ACCIDENT

Aircraft Type and Registration:	Aerospatiale SA.341G Gazelle, HA-LFB	
No & Type of Engines:	1 Turbomeca Astazou IIIB	
Year of Manufacture:	1973	
Date & Time (UTC):	8 March 2011 at 1907 hrs	
Location:	Near Honister Slate Mine, Keswick, Cumbria	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - 1 (Fatal)	Passengers - N/A
Nature of Damage:	Extensive	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	45 years	
Commander's Flying Experience:	N/k hours (of which n/k were on type) Last 90 days - n/k hours Last 28 days - n/k hours	
Information Source:	AAIB Field Investigation	

Synopsis

The helicopter crashed in a valley during a night flight in meteorological conditions that included reduced visibility and low cloud. The investigation found that there were irregularities in the helicopter's maintenance and airworthiness, but no evidence was found of mechanical failure. The pilot was not qualified to fly at night.

History of the flight

The pilot routinely used the helicopter to commute between his home and various locations in the Lake District. On 9 March he flew the helicopter to a slate mine at the top of the Honister Pass. He spent the day there and at other sites nearby to which he travelled by road. After his last appointment, which was near Keswick, he drove back to the mine with the intention of flying home. The flight time would, in good conditions, be less than ten minutes; the journey by car would have taken half an hour or less[1].

The mine is located at a saddle in the Honister Pass (Figure 1). To the west of the mine, the Honister Pass extends north-west towards Buttermere and Crummock Water; to the east, the Pass extends towards Seatoller, where it joins a valley orientated approximately north-south, descending to the north to meet the southern end of Derwent Water.

Footnote

[1] Journey time established using a proprietary route planning application.

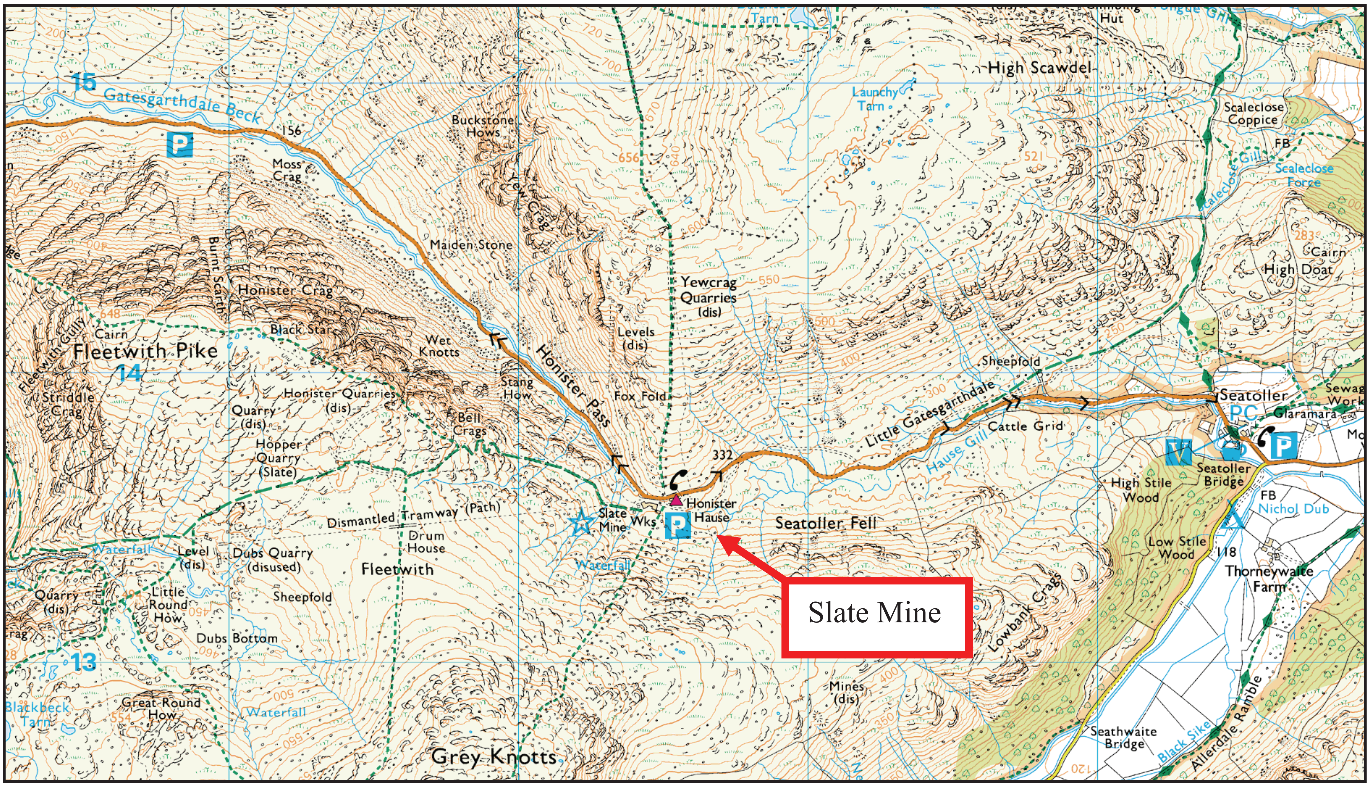

Figure 1

The area around the slate mine

The pilot telephoned his partner at their home south of Cockermouth before the flight, informing her that he was returning. He asked about the weather at home, and his partner later recalled describing it to him as "rather blustery" but with good visibility. She commented to investigators that he had flown in worse conditions. There was no evidence that the pilot obtained any other meteorological briefing before the flight.

Video evidence from closed circuit television (CCTV) security cameras showed the pilot arriving at the mine in his car, which he parked adjacent to the helicopter pad; the car's interior light was left on. Forty seconds later, the interior light in the helicopter illuminated. One minute and 55 seconds later, the helicopter's navigation lights and strobe light were activated. After a further 55 seconds, the helicopter lifted off, turned towards the mine building, and transitioned into climbing forward flight. Shortly after lift off, the helicopter's interior light was switched off and the landing light was switched on; it remained on for the duration of the CCTV recording (while the helicopter was in the camera's field of view). The helicopter flew west past the mine and turned to fly past again in an easterly direction, to the south side of the valley east of the mine. It was lost from the CCTV camera's view as it crossed towards the northern side of the valley. Recorded data showed that it passed over a point on the northern side of the valley at low speed, tracking north, with a relatively high pitch attitude.

There were no eyewitnesses and no further information was available about the history of the flight.

