ACCIDENT

Aircraft Type and Registration:	Agusta Westland AW139, G-LBAL
No & Type of Engines:	2 Pratt & Whitney Canada PT6C-67C turboshaft engines
Year of Manufacture:	2012 (Serial no: 31421)
Date & Time (UTC):	13 March 2014 at 1926 hrs
Location:	Near Gillingham Hall, Norfolk
Type of Flight:	Private
Persons on Board:	Crew - 2 Passengers - 2
Injuries:	Crew - 2 (Fatal) Passengers - 2 (Fatal)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Commercial Pilot's Licence (Helicopters)
Commander's Age:	36 years
Commander's Flying Experience:	Approximately 2,320 hours (of which approximately 580 were on type) Last 90 days - approximately 105 hours Last 28 days - approximately 30[1] hours
Information Source:	AAIB Field Investigation

Synopsis

The helicopter departed from a private site with little cultural lighting at night and in fog. Although the commander had briefed a vertical departure, the helicopter pitched progressively nose-down until impacting the ground. The four occupants were fatally injured. Safety action has been proposed by the CAA, and two Safety Recommendations are made.

History of the flight

Plans were made earlier in the day for a night departure from a private landing site in the grounds of Gillingham Hall to Coventry Airport, with the two pilots, the owner of the helicopter, and another passenger aboard. The planned departure time was originally 1830 hrs, but the passengers were not ready to leave until around 1920 hrs. By this time, dense fog had set in; witnesses at the departure site and in the local area described visibility of the order of tens of metres.

Shortly before the passengers arrived at the helicopter, the cockpit voice and flight data recorder (CVFDR) recorded a conversation between the two pilots[2]. One said:

Footnote

1 Detailed records were not available for part of the period.

2 Both had similar accents and in this instance their voices could not be distinguished during evaluation of the CVFDR recording.

"[unintelligible] I DON'T MIND TELLING YOU I'M NOT **** VERY HAPPY ABOUT LIFTING OUT OF HERE". The other replied: "IT SHOULD BE OK IT'S... I DON'T THINK IT IS BECAUSE YOU CAN STILL SEE THE MOON"[3].

The co-pilot, who was to be the pilot not flying, escorted the passengers to the helicopter and assisted them aboard while the commander, who was to be pilot flying, started the engines. The co-pilot remarked to the commander that he had informed the passengers of the urgent need to depart, and that if a further delay in their embarkation had ensued, departure would not be possible.

The engines were started at approximately at 1922 hrs.

Figure 1

The paddock and helipad (foreground) and accident site (in nearest ploughed field).
Yarmouth Road runs across the middle of the picture,
Raveningham Road joins it at the T-junction

The paddock (see Figure 1) was of irregular shape, with a helipad to one side. Although the centre of the paddock was unlit, floodlights had been installed at ground level to illuminate trees at its edges. Work had also been done to clear the area in the centre of the paddock of trees to allow for helicopter manoeuvring. It was usual for the helicopter to approach and depart to/from the middle of the paddock; the helicopter would be hover-taxied to and from the helipad. One of the usual departure routes was in the direction of the accident flight, taking advantage of lower trees on the perimeter of that side of the paddock.

The commander briefed the co-pilot: "RIGHT ALL I'M GOING TO DO, TAKE IT OVER TO THE CENTRE OF THE FIELD, AND THEN JUST PULL THE POWER, WE'LL GO VERTICALLY UP, I'LL GO FOR THE STROBE AND JUST MAKE SURE THE HEADING BUG IS CENTRAL FOR US IF YOU CAN". The recorded position of the heading bug was 298°. This briefing did not cover the manner in which transition to forward flight would be achieved and no heights or speeds were mentioned.

Footnote

3 The moon was waxing gibbous, at which 91% of its disc was lit, bearing 130°T from the helicopter's location, at an elevation of 37° above the horizon.

The helicopter lifted from the helipad into a hover at 1924 hrs, and hover-taxied to the middle of the paddock where it came to the hover again; the pitch attitude in the hover was slightly nose-up. The helicopter then began to climb, almost vertically at first. At a height of approximately 32 ft agl, its pitch attitude changed from the slightly nose-up hover attitude, pitching nose-down, before the helicopter began picking up forward speed, continuing to climb.

At about 120 ft above the ground and with a nose-down pitch attitude of approximately 15°, the co-pilot said "NOSE DOWN [COMMANDER'S FIRST NAME]". It could not be determined from the recorded voice whether this was to highlight the nose-down pitch attitude or a prompt for more nose-down pitch, but more forward cyclic input was applied. In the following second the helicopter crossed the boundary trees and started to descend with increasing ground speed, forward cyclic input and nose-down pitch attitude. Progressively more collective was also being applied, with the resultant increase in engine torques.

