*. In-flight icing occurs when supercooled water freezes on impact with any part of the external structure of an aircraft that is at a temperature of 0 °C or lower. Icing conditions exist when air contains droplets of supercooled water. Known icing conditions are *'conditions where actual ice is observed visually to be on the aircraft by the pilot or identified by on-board sensors'* (Ref: Guidance Material for Regulation (EU) 965/2012 *'Air Operations'*).



The Helicopter's engine (serial number L-29869-48A) was manufactured on 21 September 2004. The Helicopter was not fitted with an autopilot system, nor was it required to be.



Photo No. 1: The subject Robinson R44 Helicopter (*used with permission of photographer*)

1.6.2 Fuel Consumption

The POH for the helicopter does not provide any information on the helicopter's fuel consumption. The Helicopter Manufacturer's website states that the maximum range of the Helicopter is approximately 300 NM. The Helicopter Manufacturer's *'Estimated Operating Costs'* document (dated 1 July 2023) refers to a fuel consumption rate of 15 US gallons per hour (GPH) for *'average use'* (56.8 litres per hour). According to the Engine Manufacturer's *Operator's Manual* (4th edition, June 2006), the fuel consumption rate for the IO-540 AE Series, as fitted to the subject Helicopter, is 15 US GPH at *'Performance Cruise (75% rated)'* and 13.5 US GPH (51.1 litres per hour) at *'Economy Cruise (65% rated)'*. A pilot, who had regularly flown the subject Helicopter, advised the Investigation that, in their experience, a fuel consumption rate of 14 US GPH (53 litres per hour) was achieved and that a total of three hours of operation was possible. Another pilot, who had experience on the helicopter type, said a fuel consumption rate of 1 L per minute or 58 to 60 litres per hour (15.3 to 15.8 US GPH) was typical.

1.6.3 Airworthiness/Maintenance Information

The subject Helicopter's Certificate of Airworthiness was issued by the FAA on 28 February 2005. The last 100-hour/Annual Inspection was certified on 7 June 2022, by an approved Aircraft Maintenance Engineer, at a total airframe and engine operating time of 973.8 hours (in this case, the Helicopter and engine operating hours quoted in the logbooks were the same).

The Annual Inspection included an engine cylinder compression check, the scheduled replacement of the ignition magnetos¹⁸ and a scheduled check for compliance with the applicable airframe and engine Airworthiness Directives (ADs). The engine oil was replaced, as was the oil filter and air filter. The Annual Inspection also recorded a scheduled check of the Helicopter's cockpit-mounted carbon monoxide detector.

¹⁸ **Magnetos:** Self-contained generators that provide timed, high electrical voltage to an engine's spark plugs.

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The technical records indicate that the most recent maintenance inspection was a 50-hour Inspection, which was performed on 10 October 2022 and included the replacement of the engine oil and filter. An inspection of the removed oil filter was recorded as '*found satis* [satisfactory]'. The total Helicopter and engine operating time recorded on this date was 1,001.1 hours. Records indicate that the Helicopter flew for approximately seven hours and 45 minutes since the 50-hour Inspection (not including the day of the accident) and therefore its total operating hours up to the date of the accident was approximately 1,008 hours.

1.6.4 Fuel Tank Service Bulletin

Service Bulletin SB-78, '*Bladder Fuel Tank Retrofit*', was issued by the Helicopter Manufacturer on 20 December 2010. This was followed by subsequent revisions. The Service Bulletin (SB) is also the subject of EASA Airworthiness Directive 2014-0070. The SB '*requires R44 helicopters with all-aluminium fuel tanks to be retrofitted with bladder-type tanks*' (an aluminium fuel tank lined with a bladder) and other fuel system components, to improve the fuel system's resistance to a post-accident fuel leak and consequent fire. Maintenance records indicate that SB-78A was embodied on the subject Helicopter since 3 November 2012.

1.6.5 Technical Logbook

The Investigation recovered the Helicopter's technical logbook at the accident site. It had sustained some fire damage; however, the entries remained legible. Information recorded in the technical logbook for each flight included the following details: departure and arrival airfields; date of flight; take-off and landing fuel quantities (% full); take-off and landing times; flight time; and total operating time of the Helicopter.

The Investigation reviewed all technical logbook entries made during the 12 months prior to the accident. The technical logbook records that the Helicopter flew from Ballygarrett 47 times during that period. On four of these occasions, the take-off fuel quantity recorded was greater than the landing fuel quantity recorded¹⁹. Three of the four occasions were for local flights (i.e. from Ballygarrett to Ballygarrett). The first of these was on 19 June 2022, when the take-off fuel recorded was 60%, whereas the landing fuel recorded on the previous flight that day was 10%, i.e. an increase of 50% (23.25 US gallons). The second local flight was on 3 July 2022, when the take-off fuel recorded was 40%, whereas the landing fuel recorded following a flight on 19 June 2022, which was the previous flight recorded, was 30%, i.e. an increase of 10% (4.65 US gallons). The third local flight was on 28 August 2022, when the take-off fuel recorded was 60%, whereas the landing fuel recorded following a flight on 26 August 2022, which was the previous flight recorded, was 50%, i.e. an increase of 10% (4.65 US gallons). The other occasion was on 27 November 2022 for a flight to another airfield by another pilot, when the take-off fuel recorded was 100%, whereas the landing fuel recorded following a flight on 14 November 2022, which was the previous flight recorded, was 80%, i.e. an increase of 20% (9.3 US gallons). The flight on 27 November 2022 was the only flight from Ballygarrett to another airfield recorded in the technical logbook in the 12-month period, which had a take-off fuel quantity recorded that was greater than the landing fuel quantity recorded. It was also the only flight from Ballygarret recorded as departing with full (100%) tanks.

¹⁹ There was a trailer-mounted fuel bowser located at Ballygarrett (**Section 1.18.1**).



The technical logbook records a total of three flights on 27 November 2022: the flight from Ballygarrett to another airfield (as noted above), a local flight at the other airfield, and a flight back to Ballygarrett. The entry indicates that the Helicopter departed the other airfield with full ('100%') tanks. The flight time recorded for the return leg was one hour.

The technical logbook also indicates that 15 of the 47 flights from Ballygarrett were to EIKH and that the Helicopter departed with between 20% and 90% fuel on these flights and landed at EIKH with 10% fuel on three occasions. The technical logbook indicates that the flights from Ballygarrett to EIKH took between 21 minutes and 47 minutes to complete.

A total of 22 flights from EIKH are recorded, which indicate that each time the Helicopter departed EIKH for another destination (17 times), including Ballygarrett (15 times), it did so with full ('100%') tanks.

1.7 Meteorological Information

1.7.1 Forecasts

1.7.1.1 Terminal Aerodrome Forecasts

The Investigation asked *Met Éireann*, the Irish meteorological service, to provide the Terminal Aerodrome Forecasts (TAFs) that were valid on the accident date. These provide weather forecasts for major airfields and are available to pilots via an online '*Met Self Briefing System*' and through a variety of apps. The closest airfield to EIKH for which a TAF was available was Casement Aerodrome (EIME) in Baldonnel, Co. Dublin. This airfield is located approximately 20 NM north-east of EIKH. The TAF for EIME contained the following information:

```
TAF EIME 111400Z 1115/1124 25006KT 3000 BR BKN002  
TEMPO 1115/1124 7000 NSW SCT002  
PROB40 TEMPO 1115/1124 0500 FZFG BKN001=
```

The information contained on the first line includes the following: the date and time (11th of the month, 14:00Z); the validity period (15:00 to midnight); wind direction and speed (250 degrees and 6 kt); visibility (3,000 m); mist (BR – from a French word for mist/fog); and sky condition (broken clouds, with bases at 200 ft above aerodrome elevation).

The second '*TEMPO*' line, which is used if conditions are notable, but are expected to last for less than an hour, includes the following: the validity period (15:00 to midnight); visibility (7,000 m); no significant weather (NSW); and sky condition (scattered cloud, with bases at 200 ft).

The final line is a probability forecast. PROB40 is a probability of 40%. The following information is included: the validity period (15:00 to midnight); visibility (500 m); freezing fog; and sky condition (broken cloud at 100 ft).

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1.7.1.2 Low-Level Significant Weather Charts

Met Éireann also provided the Investigation with the low-level significant weather charts that were valid for 12:00 hrs (issued at 06:28 hrs) and 18:00 hrs (issued at 11:36 hrs).

The chart valid for 12:00 hrs (**Appendix B1**) forecasted, *inter-alia*, a visibility of greater than 10 km, with occasional visibility of 3,000 to 4,000 m inland, and isolated occasional visibility inland in southern Ireland of 300 to 1,000 m, with mist, fog, freezing fog, and isolated hill fog. Regarding cloud, the chart forecasted isolated inland occasional scattered/broken cloud with bases at between 0 ft and 400 ft.

The chart valid for 18:00 hrs (**Appendix B2**) forecasted, *inter-alia*, isolated occasional visibility inland of 200 to 3,000 m, with rain/snow showers, mist, fog, freezing fog, and isolated hill fog. Regarding cloud, the chart forecasted isolated inland occasional scattered/broken cloud with bases between 500 ft and 1,400 ft, and isolated inland occasional scattered/broken cloud with bases between 100 ft and 400 ft.

1.7.2 Aftercasts

The Investigation asked *Met Éireann*, to provide an aftercast of the meteorological conditions prevailing in the Kennycourt/Kilrush areas around the time of the accident. *Met Éireann* was also asked to provide aftercasts for Tagoat, from where the Helicopter had departed on the accident flight, and for Ballygarrett, from where the Helicopter had departed for Tagoat. *Met Éireann* stated that the reports use data from the national climate archive to give the best estimate of conditions for the locations requested, with a bias towards the most representative stations at Johnstown Castle, Co. Wexford; Oak Park, Co. Carlow; and Baldonnell, Co. Dublin (annotated later in **Figure No. 3**).

1.7.2.1 Meteorological Conditions in the Kennycourt/Kilrush Areas

The estimated meteorological conditions for the Kennycourt/Kilrush area on 11 December 2022 at 15:45 hrs, as provided by *Met Éireann*, are outlined in **Table No. 3**.

Meteorological Situation:	Ireland lies in a light to moderate north-easterly airflow between an anticyclone over Greenland and a weak depression centred near the south coast of England.
Surface Wind:	Variable, 2-5 Knots (kt).
Wind at 2,000 ft:	North to north-east, 10-15 kt.
Between Surface and 300 ft:	North to north-east, 5 kt.
Visibility:	Generally, 3-5 kilometres (km), with pockets down to 300-800 m.
Weather:	Overcast and misty with pockets of freezing fog ²⁰ .

²⁰ **Freezing Fog:** When fog forms in temperatures that are below freezing, water droplets in the air become supercooled and remain as liquid, even though they are below freezing temperature. Supercooled liquid water droplets in fog can freeze instantly on exposed surfaces when surface temperatures are at or below freezing.



Cloud:	Generally, an overcast layer (8 oktas ²¹) of cloud with bases ²² between 100 ft and 500 ft (AMSL ²³). Cloud would have been lower and thicker in the fog patches. The low cloud and fog blanket was not deep, in the order of tens to a couple of hundred feet. Largely clear skies above the layer at 2,000 ft (AMSL).
Surface Temperature/Dew Point:	0 ° Celsius (C)/ –1 °C.
Mean Sea Level (MSL) Pressure:	1010 hectopascals (hPa).
Freezing Level²⁴:	Surface to <1,000 ft.

Table No. 3: Meteorological aftercast for the Kennycourt/Kilrush Airfield areas

1.7.2.2 Meteorological Conditions in Tagoat

The estimated meteorological conditions for the Tagoat area on 11 December 2022 at 15:00 hrs, as provided by *Met Éireann*, are outlined in **Table No. 4**.

Surface Wind:	North to north-west, 7-10kt.
Wind at 2,000 ft:	North to north-east, 15 kt.
Between Surface and 300 ft:	North to north-west, 8-12 kt.
Visibility:	30+ km.
Weather:	Clear and dry with crisp winter sunshine.
Cloud:	Few clouds (1-2 oktas) with bases around 4,000 ft.
Surface Temperature/Dew Point:	3 °C/–1 °C.
Mean Sea Level (MSL) Pressure:	1009 hPa.
Freezing Level:	<1,000 ft.

Table No. 4: Meteorological aftercast for Tagoat

The Investigation was provided with photographs of the Helicopter that were taken at the departure site in Tagoat (**Section 1.1.1.2**) in which the sky appeared to be clear and blue (**Photo No. 2**).

²¹ **Okta:** Unit of cloud amount, expressed as number of eighths of the sky dome that is covered by clouds.

²² **Cloud Base:** The lowest altitude of the visible portion of a cloud.

²³ **AMSL:** Above Mean Sea Level.

²⁴ **Freezing Level:** The lowest altitude in the atmosphere over a given location, at which the air temperature is 0°C.



Photo No. 2: Helicopter at Tagoat prior to departure (*used with permission of photographer*)

1.7.2.3 Meteorological Conditions in Ballygarrett

The estimated meteorological conditions for the Ballygarrett area on 11 December 2022 at 14:30 hrs, as provided by *Met Éireann*, are outlined in **Table No. 5**.

Surface Wind:	Northerly, 3-5 kt.
Wind at 2,000 ft:	North to north-east 15 kt.
Between Surface and 300 ft:	North to north-west 5-10 kt.
Visibility:	30+ km.
Weather:	Clear and dry with crisp winter sunshine.
Cloud:	Few clouds (1-2 oktas) with bases around 4,000 ft.
Surface Temperature/Dew Point:	4 °C/1 °C.
Mean Sea Level (MSL) Pressure:	1009 hPa.
Freezing Level:	<1,000 ft.

Table No. 5: Meteorological aftercast for Ballygarrett

1.7.3 Satellite Image of Cloud/Fog Conditions

Met Éireann provided a satellite image of what was described as ‘*low cloud and fog*’ at 14:30 hrs over the south-east of Ireland (**Figure No. 3**). The image shows clear sky over Ballygarrett and Tagoat and an area of cloud/fog further inland. Clear skies are also visible to the east. The Wicklow Mountains area is also visible (approximately 3,000 ft maximum elevation). *Met Éireann* stated that at 15.45 hrs, the visible satellite imagery quality was ‘*poor due to darkness*’ but that fog and low cloud coverage was similar at that time.

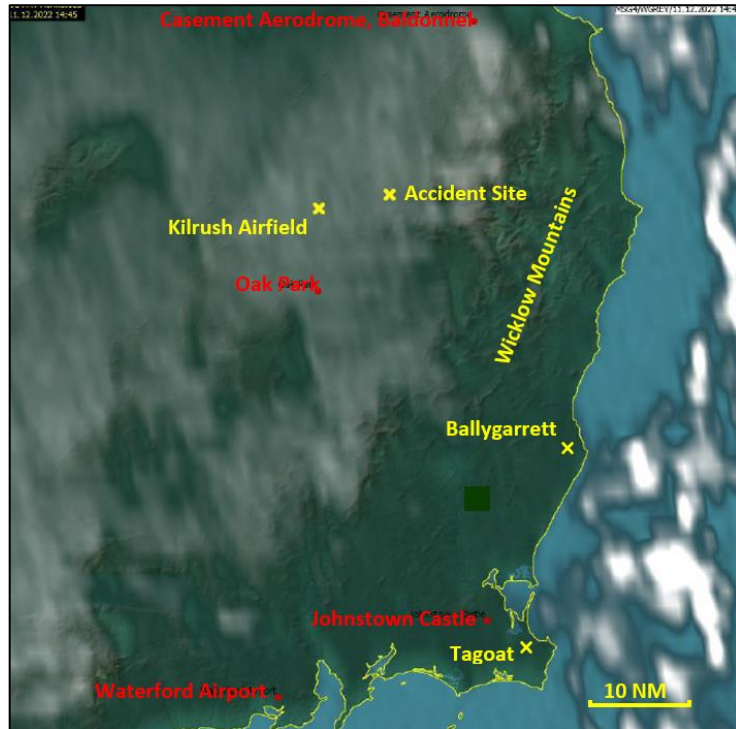


Figure No. 3: Satellite image at 14:30 hrs (adapted from Met Eireann image)

Met Éireann noted that there would have been largely clear conditions through Co. Wexford, which is in the south-east of Ireland, and that fog and low cloud below the flight level would have been encountered through counties Carlow and Kildare. *Met Éireann* also noted that surface temperatures across Leinster between 15:00 hrs and 16:00 hrs on the accident date ranged between $-1\text{ }^{\circ}\text{C}$ and $+2\text{ }^{\circ}\text{C}$ and that patches of freezing fog would have been expected but that they did not have observations at their sites at that time.

1.7.4 Observations from Synoptic Stations

Met Éireann also provided observations from three synoptic stations recorded at 16:00 hrs on the accident date (Table No. 6) (locations shown on Figure No. 3).

	Oak Park, Co. Carlow	Baldonnel, Co. Dublin	Johnstown Castle, Co. Wexford
	Automatic	Manual	Automatic
Wind Speed:	4 kt	7 kt	8 kt
Wind Direction:	340	220	330
Visibility:	9 km	2 km	40 km
Cloud amount and base height:	8 oktas/500 ft	7 oktas/200 ft	1 okta/4,100 ft
Air temperature/dew point temperature:	$-0.2^{\circ}\text{C}/-0.9^{\circ}\text{C}$	$0.2^{\circ}\text{C}/-0.1^{\circ}\text{C}$	$1.3^{\circ}\text{C}/-0.9^{\circ}\text{C}$

Table No. 6: Meteorological observations at three *Met Éireann* synoptic stations

Met Éireann stated that *Oak Park* (elevation 190 ft approximately), which is approximately 13 NM south-south-west of EIKH, was in fog and low cloud for the duration of the day, with cloud bases varying between the surface and 500 ft.

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1.7.5 Weather Conditions at Kilrush

The Investigation interviewed a pilot who was at EIKH at 14:30 hrs on the day of the accident to carry out maintenance work on an aircraft. He left shortly after that time and said he did not hear a helicopter when he was there. The pilot said that the temperature was 0 °C, as indicated by the temperature display in his car, and that there was no wind. He noted that due to the fog, it was not possible to see the intersection of the two runways from where he was located, which was subsequently measured to be approximately 250 m away. He said that blue sky was visible through gaps in the fog and that there was only one other person at the airfield, who was running an aircraft engine.