The pilot's partner became concerned when he did not arrive home, and telephoned a member of the mine staff who lived in Seatoller. The staff member went to the mine and found the pilot's car with the keys in the ignition and the interior light still on; the helicopter was not on its pad. The pilot's partner made further informal enquiries and at 2210 hrs informed the emergency services that he was missing. A search began shortly thereafter, and at about 0045 hrs members of the local Mountain Rescue Team (MRT) located wreckage of the helicopter approximately 330 m east of the landing site at the mine. The pilot was fatally injured.

Meteorology

The Met Office provided an aftercast of weather conditions near the accident site. The meteorologist stated:

> *'The situation was a cold front clearing to the southeast, but replaced from the northwest by a showery flow.*
>
> *Gradient wind (2000ft wind) at the site of the accident at 1800 UTC on 08th March 2011 estimated to be 260 degrees 35 knots… and at 0000 UTC on 9th March 2011 estimated to be 280 degrees 40 knots.*
>
> *The prevailing visibility in the area was initially rather poor and typically between 2500M and 8KM at 2000 UTC on 08th March 2011. The prevailing visibility generally improved to 10KM or more by 2200 UTC on 08th March 2011, but still with the likelihood of 200M or less in hill fog patches.*
>
> *The cloud base was variable and, whilst there were various cloud bases of stratocumulus between 1200FT and 1700FT AGL, there were also areas of SCT to BKN stratus at between the 300FT and 900FT AGL.*
>
> *There was some precipitation in the Honister area until around 2000 UTC on 08th March 2011, this being mainly light rain or drizzle. A drier spell followed, though with showers then moving in around midnight.'*

Lighting

The accident occurred at night. Almost no cultural lighting existed in the valley either side of the slate mine for some distance. Some lights at the mine may have been on, illuminating the building and area immediately around it. The interior light in the pilot's car was on, apparently because the door was ajar.

The phase of the moon was such that it would have provided little illumination and at ground level it would have been obscured by cloud.

Recorded data

The helicopter was not fitted with any crash protected recorders. The GPS receiver fitted to the helicopter was not of a type that records a track log.

Dynon EFIS-D10A unit

The helicopter was fitted with a Dynon EFIS-D10A unit with associated remote compass module connected to the GPS receiver. The unit uses internal solid state sensors coupled to pitot static inputs to sense the attitude, vertical acceleration, barometric altitude and airspeed of the helicopter. The remote compass module senses the magnetic heading and the GPS input provides GPS position, altitude, ground speed and track angle. The installation does not enable GPS time or date information to be transmitted to the EFIS unit so no date information is recorded and time data relate to the time manually set in the unit. An internal battery maintains power to the internal clock.

No documentation was found relating to the installation specific to this helicopter. The installation was set up to record a snapshot of parameters every 10 seconds. The EFIS recorded 14,291 sample points. The last 13 were consistent with the accident flight, 7 while in the air. The unit contained a battery to maintain power to the display in the event of loss of electrical power provided by the helicopter and no trigger for ending the recording was found other than impact damage. The manufacturer stated that there should be no significant delay in recording the data to memory after sampling.

Radar data

Due to the high surrounding terrain there were no recorded radar tracks for the accident flight. Recordings were available from three CCTV cameras located at the departure site. The quality of recordings made at night was very limited, mostly containing a black image with electrical noise. However, the lights from the pilot's car, the lights on the helicopter when in frame, and reflections of these lights on other surfaces such as the valley side, were visible in the recordings. The helicopter was only directly in the frame of the recording at the start of the flight and briefly when the helicopter was tracking towards the northern side of the easterly valley near the end of the flight. Given that the outline of the helicopter was not captured, the distance of the helicopter from the camera could not be gauged accurately. Therefore, the position and altitude of the helicopter could not be calculated from the CCTV recording. The CCTV did provide a time source that coincided approximately with UTC and for the purposes of this report is treated as such.

The EFIS recorded time was approximately 1 minute and 4 seconds behind the CCTV camera recorded time. All times relating to the EFIS recorded data have been adjusted to reflect the CCTV recorded time, taken as UTC.

Dynon EFIS-D10A recording characteristics

The EFIS started recording fresh GPS information soon after takeoff. It did not update the GPS altitude parameter until the last sample of the accident flight and to a value inconsistent with the barometric altitude recorded, even accounting for atmospheric conditions and filtering of the barometric parameters. This indicates satellite reception unfavourable for a 3D fix for the majority of the flight, but capable of providing 2D positional information and therefore also ground speed and ground track information. The resolution of the recorded GPS latitude and longitude parameters limited the position accuracy to approximately 19 m in north/south directions and 10 m in the east/west directions. Therefore, the recorded GPS data may not have had the accuracy of which the system is normally capable. However, it does still provide an indication of the flight path of the aircraft.

Altitude data is derived from air pressure sensed 64 times a second, filtered to be effectively an average over the last second. The vertical speed uses the filtered altitude data to derive a vertical speed parameter which is itself filtered to be effectively an average over the last two seconds. This reduces the effect of random errors in the process and so provides better accuracy during stable flight. Under the conditions of increasing vertical speed, the effect of the filtering will result in altitude and vertical speed figures that are under-reading as is typical with this type of instrument.

The lowest valid airspeed is 15 kt. Below this an airspeed of 0 kt is recorded.

The EFIS was installed on the helicopter instrument panel, forward of the aircraft centre of gravity so the sensed normal acceleration would have been affected by any rotational acceleration in pitch.

A review of the EFIS data recorded during previous flights showed that the magnetic heading was nearly always greater than the track, taking magnetic variation into account, regardless of direction of flight. The remote compass module was found to be installed at right angles to the manufacturer recommended installation orientation. This 90° difference was reflected in the earliest recorded flights. The relationship between magnetic heading and track then had a step change, likely associated with a calibration. However, a distinct discrepancy between heading and track was evident and remained stable for the rest of the recorded flights. Those with a valid GPS track, a roll angle of less than 10° and an airspeed of greater than 80 kt, showed an average difference between true track and magnetic heading of 23.7°. This is greater than the local difference due to magnetic variation and is too consistently positive to relate to wind drift. The data used in this report has been adjusted by this amount to give a true heading that is likely to be more accurate on average but may not have been the actual value.

The following amalgamates EFIS and CCTV evidence.

Accident flight

Figures 2 and 3 show data from the EFIS recordings. The recordings started at 1905:34 hrs with the helicopter stationery at the takeoff location and with a heading of approximately 025°(T). The barometric altitude varied whilst still on the ground during the helicopter start up, as would be expected. The CCTV showed the various lights and beacons becoming active. The helicopter took off at 1906:25 hrs and turned to head north-west with an airspeed of approximately 25 kt, climbing slowly. The helicopter then carried out a climbing turn and headed south-east towards the southern side of the eastern valley. The helicopter reached its highest recorded altitude in a left turn away from the valley side. The next and final recorded point, at 1907:34 hrs, placed the helicopter nearer the north side of the valley with no valid airspeed (ie below 15 kt), a ground speed of 34 kt, a track of 355°(T), a heading of approximately 20°(T), a descent rate recorded as -735 ft/min, 25.75°of nose-up pitch, 3.75° of right roll and a turn rate of 3°/s to the right. This implies a slow rotation to the right with little roll and a nose-up attitude, low airspeed, forward ground speed and in a descent.

Comparison with previous flight

Previous recorded tracks to and from the takeoff point sometimes involved flight paths that took the helicopter closer to the northern side of the valley than the last recorded point of the accident flight. However, these involved flight paths approximately in line with the valley and not across the valley. Turns in the valley on approach to or departing the area were carried out near or above the southern slopes of the valley or in the valley to the west of the slate mine facilities.

The final recorded point had no valid airspeed (less than 15 kt), 25.75°of nose-up pitch and a calculated height of approximately 550 ft agl. A review of the previous flights showed that, with one exception, each occasion the pitch was recorded as greater than 20° nose-up was associated with a flare before landing. The one exception was associated with flight involving a number of high pitch and roll manoeuvres at speed. The highest nose-up pitch angle recorded with a calculated height of 500 ft agl or higher, during previous flights, was 8.75°

Other than the final recorded point during the accident flight, with a calculated height of approximately 550 ft agl, no other flight recorded an invalid speed at a calculated height of more than 230 ft agl. The penultimate recorded point also indicated a lower speed than previously recorded for the given calculated height above terrain.