1.7.6 Weather Conditions at Punchestown at 10:35 hrs on the Morning of the Accident

The Punchestown area of Co. Kildare is located approximately 4.5 NM north-east of the accident site. A person who was in the Punchestown area at 10:35 hrs on the day of the accident (approximately five hours prior to the accident) provided the Investigation with aerial images taken with a Remotely Piloted Aircraft System (RPAS). The images showed low-lying cloud/fog and poor visibility in that area at that time. Ground frost is also visible (**Photo No. 3** and **Photo No. 4**).



Photo No. 3: Aerial image of conditions at 10:35 hrs, 4.5 NM north-east of accident site (looking south-east) (*used with permission of photographer*)



Photo No. 4: Aerial image of conditions at 10:35 hrs, 4.5 NM north-east of accident site (looking south-west) (*used with permission of photographer*)

1.7.7 Flight Planning

The extent of flight planning undertaken by the Pilot could not be determined. However, family members reported to the Investigation that the Pilot would always check the weather forecasts and that he would not fly unless the weather was suitable.

1.7.8 Daylight Hours

Section 2.7 of the IAA's Aeronautical Information Publication (AIP), dated 13 October 2016, contains the times of civil morning twilight, sunrise, sunset and civil evening twilight²⁵ for Ireland's main airports at three-day intervals for one calendar year. The AIP notes that sunset at Dublin Airport, the nearest main airport to the accident site, is 16:05 hrs on 12 December (the day after the occurrence) and that civil twilight ends at 16:50 hrs.

The Astronomical Applications Department of the US Naval Observatory's website includes a facility for obtaining Sun and Moon data for any location. It indicates that the times of sunset and the end of civil twilight at Kilrush Airfield, and Ballygarrett, on the date of the accident were 16:10 hrs and 16:52 hours respectively.

Article 2, paragraph 97, of Regulation (EU) 923/2012, laying down '*the common rules of the air and operational provisions regarding services and procedures in air navigation*' (SERA – Standardised European Rules of the Air) defines night as: '*[...] the hours between the end of evening civil twilight and the beginning of morning civil twilight [...]*'.

²⁵ **Civil Evening Twilight:** Civil evening twilight ends when the centre of the sun's disc is six degrees below the horizon.

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1.8 Aids to Navigation

1.8.1 General

The subject Helicopter's flight instruments included an Attitude Indicator (Artificial Horizon)²⁶ and a Directional Gyro (Heading Indicator)²⁷. Maintenance records indicate that a Garmin GPS²⁸ navigation unit had been fitted to the Helicopter in February 2005.

1.8.2 Mobile Phone and Computer Tablet

A mobile phone, and a computer tablet and associated mount were found in the wreckage of the Helicopter. Both devices sustained substantial damage (**Section 1.11.1**). Aviation GPS navigation applications (apps) can be installed on such devices. The Investigation established that the Pilot made use of such an application to assist in navigation. The Investigation obtained details from a navigation application provider for several flights completed by the Helicopter, including a local flight that was conducted on 3 December 2022. There were no details available from the navigation application provider for the accident flight.

1.9 Communications

The flight operated entirely in Class G²⁹ airspace within the Shannon Flight Information Region³⁰ (FIR). Neither a flight plan nor ATC clearance is required when operating in Class G airspace. Notwithstanding this, the Pilot informed Shannon FIS, via radio, of his intentions as the flight commenced and as it progressed. The Pilot confirmed to Shannon FIS that the communications were for '*information only*'. Shannon ATC provided the Investigation with recordings of the radio communications. The communications are detailed in **Appendix A**.

1.10 Aerodrome Information

The Pilot advised Shannon FIS and witnesses at Tagoat, from where the accident flight departed, that his intention was to fly to Kilrush. This airfield is located in Co. Kildare, approximately 52 NM (96.3 km) north-west of Tagoat, 37 NM (68.5 km) north-west of Ballygarrett, and approximately 7 NM (13 km) south-west of the accident site.

The airfield has two runways – Runway (RWY) 01/19 and RWY 11/29. According to the Kilrush Airfield website, the airfield's elevation is 260 ft AMSL. Self-service refuelling for Avgas is available at the airfield on an account basis. The Pilot had an account and had used self-service fuelling previously.

The Investigation was informed that the Pilot did not advise airfield personnel regarding the intention to fly there on the day of the accident and that he did not need to do so as he routinely operated to the airfield. The airfield was not manned on the afternoon of the accident, nor was it required to be. There is an on-line-accessible camera at the airfield. However, it was not possible to establish if the Pilot had accessed the camera on the day of the accident.

²⁶ An Artificial Horizon/Attitude Indicator indicates the Helicopter's pitch and roll orientation.

²⁷ A Directional Gyro/Heading Indicator, when correctly set with reference to the Helicopters magnetic compass, indicates the Helicopter's heading.

²⁸ **GPS:** Global Positioning System – a satellite-based navigation system.

²⁹ **Class G:** Airspace within which aircraft are not under the control of ATC.

³⁰ **Flight Information Region (FIR):** Airspace of defined dimensions designated by the appropriate Air Traffic Service (ATS) authority within which Flight Information Service (FIS) and Alerting Service are provided.



1.11 Flight Recorders

1.11.1 Introduction

The Helicopter was not fitted with a Cockpit Voice Recorder (CVR) or a Flight Data Recorder (FDR), nor was it required to be. The Helicopter Manufacturer advised the Investigation that audio/video recorders are now being installed in all R44 models at manufacture. The Investigation obtained recorded data relevant to the flight from several sources, as outlined below. In addition, a mobile phone and a computer tablet were found at the accident site (**Section 1.8.2**). A computer tablet mount, incorporating three suction pads, was also found. The computer tablet and mobile phone sustained substantial damage in the accident; therefore, the Investigation sought assistance from an organisation that specialises in the recovery of data from damaged devices. Extensive preparatory and repair work was carried out on both devices. However, the damage sustained was such that no data could be retrieved.

1.11.2 ATC Radar Data

Several ground-based radar heads are located throughout Ireland to provide primary and secondary radar data for ATC purposes. ATC radar heads sweep every four or six seconds, depending on their location. Primary radar operates by transmitting a radio signal and analysing the reflection (return) from an aircraft to establish its range and bearing from the radar antenna. Successive returns permit radar systems to calculate an aircraft's ground speed. Secondary radar interrogates an aircraft's transponder to identify the aircraft and obtain its pressure altitude, which the transponder references to 1013.2 hPa to ensure transmitted altitudes from all aircraft are referenced to a common datum.

The information from several radar heads is combined and continuously processed by the ATC Air Traffic Management (ATM) Surveillance Tracker and Server (ARTAS). The ARTAS system obtains the pressure altitude received from an aircraft. At aircraft pressure altitudes up to 5,000 ft (the '*transition altitude*' in Ireland), ATC systems adjust the data for the sea-level air pressure on the day (QNH) before it is displayed on the Air Traffic Controller's screen. An adjustment of 27.1 ft is applied for every 1 hPa difference between 1013.2 hPa and QNH. If the QNH is lower than 1013.2 hPa, the aircraft's actual altitude will be lower than that transmitted by the transponder.

ATC provided the Investigation with the radar data for the accident flight from two of the Dublin-based radar heads and the ARTAS system data. Due to its location relative to the radar heads, the Helicopter was only detected above a certain altitude. The data obtained included the Helicopter's position, track, ground speed and pressure altitude (referenced to 1013.2 hPa) and was used by the Investigation to assess the path of the accident flight from the time that the Helicopter was first detected by radar until the time that it was last detected.

The Helicopter was first recorded by radar at time 15:28:45 when it was approximately 5.5 NM south-east of EIKH and travelling north-westerly towards EIKH. The pressure altitude, as received by ATC systems from the Helicopter's transponder, was 2,400 ft, which, as outlined above, is referenced to 1013.2 hPa. The meteorological aftercast indicated that the MSL air pressure in the Kennycourt/Kilrush area was 1010 hPa (**Section 1.7.2.1**). The 3.2 hPa difference (1013.2 – 1010) equates to a height difference of approximately 100 ft ($3.2 \times 27.1 = 86.7$). Therefore, the actual altitude of the Helicopter when it was first detected by radar was approximately 2,300 ft. For clarity, all altitudes in **Section 1.11.2.1** and **Section 1.11.2.2** below have been corrected for the air pressure in the area on the day (i.e. transponder transmitted altitude minus 100 ft).

The flight path, as indicated by the ARTAS data, is shown in **Figure No. 4** and **Figure No. 5**. The ARTAS system is calibrated for cruising aircraft, therefore the path shown may not reflect the exact nature of the turns performed by the Helicopter but is considered to be generally representative.

1.11.2.1 Initial Flight Path

The earlier part of the flight path is annotated by letters **A** to **L** in **Figure No. 4**. Time, altitude and ground speed are also indicated. The figures included below for altitude and ground speed are to be considered approximate values.



Figure No. 4: Flight path, with time, altitude (corrected for the air pressure on the day), and ground speed as indicated by ARTAS data (**Note:** The terrain image is historic and does not represent the meteorological conditions prevailing on the day of the accident)

The following details are indicated by the ARTAS data:

- A.** The first point recorded by radar was at time 15:28:45, when the Helicopter was approximately 5.5 NM south-east of EIKH at an altitude of 2,300 ft³¹ (the Pilot had informed Shannon FIS that he was ‘switching now to Kilrush frequency’ at time 15:26:19). The Helicopter was tracking north-westerly in the general direction of EIKH at a ground speed of 58 kt³². The ground elevation at this point was approximately 300 ft. The Helicopter maintained 2,300 ft for a period of approximately 25 seconds.

³¹ All altitudes in this Section have been corrected for the air pressure on the day.

³² The ground speed recorded at this stage was unlikely to be accurate because it was the first point recorded, and successive points are needed to permit speed calculation.



- B.** The Helicopter then descended over a period of 45 seconds, while continuing on a north-westerly track at ground speeds of between 83 kt and 93 kt. The Helicopter's altitude was 1,900 ft at time 15:29:55. At this stage, the Helicopter was approximately 3.4 NM south-east of EIKH.
- C.** At time 15:30:40, when the Helicopter was approximately 2.4 NM south-east of EIKH, it appeared to deviate to the left. Its ground speed was 80 kt. Its altitude was unchanged at 1,900 ft.
- D.** The Helicopter then descended to 1,800 ft, which it reached at time 15:31:15. Its ground speed at this stage was 87 kt.
- E.** The Helicopter briefly descended to 1,700 ft, before returning to 1,800 ft.
- F.** At time 15:32:20, when the Helicopter was approximately 0.7 NM south-west of EIKH, it turned right (north-east) in the direction of the airfield. The Helicopter was at an altitude of 1,800 ft and a ground speed of 83 kt.
- G.** At time 15:32:55, the Helicopter flew directly overhead EIKH (airfield elevation 260 ft), travelling north-eastwards at a ground speed of 76 kt. Its altitude was 1,800 ft. The distance flown from Tagoat until when the Helicopter was overhead EIKH was measured to be approximately 52 NM.
- H.** The Helicopter climbed to an altitude of 1,900 ft, which it reached at 15:33:10. The ground speed at this stage was 82 kt.
- I.** During the subsequent 30 seconds, the Helicopter's altitude remained at 1,900 ft, as it continued on a north-easterly track at a ground speed of 87 kt. The Helicopter then commenced a climb to 2,000 ft, which it reached at time 15:33:45. The ground speed was 91 kt at this stage.
- J.** At time 15:34:35, the Helicopter had descended to 1,900 ft. The ground speed was 94 kt. The Helicopter's altitude returned to 2,000 ft and continued at this altitude for approximately 40 seconds at a ground speed of 96 kt.
- K.** Commencing at time 15:35:30, the Helicopter began climbing.
- L.** The Helicopter reached an altitude of 2,300 ft at time 15:36:20. The Helicopter's ground speed was 96 kt at this stage.

1.11.2.2 Subsequent Flight Path

The latter part of the flight, as indicated by the ARTAS data is shown in **Figure No. 5**. Time, ground speed and altitude are also indicated (as noted earlier, for clarity, altitude figures have been corrected for the air pressure on the day). The altitude profile and ground elevation are shown in **Figure No. 6**.

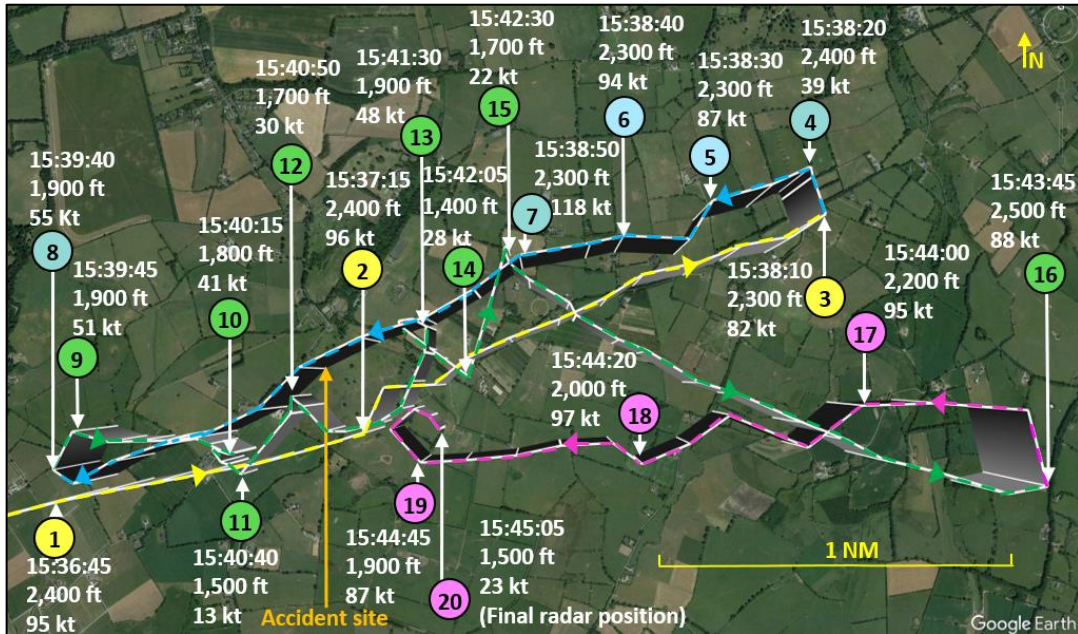


Figure No. 5: Latter part of flight path as indicated by ARTAS data (altitudes corrected for the air pressure on the day) (For clarity, coloured dashed lines divide the flight path into separate sections: yellow, followed by blue, then green, then magenta)



Figure No. 6: Altitude profile as indicated by ARTAS data and ground elevation (Helicopter altitude corrected for the air pressure on the day)



Altitude information from a transponder may not be continuously received, and the previous information received is retained. The age of the altitude information was generally between one and four seconds. It is included below when it was greater than four seconds. The following details are indicated by the ARTAS data. The figures included below for altitude and ground speed are to be considered approximate values.

First Part (Dashed Yellow Line – Points 1 to 3)

1. At time 15:36:45, the Helicopter was travelling generally north-eastwards and had climbed to an altitude of 2,400 ft³³. The ground speed was 95 kt and the Helicopter was 6.2 NM north-east of EIKH.
2. At time 15:37:15, at a ground speed of 96 kt, and an altitude of 2,400 ft, the Helicopter's track changed from north-east to a more north-north-easterly direction and the Helicopter descended to an altitude of 2,300 ft, before briefly turning to the east and then towards the north-east again. The Helicopter then continued on a north-easterly track at an altitude of 2,300 ft and at ground speeds of between 75 kt and 95 kt.
3. At time 15:38:10 and while at an altitude of 2,300 ft and a ground speed of 82 kt, the Helicopter turned left. It was approximately 8.3 NM north-east of EIKH at this stage.

Second Part (Dashed Blue Line – Points 4 to 8)

4. The Helicopter flew briefly towards the north-north-west. It then climbed briefly to 2,400 ft and turned left at time 15:38:20 onto a south-westerly track. The ground speed was 39 kt.
5. The Helicopter descended to 2,300 ft and at time 15:38:30 and a ground speed of 87 kt, it turned left onto a more southerly track, before turning right onto a westerly track.
6. The Helicopter then turned left at time 15:38:40, onto a west-south-westerly track. The altitude remained at 2,300 ft during these turns. The ground speed was 94 kt.
7. At time 15:38:50 and an altitude of 2,300 ft, and while travelling on a south-westerly track at a ground speed of 118 kt (the wind at 2,000 ft was north to north-east at 10-15 kt, i.e. a tail wind), the Helicopter started to descend.
8. At time 15:39:40 and at 1,900 ft, the Helicopter turned right onto a north-north-easterly track. It was approximately 2.2 NM from **Point 4** at this stage. The ground speed was 55 kt.

Third Part (Dashed Green Line – Points 9 to 16)

9. At time 15:39:45 and at ground speed of 51 kt, the Helicopter turned right onto an easterly track.

³³ All altitudes in this Section have been corrected for the air pressure on the day.

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10. At time 15:40:15, the Helicopter had descended to 1,800 ft. The ground speed was 41 kt. The Helicopter then turned around and briefly flew back towards the north-west, before turning left onto a south-easterly track and descended further.
11. At time 15:40:40, and at an altitude of 1,500 ft (age of altitude information was 12.75 seconds) and a ground speed of 13 kt, the Helicopter turned left towards the north-east and climbed. The radar positional data continued to be recorded around this location.
12. At time 15:40:50, the Helicopter had climbed to 1,700 ft. The Helicopter's ground speed was 30 kt. The Helicopter then turned right, towards the south-east, while continuing to climb.
13. The Helicopter turned left, and then left again onto a north-easterly track and climbed to an altitude of 2,000 ft, before descending again. At time 15:41:30, the Helicopter's altitude was 1,900 ft. The Helicopter's ground speed was 48 kt.
14. The Helicopter then turned left and left again and descended towards the south-east and reached 1,400 ft at time 15:42:05. The age of the altitude information was 16.5 seconds. The Helicopter was approximately 750 m east of the accident site at this stage and was at a ground speed of 28 kt. The witness (**Section 1.1.1.1**), who thought that the Helicopter was going to land, before it climbed '*nose straight up*' and was heard operating for a further '*three to four minutes*', was located close to this point. The Helicopter turned left towards the north-east.
15. No further points were recorded until 25 seconds later, at time 15:42:30. The Helicopter's altitude was 1,700 ft. The Helicopter's ground speed at this stage was 22 kt.
16. The Helicopter then turned right, towards the south-east, and climbed during the following one minute and 15 seconds, reaching 2,500 ft at time 15:43:45. The Helicopter's ground speed was 88 kts. It was approximately 2.5 NM from **Point 8** at this stage.

Final Part (Dashed Magenta Line – Points 17 to 20)

17. The Helicopter had turned left towards the north and had begun to descend. It then turned left again onto a westerly track. At time 15:44:00, the Helicopter's altitude was 2,200 ft. The Helicopter's ground speed was 95 kt.
18. The Helicopter then turned left towards the south-west and then right, towards the north-west and then left again towards the south-west, while descending. At time 15:44:20, the Helicopter was at an altitude of 2,000 ft. The Helicopter's ground speed was 97 kt.
19. The Helicopter then travelled generally westwards, and at time 15:44:45, its altitude was 1,900 ft. The Helicopter's ground speed was 87 kt. The Helicopter then turned right, right again, and right again over a period of approximately 20 seconds, while descending.
20. The Helicopter was last recorded on radar at time 15:45:05 at an altitude of 1,500 ft. This point was approximately 0.38 NM (704 m) south-east of the accident site.



1.11.3 Open-Source Aircraft Tracking

Open-source aircraft tracking data was obtained for the flight. However, it provided no further useful information than that obtained from the ARTAS system data.

1.11.4 Video Recordings

1.11.4.1 Introduction

Video footage, which was captured by a camera located approximately 350 m to the south-west of the accident site and at an elevation of approximately 525 ft (160 m)³⁴, was provided to the Investigation. The video footage had a resolution of 2,688 × 1,520 pixels. The frame rate of the video, when the Helicopter was visible, was 25 frames per second (fps). The video footage shows the final 0.8 seconds approximately of the flight, in which the Helicopter can be seen travelling towards the ground on a steep trajectory (**Figure No. 7**), albeit with some motion from right to left (approximately east to west). The entire Helicopter was visible for approximately 0.5 seconds. The main rotor blades were visible in the video for approximately 0.3 seconds. The actual impact was obscured from view by terrain. The video footage shook moments after the Helicopter disappeared from view. The time at this stage, as indicated by the video's on-screen clock, was 15:45:50 hrs. This was followed by a rising plume of smoke. There was no evidence in the video footage of a fire prior to impact.



Figure No. 7: Image extracted from video (dashed line indicates trajectory of Helicopter)

1.11.4.2 Video Recording Review

Introduction

To better understand the Helicopter's attitude, speed, and main rotor rpm in the final moments of the accident flight, the Investigation sought the assistance of the Office of Research and Engineering at the National Transportation Safety Board (NTSB) of the United States (US) (representing the state of design/manufacture/registration of the Helicopter) in analysing the video footage.

³⁴ The elevation of the accident site was approximately 476 ft (145 m) above mean sea level (AMSL) (**Section 1.12.1**).

Main Rotor RPM

The Helicopter's main rotor blades rotate counterclockwise when viewed from above. In order to analyse the main rotor rpm, the NTSB orientated a reference image of an R44 Helicopter (**Figure No. 8**) to match the attitude of the Helicopter visible in **Figure No. 7**. This showed that the video recorded the lower surfaces of the main rotor blades; therefore, the direction of rotation of the main rotor blades in the video was assessed to be clockwise.



Figure No. 8: Reference image orientated to match Helicopter attitude as in **Figure No. 7**
(**Note:** Rotor blades are not in the same position)

Using the video frame rate and the angular position of the rotor blades in a sequence of video frames, the NTSB's video analysis estimated the main rotor speed to be approximately 375 rpm. Due to a lack of clarity in some of the video frames, a tolerance of ± 15 rpm was assigned, i.e. the rotor speed was estimated to be 375 ± 15 rpm.

Helicopter Trajectory

To determine the trajectory and descent rate of the Helicopter, the NTSB used a camera optics computer model, which was calibrated using the position of the camera and other reference points in the camera's field of view. Once calibrated, the computer model was used to estimate the location of the Helicopter in a sequence of video frames. A constant descent rate was identified, which was estimated to be 43 metres per second (m/s) (8,465 ft per minute). It was estimated that the trajectory of the Helicopter nose (as shown in **Figure No. 7**) was along a path inclined by 72° relative to the ground with a nose-down pitch angle of 45° .

Using the position of the Helicopter's nose relative to the east-west direction in each video frame, it was estimated that the Helicopter's nose was travelling at 14.3 m/s in a westerly direction ($270^\circ \pm 15^\circ$). From this, the total speed of the Helicopter was estimated to be 45.3 m/s (88.1 kt) (the vector sum of the descent speed and the speed in the westerly direction).

The video analysis estimated that when the nose of the Helicopter reached the crest of the grass-covered hill in the foreground, it was approximately 7 m above the ground at the accident location.



Other Information

Using the estimated descent rate of 43 m/s and the video frame rate, the Investigation estimated the distance between the crest of the grass-covered hill in the foreground of the image and the upper edge of the video frame to be 34 m (112 ft).

1.12 Wreckage and Impact Information

1.12.1 Accident Site

The accident site was located in the Kennycourt area in a grass-covered agricultural field situated in rolling hills, approximately 7 NM north-east of EIKH and approximately 1 NM south-east of Brannockstown, Co. Kildare. The accident site was approximately 53 NM north-west of Tagoat and approximately 36 NM north-west of Ballygarrett. The elevation of the site was approximately 476 ft (145 m) above mean sea level (AMSL).

1.12.2 Gas Transmission Pipeline

An underground natural gas transmission pipeline ran in a north-easterly direction through the agricultural field at a depth of approximately 1.5 m. The accident occurred approximately 6 m from this pipeline. The ground directly above the pipeline was not disturbed by the accident or during wreckage recovery. Gas Networks Ireland, which owns and operates the natural gas network in Ireland, subsequently performed a technical examination of the pipeline at the accident site, and no defects were noted.

1.12.3 Examination of Helicopter Wreckage

1.12.3.1 General

The Helicopter was destroyed due to the impact and a fire. The fire resulted in significant destruction of the Helicopter and the melting of aluminium³⁵ structure and components. The accident site was compact, and all parts of the Helicopter were situated close to the main wreckage, except for a piece of a main rotor blade, 0.74 m in length, which was located approximately 60 m to the south-west, and a large fragment of a portable fire extinguisher, which was found approximately 38 m away, also to the south-west. The remains of the fuel tanks indicated that they were the bladder type (**Section 1.6.4**).

The front sections of the Helicopter's two landing skids (approximately 0.91 m long) had penetrated the soil at a steep angle, to a depth of 0.75 m for the left skid and 0.67 m for the right skid and had fractured just above the surface of the soil.

Both main rotor blades sustained extensive impact damage (**Photo No. 5** and **Photo No. 6**). One of the two main rotor blades (annotated as '*Blade A*') had separated into three sections. The piece found 60 m from the main wreckage was the middle section of this rotor blade. The inner section of this rotor blade remained attached to the rotor head; this section sustained fracture damage, such that it had almost separated into two pieces, 1.9 m long and 0.7 m long approximately. The outer section of this rotor blade, approximately 1.3 m in length, was partially embedded along its length, leading edge down, in the surface of the field close to the main wreckage. A slice-like ground mark extended outwards from this blade section.

³⁵ The melting point of aluminium is approximately 660 °C.

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The other blade (annotated as **Blade B** in **Photo No. 5**) remained attached to the rotor head. It had sustained significant fracture damage, approximately 1.25 m from the blade root, but remained in one piece. The outer portion of this blade, approximately 3.5 m long, was embedded along its length, leading edge down, in the surface of the field.



Photo No. 5 (left) and **Photo No.6** (right): Damage to main rotor blades and surface of field (Photos taken on the morning after the accident)

The tailcone sustained fire damage adjacent to where it attached to the fuselage and exhibited crumpling damage along its length (**Photo No. 7**). The empennage had separated from the tailcone (**Photo No. 8**). There was no evidence of main rotor blade contact with the tail cone or empennage. The two tail rotor blades sustained bending damage close to the roots of the blades. One blade was partially fractured at the bending damage. The leading edge of each blade was undamaged.



Photo No. 7: Fire damage and crumpling to tailcone (highlighted) (Photo taken on the morning after the accident)



Photo No. 8: Separated empennage (highlighted) (Photo taken on the morning after the accident)



The tail rotor gearbox housing was broken (**Photo No. 9**). The tail rotor pitch control rod in the tailcone had fractured close to the where it connected to the pitch change lever at the tail rotor gearbox housing (**Photo No. 10**); there was evidence of soil and grass where the rod connects to the pitch change lever. The fracture surfaces were inclined on approximately 45° shear planes, consistent with instantaneous overload fracture.



Photo No. 9: Broken tail rotor gearbox (circled) (Photo taken on the morning after the accident)

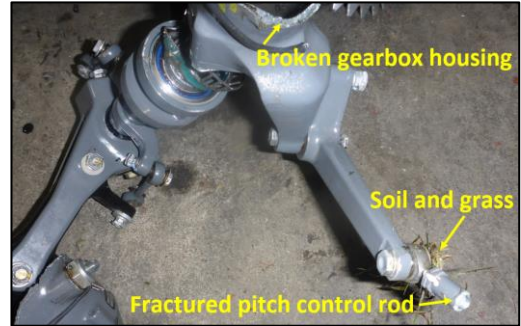


Photo No. 10: Fractured pitch change control rod (Photo taken during subsequent examination)

Due to the extent of the Helicopter damage, it was not possible to verify the continuity of the main rotor and tail rotor control systems. However, the flight control linkages/rods at the main rotor head were found to be connected/intact (**Photo No. 11**). The linkages/rods at the tail rotor pitch change mechanism were also intact (**Photo No. 12**).

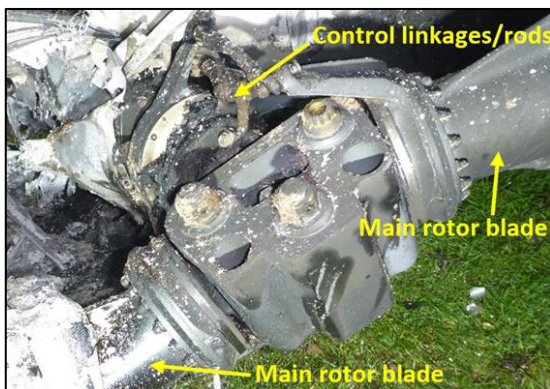


Photo No. 11: Main rotor head (Photos taken on the morning after the accident)

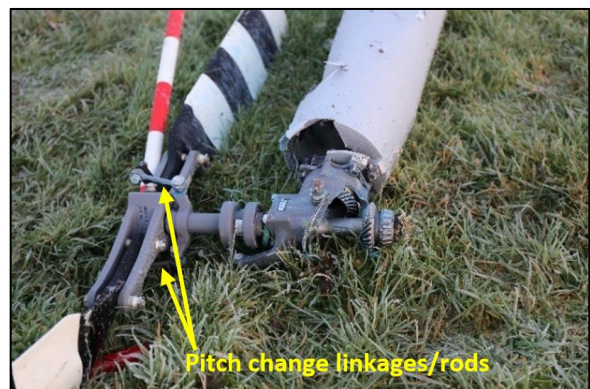


Photo No. 12: Tail rotor head /gearbox (Photos taken on the morning after the accident)

The wreckage was recovered from the accident site and transported under escort to the AAIU's wreckage examination facility in Gormanston Co. Meath for further examination. The two elastomeric teeter³⁶ stops installed on the main rotor hub assembly were found to be damaged. However, their associated mounting brackets were undamaged. The Helicopter Manufacturer advised that *'the damage to the teeter stops is "highly likely" to be from the main rotor blades contacting the ground at impact'*.

In Summary, the Investigation found no evidence of any pre-existing defects that would have prevented the Helicopter from normal operation.

³⁶ Two-bladed semi-rigid main rotors, as on the subject helicopter type, 'teeter' or see-saw about a teetering/flapping hinge. The teeter stops cushion the contact between the main rotor blade roots and the main rotor driveshaft in the event of maximum teetering of the main rotor.

1.12.3.2 Instrumentation and Warning Lights

The remains of the Helicopter's instrument panel, which included the airspeed indicator (ASI), were recovered at the accident site. The ASI's indicator needle was close to the 80 kt position (**Figure No. 9**)³⁷. When the indicator needle was moved, an outline mark, which was similar in shape and size to the indicator needle, was visible on the dial of the ASI at the position the needle was found in.

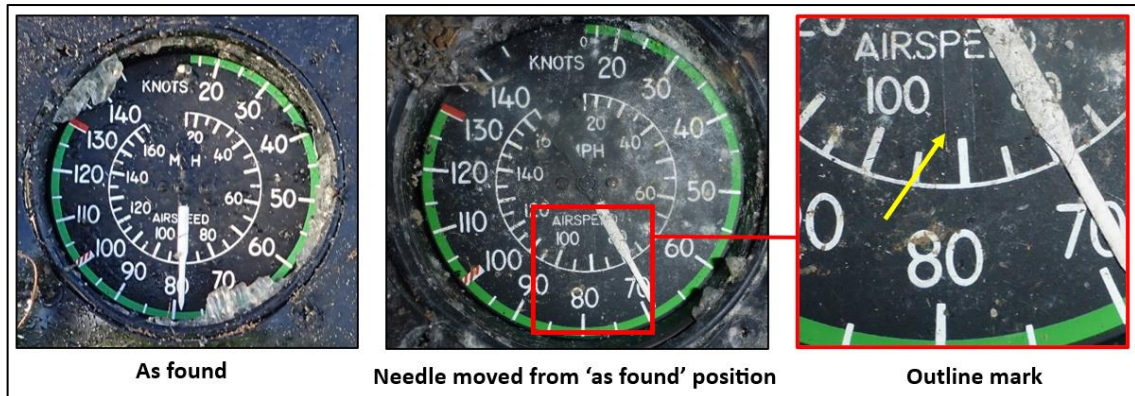


Figure No. 9: ASI indicator needle position and outline mark

The panel also contained several warning light assemblies, including the *LOW RPM* (main rotor) and the *LOW FUEL* warning light assemblies (**Photo No. 13**).



Photo No. 13: Instrument panel with warning light assemblies

The analysis of light bulbs following an accident may provide an indication regarding whether or not a particular bulb was illuminated (lit) at the time of impact. If an impact occurs when a bulb is illuminated, its (hot) filament may stretch and fail, whereas, if an impact occurs when a bulb is not illuminated, its (cold) filament may remain intact or may shatter or break in an unstretched condition.

The Investigation examined the *LOW FUEL* and *LOW RPM* warning light assemblies. The *LOW RPM* warning light assembly was undamaged. The bulb was removed from the assembly and examined. Its filament was found to be intact and unstretched, but it had disengaged from the filament support (**Photo No. 14**).

³⁷**Note:** In accordance with the Helicopter Manufacturer's Service Bulletin SB-90, if the ASI has a green arc from 0-130 kt (as per **Figure No. 9**), a decal stating '*DO NOT EXCEED 110 KIAS* [Knots Indicated Airspeed] *EXCEPT IN SMOOTH AIR*' must be installed below the ASI. The required decal was found fitted (later versions of the ASI have a yellow arc between 110 and 130 kt).

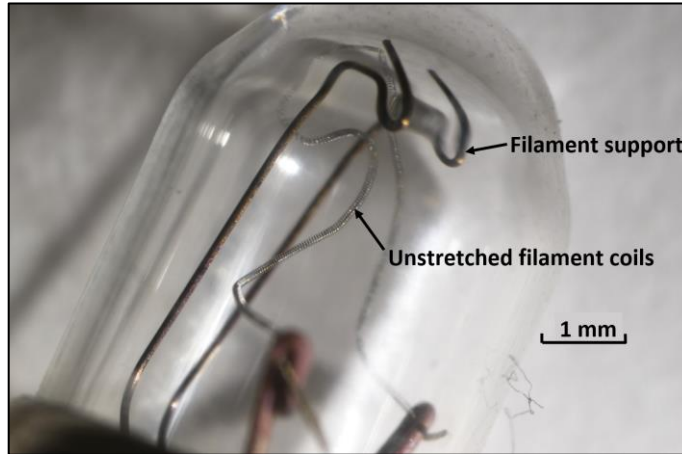


Photo No. 14: Bulb from LOW (main rotor) RPM warning light

The LOW FUEL warning light assembly sustained significant damage in the accident. When examined visually, it was not possible to identify any remaining filament. To conduct further examination, the Investigation sought the assistance of a laboratory equipped with a Scanning Electron Microscope (SEM). The SEM images showed some remaining sections of filament located within the cap of the bulb. Some areas of the coils showed evidence of what appeared to be stretching. However, others appeared unstretched (**Figure No. 10**).

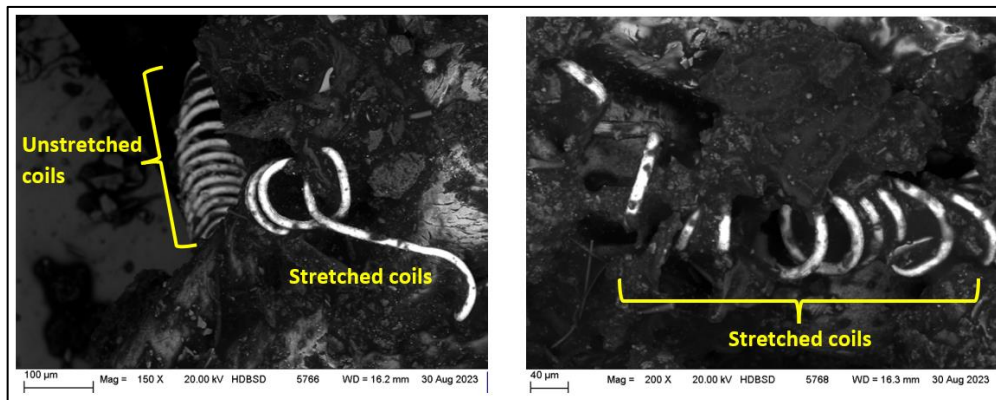


Figure No. 10: SEM images of bulb from LOW FUEL warning light

The faceplate of an altimeter, which included its subscale, was found in the debris recovered from the accident site. Before flight, a pilot will normally adjust the altimeter's subscale to the local sea level air pressure (QNH), if known. This ensures that the altimeter accurately indicates height above sea-level. Adjusting the altimeter before flight, so that it indicates the local elevation has the same effect; when the altimeter is set to the local elevation, the QNH subscale will reflect the local QNH. The subscale aligns with an indicator mark in the centre of the subscale window. For every 1 hPa adjustment of the subscale, the altimeter needle moves by approximately 30 ft (27.1 ft). The recovered faceplate and subscale had sustained significant impact and fire damage. However, the subscale remained legible. When compared to a new altimeter, it appeared to be set to 1011 (**Figure No. 11**). This was the QNH that was advised by Shannon FIS to the Pilot on departure from Ballygarret on the day of the accident.