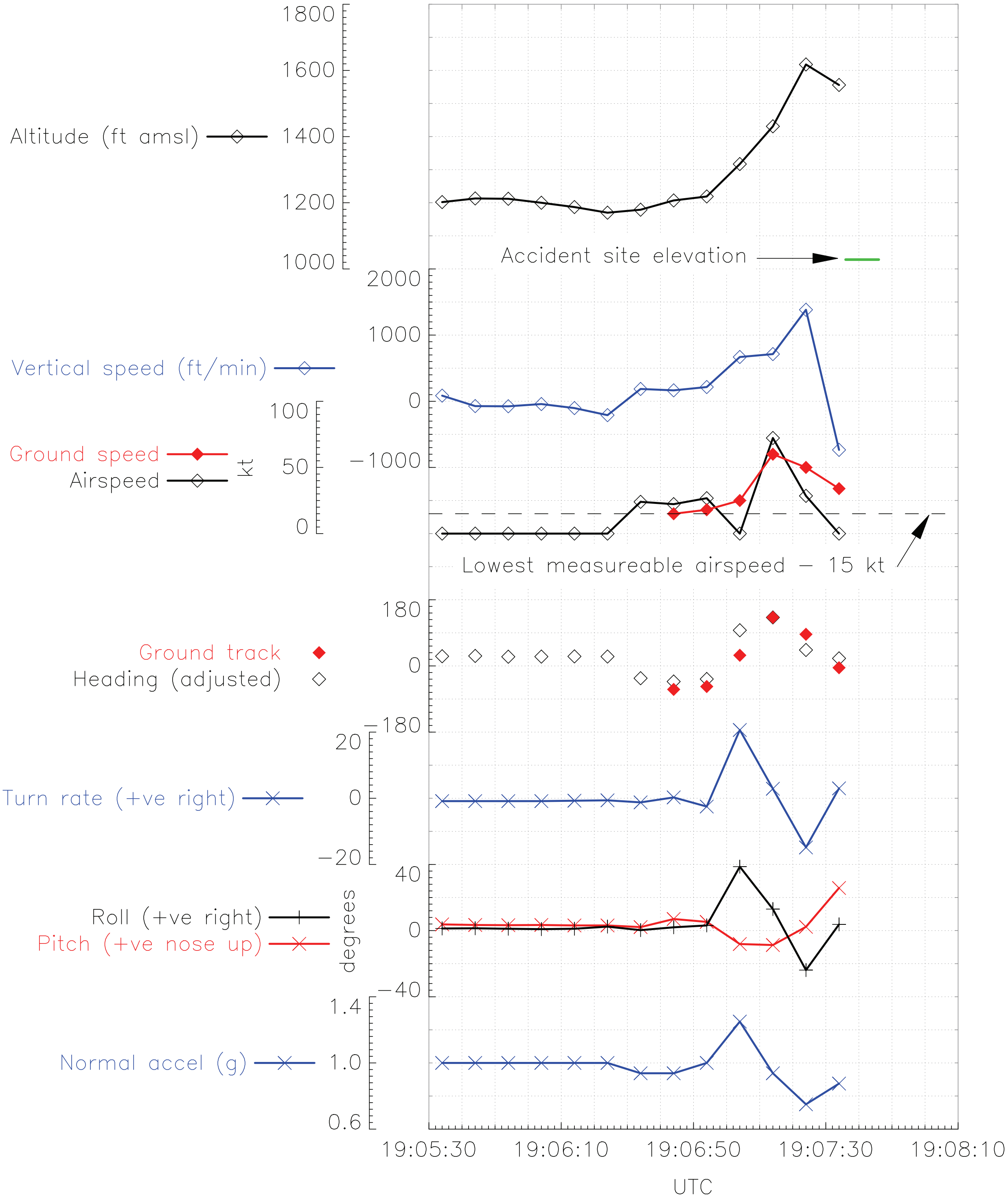

Figure 2

EFIS recorded data

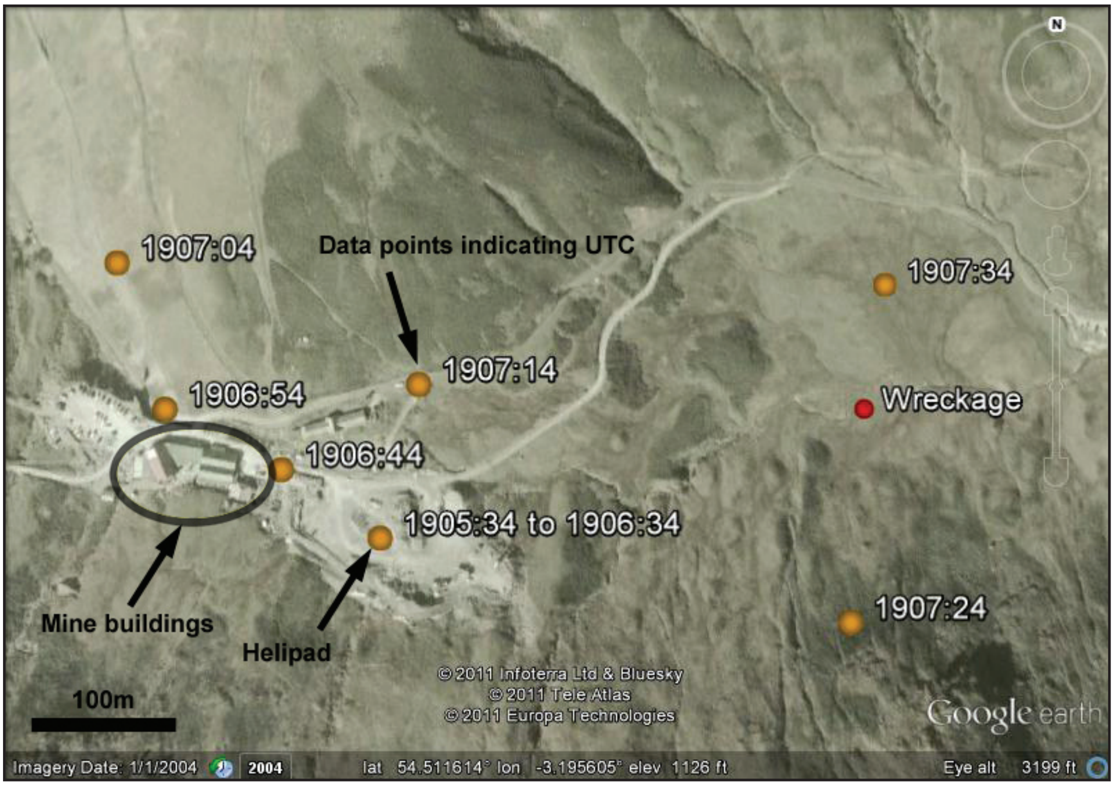

Figure 3

Recorded GPS positions during the accident flight

Routes between Honister and Cockermouth

The pilot's flying frequently took him between three sites in the Lake District: his home, south of Cockermouth; the mine at Honister, and another site north of Keswick. This is illustrated by the GPS recordings of his recent flights (Figure 4)

The pilot habitually flew more or less directly between these locations, although the tracks varied. The route from the slate mine directly to his home involved crossing the Honister Pass, and then following Buttermere and Crummock Water before reaching low-lying ground near his home. This route is through relatively deep and steep-sided valleys among high ground rising to a maximum of 2,792 ft. His route from the mine to the site near Keswick is down the valley towards Seatoller and then following falling ground into a wider valley towards Derwent Water and Keswick itself. From Keswick, a possible route to his home would follow the main road along low-lying ground from Keswick towards Cockermouth. This latter route featured more cultural lighting.

The pilot

The pilot flew fixed wing and microlight aircraft before taking up helicopter flying in 1993. He obtained a PPL (H) in 1993, and then owned or hired Robinson 22 and 44, Bell 206, and Enstrom 280C helicopters until 2005, when he bought a Gazelle helicopter, which he later sold. At the time of the accident he owned two similar Gazelles, both on the Hungarian civil register.

He held a crew member certificate issued by the Hungarian Civil Aviation Administration which validated his PPL for flight in Hungarian-registered aircraft.

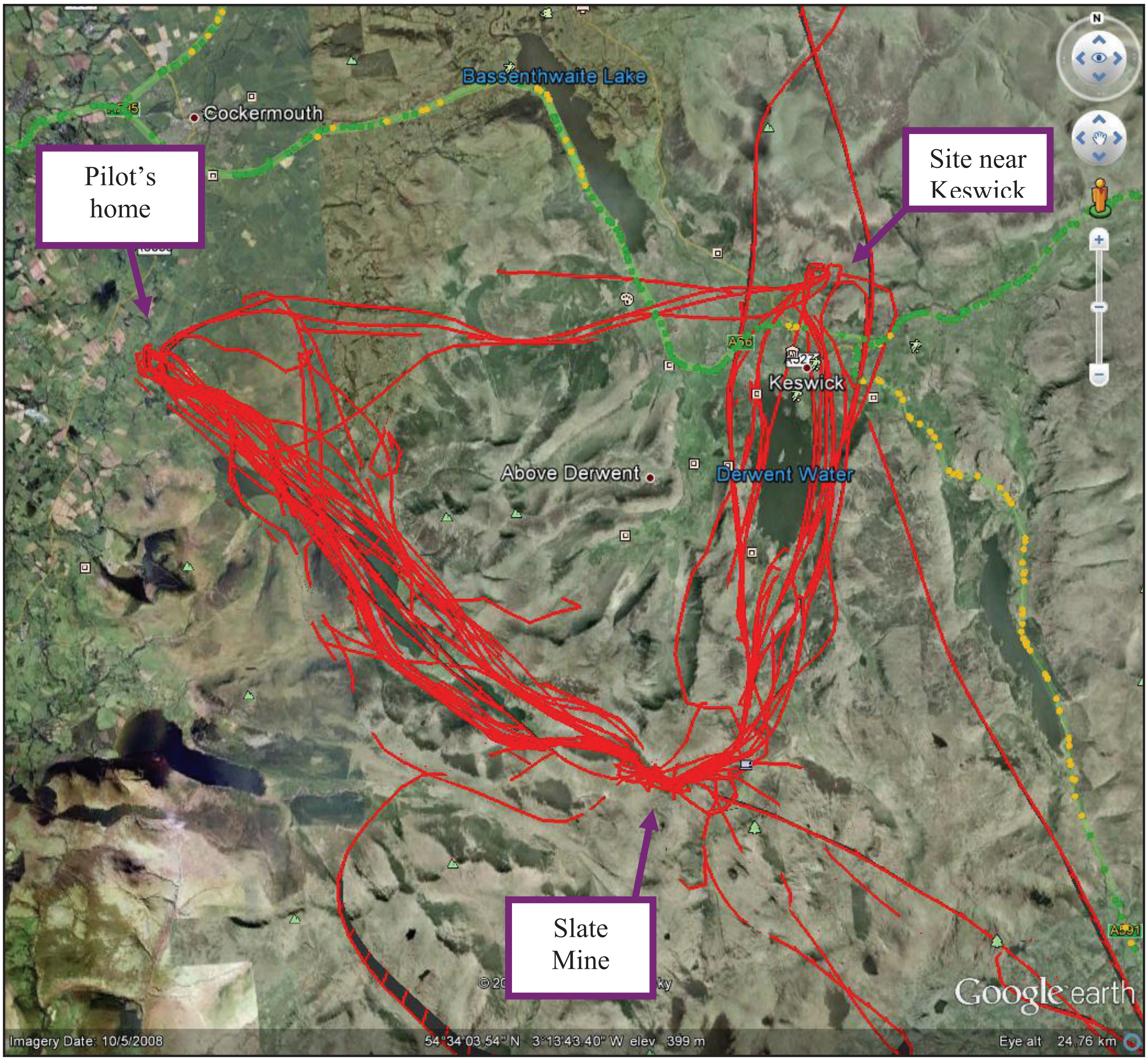

Figure 4

The pilot's usual routes within the Lake District (GPS tracks shown in red)