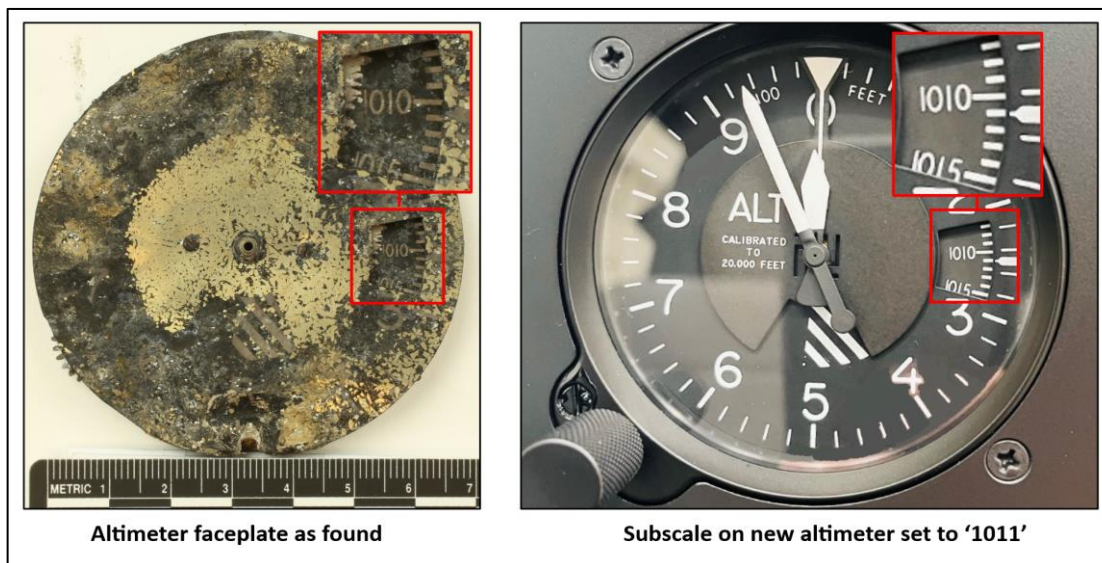


Figure No. 11: Altimeter subscale setting

1.12.4 Engine Examination

The Investigation conducted a preliminary examination of the engine in situ, which identified that the crankcase and cylinders were intact. The Investigation removed the engine from the wreckage to permit further examination. It was observed that engine ancillary components, pipework, and wiring looms had sustained significant impact and fire damage. The engine was shipped to a United Kingdom (UK) Civil Aviation Authority (CAA)-approved engine overhaul organisation located in the UK, where it was dismantled and examined in the presence of the Investigation.

It was noted that the forward-facing section of the engine oil sump sustained impact damage, resulting in a hole in the outer wall of an integral oil supply port that supplies engine lubrication oil from the main oil screen in the oil sump to the inlet of the oil pump (Photo No. 15). The tubular oil screen was removed from its housing in the sump and was found to be intact and clean. The oil pump was removed from the engine. Debris, in the form of metallic chips, was found at the gears within the oil pump (Photo No. 16).

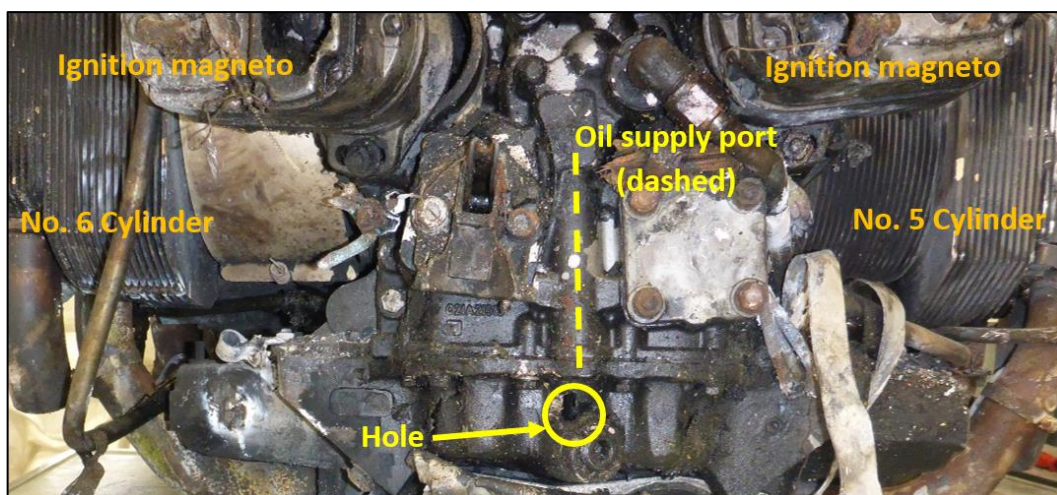


Photo No. 15: Hole in oil pump supply port at front of engine



Photo No. 16: Metallic chips in the engine oil pump (circled)

Pressurised oil from the oil pump is filtered by the main oil filter before it is supplied to other components for lubrication and cooling purposes. The main oil filter and its mount, which are located on the forward-facing section of the engine, sustained significant impact and fire damage (**Figure No. 12**). Due to the extent of the damage, further examination was not performed as results would not have been meaningful.

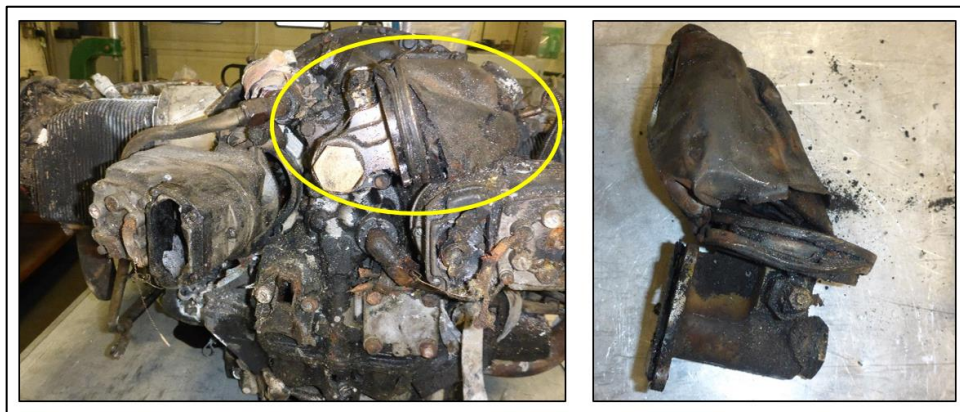


Figure No. 12: Oil filter and mount in-situ (circled in left image) and removed (right image)

Following the removal of the ignition magnetos and the oil pump, the engine was rotated by hand. Engine rotation was unrestricted, except for what was considered to be normal cylinder compression. The engine's six cylinders were removed to permit further examination. The pistons and the cylinder heads showed what appeared to be normal levels of carbon/coking. All piston rings were free to move in their piston ring grooves. The crankcase piston cooling oil jets were found to be clear. The conrod bushes (small-end bearings) and piston pins (gudgeon pins) appeared to be undamaged. All inlet and exhaust valves also appeared to be undamaged, and the engine valve timing (crankshaft to camshaft) was found to be correct.

All conrods were free to rotate at their big-end bearings. When the conrods were removed from the crankshaft, all big end bearings had a normal appearance. All crankshaft main and big-end journals were smooth and were not discoloured. Big end bearing No. 2 was found to have a circumferential score mark along its entire circumference. The associated crankshaft journal was found to be unmarked. All other main bearings appeared to be normal. There was no obvious wear on the lobes of the camshaft or on its bearing journals.

In summary, engine disassembly found no evidence of any pre-existing defects that would have prevented the engine from operating normally.

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1.13 Medical and Pathological Information

The Investigation was provided with a copy of the post-mortem report for the Pilot. The report stated that *'the cause of death was extensive traumatic injuries sustained in a helicopter crash. Whilst there is evidence of ischaemic heart disease³⁸ there is no evidence of any recent ischaemia'*. The report also stated that there were *'no other underlying pathological abnormalities identified'*, and that toxicology (drugs and alcohol) was *'negative'*.

1.14 Fire

A fire occurred, which was subsequently extinguished by fire services that had attended the scene. The video showing the final moments of flight showed no evidence of a fire prior to impact (**Section 1.11.4.1**).

1.15 Survival Aspects

The analysis of the video showing the final moments of the accident flight estimated the speed of the Helicopter at impact to be 45.3 m/s (88.1 kt). The forces involved during the accident sequence were such that the accident was not survivable.

1.16 Tests and Research

1.16.1 Spatial Disorientation

1.16.1.1 Introduction

Spatial Disorientation can be defined as *'A state of confusion concerning the subject's true position in space in relation to the surface of the earth³⁹'*.

The FAA's General Aviation Joint Steering Committee Safety Enhancement Topic leaflet on Spatial Disorientation (AFS-850 16-05) states:

'Sight, supported by other senses, allows a pilot to maintain orientation while flying. However, when visibility is restricted (i.e. no visual reference to the horizon or surface detected) the body's supporting senses can conflict with what is seen. When this spatial disorientation occurs, sensory conflicts and optical illusions often make it difficult for a pilot to tell which way is up.'

Contributing to these phenomena are the various types of sensory stimuli: visual, vestibular (organs of equilibrium located in the inner ear), and proprioceptive (receptors located in the skin, muscles, tendons and joints). Changes in linear acceleration, angular acceleration, and gravity are detected by the vestibular system and the proprioceptive receptors, and then compared in the brain with visual information.'

In a flight environment, these stimuli can vary in magnitude, direction, and frequency, resulting in a "sensory mismatch" that can produce illusions and lead to spatial disorientation'.

³⁸ **Ischaemic heart disease:** Heart problems caused by narrowed heart (coronary) arteries that supply blood to the heart muscle.

³⁹ Kumar, B (2005) *An illustrated dictionary of aviation*. New York: McGraw-Hill.



'Ernsting's Aviation Medicine'⁴⁰ states the following regarding 'Disorientation in helicopter operations':

[...]. There are certain features of the way helicopters fly and the way in which they are operated that lead to specific types of disorientation. Helicopter operations are generally carried out at low level and although this does not of itself increase the likelihood of disorientation, it may leave little time to recover from an unexpected attitude.

Unlike a fixed-wing aircraft, a helicopter has no motive power in the longitudinal axis of the fuselage. In order to transition from the hover to forward flight, the nose of the helicopter is pitched down, so that a component of the lift provided by the main rotor now accelerates the aircraft [helicopter] in the forward direction. As ever, forward acceleration of an aircraft causes it to feel more pitched up than it really is. Initially, before significant aerodynamic drag builds up, the pitch-up sensation of forward flight exactly balances the actual pitch-down of the aircraft, so that it continues to feel level, just as it did in the hover.

*Likewise, in order to transition from forward flight into the hover, the pilot brings the nose of the aircraft up so that a component of the rotor lift now acts in the rearward direction and decelerates the aircraft. A decelerating aircraft feels more nose-down than it actually is, and this sensation exactly balances the effect of the actual nose-up tilt and again causes the aircraft to feel level. The situation is not significantly different in the roll axis. A helicopter tilted in roll will tend to side-slip with increasing lateral velocity and as a result will continue to feel level. **In summary, a helicopter will tend to feel level whatever its true attitude.** [...]' (emphasis added by the Investigation).*

1.16.1.2 Degraded Visual Environment (DVE)

According to information on the EASA website, the European Strategic Safety Initiative (ESSI) was an aviation safety partnership between EASA, other regulators, and the industry. It has been replaced by the European Safety Promotion Network Rotorcraft (ESPN-R). One of the pillars of ESSI was the European Helicopter Safety Team (EHST), which produced several training leaflets. These leaflets are available on the IAA and EASA websites. Section 1 of leaflet HE1 ('Safety Considerations') relates to 'Degraded Visual Environment (DVE)' and states:

'A continuing significant number of accidents are due to pilot disorientation in a degraded visual environment (DVE). Research has demonstrated the strong relationship between helicopter handling characteristics and available visual cues'.

The EHST leaflet also states that:

'Analysis indicates that any, or a combination of, the following three scenarios could result in a serious accident:

- A. *Loss of control when attempting a manoeuvre to avoid a region of impaired visibility, i.e. backtracking, climbing above or descending below the DVE.*

⁴⁰ Gradwell, DP; Rainford, DJ (2006) *Ernsting's Aviation Medicine*, 4E. Abingdon, London: Hodder Arnold.
www.aaiu.ie

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- B. *Spatial disorientation or loss of control when transferring to instrument flight following an inadvertent encounter with IMC.*
- C. *Loss of situational awareness resulting in controlled flight into terrain/sea/obstacles or a mid-air collision’.*

[...] *The inherent instability of the helicopter is a major factor in such accidents’.*

An EHEST video on ‘*Degraded Visual Environment and Loss of Control*’⁴¹ is available on the EASA website.

On 19 December 2019, the UK CAA published Aeronautical Information Circular (AIC) P127/2019 on the subject of ‘*Helicopter Flight In Degraded Visual Conditions*’. The AIC, which contains information ‘*distilled from research into helicopter flight in degraded visual conditions, carried out for the CAA [...]’ (PAPER 2007/03, September 2007)*, states the following:

‘[...] for an average VFR-only certificated helicopter without ASE [Artificial Stability Equipment], the pilot workload (attentional demand) for flight control alone is likely to rise rapidly from around 25-30% in VMC to 100% in poor visual conditions’.

1.16.1.3 Helicopter Manufacturer’s Safety Notice

A Safety Notice (SN-18) titled ‘*LOSS OF VISIBILITY CAN BE FATAL*’ was published by the Helicopter Manufacturer (revised June 1994). The notice is contained within the Helicopter’s POH and states the following:

‘Flying a helicopter in obscured visibility due to fog, snow, low ceiling or even a dark night can be fatal. Helicopters have less inherent stability and much faster roll and pitch rates than airplanes. Loss of pilot’s outside visual references, even for a moment, can result in disorientation, wrong control inputs, and an uncontrolled crash. This type of situation is likely to occur when a pilot attempts to fly through a partially obscured area and realizes too late that he is losing visibility. He loses control of the helicopter when he attempts a turn to regain visibility but is unable to complete the turn without visual references.

[...]’.

1.16.2 Plan Continuation Bias

Plan continuation bias (also known as ‘*get-there-itis*’, ‘*get-home-itis*’ or ‘*press-on-itis*’) is described in an article⁴² on cognitive biases, in the July/August 2020 ‘*FAA Safety Briefing*’ magazine. The article defines it as an ‘*unconscious cognitive bias to continue with an original plan, despite changing circumstances indicating that a new plan is required*’. It was cited as a factor in at least two AAIU aircraft accident investigation reports in recent years (Report No. 2018-003 and Report No. 2020-015)⁴³.

⁴¹<https://www.easa.europa.eu/en/document-library/general-publications/ehest-video-degraded-visual-environment-and-loss-control> (accessed April 2024).

⁴² Woods, S. (2020, July August). Just a bit biased, *FAA Safety Briefing*, 10-12.

⁴³ Available on AAIU.ie.



An article on 'get-home-itis' in the March/April 2013⁴⁴ 'FAA Safety Briefing' magazine states the following:

'Get-home-itis is when the desire to get to a destination overrides logic, sound decision-making, and basic instinct. This urge to push on regardless of the data telling you that it might not be the best decision can often result in mishap, and it's a prevalent issue for the general aviation (GA) community'.

The article on cognitive biases in the July/August 2020 'FAA Safety Briefing' magazine notes the following:

'The closer to the destination, the worse the [plan continuation] bias gets. Our decisions are further influenced by the emotional, financial, and time investments that have already been made in accomplishing the goal'.

The article lists some strategies to mitigate cognitive biases, including the following:

- '1. Perform a Self-Assessment: Understand that you ARE human and therefore CAN become biased. Know thyself and understand what stressors or fatigues may increase your own personal potential to be biased.'*
- '2. Make a Backup Plan: Don't expect the standard strategy to always work. Have alternative plans. Think about what would happen if the "go to" option is no longer available'.*

The IAA is responsible for the safety regulation of Irish Civil Aviation and publishes or provides links to a wide range of safety information, including information relevant to General Aviation. Information relating to Plan Continuation Bias, specifically in relation to General Aviation, is not readily apparent.

1.16.3 Accident Reports

1.16.3.1 Introduction

The accident reports described in this Section relate to fatal helicopter accidents where spatial disorientation was included as a probable cause. Plan continuation bias was also deemed a factor in the NTSB report outlined in **Section 1.16.3.4**.

1.16.3.2 Air Accident Investigation Unit Report No. 2006-019

AAIU Report No. 2006-019⁴⁵ relates to an accident involving a Robinson R44 helicopter that occurred in July 2005. The helicopter was on a VFR flight from New Ross, Co. Wexford, to its base near Galway Airport. While en route, it entered an area of rising terrain and low cloud base. Radar tracking indicated that the helicopter slowed down, and then made a sharp turn before disappearing from the screen. The helicopter collided with terrain near Derrybrien, Co. Galway. A passenger was fatally injured in the accident, and another passenger suffered serious injuries. The Pilot was seriously injured and died of his injuries later in hospital.

⁴⁴ Woods, S. (2013, March/April). Get-home-itis, *FAA Safety Briefing*, 9-12 and 26.

⁴⁵ Available at AAIU.ie.

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The AAIU determined the probable cause of the accident to be:

'the pilot's loss of spatial orientation resulting from inadequate visual reference with the ground due to limited visibility'.

1.16.3.3 UK Air Accidents Investigation Branch Report EW/C2018/05/02

A Report (EW/C2018/05/02⁴⁶) was published by the UK Air Accidents Investigation Branch (AAIB), which relates to a fatal Bell 206B-3 Jet Ranger III helicopter accident in the UK in May 2018. The report notes that the pilot was flying the helicopter to a maintenance facility for its annual maintenance check.

The report states that:

'The weather conditions en route were challenging with low cloud and reduced visibility. The helicopter was seen by several witnesses to be flying normally before climbing steeply into cloud. It was then seen to emerge from the cloud, rotate through 540°, then descend rapidly, striking the ground in an approximately level attitude. The helicopter became inverted and caught fire. The pilot was fatally injured. The investigation did not find any evidence of pre-existing defects with the helicopter or its engine. It could not be determined why the helicopter entered cloud but it is probable that the pilot was distracted or became disorientated in the poor weather conditions. Having entered cloud it is likely that the pilot became spatially disorientated and was unable to maintain control of the helicopter'.

1.16.3.4 US National Transportation Safety Board Report NTSB/AAR-21/01

The NTSB published an investigation report relating to a Sikorsky S-76B helicopter accident (Report No. NTSB/AAR-21-01⁴⁷) that occurred in January 2020. The pilot and eight passengers were fatally injured in the accident.

The report notes that approximately two minutes before the accident, while the helicopter was flying west at an altitude of about 1,370 ft AMSL (450 ft Above Ground Level (AGL)) over US Route 101 (a major highway) and rising terrain, the pilot announced to ATC that he was initiating a climb to get *'above the [cloud] layers'* and the helicopter immediately began climbing at a rate of about 1,500 ft per minute.

The report also notes that about the same time, the helicopter began a gradual left turn, and its flight path generally continued to follow US Route 101 below. About 36 seconds later and while still climbing, the helicopter began to turn more tightly to the left, and its flight path diverged from its overflight of US 101. The helicopter reached an altitude of approximately 2,370 ft AMSL (about 1,600 ft above ground level) before descending rapidly in a left turn to the ground. While the helicopter was descending, ATC asked the pilot to *'say intentions'* and the pilot replied that the helicopter was climbing to 4,000 ft (AMSL). A witness near the accident site first heard the helicopter then saw it emerge from the bottom of the cloud layer in a left-banked descent approximately one or two seconds before impact. The NTSB determined the probable cause of the accident to be:

⁴⁶ Available at <https://www.gov.uk/aaib-reports/aaib-investigation-to-bell-206b3-jet-ranger-iii-g-open>

⁴⁷ Available at <https://www.nts.gov/investigations/Pages/DCA20MA059.aspx>



'[...] decision to continue flight under visual flight rules into instrument meteorological conditions, which resulted in the pilot's spatial disorientation and loss of control. Contributing to the accident was the pilot's likely self-induced pressure and the pilot's plan continuation bias, which adversely affected his decision-making [...]'.

1.16.4 Fuel Planning

Another EHEST training leaflet available through the EASA website is HE2 'Helicopter Airmanship'. This leaflet is also available on the IAA's website. Section 2 of the leaflet relates to 'Pre-Flight Preparations', and in Section 2.7 discusses 'Fuel Planning'. It states, *inter-alia*, the following: *'Ideally plan to land with no less than a 1/4 tank of fuel [...]'*

A Safety Sense Leaflet (No. 17) published by the UK CAA and revised in April 2024 also relates to 'Helicopter Airmanship' and includes similar information regarding fuel planning. It states: *'The CAA recommends landing with not less than 1/4 tank or 45 minutes fuel endurance remaining'.*

Similarly, the Helicopter Manufacturer's Safety Notice SN-15 (dated August 1983), as contained in the POH recommends to *'always land to refuel before the main tank fuel gage reads less than 1/4 full'.*

1.16.5 Main Rotor Stall

A Safety Notice (SN-24) titled 'LOW RPM ROTOR STALL CAN BE FATAL' was published by the Helicopter Manufacturer (revised June 1994). The notice is contained within the Helicopter's POH and states the following:

'[...]

Rotor stall is very similar to the stall of an airplane wing at low airspeeds. As the airspeed of an airplane gets lower, the nose-up angle, or angle-of-attack, of the wing must be higher for the wing to produce the lift required to support the weight of the airplane. At a critical angle (about 15 degrees), the airflow over the wing will separate and stall, causing a sudden loss of lift and a very large increase in drag. The airplane pilot recovers by lowering the nose of the airplane to reduce the angle-of-attack below stall and adds power to recover the lost airspeed.

The same thing happens during rotor stall with a helicopter except it occurs due to low [main] rotor RPM instead of low airspeed. As the RPM gets lower, the angle-of-attack of the rotor blades must be higher to generate the lift required to support the weight of the helicopter. Even if the collective is not raised to provide the higher blade angle, the helicopter will start to descend until the upward movement of the air to the rotor provides the necessary increase in blade angle-of-attack. As with the airplane wing, the blade airfoil will stall at a critical angle, resulting in a sudden loss of lift and a large increase in drag.

The increased drag on the blades acts like a huge rotor brake causing the rotor RPM to rapidly decrease, further increasing the rotor stall. As the helicopter begins to fall, the upward rushing air continues to increase the angle-of-attack on the slowly rotating blades, making recovery virtually impossible, even with full down collective.

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When the rotor stalls, it does not do so symmetrically because any forward airspeed of the helicopter will produce a higher airflow on the advancing blade than on the retreating blade. This causes the retreating blade to stall first, allowing it to dive as it goes aft while the advancing blade is still climbing as it goes forward.

The resulting low aft blade and high forward blade become a rapid aft tilting of the rotor disc sometimes referred to as “rotor blow-back”. Also, as the helicopter begins to fall, the upward flow of air under the tail surfaces tends to pitch the aircraft [helicopter] nose-down. These two effects, combined with aft cyclic by the pilot attempting to keep the nose from dropping, will frequently allow the rotor blades to blow back and chop off the tailboom as the stalled helicopter falls. Due to the magnitude of the forces involved and the flexibility of the rotor blades, rotor teeter stops will not prevent the boom chop. [...].’

As noted in **Section 1.12.3**, examination of the Helicopter wreckage found no evidence of main rotor blade contact with the tail section.

1.16.6 Icing

1.16.6.1 Rotor Icing

Rotor icing can occur if a helicopter’s rotor blades are at a temperature of 0 °C or lower and the surrounding air contains droplets of supercooled water.

The adverse effects of rotor icing are outlined in Chapter 74 of ‘*Helicopter Aerodynamics*⁴⁸’ by R.W. Prouty, which states that ice degrades the aerodynamic characteristics of the rotor blades ‘*by forming irregular shapes that increase drag and decrease maximum-lift capabilities*’. To overcome the additional drag, an increase in engine power will be required, which may alert a pilot to the presence of ice. Prouty also states that blade ice will eventually shed due to ‘*centrifugal forces, airloads, blade flexing, or flying into warmer air*’. However, although ice shedding may in theory be beneficial, it is highlighted that blade shedding can be asymmetric which can result in ‘*severe vibration in the cockpit and damaging cyclic loads in the main-and/or tail rotor support structures. At the same time, damage to the tail rotor may result from ice thrown off the main rotor or vice versa*’.

1.16.6.2 Airframe Icing

When supercooled droplets contact parts of the airframe such as the windshield, icing can occur. The Helicopter Manufacturer informed the Investigation that it was not aware of any R44 events where icing on the windshields resulted in a complete loss of visibility.

1.16.6.3 Induction System Icing

Induction system icing can affect all piston engines (carburettor fed and fuel-injected). There are three main types of induction icing: Carburettor Icing, Fuel Icing, and Impact Ice. The subject Helicopter was fitted with a fuel-injected engine. According to the UK CAA’s Safety Sense Leaflet 14 on ‘*Piston Engine Icing*’ (June 2023), fuel injected engines ‘*do not experience carburettor icing, however they may be subject to “impact” ice or fuel system icing*’.

⁴⁸ Prouty, RW (2007) *Helicopter Aerodynamics*. Ohio: Eagle Eye Solutions.



Regarding impact icing, the leaflet states:

'Impact or intake icing is where ice builds around or inside the air intake, restricting airflow to the engine. The air filter may also become blocked, especially in heavy precipitation. Impact ice may accumulate when flying in visible moisture with the temperature below 0 °C, but is more likely in snow, sleet or freezing rain'.

Regarding fuel system icing, the leaflet states:

'The aircraft's fuel tank and system may contain water, for example from condensation or rainwater ingress. Dissolved water may also be present in the fuel, which in normal conditions would go unnoticed but may cause a problem in low temperatures. The combination of an aircraft being left outside in a wet or humid environment, followed by a flight in cold air is conducive to fuel system icing.

As the temperature drops, air present in the fuel tank and system may cause additional condensation and therefore a source of ice. The fuel lines in light aircraft are normally very thin and particularly around bends, it may only take a small amount of ice to block the fuel flow. Blockage of fuel filters is also a possibility'.

1.17 Organisational and Management Information

Not applicable

1.18 Additional Information

1.18.1 Trailer-Mounted Fuel Bowser

The Investigation established that there was a trailer-mounted fuel bowser located at Ballygarrett. The capacity of the bowser was reported to be 1,000 litres. A family member informed the Investigation that the bowser was stored in a separate shed and that it was rarely used. Subsequent to the accident, ownership of the bowser changed. The new owner advised that the bowser, which was reported to be in good condition, was approximately half full of Avgas when he acquired it.

1.18.2 Fuel Uplifts and Fuel Consumption Rate

According to the technical logbook (**Section 1.6.5**), each time the Helicopter departed EIKH for another destination in the 12 months prior to the accident (a total of 17 times), it did so with full ('100%') tanks. The Investigation reviewed the available invoices for fuel uplifted at EIKH during the 12 months prior to the accident. Each invoice recorded the date that the fuel was uplifted and the quantity of fuel uplifted. The Investigation correlated the dates of the uplifts with the total Helicopter hours, as recorded in the technical logbook on those dates, and obtained an average fuel consumption rate of 13.2 US GPH (50 litres per hour). The Investigation asked the Helicopter Manufacturer to comment on this figure; the Helicopter Manufacturer considered the figure to be low but that it may be indicative of operating economically on consistent routes with light loads.

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1.18.3 Flights since Refuelling

The Pilot told witnesses at Tagoat that he was going to fly to Kilrush for fuel and that he intended to return to Ballygarrett before sunset.

In order to estimate the fuel onboard at the time of the accident (**Section 2.6.4**), the Investigation reviewed the most recent flights undertaken. The Pilot's logbook records a flight from Ballygarrett to another airfield on 27 November 2022. The date of the return flight from that airfield to Ballygarrett is recorded as '3/12' (3 December 2022). This is the last flight recorded in the Pilot's logbook. The owner of that airfield advised that the Helicopter departed there on 27 November 2022 and not 3 December 2022, and that the Helicopter had been fully refuelled prior to its return flight. This is reflected in the technical logbook. The Investigation obtained data from a navigation application provider for the flight, which also indicated that the flight took place on 27 November 2022. The data indicated that the distance flown was approximately 60 NM. The technical logbook records the flight time as one hour. Open-source aircraft tracking data was available for a portion of that flight.

The Investigation also obtained details from a navigation application provider of a local flight that the Helicopter completed on 3 December 2022. The Helicopter took off from Ballygarrett at 15:16 hrs and flew indirectly to Tagoat, covering a distance of approximately 33 NM (the direct distance between Ballygarrett and Tagoat is 20 NM). The flight from Ballygarrett to Tagoat took approximately 19 minutes. The data indicates that the Helicopter did not land in Tagoat but returned indirectly to Ballygarrett and arrived there at 16:10 hrs. The total flight time was approximately 54 minutes. The total distance flown was approximately 83 NM. The Investigation found no record of any flight occurring after this flight, until the flights conducted on the day of the accident.

1.18.4 Previous Approach to Kilrush

When the Helicopter departed Tagoat on the accident flight, it initially flew towards EIKH before deviating to the left and flying to the south-west of EIKH before then turning towards it. The Pilot's logbook records that a flight from Ballygarrett to EIKH and a return flight were flown on 14 November 2022. The Investigation obtained data from a navigation application provider for those flights and reviewed the approach undertaken to EIKH on that date.

The data for the flight from Ballygarrett to EIKH on 14 November 2022 indicates that the Helicopter departed Ballygarrett at 14:35 hrs and flew to the west of the airfield and beyond it, before turning towards the airfield and approaching it from the north-west (**Figure No. 13**). The data indicates that the Helicopter arrived at EIKH at 14:59 hrs. The data for the return flight indicates that the Helicopter flew directly to Ballygarrett. The Investigation obtained information from *Met Éireann* regarding the wind conditions at EIKH at approximately 15:00 hrs on 14 November 2022. *Met Éireann* estimated that the wind was south to south-easterly, 10-15 kt, with gusts 18-22 kt.

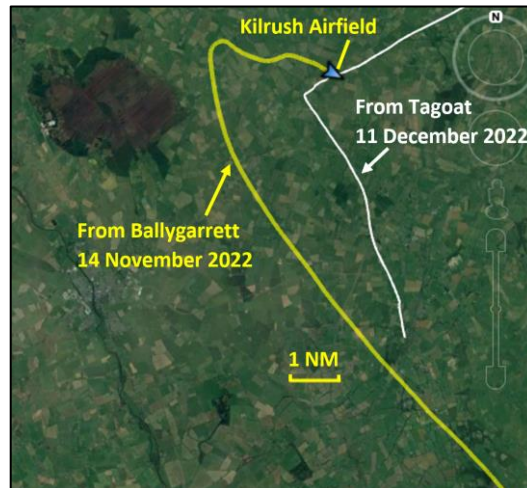


Figure No. 13: Flight Track from Ballygarrett to EIKH 14 November 2022 (yellow line)

1.19 Useful or Effective Investigation Techniques

The Investigation requested the assistance of the NTSB, representing the state of manufacture/registration, in conducting analysis of the video recording of the final moments of the flight. The results of this analysis are outlined in **Section 1.11.4.2**.

2. ANALYSIS

2.1 Pilot Licence and Medical Aspects

The Pilot's Licence and Medical Certificate were valid. Post-mortem examination of the Pilot found '*no evidence of any recent ischaemia*' and '*no other underlying pathological abnormalities*'.

2.2 Technical Aspects

The Helicopter's airworthiness certification was valid. Records indicate that all scheduled maintenance was performed on the Helicopter as required, including the completion of a 50-hour inspection approximately two months prior to the accident flight. In addition, a video recording showing the Helicopter departing Tagoat on the accident flight indicated that it was operating normally at that time.

The analysis of the video showing the final moments of the accident flight estimated the speed of the Helicopter at impact to be 45.3 m/s. This equates to 88.1 kt – a speed that is consistent with the position of the airspeed indicator needle, as observed at the accident site (close to 80 kt). The outline mark on the airspeed indicator dial that was visible when the needle was moved, which was the same shape and size of the needle, may have been caused by the needle impacting the dial during the accident sequence or by dust and debris settling.

The Helicopter was destroyed due to the impact and a fire. The video footage shows a rising plume of smoke following impact. There is no indication in the video of a fire prior to impact and therefore the Investigation considers that the fire was as a result of the accident.

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Examination of the Helicopter's engine identified that the forward-facing section of the oil sump sustained impact damage, resulting in a hole in the outer wall of the integral oil supply port. This port supplies engine lubrication oil from the main oil screen in the oil sump to the inlet of the engine's oil pump. Debris, in the form of metallic chips, was found within the gears in the oil pump. The metallic chips would have to have originated from the oil in the sump or from the damaged oil supply port. The tubular oil screen, which filters oil from the sump before it enters the oil pump, was removed from its housing in the sump and was found to be intact and clean. This indicates that the oil in the sump was also clean and that the metallic chips were not from the sump. It is therefore probable that the metallic chips resulted from impact damage to the oil pump supply port. The fact that the metallic chips were located at the gears within the oil pump indicates that the engine was running at the time of impact. This is supported by accounts from witnesses who heard the sound of an engine running until an impact was heard. In addition, disassembly of the Helicopter's engine and examination of the engine components did not find any pre-existing defects which would have prevented the engine from operating.

The analysis of the video of the final moments of the flight estimated that the main rotor speed was 375 ± 15 rpm, i.e. 360 to 390 rpm. The *LOW RPM* warning light illuminates when the main rotor speed falls below 388 rpm. The Investigation examined the bulb from the *LOW RPM* warning light assembly. Its filament was found to be intact and unstretched, which indicates that the bulb was not illuminated at the time of impact. Therefore, the main rotor speed was likely to have been above 388 rpm, which is consistent with powered rotation. Furthermore, the damage to the main rotor blades, which had fragmented into several sections, and the leading-edge-down orientation of the embedment in the surface of the field of a large section of one of the blades is indicative of powered rotation at impact.

The leading edges of the tail rotor blades were undamaged; however, it is probable that this was due to the tail rotor drive stopping when the main blades contacted the ground during the impact sequence. The tail rotor gearbox housing was broken, and the empennage had separated from the tail cone. There was no evidence of main rotor contact with the tail section. The tail rotor pitch control rod in the tailcone had fractured close to where it connected to the pitch change lever at the tail rotor gearbox housing. There was evidence of soil and grass where the pitch change rod connects to the pitch change lever. The fracture surfaces were inclined on approximately 45° shear planes, which is consistent with instantaneous overload fracture. It is probable therefore that the broken tail rotor gearbox and pitch change rod, and the separation of the empennage were caused when the tail section struck the surface of the field during the impact sequence.

In summary, the Investigation found no evidence of any pre-existing defects with the Helicopter or its engine that would have prevented normal operation.

2.3 Fuel Consumption Rate

By reviewing the available invoices for fuel quantities uplifted during the 12 months prior to the accident, in conjunction with the operating hours as recorded in the Helicopter's technical logbook, the Investigation calculated that the average fuel consumption rate of the Helicopter was 13.2 US GPH during that period.



The Investigation acknowledges the limitations in accurately assessing fuel consumption rates. However, the figure attained, although slightly lower, is reasonably consistent with the Engine Manufacturer's economy cruise fuel consumption rate of 13.5 US GPH, and with the fuel consumption rate outlined by another pilot, who had regularly flown the subject Helicopter (14 US GPH). The Helicopter Manufacturer considered a fuel consumption rate of 13.2 US GPH to be low but that it may be indicative of operating economically on consistent routes with light loads. The Helicopter Manufacturer's *'Estimated Operating Costs'* document (dated 1 July 2023) refers to a fuel consumption rate of 15 US GPH for *'average use'*. The POH for the Helicopter does not provide information on the Helicopter's fuel consumption. However, the Pilot had over 100 hours' flight experience on the helicopter type and therefore would have been aware of its actual fuel consumption.

2.4 Trailer-Mounted Fuel Bowser

The Investigation reviewed all technical logbook entries made during the 12 months prior to the accident. The technical logbook records that the Helicopter flew from Ballygarrett 47 times during that period and indicates that on four of the 47 flights, the take-off fuel quantity recorded was greater than the landing fuel quantity recorded. The Investigation established that the Pilot had a trailer-mounted fuel bowser at Ballygarrett, and it is therefore likely that it was used to uplift fuel to the Helicopter prior to each of those four flights.