No recent flying logbook was located during the investigation[2]. Log books of helicopter flying between 1993 and February 2007 were found, which showed that by the latter date the pilot had accumulated a total of 371 hours flying experience in helicopters, of which 116 were in Gazelles. He continued to fly helicopters between 2007 and the date of the accident, but it was not possible to determine details of his flights. During his last medical examination, in July 2009, the pilot stated that he had accrued a total of 1,700 flying hours, 400 of which had been in the preceding two years.

Footnote

[2] The pilot reported to the CAA on 18 October 2010 that his log book had been in his car when the car was stolen.

The pilot completed a licence proficiency check with a freelance examiner, formerly a British military pilot, in July 2010. The examiner stated that he had conducted a number of proficiency checks with the pilot in recent years and considered him to be of above average flying ability, adding that his skill level was similar to that of a British military helicopter pilot of two or three years operational experience.

The pilot did not hold a night qualification, and there was no evidence that he had undertaken training towards one. His log book contained an entry in 2006 annotated:

> *'land 200 m away from home at night.'*

No other entries relating to night flying were found.

The pilot had lived in the Lake District all his life and, according to those who knew him well, was very familiar with the area, its terrain, and its features.

Supervision of flying activities

The helicopter was operated under the oversight of a Hungarian company responsible for the aircraft's airworthiness and the validity of the pilot's qualifications, but this oversight did not extend to the approval of each planned flight. The operator did require meteorological forecasts to be obtained before each flight and carried aboard the helicopter.

Canopy misting

If a helicopter has been parked in low temperatures, the canopy may mist up before, during, or after, engine start, as warm, moist, air meets the cold transparency. This effect may be exacerbated if an occupant or occupants board a helicopter in damp clothing. In serious cases, visibility may be reduced to the point at which the pilot can no longer maintain visual references outside the helicopter. A previous AAIB investigation[3] identified this as a causal factor in a fatal accident.

An examiner familiar with the Gazelle helicopter stated that prior to flight in these circumstances, the canopy should be wiped inside and out with a cloth which should be wrung out regularly, and that the bleed air demisting system was only effective five minutes or more after engine start.

It was not possible to determine if canopy misting had occurred in this case.

Night flight in helicopters

Night flight in helicopters presents several challenges different from flight by day. In particular, poor visual cues may require the pilot to make reference to flight instruments. In the absence of cultural lighting or clear moonlight, the pilot may have difficulty determining the presence of cloud and an inadvertent encounter with instrument meteorological conditions may be more likely. Without appropriate lighting at the destination, the approach to land may be particularly demanding, and emergency landings away from prepared landing sites, with or without power, are particularly challenging.

Vortex ring state

A vortex ring state is a condition in which the main rotors of a helicopter operate in the turbulent downwash they have created, reducing lift and causing control difficulties. Conditions for the onset of a vortex ring state include low forward airspeed, a rate of descent of more than a few hundred feet per minute relative to the air mass in which the helicopter is flying, with power

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Footnote

[3] Accident to Agusta Bell 206B, G-FLYR at Glamis Castle, Forfar, Scotland, AAIB reference EW/C97/7/2.

(collective pitch) applied. A vortex ring may be entered, for example, in a low-speed near-vertical descent, or in a quick-stop manoeuvre.

Flight in mountainous terrain and strong winds

The combination of mountainous terrain and strong winds can cause turbulence, rotor and windshear. The strength of these phenomena is approximately proportional to the strength of the wind. The complexity, size and shape of the terrain also have an influence. The terrain around Honister, with a series of complex hills and valleys with slopes of considerable size and gradient, mean that turbulence, rotor, and windshear may have been encountered.

Landing lights, strobe lights, and low cloud at night

Reflection of landing lights or strobes on fog or cloud can be disorientating or degrade night vision.

Pathology

An aviation pathologist carried out a post-mortem examination on the pilot. No medical or toxicological factor was identified as having caused or contributed to the accident, but the pathologist commented:

> *'While it is unlikely to have had any effect on survivability in this particular accident, the fact that [the pilot] was not using the shoulder straps which were fitted to his seat could have compromised survivability had the crash forces been of a lesser magnitude.'*

Aircraft description

The Gazelle was originally designed for military use as a light battlefield support and observation helicopter and has been operated extensively in its military specification. A civilian version was later developed and certified, originally by the French DGAC and then by the EASA. The Gazelle is noted to have significantly better performance than most other civilian light helicopters in this category due to its power-to-weight ratio and has a reputation for being agile and manoeuvrable. Whilst the large vertical fin provides good stability in yaw at moderate or high speeds, accurate handling in yaw at low speeds may be demanding.

A single pilot normally flies the helicopter from the right seat, with removable dual controls for the left seat. Three passengers can be carried on the rear bench seat. The cabin structure is minimal with large, domed floor-to-roof Perspex panels forming the majority of the front surface of the helicopter. It has a main door on both sides that opens forwards and a smaller rearward opening door that the main door closes against, also on both sides. These doors form the sides of the cabin, with two Perspex panels forming the majority of the roof.

A narrow ceiling panel runs down the centre of the roof containing ducts and a diffuser to supply warm air from the engine for cabin heating. This arrangement also directs air onto the forward transparencies to provide a de-misting action. The engine throttle, emergency fuel shutoff, rotor brake, and heating mixer control are also located at the front of this roof panel. Below the cabin floor panels, a box section structure provides the main structural rigidity for the cabin and houses the flying control system and avionics cabling.

Between the cabin bulkhead and the rear bulkhead are the main fuel tank, luggage area and items of mechanical and avionic equipment. Several fuel system components are located on the back face of the rear bulkhead. Above the fuel tank is the transmission platform where the main rotor gearbox is attached to a flexible mounting plate and two V-frame mounts. An Astazou IIIA turbine engine is mounted behind this at the interface between the fuselage and the tail boom. The engine shaft is connected to the main rotor gearbox, through a clutch and flywheel arrangement, by a drive shaft and cardan ring assembly. As well as the main rotor head, the main gearbox also drives the tail rotor shaft, an internal oil pump, and a hydraulic pump to provide hydraulic pressure for the flying controls.