Three of the four flights were local flights (i.e. Ballygarrett to Ballygarrett). The other occasion was for a flight to another airfield by another pilot; this flight was the only flight from Ballygarrett to another airfield recorded in the technical logbook in the 12-month period, which had a take-off fuel quantity recorded that was greater than the landing fuel quantity recorded. It was also the only flight from Ballygarrett recorded as departing with full (100%) tanks. It is possible that, because the flight was being operated by another pilot, the Helicopter was fuelled to 100% in preparation for that flight.

The technical logbook indicates that in the 12 months prior to the accident, the Helicopter flew from Ballygarrett to EIKH on 15 occasions and that it departed Ballygarrett with between 20% and 90% fuel on those flights and landed at EIKH with 10% fuel remaining on three occasions. The technical logbook also indicates that each time the Helicopter departed EIKH for another destination, including Ballygarrett, in the 12 months prior to the accident, it did so with full (*'100%'*) tanks. Therefore, while it cannot be completely ruled out, these factors, in combination with the fact that the Pilot told witnesses at Tagoat that he was flying to EIKH for fuel, suggest that the fuel bowser at Ballygarrett was not used in preparation for the flights on the day of the accident.

2.5 Fuel On Board at Departure from Tagoat on the Accident Flight

The Pilot's logbook records a flight from Ballygarrett to another airfield on 27 November 2022. The date of the return flight is recorded as *'3/12'* (3 December 2022). This is the last flight recorded in the Pilot's logbook. However, the owner of the other airfield advised that the Helicopter departed there on 27 November 2022 and not 3 December 2022. The technical logbook also indicates the return flight was completed on 27 November 2022, as does the details obtained from a navigation application provider and open-source aircraft tracking data. Therefore, the Investigation considers that the date entered in the Pilot's logbook for the return flight was likely an error.

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The owner of the other airfield advised that the Helicopter had been fully refuelled there prior to its return flight; this is reflected in the technical logbook. Data obtained from a navigation application provider for the return flight to Ballygarrett on 27 November 2022 indicated that the distance flown was approximately 60 NM. The technical log records the flight time as one hour.

The Investigation also obtained data from a navigation application provider for a local flight that the Helicopter completed on 3 December 2022. This flight was not recorded in the technical logbook or the Pilot's logbook; however, the date of the flight may have been a factor in the likely date error outlined above. The data indicated that the distance flown for the local flight was approximately 83 NM, which took approximately 54 minutes.

There is no record of any flight occurring after the 3 December 2022 flight until the flights conducted on the day of the accident. The Investigation therefore estimated that the total flight time following refuelling on 27 November 2022 and prior to the flights on the day of the accident, was one hour and 54 minutes (1.9 hours). The total distance flown was estimated to be approximately 143 NM (**Table No. 7**).

Date	Distance flown	Duration
27 Nov 22	60 NM	One hour
3 Dec 22	83 NM	54 minutes
Total	143 NM	114 minutes (one hour and 54 minutes) (1.9 hours)

Table No. 7: Distance and time flown since refuelling and prior to accident date

A flight time of 1.9 hours would consume approximately 25.1 US gallons of fuel at a fuel consumption rate of 13.2 US GPH (1.9 hours × 13.2 GPH). The Helicopter's total usable fuel quantity according to the Helicopter Manufacturer is 46.5 US gallons. The Investigation therefore estimated that when the Helicopter departed Ballygarrett on the day of the accident, there may have been approximately 21.4 US gallons of fuel remaining on board (46.5 US gallons – 25.1 US gallons). This equates to approximately 46% full, which at a fuel consumption rate of 13.2 US GPH, would be sufficient for a further flight time of approximately one hour and 37 minutes (1.62 hours) (21.4 US gallons ÷ 13.2 GPH).

The direct distance between Ballygarrett and Tagoat is approximately 20 NM. The Pilot's communications with Shannon FIS indicated that the Helicopter took off from Ballygarrett at approximately 14:32 hrs and landed in Tagoat at 14:42 hrs approximately. This is consistent with the landing time reported by witnesses at Tagoat and indicates a flying time of 10 minutes. However, not considering wind conditions, this would require the journey to be flown at 120 kt. This is higher than the approximately 85 kt average speed the Helicopter was flown at on the flight towards EIKH (the accident flight). Based on a speed of 85 kt, the Investigation considered it reasonable to estimate a flight time of 15 minutes between Ballygarrett and Tagoat. The Investigation therefore estimated that when the Helicopter departed Tagoat on the accident flight, it had flown for a total time of approximately two hours and nine minutes (2.15 hours) since refuelling and had covered a total distance of approximately 163 NM (**Table No. 8**).



	Distance flown	Duration
Total prior to date of accident	143 NM	114 mins (One hour and 54 minutes) (1.9 hours)
Ballygarrett to Tagoat on accident date	20 NM	15 minutes (0.25 hours)
Total before accident flight	163 NM	129 mins (two hours and nine minutes) (2.15 hours)

Table No. 8: Distance and time flown since refuelling and prior to accident flight

Considering the estimated 2.15 hours flown since refuelling and a fuel consumption rate of 13.2 US GPH, the Helicopter is estimated to have consumed 28.4 US gallons (2.15 hours × 13.2 GPH) since refuelling and therefore may have departed from Tagoat on the accident flight with an estimated 18.1 US gallons of usable fuel on board (46.5 – 28.4); this equates to approximately 39% full, which would be sufficient for a further flight time of approximately 82 minutes ((18.1 US gallons ÷ 13.2 GPH) × 60).

As outlined earlier, the fuel consumption rate of 13.2 US GPH, as calculated by the Investigation, was lower than the economy cruise fuel consumption rate of 13.5 US GPH, as contained in the Engine Manufacturer’s Operator’s Manual. It was also less than the rate outlined in the Manufacturer’s ‘*Estimated Operating Costs*’ document (15 US GPH) and the rate used by another pilot, who had regularly flown the subject Helicopter (14 US GPH). The fuel consumption rate was therefore unlikely to have been any lower than 13.2 US GPH. However, it is possible that it was actually higher than that calculated by the Investigation and therefore the quantity of fuel remaining on board prior to departure on the accident flight, and at the time of the accident, may have been less.

2.6 The Accident Flight

2.6.1 General

As evidenced by the Pilot’s initial communications with Shannon FIS, it was his intention to fly to EIKH following a flight from Ballygarrett to Tagoat. When the Helicopter departed from Tagoat on the accident flight, the Pilot advised Shannon FIS that he was ‘*lifting out of Rosslare for Kilrush Airfield*’. The Pilot likely used the term ‘*Rosslare*’ in communications with Shannon FIS, rather than Tagoat, as the location of Rosslare is well known, and is only 1.6 NM north of Tagoat. The flight was being conducted entirely in Class G airspace (uncontrolled); therefore, radio communications, although good practice, were not required. The Pilot confirmed with Shannon FIS that the communications were for ‘*information only*’. The Pilot’s communications sounded calm and professional.

It is not known what weather information was obtained by the Pilot before the flight. However, family members reported to the Investigation that the Pilot would always check the weather forecasts and that he would not fly unless the weather was suitable. The aftercast for Ballygarrett, from where the Helicopter departed on the flight to Tagoat, indicated that the weather was ‘*clear and dry with crisp winter sunshine*’, that the temperature was 4 °C, and that the visibility was ‘*30+ km*’. The aftercast noted that there were ‘*few clouds (1-2 oktas) with bases around 4,000 ft*’. The aftercast for Tagoat, from where the Helicopter departed on the accident flight, was similar but with a slightly lower surface temperature of 3 °C. The sky appeared clear and blue in the video recording showing the Helicopter departing Tagoat.

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It is therefore likely that, as indicated by the aftercast, the sky was clear when the Helicopter departed Ballygarrett (which is approximately 20 NM north-east of Tagoat); this is supported by the satellite image provided by *Met Éireann* (**Section 1.7.3, Figure No. 3**), which showed clear sky over Ballygarrett and Tagoat around the time of departure. When the Helicopter departed Tagoat for EIKH in clear conditions, the Pilot likely expected that the en route weather conditions would have remained favourable. He may also have expected that due to the clear skies (i.e. no visible moisture), there was no risk of icing (**Section 2.8.3**).

The Investigation notes that when the accident occurred, there was approximately 25 minutes remaining until sunset (16:10 hrs at Kilrush Airfield and Ballygarrett) and a further 42 minutes approximately until the end of civil twilight (16:52 hrs at Kilrush Airfield and Ballygarrett). Therefore, as evidenced by the video showing the final moments of the flight, the accident flight took place in daylight conditions. However, it is also noted that if the Helicopter had landed at EIKH as planned, it would have landed at approximately 15:35 hrs, which would have left limited time to refuel and return to Ballygarrett before sunset (the technical logbook records a minimum flight time of 21 minutes for flights from EIKH to Ballygarrett in the previous 12 months).

2.6.2 Flight Path Followed

2.6.2.1 Introduction

The flight path of the Helicopter, as indicated by the ARTAS data, is shown in **Figure No. 4** and **Figure No. 5** in **Section 1.11.2**. For convenience, the figures are reproduced below as **Figure No. 14** and **Figure No. 15**. As previously noted, the ARTAS system is calibrated for cruising aircraft, therefore the flight path shown may not reflect the exact nature of the turns performed by the Helicopter but is considered to be generally representative.

2.6.2.2 Initial Flight Path

The Helicopter departed Tagoat for EIKH at approximately 14:58 hrs. It was first recorded by ATC radar at time 15:28:45 when it was approximately 5.5 NM south-east of EIKH and travelling north-westerly towards EIKH at an altitude of approximately 2,300 ft (**Point A** in **Figure No. 14**). The radar-generated ground speed was 58 kt; however, it was unlikely to have been accurate at this stage, as it is calculated using the difference in positions recorded versus the time elapsed between positions, and this was the first position recorded.

The ARTAS data indicated that the Helicopter began to descend approximately 30 seconds later and reached approximately 1,900 ft at time 15:29:55 (**Point B** in **Figure No. 14**). The Investigation established that the Pilot made use of a GPS navigation application to assist in navigation. A mobile phone, and a computer tablet and associated mount were found in the wreckage of the Helicopter. As the flight path was initially in the direction of EIKH, the Investigation considers it likely that the navigation application was being used to assist in navigation during the accident flight; the descent may indicate that the Pilot was aware that he was nearing EIKH.



Figure No. 14: Flight path indicated by ARTAS data (altitudes corrected for the air pressure on the day) (**Note:** The terrain image is historic and does not represent the meteorological conditions prevailing on the day of the accident)

The ARTAS data indicated that the Helicopter, now at approximately 1,900 ft and a ground speed of 80 kt, appeared to deviate slightly to the left at time 15:30:40 (**Point C in Figure No. 14**), which resulted in it tracking to the south-west of EIKH.

The exact reason for the deviation is unknown. It is considered likely that visual contact with the surface had been maintained in the earlier part of the flight from Tagoat and that the skies remained clear at the Helicopter’s operating altitude. However, visibility of the surface below the Helicopter likely deteriorated as the flight continued, as indicated by the meteorological aftercasts; the information provided by Met Éireann, which noted that Oak Park (13 NM south-south-west of EIKH) was in fog and low cloud for the duration of the day, with cloud bases varying between the surface and 500 ft; and the account of a person who was located 5 NM southeast of EIKH at approximately 14:55 hrs, who noted that the cloud height was 40 ft to 50 ft. It is possible that the Pilot may have noticed an area where there was a clearer view of the surface and initially turned towards it, with the intention of descending and approaching the airfield at a lower altitude. This possibility is supported by the fact that another pilot, who was at EIKH approximately one hour earlier, noted poor visibility at the airfield, but that blue sky was visible through gaps in the fog.

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It is also possible that the deviation was to facilitate an approach into wind, as according to the meteorological aftercast for the Kennycourt/Kilrush area, the wind at 2,000 ft was north to north-east at 10-15 kt. This possibility is supported by the fact that during a flight from Ballygarrett to EIKH on 14 November 2022, the Helicopter travelled in a north-westerly direction beyond EIKH, before turning and approaching EIKH from the north-west. On that day, the wind was south to south-easterly, and an approach from the north-west would have been into wind. However, there may have been other factors on the flight on 14 November 2022, including integration with other visible traffic operating in the vicinity of EIKH.

The ARTAS data indicates that when the Helicopter was approximately 0.7 NM to the south-west of EIKH, it turned right (north-east) in the direction of the airfield (**Point F in Figure No. 14**). The sharpness of the turn indicated is likely an artefact of the sample interval of the ARTAS data. The Helicopter flew directly overhead EIKH at approximately 1,800 ft (**Point G in Figure No. 14**). The data indicates that the Helicopter's groundspeed reduced slightly (to 76 kt), which may be an indication of an attempt to acquire visual contact with the airfield. However, the Helicopter's altitude and track did not vary significantly as it flew overhead the airfield (airfield elevation 260 ft according to the airfield website), which indicates that there was no attempt made to land there at that time. This was likely due to poor visibility of the airfield at that stage. Aerial photographs taken several hours earlier on day of the accident in the Punchestown area, which is approximately 4.5 NM north-east of the accident site (**Section 1.7.6, Photo No. 3 and Photo No. 4**), may provide an indication of the prevailing conditions in the Kennycourt/Kilrush area around the time of the accident.

The ARTAS data indicates that the Helicopter then flew north-eastwards past EIKH at altitudes of between 1,900 ft and 2,300 ft (**Points H to L in Figure No. 14**), where, according to the meteorological aftercast, the skies were likely to be clear. The satellite image of the conditions at 14:30 hrs over the south-east of Ireland shows cloud/fog over a large area, which included Kilrush and Kennycourt; meteorological aftercasts and witness evidence also reported the presence of fog and cloud. The satellite image shows clearer conditions to the east with no indication of cloud over the Wicklow mountains. It is possible that the flight towards the north-east was an attempt to acquire a clearer view of the surface, with the intention of landing or descending and attempting to fly back towards EIKH at a lower altitude. Based on the radar data, the Helicopter flew approximately 8.3 NM beyond EIKH, which seems like a significant distance; however, it took just under five and a half minutes – a short period of time. This equates to an average ground speed of 89 kt.

The Investigation also considered the possibility that the Pilot believed that he had not reached EIKH and initially flew towards the north-east to what he thought was its location. However, the Investigation considers this unlikely, as the earlier part of the flight from Tagoat was in the general direction of EIKH, which suggests that a navigation application was being used to assist with navigation during the flight. Also, the Helicopter flew directly overhead the airfield when travelling to the north-east and the Pilot had regularly flown to EIKH.

2.6.2.3 Subsequent Flight Path

The ARTAS data indicates that when the Helicopter was approximately 8.3 NM beyond EIKH (**Point 3 in Figure No. 15**), it turned around, and in the subsequent one and a half minutes, flew approximately 2.3 NM towards the south-west, i.e. back in the general direction from which it had come, while at the same time descending. (**Note:** The terrain image in **Figure No. 15** is historic and does not represent the meteorological conditions prevailing on the day of the accident).

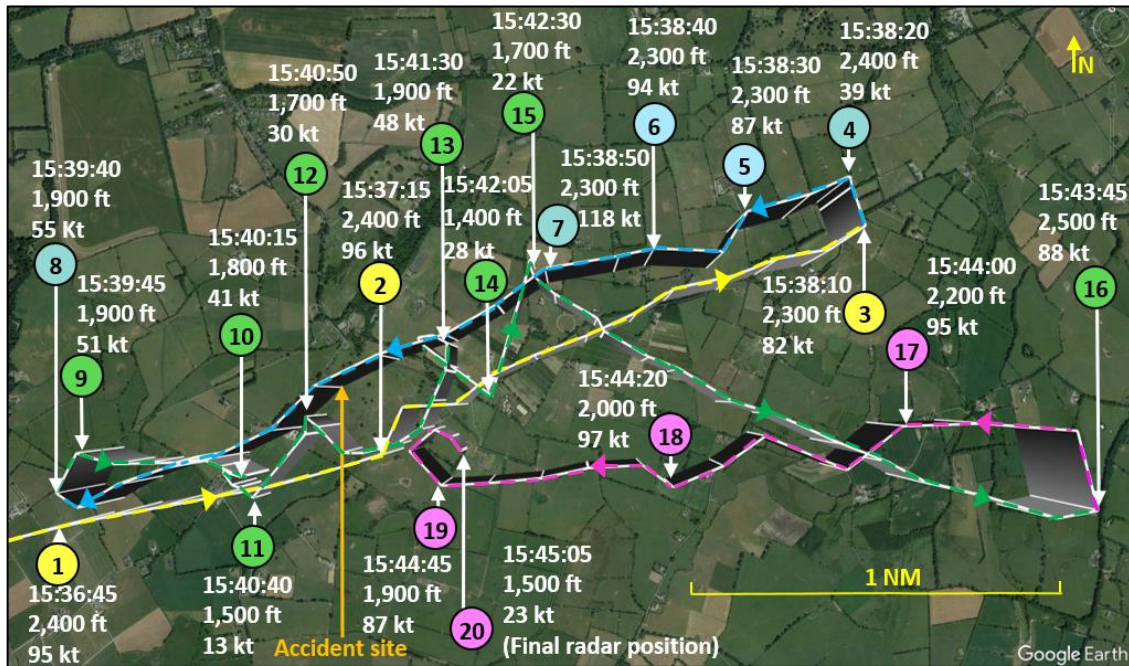


Figure No. 15: Flight path indicated by ARTAS data (altitudes corrected for the air pressure on the day) (coloured dashed lines divide the flight path into separate sections: dashed yellow line, followed by blue, then green, then magenta)

The ARTAS data indicates that the Helicopter turned around again (**Point 8 in Figure No. 15**) and flew generally eastwards on a zigzag path. The data indicates that at one point during this stage of the flight, at time 15:40:40, approximately five minutes before the accident, the Helicopter descended to approximately 1,500 ft (and approximately 1,000 ft AGL), while its ground speed reduced to 13 kt (**Point 11 in Figure No. 15**). Although the radar positional data continued to be recorded around this location, the age of the last altitude data received by radar was 12.75 seconds and therefore the Helicopter's altitude was potentially lower at this point. It is possible that the back-and-forth pattern and this descent was an attempt to locate an area where there was a clearer view of the surface, with the intention of landing. It is also possible that at this stage, the Pilot believed that he was close to EIKH and was attempting to locate it visually.

The ARTAS data indicates that the Helicopter then climbed before descending towards the south-east, and at time 15:42:05, reached approximately 1,400 ft, the lowest altitude recorded by radar (**Point 14 in Figure No. 15**). The age of the altitude data received by radar (Mode C) was 16.5 seconds at this stage and therefore the Helicopter's altitude could have been lower. The Helicopter's ground speed was 28 kt and it was approximately 750 m east of the accident site. The witness (**Section 1.1.1.1**), who thought that the Helicopter was going to land, before it climbed 'nose straight up' into cloud and was heard to be operating for a further 'three to four minutes', was located close to this point. ATC radar heads sweep every four or six seconds depending on their location; however, no further data was recorded until 25 seconds later at time 15:42:30 (**Point 15 in Figure No. 15**), which indicates that the Helicopter had descended below radar coverage and was not recorded again until it climbed.

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The ARTAS data indicates that the Helicopter then travelled towards the south-east for approximately 1.5 NM, while continuing to climb to an altitude of approximately 2,500 ft (**Point 16** in **Figure No. 15**). This took one minute and 15 seconds, equating to a ground speed of approximately 72 kt. The climb to this altitude may have been an attempt to survey the cloud cover and locate an area with a clearer view of the surface. The Helicopter then turned around and flew generally westwards for approximately 1.7 NM at an average ground speed of 94 kt approximately and at an altitude of no less than 1,900 ft, where the Helicopter was likely above the layer of cloud/fog (**Points 17, 18 and 19** in **Figure No. 15**).

The final radar position was recorded at time 15:45:05 at an altitude of approximately 1,500 ft (**Point 20** in **Figure No. 15**). The ARTAS data indicates that the Helicopter was approximately 0.38 NM (704 m) south-east of the accident site at that stage and travelling at a ground speed of 23 kt. The Helicopter had just turned right, right again, and right again over a period of approximately 20 seconds, while descending. It is likely that the Helicopter descended further, with the result that it was no longer detectable by radar and the Helicopter travelled closer to where the accident occurred.

2.6.2.4 Flight Path Summary

In summary, the Helicopter departed Tagoat on the accident flight at approximately 14:58 hrs. The Helicopter was first recorded by radar at time 15:28:45, when it was approximately 5.5 NM south-east of EIKH and travelling north-easterly towards EIKH at an altitude of approximately 2,300 ft. The ARTAS data indicates that the Helicopter began to descend approximately 30 seconds later and reached approximately 1,900 ft at time 15:29:55. As the flight path was initially in the direction of EIKH, the Investigation considers it likely that a GPS navigation application was being used to navigate during the accident flight; the descent to 1,900 ft may indicate that the Pilot was aware that he was nearing EIKH. ARTAS data indicates that at time 15:32:55, the Helicopter flew directly overhead EIKH in a north-easterly direction at an altitude of approximately 1,800 ft (where the skies were likely to be clear). The data also indicates that the Helicopter's groundspeed reduced slightly (to 76 kt), which may be an indication of an attempt to acquire visual contact with the airfield. No descent was recorded, which is an indication that there was no attempt to land at EIKH. The Investigation considers that this was likely due to poor visibility of the airfield at that stage. The data indicates that the Helicopter continued past EIKH in a north-easterly direction for approximately 8.3 NM (15.4 km), before turning around at time 15:38:10 and flying back-and-forth and descending and climbing in the Kennycourt area for a number of minutes.

The Helicopter was last recorded by radar at time 15:45:05, at an altitude of 1,500 ft, a ground speed of 23 kt, and was approximately 0.38 NM (704 m) south-east of the accident site. The Helicopter had just turned right, right again, and right again over a period of approximately 20 seconds, while descending. It is likely that the Helicopter then descended further, with the result that it was no longer detectable by radar and travelled closer to where the accident occurred. The back-and-forth flight pattern and the descents in the Kennycourt area were likely conducted to attempt to locate an area where there was a clearer view of the surface, in order to land or travel back towards EIKH at a lower altitude.



2.6.3 Altimeter Accuracy

Before flight, a pilot will normally adjust the subscale of the aircraft's/helicopter's altimeter to the local sea level air pressure (QNH), if known. This ensures that the altimeter accurately indicates height above sea-level. When the Helicopter took off in Ballygarrett, Shannon FIS advised the Pilot that the Shannon area QNH (MSL air pressure at the time) was '*one zero one one*' (1011). This was acknowledged by the Pilot. Following receipt of such information, a pilot will normally adjust the aircraft/helicopter altimeter's subscale to this figure. For every 1 hPa adjustment of the subscale, the altimeter needle moves by approximately 30 ft. The faceplate of an altimeter, which included a subscale set to 1011, was found in the debris recovered from the accident site (**Section 1.12.3.2, Figure No. 11**).

The meteorological aftercast for the Kennycourt/Kilrush area estimated that the local QNH was 1010 hPa. This is only a difference of 1 hPa to what was set on the Helicopter's altimeter (approximately 30 ft). Therefore, the Investigation considers that the Helicopter's altimeter was providing the Pilot with reasonably accurate altitude information during the flight and consequently was unlikely to have been a factor in the accident.

2.6.4 Fuel Remaining

2.6.4.1 General

Based on the radar data and the Pilot's communications with Shannon FIS, the Investigation estimated the flight time between Tagoat and the Helicopter being overhead EIKH to be approximately 35 minutes (0.58 hours). The distance flown was approximately 52 NM. As previously outlined, the Investigation estimated that the Helicopter departed from Tagoat with approximately 18.1 US gallons of fuel remaining on board. Using a fuel consumption rate of 13.2 US GPH, the 35-minute flight towards EIKH would have consumed 7.7 US gallons (13.2 GPH × 0.58 hours). Therefore, if the Helicopter had landed at EIKH as planned, it is possible that there would have been approximately 10.4 US gallons of fuel remaining on board (18.1 US gallons – 7.7 US gallons) (22 % full), which is consistent with the quantity recommended in the Helicopter Manufacturer's Safety Notice SN-15 and other helicopter airmanship publications (25 % full). Using a fuel consumption rate of 13.2 US GPH, a total of 10.4 US gallons of fuel would be sufficient for a further flight time of approximately 47 minutes until the available fuel was exhausted ((10.4 US gallons ÷ 13.2 GPH) × 60).

Ballygarrett is approximately 37 NM south-east of EIKH. The Helicopter's technical logbook records flight times of between 21 minutes (0.35 hours) and 47 minutes (0.78 hours) for flights from EIKH to Ballygarrett in the previous 12 months. Using a median time of 0.57 hours (34 minutes), the Investigation estimated that returning directly to Ballygarrett when overhead EIKH would require approximately 7.5 US gallons of fuel (0.57 hours × 13.2 GPH).

The ARTAS data indicates that the flight time from EIKH towards Kennycourt, and the back-and-forth flight pattern in the Kennycourt area, was approximately 12 minutes (approximately 16 NM). The Investigation therefore estimated that at the time of the accident, the Helicopter had flown for approximately 47 minutes (35 minutes + 12 minutes) and covered a distance of approximately 68 NM (52 + 16) since departing Tagoat.

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It was therefore estimated that at the time of the accident, the Helicopter had flown for a total time of approximately two hours and 56 minutes (2.93 hours) and approximately 231 NM (163 NM + 68 NM) since being fully refuelled (**Table No. 9**). A fuel consumption rate of 13.2 US gallons per hour, would result in a total of 38.7 US gallons of fuel being consumed (13.2 GPH × 2.93 hours). Therefore, there may have been approximately 7.8 US gallons of usable fuel remaining on board at the time of the accident (46.5 US gallons – 38.7 US gallons). This equates to approximately 17% full and may have been sufficient for a further 35 minutes of flight approximately, until the available fuel was exhausted.

Location	Distance since refuelling	Duration since refuelling	Fuel remaining	Remaining endurance (no reserve)
Tagoat	163 NM	129 mins (Two hours and nine minutes) (2.15 hours)	18.1 (39%)	82 minutes
Overhead EIKH	215 NM	164 minutes (Two hours and 44 minutes) (2.73 hours)	10.4 (22%)	47 minutes
Accident Site	231 NM	176 mins (Two hours and 56 minutes) (2.93 hours)	7.8 (17%)	35 minutes

Table No. 9: Estimation of fuel remaining (using 13.2 US GPH consumption rate)

The preceding calculations were based upon a historically calculated fuel consumption rate of 13.2 US GPH. However, as outlined earlier (**Section 2.5**), it is possible that the remaining fuel quantity at the time of the accident was lower. For example, if a fuel consumption rate of 14 US GPH is applied to the 2.93 hours estimated total flight time since refuelling, the total quantity consumed would be approximately 41 US gallons (14 GPH × 2.93 hours), which would have resulted in approximately 5.5 US gallons of fuel remaining when the accident occurred (approximately 12% full); this would be sufficient for a further 25 minutes of flight until the available fuel was exhausted ($(5.5 \div 13.2) \times 60$). If a consumption rate of 15 US GPH is applied to the 2.93 hours estimated total flight time since refuelling it would result in approximately 2.55 US gallons of fuel remaining when the accident occurred (5.5% full), which is below the *LOW FUEL* warning trigger point. This would be sufficient for a further 11.5 minutes of flight until the available fuel was exhausted ($(2.55 \div 13.2) \times 60$).

2.6.4.2 Low Fuel Warning Light

In addition to estimating the Helicopter's fuel consumption rate, the Investigation sought to establish if the Helicopter's *LOW FUEL* warning light, which illuminates when the remaining usable fuel quantity reduces to 2.9 US gallons (11 L), illuminated near the end of the flight.

The Investigation examined the bulb from the warning light assembly. The bulb had sustained significant damage during the accident, which rendered the visual identification of any remaining filaments difficult. Notwithstanding this, SEM imagery identified broken sections of the bulb's filament within the cap of the bulb, some of which appeared to have stretched. This may indicate that the *LOW FUEL* light was illuminated at the time of impact. However, video footage of the final moments of the flight showed the Helicopter travelling towards the ground on a steep trajectory, in a semi-inverted attitude, which likely adversely affected the fuel quantity indicating system. This could have resulted in the warning light being illuminated at the time of impact at a fuel quantity above the normal *LOW FUEL* trigger point.



2.6.4.3 Fire

There was no indication of a fire in the video showing the final moments of the flight. Therefore, the Investigation considers that the fire was as a result of the accident. The Investigation's fuel calculations indicate that a quantity of fuel was on board the Helicopter at impact. The extent of the fire damage, including the melting of aluminium structure, which melts at approximately 660 °C, is consistent with a fuel-fed fire. Following impact, the Helicopter's electrical systems, and/or heat from the engine exhaust, would have provided ignition sources.

Maintenance records and wreckage examination indicated that the Helicopter was fitted with bladder-type fuel tanks, as outlined in the Helicopter Manufacturer's Service Bulletin, SB-78, and associated revisions and Airworthiness Directive. The intent of this Service Bulletin is to improve the fuel system's resistance to a post-accident fuel leak and consequent fire. In this case, a post-crash fire occurred; however, the severity of the impact was such that fuel tank destruction and consequent fuel leak was inevitable, regardless of the type of fuel tanks installed.

2.6.5 Human Factors

2.6.5.1 Plan Continuation Bias

The meteorological conditions were such that visual contact with the surface likely deteriorated as the Helicopter neared EIKH. This might have prompted consideration of a return to Tagoat (52 NM from EIKH) or Ballygarrett (37 NM from EIKH), or to land in a suitable field, and it is likely that there would have been sufficient fuel remaining for each of these courses of action. However, the Pilot had regularly flown the route; this fact and the likely use of a GPS navigation application, may have provided a degree of confidence in continuing the flight.

Plan continuation bias, which is an unconscious cognitive bias to continue with an original plan, despite changing circumstances indicating that a new plan is required, was also likely to have been a factor in continuing towards EIKH in the earlier part of the flight and later during the back-and-forth flight pattern in the Kennycourt area. As outlined by the FAA in an article on plan continuation bias (also known as '*get-there-itis*', '*get-home-itis*' or '*press-on-itis*'), the closer someone is to their intended destination, the worse the bias becomes, and decisions made are further influenced by investments, such as time, that have already been made to accomplish the goal, which in this case, was to reach EIKH. The bias is such that other possible courses of action, such as turning back or flying towards an area where the visibility of the surface was better, may not have been apparent. Plan continuation bias was cited by the NTSB as a factor in a fatal helicopter accident that occurred in the USA in 2020 (**Section 1.16.3.4**) and in at least two aircraft accidents investigated by the AAIU (**Section 1.16.2**).

The IAA is responsible for the safety regulation of Irish Civil Aviation and publishes or provides links to a wide range of safety information, including information relevant to General Aviation. However, information regarding Plan Continuation Bias, particularly in relation to General Aviation, is not readily apparent. The Investigation considers that the promulgation of such information, including the identification of mitigation strategies that could be used, would raise awareness of this important safety-related subject. Therefore, the Investigation makes the following Safety Recommendation to the IAA:

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Safety Recommendation No. 1

The IAA should promulgate information on the effects of Plan Continuation Bias and on strategies to counter the effects of such biases, particularly in relation to General Aviation (IRLD2024002).

2.6.5.2 Nature of Flight Path in the Kennycourt Area

The continuously changing flight path in the Kennycourt area in the latter stages of the flight path, and the descents and climbs, are consistent with attempts to locate an area where there was a clearer view of the surface with the intention of landing or possibly descending and routing back to EIKH at a lower altitude. Any reduction in visibility arising from an attempt to descend through the cloud/fog would have resulted in an increased workload in relation to control of the Helicopter, as noted in the UK CAA's AIC on '*Helicopter Flight in Degraded Visual Conditions*', and an associated increasing degree of pressure. The Pilot may also have been concerned regarding reaching EIKH in sufficient time to permit refuelling and a return to Ballygarrett before the end of daylight. The Investigation considered whether or not the remaining fuel on board would have added to any increase in pressure on the Pilot. Regardless of the *LOW FUEL* warning light, and the exact fuel quantity remaining, the Pilot would have been aware of a decreasing fuel quantity as indicated by the fuel quantity gauges and from his experience operating the Helicopter. Therefore, the Pilot may have felt increasing pressure to land or get to his planned destination (EIKH).

2.6.5.3 Spatial Disorientation

Publications relating to spatial disorientation highlight that a helicopter will tend to feel level whatever its true attitude and that when spatial disorientation occurs, sensory conflicts and optical illusions often make it difficult for a pilot to tell which way is up. Publications also highlight that loss of a pilot's external visual references in a helicopter, even for a moment, can result in spatial disorientation. A training leaflet (*HE1 'Safety Considerations'*) published by the European Helicopter Safety Team (EHST), and available through the IAA and EASA websites, discusses '*Degraded Visual Environment (DVE)*' and highlights the potential for loss of control to occur when attempting a manoeuvre '*to avoid a region of impaired visibility, i.e. backtracking, climbing above or descending below the DVE*'. The Helicopter Manufacturer notes in its Safety Notice, SN-18, that '*this type of situation is likely to occur when a pilot attempts to fly through a partially obscured area and realizes too late that he is losing visibility [...]*'.

In the meteorological conditions described by the witnesses, if the Pilot obtained clear visual contact with the surface and attempted a descent, it would likely have been difficult to maintain the visual contact throughout the descent, and any reduction in visual contact or forward visibility would likely result in the descent (or attempted landing) being abandoned. During subsequent climbs, maintaining adequate visual contact with the surface would be more difficult due to an associated increase in the Helicopter's pitch angle, and it is likely that the Pilot would have experienced considerable pressure in the situation he was faced with.



If external visual references were lost, it would likely result in spatial disorientation, and at a relatively low height above the ground, a controlled flight into terrain (CFIT) accident or loss of control and consequent impact with terrain was likely. The semi-inverted, steeply nose-down attitude of the Helicopter as evident in the video of the final moments of the flight is indicative of a loss of control. Spatial disorientation has been highlighted as a factor in several accident investigation reports (**Section 1.16.3**) and the Investigation considers it probable that it occurred in this case.

2.7 Survivability

The forces involved during the accident sequence were such that the accident was not survivable.

2.8 Main Rotor Stall and Icing-Related Factors

2.8.1 Introduction

For completeness, the Investigation considered other possible factors such as main rotor stall, main rotor icing, airframe icing, and engine induction system icing.

2.8.2 Main Rotor Stall

Main rotor stall can occur if the main rotor speed is allowed to decrease in flight. To reduce the possibility of a main rotor stall occurring, the subject helicopter type is fitted with a low rotor rpm warning system, which includes a horn that sounds when the main rotor speed drops below 97% (approximately 388 rpm) and a *LOW RPM* warning light. In addition, the helicopter is fitted with an rpm governor that assists in controlling the engine rpm under normal conditions, and a throttle correlator which opens the throttle as the collective lever is raised. The Investigation examined the bulb from the *LOW RPM* warning light assembly. Its filament was found to be intact and unstretched, which indicates that the bulb was not illuminated at the time of impact and therefore that the main rotor speed was likely above 388 rpm. This is further evidenced by the analysis of the video of the final moments of the flight, which estimated that the main rotor speed was 375 ± 15 rpm, i.e. 360 to 390 rpm. The upper figure is above the *LOW RPM* warning threshold.

Furthermore, according to the Helicopter Manufacturer's Safety Notice on the subject of low rpm rotor stall (SN-24), *'it will frequently allow the rotor blades to blow back and chop off the tailboom as the stalled helicopter falls'*. The video recording of the final moments of the flight shows the tailboom attached and examination of the Helicopter wreckage did not find any evidence of main rotor impact with the tail section. The Safety Notice also states that *'as the helicopter begins to fall, the upward flow of air under the tail surfaces tends to pitch the aircraft [helicopter] nose-down'*. The Helicopter appears to be in a semi-inverted attitude in the video recording rather than falling in a purely nose down attitude (**Section 1.11.4.1, Figure No. 7**).

In light of the factors outlined above, the Investigation considers that main rotor stall was unlikely to have occurred in this case.

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2.8.3 Icing

When a liquid such as water is below its freezing point without it becoming a solid, it is described as *'supercooled'*. In-flight Icing occurs when supercooled water freezes on impact with any part of the external structure of an aircraft/helicopter that is at a temperature of 0 °C or lower. The meteorological aftercast for the Kennycourt/Kilrush area estimated a surface temperature of 0 °C and a freezing level of *'Surface to <1,000 ft'*, and that the weather was *'overcast and misty with pockets of freezing fog'*. The estimated temperature is consistent with the report from a pilot who was at EIKH (7 NM south-west of the accident site) approximately one hour before the accident, who said that the temperature there was 0 °C, as indicated by the temperature display in his car.