The tail rotor drive shaft runs from the main gearbox, via an intermediate bevelled gearbox, then along the top of the large diameter tail boom. The tail boom ends with a large vertical fin to accommodate a fenestron tail rotor and gearbox. Horizontal stabilisers with vertical endplates are also fitted on either side of the tail boom. The helicopter has four hydraulically assisted flying control actuators, one for each of the main rotor blades and one to change the angle of the fenestron blades. The main rotor actuators are connected to the cyclic and collective by conventional torque tubes and mechanical mixer units. The yaw pedals are connected to the fenestron actuator, via torque tubes, a pulley unit and then by control cables that run alongside the tail rotor shaft on the top of the tail boom. A simple stand-alone oil filled piston and restricted bypass attached to the crosstube provide rate damping for the yaw controls. In the event of a hydraulic system failure, the actuators revert to mechanical connections, but are sufficiently balanced to allow the helicopter to be controlled without excessive pilot effort.

The Astazou IIIA is a coupled turboshaft engine, with a reduction gearbox that drives a centrifugal clutch and freewheel assembly. The compressor section comprises a single stage axial compressor, followed by a centrifugal compressor. Fuel is delivered to the annular combustion chamber by centrifugal injection, with exhaust gas passing through a three-stage turbine. P2 air bleeds from the engine provide air for the cabin heating and purge the igniters following engine start. P2 air is also supplied to a flow limiter in the fuel system, to control the rate of increase in fuel supply to prevent engine surge following a high demand input.

During normal operation, once the throttle on the cabin roof is moved to the flight detent, the engine is designed to maintain a constant 43,500 rpm (+400/-0) irrespective of power demand, giving a nominal main rotor speed of 380 rpm. Fuel pressure is provided by an engine driven pump and maintained at a constant level, regardless of demand, by a differential pressure valve. A metering valve controls fuel flow. The engine has a speed governor, which uses a bob-weight system to sense changes in engine speed. If the speed is too low or too high, the governor ports oil to the appropriate side of the metering valve servo to open or close the valve, until the engine speed returns to nominal. When the metering valve opens fully, an alarm light on the instrument panel illuminates. This is a multi-function light but during flight, it advises the pilot that the engine has reached maximum fuel flow and therefore maximum engine power[4].

The instrument panel has a number of emergency and caution warning lights. The main central warning panel group of lights confirm the status of the major aircraft systems. This group includes a pitot heat warning light, which illuminates when the electrical pitot probe heater is switched off or has failed. There is also a light located on the torquemeter which flashes when the torque exceeds 97.5%, then remains on steady when the torque exceeds 102.5%.

Footnote

[4] During rapid transition from a low power demand to a higher power demand, the metering valve can open fully and illuminate the alarm light. The light will extinguish again as soon as the engine speed recovers.

Some military versions of the Gazelle are fitted with a variant of the Astazou engine designated the IIIB. Although identical to the IIIA in architecture, the engine has not been subject to a certification process and due to the non-standard nature of military operations, it is not listed as an approved model on the EASA type certificate for the Astazou engine. As such, if a IIIB engine is subsequently fitted to a civilian aircraft, it invalidates the aircraft's EASA Certificate of Airworthiness.

When granting FAA certification, the FAA added a number of special conditions to the Type Approval for the civilian SA341G, including the requirement for an engine fire detection system.

Accident site and ground marks

The accident site was located across both sides of Hause Gill stream in the relatively flat bottom of the U-shaped valley that forms Honister Pass. The majority of the wreckage came to rest approximately 330 m east of and 50 m vertically lower than the helicopter-landing site at the mine. The first ground mark was north of the main wreckage site and formed a relatively shallow, roughly triangular depression. It contained several items of wreckage from the lower surface of the cabin including the belly panel and the radar altimeter antennae. Both the rear sections of the skids and the vertical endplate from the left horizontal stabiliser were located immediately to the east of this ground mark. South-east of the ground mark was a deep, narrow ditch the length of a main rotor blade, with a circular hole at the end. Debris from the wreckage and large clumps of earth were scattered in a cone shape southwards originating from the initial ground mark, and extending each side of and beyond the main wreckage of the fuselage.

Initial wreckage inspection

The helicopter was heavily disrupted from the start of the tail boom forward. The tail boom rearwards was essentially intact and lay on its right side, roughly along an east-west axis with the vertical fin pointing north. The vertical fin was bent to the left (looking rearward) and the aerial on the right side of the fin (looking rearward) was flattened and distorted. The anti-collision beacon on the top of the fin had been knocked off. The underside of the join between the tail boom and the fuselage had crumpled and was heavily folded and creased. The main body of the fuselage also lay on its right side, with the remains of the cabin at approximately 90º to the tail, pointing towards the south. The cabin was completely disrupted and had extended forwards, held together only by electrical cabling, with the instrument panel the furthest item of wreckage still attached to the main fuselage. The pilot was found still strapped to his seat by the lap strap, but projected clear of the main wreckage. His shoulder straps had not been fastened.

The engine mounts had failed, as had the drive shaft to the main gearbox and the tail rotor drive shaft, both ends of the intermediate gearbox and at the main gearbox. The main gearbox was still attached to the transmission platform, but this had rotated backwards 90°, such that the rotor head pointed towards the tail. The main rotor blades remained attached at the rotor head, though the blade coning stops and top section of the rotor head had been damaged. The blade structure was severely damaged and delaminated along the length of all three blades. Various sections of some of the blades had detached during the impact, though these sections were still present around the accident site. The main flexible 'bag' fuel tank had been damaged and the contents had leaked away. The auxiliary fuel tank had been thrown clear of the main wreckage. It had been heavily disrupted in the impact and was also empty.

Detailed wreckage inspection

A significant amount of debris was found in the engine intake wire mesh guard. As air enters from the rear of the intake cover, this debris had been drawn into the intake by the pressure drop resulting from an operating engine. The engine was identified as an Astazou IIIB and was sent for strip and inspection at the manufacturer. Mud and debris were found in the compressor gas path as far back as the centrifugal compressor, with associated foreign object impact damage on the axial compressor blades and vanes. Heavy rotational rub marks were found on various components within the engine. These findings together confirmed that the engine was operating at speed at the point of impact with the ground. Unburnt fuel was found in the P2 air tapping, indicating that fuel was being supplied to the combustion chamber at impact and that the helicopter had rolled over at some point during the impact sequence. The engine's reduction gearbox was stripped and inspected. No defects were identified, but clear impression marks from the cogs were present on the casing, indicating the engine had experienced a significant frontal impact force. The gearbox and rotor shaft turned smoothly, without restriction.