One witness who was in the Kennycourt area said that the Helicopter became low enough to briefly see its underside before it climbed and *'re-entered the clouds'* and another said that they thought the Helicopter was going to land, before it climbed *'nose straight up'* into cloud. Evidence of fog can be seen in the background of the video recording of the final moments of the flight (**Section 1.11.4.1, Figure No. 7**). Whenever the Helicopter entered cloud/fog in the prevailing temperature, there was a potential for rotor icing and/or airframe icing, such as windshield icing, to occur. However, the back-and-forth flight pattern of the Helicopter in the Kennycourt area, as indicated by ATC radar, was mainly above 1,900 ft and was therefore likely to have been conducted mainly in clear conditions, where ice was unlikely to form. Consequently, it is considered unlikely that rotor blade icing was a factor in this accident. Regarding windshield icing, the Helicopter's cabin heating system would likely reduce the possibility of this occurring. The Helicopter Manufacturer was not aware of any events where icing on the windshields resulted in a complete loss of visibility.

The Investigation also considered other icing effects, such as engine induction system icing, including fuel system icing. However, these types of icing would result in a loss of engine power or the engine shutting down completely. As outlined earlier, the Investigation established that the engine was likely providing significant power at impact and therefore considers that induction system or fuel system icing were unlikely to have occurred in this case.

2.9 Analysis Summary

The Pilot's Licence and Medical Certificate were valid and post-mortem examination determined that the cause of death was as a result of the accident. The Helicopter's airworthiness certification was also valid, and records indicate that all scheduled maintenance had been performed on the Helicopter as required. Examination of the Helicopter wreckage did not identify any pre-impact anomalies, and disassembly of the Helicopter's engine and examination of the engine components did not identify any pre-existing defects which would have prevented the engine from operating normally. Furthermore, witness accounts, video analysis, and accident site and wreckage examination all indicate that the engine was providing power at the time of impact.

The sky appeared clear and blue in the video recording showing the Helicopter departing on the accident flight and the Pilot likely expected that the en route weather conditions would have remained favourable. As indicated by the meteorological aftercasts, the sky was likely clear at the Helicopter's operating altitude as it flew towards EIKH (1,800 ft to 2,400 ft). However, visibility of the surface likely deteriorated as the flight proceeded.



The Investigation considers it likely that plan continuation bias (an unconscious cognitive bias to continue with an original plan, despite changing circumstances indicating that a new plan is required), was a factor in continuing with the flight at this stage, instead of returning to Tagoat or Ballygarrett. Plan continuation bias was also likely to have been a factor in the back-and-forth flight pattern in the Kennycourt area. This flight pattern suggests that, while remaining at altitudes where the sky was likely to be clear, the Pilot was searching for an area with a clearer view of the surface and with sufficient forward visibility, through which to descend and land, or operate back towards EIKH at a lower altitude. It is likely that this would have resulted in the Pilot experiencing an increase in workload and an increasing degree of pressure, and during an attempted or aborted descent, it is probable that the Pilot lost external visual references, became spatially disorientated, and lost control of the Helicopter.

The Investigation estimated that at the time of the accident, there may have been sufficient fuel remaining for a further 35 minutes of flight. However, due to the limitations in accurately estimating the fuel consumption rate, it is possible that the remaining quantity may have been less than this, and the Pilot may have been concerned regarding the reducing fuel quantity and felt increasing pressure to land or get to his planned destination (EIKH).

3. CONCLUSIONS

3.1 Findings

1. The Pilot's licence and medical certificate were valid.
2. Post-mortem examination determined that the cause of death was as a result of the accident.
3. The Helicopter's airworthiness certification was valid.
4. The Investigation found no evidence of any pre-existing defects with the Helicopter or its engine that would have prevented normal operation.
5. The Investigation estimated that the Helicopter departed Tagoat on the accident flight with 18.1 US gallons of usable fuel on board (approximately 39% full), which would be sufficient for a further flight time of approximately 82 minutes.
6. The Investigation estimated that when the accident occurred, the Helicopter had flown for approximately 47 minutes (approximately 68 NM) since departing Tagoat and had flown for a total time of approximately two hours and 56 minutes since refuelling.
7. The Investigation estimated that there may have been 7.8 US gallons of usable fuel remaining on board at the time of the accident, which equates to approximately 17% full and would be sufficient for approximately a further 35 minutes of flight; however, due to the limitations of accurately estimating the fuel consumption rate, it is possible that the remaining quantity was less than this.

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8. The weather at Tagoat, from where the Helicopter departed on the accident flight at approximately 14:58 hrs, was clear and dry, with crisp winter sunshine. The meteorological aftercast indicated that the visibility was in excess of 30 km and the surface temperature was 3 °C.
9. On the afternoon of the accident, the weather at EIKH, which was the intended destination, was overcast and misty, with low cloud and limited visibility. The meteorological aftercast indicated that the cloud bases were between 100 ft and 500 ft, there were pockets of freezing fog, and that the surface temperature was 0 °C.
10. The weather in the Kennycourt area at the time of the accident was similar to that at EIKH.
11. Radar data indicated that at 15:33 hrs approximately, the Helicopter flew directly overhead EIKH (elevation 260 ft) in a north-easterly direction at an altitude of approximately 1,800 ft (where the skies are likely to have been clear), a ground speed of approximately 76 kt, and that there was no attempt to land there.
12. Radar data indicated that the Helicopter continued past EIKH in a north-easterly direction for 8.3 NM (15.4 km), before turning around at time 15:38:10 and flying back in the general direction of EIKH (south-west) for approximately 2.2 NM (4 km).
13. Radar data indicated that the Helicopter flew back-and forth in the Kennycourt Area a number of times.
14. Radar data and witness accounts indicated that during the back-and-forth flight pattern in the Kennycourt area, the Helicopter conducted several descents and subsequent climbs.
15. The nature of the flight path in the meteorological conditions suggest that the Pilot was searching for an area with better visibility of the surface in which to descend and land or to route back to EIKH at a lower altitude; this likely would have resulted in the Pilot experiencing an increased workload and an increasing degree of pressure.
16. It is possible that the Pilot felt pressure to land or get to his planned destination (EIKH) due to a decreasing fuel quantity.
17. The Pilot may have been concerned regarding reaching EIKH in sufficient time to permit refuelling and a return to Ballygarrett before the end of daylight.
18. If visual contact with the surface had been obtained, it would have been difficult to maintain throughout a descent, and any reduction in visual contact or forward visibility would likely result in a descent (or attempted landing) being abandoned. During subsequent climbs, maintaining adequate visual contact with the surface would be more difficult due to an associated increase in the Helicopter's pitch angle.
19. The Helicopter was last recorded by radar at time 15:45:05. The radar data indicated that the Helicopter was at an altitude of approximately 1,500 ft, a ground speed of 23 kt, and was approximately 0.38 NM (704 m) south-east of the accident site.



20. A video of the final moments of the flight shows the Helicopter to be in a semi-inverted attitude and travelling towards the ground on a steep trajectory with a speed of 45.3 m/s (88.1 kt).
21. The Pilot likely lost external visual references, became spatially disorientated and lost control of the Helicopter during an attempted or aborted descent in sub-optimal visibility conditions.
22. Height above ground would have been lost quickly, such that recovery would not have been possible.
23. The Investigation considers it unlikely that main rotor stall, main rotor icing, induction icing, or significant windscreen icing were factors in the accident.
24. The forces involved during the accident sequence were such that the accident was not survivable.
25. A post-crash fire occurred.

3.2 Probable Cause

Loss of control due to spatial disorientation following a loss of external visual references during an attempted or aborted descent in sub-optimal visibility conditions.

3.3 Contributory Cause(s)

1. Plan continuation bias was likely a factor when the flight was continued in meteorological conditions in which visual contact with the surface was deteriorating.
2. It is possible that the Pilot felt an increasing pressure to land or get to his planned destination (EIKH) due to a decreasing fuel quantity.

4. SAFETY RECOMMENDATIONS

No.	It is Recommended that:	Recommendation Ref.
1.	The IAA should promulgate information on the effects of Plan Continuation Bias and on strategies to counter the effects of such biases, particularly in relation to General Aviation.	IRLD2024002
View the Safety Recommendation for Report 2024-007		

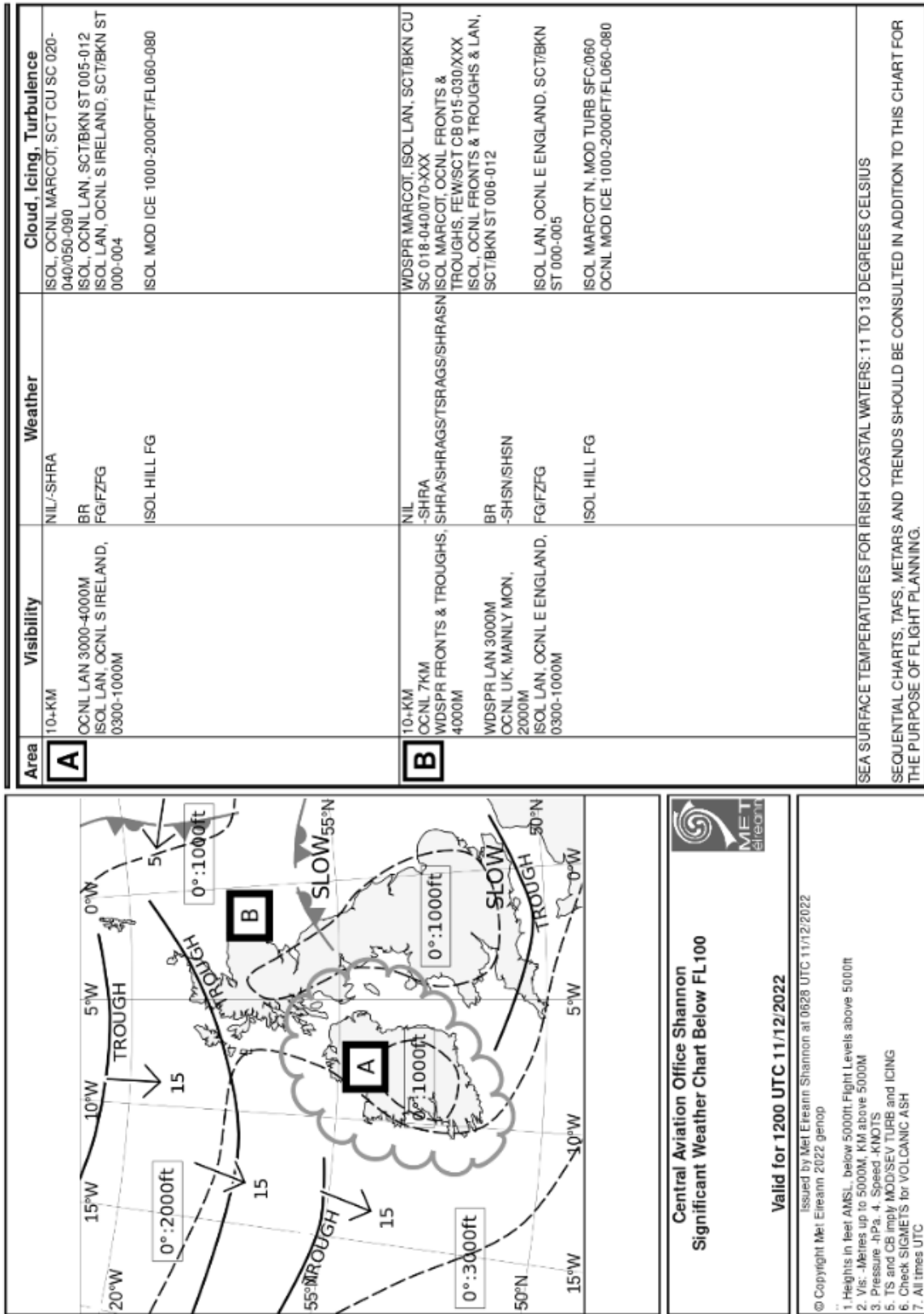
FINAL REPORT

Appendix A: Radio Communications between Pilot and Shannon FIS

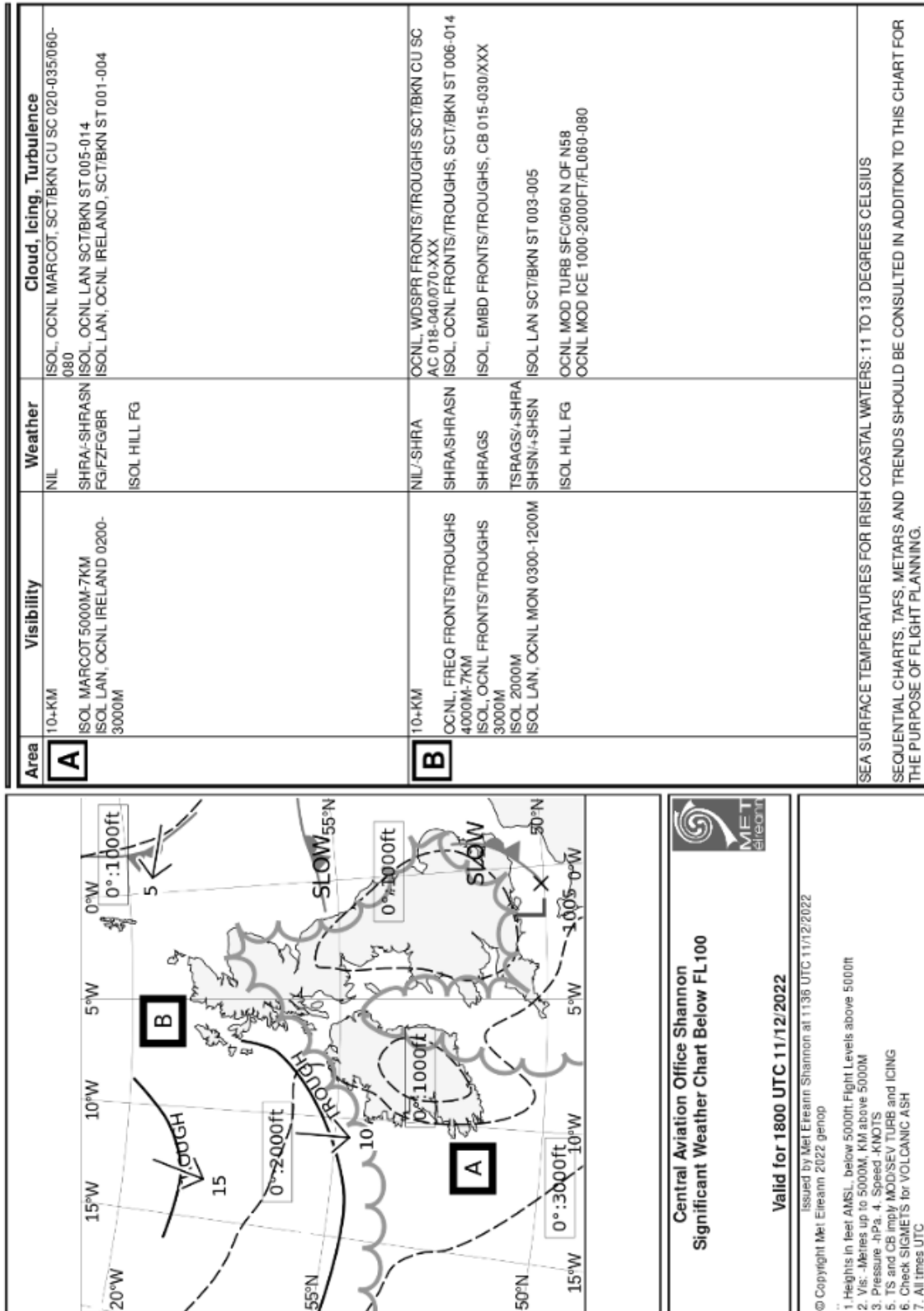
Time	From	Transmission
14:31:46	Pilot	Shannon, helicopter November nine nine nine Romeo Lima.
14:31:51	FIS	November nine nine nine Romeo Lima. Good afternoon.
14:31:53	Pilot	Good afternoon. Lifting out of Ballygarrett, in County Wexford en route to Rosslare and then over to Kilrush Airfield. I have one zero zero nine hectopascals.
14:32:06	FIS	November nine nine nine Romeo Lima, roger. The Shannon area QNH one zero one one hectopascal.
14:32:15	Pilot	Sorry, could you repeat.
14:32:17	FIS	Shannon regional QNH one zero one one hectopascal.
14:32:20	Pilot	One zero one one.
14:32:22	FIS	Nine nine nine Romeo Lima, are you information only?
14:32:25	Pilot	Information only and will report leaving the frequency.
14:32:27	FIS	Romeo Lima thank you.
14:41:26	Pilot	Shannon, helicopter November nine nine nine Romeo Lima. Leaving the frequency momentarily. Will connect when lift-off again, thank you.
14:41:36	FIS	That's copied.
14:41:39	Pilot	Romeo Lima.
14:57:57	Pilot	Shannon, helicopter November nine nine nine Romeo Lima, lifting out of Rosslare for Kilrush Airfield.
14:58:06	FIS	Nine nine nine Romeo Lima copied, no known traffic to affect, Shannon QNH one zero one one hectopascals.
14:58:11	Pilot	One zero one one hectopascals, thank you Shannon, Romeo Lima.
14:58:16	FIS	You can report setting down in Kilrush.
14:58:19	Pilot	Wilco, Romeo Lima.
15:26:19	Pilot	Shannon, helicopter November nine nine nine Romeo Lima, switching now to Kilrush frequency.
15:26:26	FIS	All copied sir. Goodnight.
15:26:29	Pilot	Thank you now, Romeo Lima.
15:26:31	FIS	All copied sir. Have a good evening.



Appendix B1: Low-Level Significant Weather Chart, issued 06:28 hrs)
(valid for 12:00 UTC on 11 December 2022)



Appendix B2: Low-Level Significant Weather Chart, issued 11:36 hrs)
 (valid for 18:00 UTC on 11 December 2022)



- END -

In accordance with Annex 13 to the Convention on International Civil Aviation, Regulation (EU) No. 996/2010, and Statutory Instrument No. 460 of 2009, Air Navigation (Notification and Investigation of Accidents, Serious Incidents and Incidents) Regulation, 2009, the sole purpose of this investigation is to prevent aviation accidents and serious incidents. It is not the purpose of any such investigation and the associated investigation report to apportion blame or liability.

A safety recommendation shall in no case create a presumption of blame or liability for an occurrence.

Produced by the Air Accident Investigation Unit

AAIU Reports are available on the Unit website at www.aaiu.ie



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