The main accessory components of the engine were inspected and performance tested on the manufacturer's test rigs. The maximum fuel flow of 4.6 litres/hr delivered by the fuel control unit was low against the minimum specification for a newly overhauled unit, but the manufacturer advised that this would not have significantly affected the maximum power available from the engine. No other defects relevant to the accident were found in the core engine and accessories. As such, no evidence was identified that would have prevented normal engine performance prior to impact.

As HA-LFB was originally registered in the USA, the engine was fitted with four bimetal strip sensors which, when heated by a fire, would cause a warning light to illuminate on the instrument panel. A defect was identified on one of the fire detection sensors that would probably have resulted in a false fire-warning signal. The indicator light bulb unit was not present in the fitting on the instrument panel when inspected after the accident, but was recovered later by the family of the pilot. Filament analysis of its bulb confirmed it had not been illuminated during an impact. Further detailed inspection of the fitting showed that the bulb unit had been removed intentionally prior to the accident flight.

The main components of the helicopter were disassembled and inspected. The hydraulic pump showed evidence of significant frontal impact force and the driveshaft shear pin had failed. However, evidence from the rotor speed indicator, which receives its signal from a tacho generator driven by the hydraulic pump, confirmed that the pin sheared as a result of the rotor blades being forcibly stopped by the ground impact. The hydraulic control actuators moved freely, with the exception of one main rotor actuator, the main piston of which had been deformed during the impact. During the disassembly and inspection of the hydraulic system, it was noted that there was much less hydraulic fluid remaining than would be expected given the required total system contents. However, there was no evidence of a significant hydraulic fluid leak on the surrounding wreckage. Although no fuel remained in the fuel tanks, the main tank sump was undamaged and still contained fuel.

There was significant damage to the flying control rods, cables, mixer units, and bell cranks. However, all the damage was consistent with overload failure during the impact. The yaw damper was found to have very little oil within it, such that there would have been no damping effect on the yaw controls. As with the hydraulic system, there was no evidence of an obvious leak path or leaked fluid.

The pitch control rod attached to one rotor blade had failed at the upper end of the rod. However, the blade to which it had been attached had been knocked vertical at the 'flapping' hinge of the rotor head during the impact with the ground. The fracture surface on the control rod was consistent with an overload failure during this process. The main gearbox, intermediate gearbox and tail rotor gearbox were internally undamaged and turned without restriction.

Rub marks on the front inside face of the fenestron housing indicated that the fenestron blades had been rotating at impact and confirmed that there had been sufficient frontal impact force to cause them to contact the housing. The driveshaft was displaced forward from its bearing housings, also indicating a significant frontal impact. Score marks on the tail rotor shaft indicated that it had been rotating at impact.

The engine throttle lever was found fully forward and still located in the flight detent. The position of the hot air rotary selector could not be confirmed because the Teleflex cable had been severed in the impact. Likewise, the pre-impact position of the hot air mixer valve could not be determined reliably, due to impact damage in the surrounding area.

Strip and inspection of the torquemeter confirmed that maximum engine torque was being applied to the rotor blades at impact. This was consistent with the position of the collective. The adjustments for outside air temperature and altitude had not been correctly set on the torquemeter. This would have resulted in the warning light being triggered incorrectly, had the torquemeter warning light not been disabled due to the modification standard of the unit.

The vertical speed indicator was frozen at full-scale deflection (3000 ft/min or more) down. Hot filament failure analysis was conducted on the warning light bulbs fitted to the instrument panel. Of the main warning lights, only the pitot heater caution light was illuminated at impact. The alarm light indicating maximum fuel flow on the engine was also illuminated at impact.

Maintenance

Although the aircraft was flown privately, it was required to be 'operated' by an organisation approved by the Hungarian CAA because it was registered on the Hungarian civil register. This operator was responsible for the maintenance and airworthiness control of the helicopter. The operator provided maintenance records for the helicopter from 2007 onwards. These were the only such records available to the investigation. Only the last engine shop visit was recorded and there was no evidence of time accrued on life-controlled components prior to 2007. According to the operator's records the only routine maintenance conducted on the aircraft had been annual checks, which were accomplished by a member of the operator's staff travelling to the UK. The operator advised that it had fitted no new components to this aircraft since the original extended maintenance check, which it completed to bring the aircraft on to the Hungarian register in 2007.

Airworthiness issues

A number of serious airworthiness issues were identified with the helicopter during the course of the investigation. None of these issues could be directly linked to the cause of the accident, but did raise concerns regarding the way the helicopter was operated. Given the number, complexity and severity of the issues found and the fact that they are common to a number of other fatal accident investigations conducted on foreign-registered aircraft in the UK, they will be covered in detail in a separate Safety Study report. However, a brief summary is provided below:

Life controlled parts

Different life-controlled components had been fitted to the airframe from those recorded by the Hungarian operator. As such, their life remaining calculations were incorrect. No service life records or EASA Form 1's for these components were found and there were no maintenance records of their installation. As such the remaining fatigue life of these items, if any, was unknown.

A number of the components fitted to the helicopter were confirmed to be ex-UK military in origin. At least one was traced back to Ministry of Defence records, which confirmed it was sold as unserviceable and with an unconfirmed service history.

Engine

The Astazou IIIB engine fitted to the helicopter is a variant for military use only. This invalidated the EASA Certificate of Airworthiness.

The engine was overhauled by an unapproved repair facility in Serbia and issued with a counterfeit EASA Form 1.

The engine manufacturer's investigation identified a large number of discrepancies relating to unapproved overhaul practices carried out at the last shop visit. These included use of non-original equipment manufacturer parts, re-use of single use items and potentially dangerous overhaul practices on critical components.

Modification standard

An early landing gear modification standard was fitted to the helicopter. This required an early modification standard main gearbox mounting plate with a locking plunger system. This modification standard is not accepted by the UK CAA on UK registered aircraft.

The torquemeter fitted had been modified to a UK military standard, designed to be compatible with night vision goggles (disabled red warning light). This modification required an alternative green warning light to be fitted to the instrument panel. This was not present and as such, there was no warning of over-torque other than the indicator needle.

Maintenance

Maintenance work had been completed to change components without the knowledge of the approved maintenance organisation responsible for the aircraft. No record was found of who carried out this work or whether they had the appropriate training and approvals.

Based on inspection of physical evidence from the wreckage, the aircraft had been operated for an indeterminate period with the fire warning light removed from the instrument panel. It is likely that the warning light had been removed because a faulty sensor in the fire detection system had resulted in a false warning.

Evidence was found of chafing between the tail rotor drive shaft and its covers and between the hydraulic pipes for the tail rotor actuator and sections of the airframe. Fluid levels within various components on the helicopter were found to be much lower than expected, with no obvious leaks identified. This might indicate poor maintenance practices or missed maintenance checks.

No evidence was found that the torquemeter had been adjusted for the replacement torque liaison shaft or the new engine, leading to potentially erroneous indications.

Records

No current pilot, engine or airframe logbooks were found in the UK, preventing confirmation of the flight hours accrued. The total hours counter on the instrument panel did not match the recorded hours supplied by the Hungarian operator.

Analysis

Recorded information

The data was recorded at 10 second intervals, insufficient alone to build an accurate picture of manoeuvres being flown, prevailing conditions and the serviceability of the helicopter.

The last recorded set of data indicated that the helicopter had low airspeed and a vertical speed of -735 ft/min. At this point the helicopter's heading was to the right of its track with a drift of approximately 25°, a turn rate of 3°/s to the right and 3.75° of right roll . The helicopter had 25.75°of nose-up pitch. The attitude and speed of the helicopter at the final recorded point of the accident flight were significantly different from those previously recorded for the calculated height above terrain. This indicates that by this point, the flight was not normal. The penultimate point also indicates an unusual combination of low speed and height compared to previous flights.

The last point indicates more ground speed than airspeed in the direction of track and heading, with a slow rate of turn, indicating general tailwind conditions. This, in combination with a descent and nose-up attitude, is unusual.

Given the EFIS installation design, it is likely that a further data point was not recorded because the ground impact disrupted the unit within 10 seconds of the last recorded point.

The helicopter was approximately 500 ft higher than the accident site at the time of the last recorded sample. This implies an average vertical speed of approximately -3,000 ft/min following the last recorded point. Taking account of the lag in recorded vertical speed due to filtering, the actual vertical speed may have been greater.

The sample rate and comparisons of flight characteristics with previous recorded flights indicate a departure from normal speed/height characteristics approximately 15 to 25 seconds before impact. The cause could not be determined from the recorded data.

It is probable that the helicopter yawed through at least 180° between the final recorded point and impact, descending at a high rate.

Engineering issues

Evidence from the accident site showed that the aircraft approached from the north. It initially impacted nose first and with high energy. This resulted in the removal of the landing gear, lower antennae and belly panel and caused significant damage to the cabin and floor box structure. The helicopter fuselage continued to pivot round to the left, whilst rolling left, most likely because the aircraft was yawing right at impact. This caused the horizontal stabiliser end plate to break off on the left side as it touched the ground. The vertical fin then contacted the ground and bent sideways, flattening the aerial and knocking off the beacon. As the aircraft continued to roll, a main rotor blade struck the ground creating the large ground mark. The reaction of the fuselage to the rotor blade strike caused it to be lifted into the air again. It continued to roll inverted about the longitudinal axis, before hitting the ground again in its final location, with the remains of the cabin then continuing forward in the main direction of impact.

The rotational and deceleration forces resulted in the pilot, still attached to his seat, being thrown clear of the main wreckage, along with many smaller items of wreckage.

No evidence was found of a mechanical failure that might have been causal to the accident. Evidence found during the engine strip inspection indicated that one of the fire detection sensors would probably have triggered an erroneous fire warning, if fitted to an otherwise serviceable indication system. However, the fire warning light bulb was confirmed not to have been illuminated during an impact and the bulb unit had been removed from the instrument panel prior to the accident flight. As such, this did not contribute to the accident. As the aircraft was unlikely to have been flying in icing conditions, the lack of pitot heat identified by the warning light was also not relevant to the accident.

The yaw damper was incorporated to restrict the rate of application of yaw control inputs; the lack of fluid in the yaw damper meant that it was not functioning as intended. This would have increased the sensitivity of the aircraft's response to pedal inputs and would have increased pilot workload when flying low airspeed manoeuvres, especially in gusting and directionally variable winds.

Physical evidence from the wreckage confirmed that the engine was operating at full power at impact consistent with a high torque load, most likely due to control inputs by the pilot. The degree of damage to the helicopter, witness marks on various components and the vertical speed indicator reading, indicate a high rate of descent at impact, with forward speed and yawing motion to the right.

Operational issues

For the pilot, flying from the mine to his home was routine. He probably knew the terrain and his usual routes well. The flight occurred at night with very little cultural lighting and little, if any, moonlight. The wind was strong. Considerable turbulence, rotor, and up- and down-draughts would therefore have been present. There was much cloud, some below the level of surrounding terrain. Visibility in the area was variable, typically as low as 2,500 m but less in places.

Although his partner provided a report of weather at home, the absence of formal meteorological briefing, and the difficulty inherent in observing the visibility and cloud in a series of valleys in the dark, probably meant the pilot did not have a comprehensive understanding of the weather conditions in the area.

The progress of the early part of the flight could not be explained but the flight path chosen by the pilot may have been influenced by his assessment of the prevailing conditions. He may have been attempting to return to the mine, perhaps having deemed the weather unsuitable, having realised that he had left his keys in the car at the mine, or that a light was on in the car. It is also possible that he was attempting to return for some reason not identified by the investigation.

Pathological evidence indicated that pilot incapacitation was not a likely cause.

The pilot's ability to maintain a safe flight path may have been affected by diminished situational awareness or a loss of control, and there was evidence of poor lighting and weather conditions that might have contributed to these difficulties, especially if the helicopter had inadvertently entered cloud. In addition, canopy misting, distracting illumination of cloud by the landing light or strobes, turbulence, and windshear are factors that may be associated with the prevailing conditions but for which there was no direct evidence.

The pilot's difficulties may have been compounded by the helicopter's handling characteristics at low speed, the degraded performance of the yaw damper and the possibility that the helicopter entered vortex ring.

There was no evidence that the pilot had received training in night flight. His decision to depart in the prevailing weather conditions, and from a site with no cultural lighting, suggested either a lack of awareness of the inherent risk or an acceptance of the risk.

Conclusion

During a flight at night in challenging circumstances, control of the helicopter was apparently lost, or the pilot became disorientated to the extent that safe flight was not maintained. The helicopter impacted terrain and the accident was not survivable. It was not possible to determine the mechanism by which control was lost or disorientation occurred, though several possible factors were identified. Although irregularities in the helicopter's maintenance and airworthiness were identified, there was no evidence of mechanical failure. The pilot was not qualified to fly at night.