The co-pilot repeated the "NOSE DOWN" words; again it could not be determined whether it was an observation or a request and again a nose-down input was made. The cyclic inputs, whilst still in the forward sense became more erratic, with one aft input recorded in the final seconds. The nose-down pitch attitude started to reduce from the peak recorded value of 35° as the helicopter descended through 100 ft agl. The collective input progressed to 100%, the engine torques increased but the rotor speed could not be sustained at the nominal 102% and started to reduce. The last nose-down pitch attitude recorded by the combined voice and flight data recorder (CVFDR) was 25° with the helicopter 82 ft above the ground, descending at 2,400 ft/min, with a ground speed of 90 kt.

The helicopter impacted a line of large hay bales lying across a field. The cabin structure was destroyed and all the occupants were fatally injured in the impact sequence.

The EGPWS recorded a descent rate of 1,458 ft/min, and a mode 3 alert trigger, associated with sinking after lift-off. The final data point recorded included a radio altitude of 65 ft.

The last CVFDR recorded torques were 142% and 158% for the left and right engines respectively, the two values being separated by one second. The engine computers recorded that the rotor speed had dropped to just below 95% before contact with the ground.

Analysis of the CVFDR audio recording, which carried on after the data was lost, indicates that rotor speed had dropped to approximately 93% at the point of impact. The helicopter's heading remained in the range 297-305° from prior to commencement of the vertical climb until impact. No flight director modes were selected during the flight.

Previous flights

The helicopter and crew departed a private landing site in Northern Ireland at 1210 hrs, and landed at another private landing site and then at Peterborough Conington, where the helicopter was refuelled with 1,201 litres of Avtur. The helicopter departed Conington at 1535 hrs and arrived at Gillingham Hall at about 1720 hrs. The two pilots discussed the weather during their flight from Conington to Gillingham Hall.

Co-pilot:	"IS HE AWARE OF THE WEATHER SITUATION IS HE"
Commander:	"TOLD [NAME OF OWNER'S PERSONAL ASSISTANT]"
Co-pilot:	"YEAH I KNOW THAT (BRIEF PAUSE) WHAT I'M SAYING IS ARE YOU GOING TO TELL HIM"
Commander:	"NO... (PAUSE) **** IT IT'S DOWN TO THEM (PAUSE) IF HE ASKS I'LL TELL HIM (PAUSE) I SAID I'LL CHECK THE WEATHER WHEN I GET TO NORWICH AND GIVE THEM AN UPDATE (PAUSE) THAT'S WHAT I'LL DO"
Co-pilot:	"IF I HAD MY CASE WITH ME I WOULDNT MIND YOU BEING SO BOLD (PAUSE) BUT (PAUSE) THE ONLY PEOPLE WHO'LL LOSE OUT IS PROBABLY ME AND YOU".

(It is probable that the co-pilot was referring to a case which he would carry with him if expecting to spend a night away from base.)

Witness information

Witness statements showed that there was some vehicular traffic on the roads around the paddock, showing headlights, as the helicopter transitioned away from the paddock. In particular, one car was travelling along Raveningham Road towards the paddock. It then turned right onto Yarmouth Road, and the driver saw the helicopter fly over the car.

Eyewitnesses at Gillingham Hall observed the helicopter's departure and one recorded video of it on a smartphone. The smartphone recording captured a discussion between two witnesses, during which one referred to the depth of the fog, noting that no stars were visible through it. Their view was towards the north-west. Throughout the recording, the helicopter's anti-collision beacon, navigation lights and landing light are visible.

Recorded data

The helicopter was fitted with a combined CVFDR. This recorded more than 25 hours of data and approximately 2 hours of audio from both crew channels and the cockpit area microphone (CAM). The CAM recording was of good quality with the engines running. However, not all quiet speech with low ambient noise prior to engine start was recorded intelligibly. A review of the cause of this is ongoing.

The CVFDR was fitted with Recorder Independent Power Supply (RIPS) designed to keep the audio recording of the cockpit area microphone working for 10 minutes after the loss of the main source of electrical power to the CVFDR. This resulted in recorded audio at the end of the accident sequence, after the initial impact, none of which was identifiable as other than mechanical in origin.

Data was recovered from the EGPWS, the engine Data Collection Units (DCUs) and the Central Maintenance Computer (CMC) card from Modular Avionics Unit (MAU) 1. The EGPWS recorded the parameters every second for the 20 seconds prior to the accident and the DCUs recorded sporadic event-driven snapshots just prior to the impact and during the subsequent seconds and is reported on in more detail in the engineering section of this report.

Flight profile

The recorded time stamps appeared reasonable and were used for the purposes of the following narrative. The audio recording of the accident flight started at 1920 hrs. Figure 2 shows the relevant recorded data and some extracts from the CVFDR. Figure 3 shows the flight profile relative to the departure point and accident site.

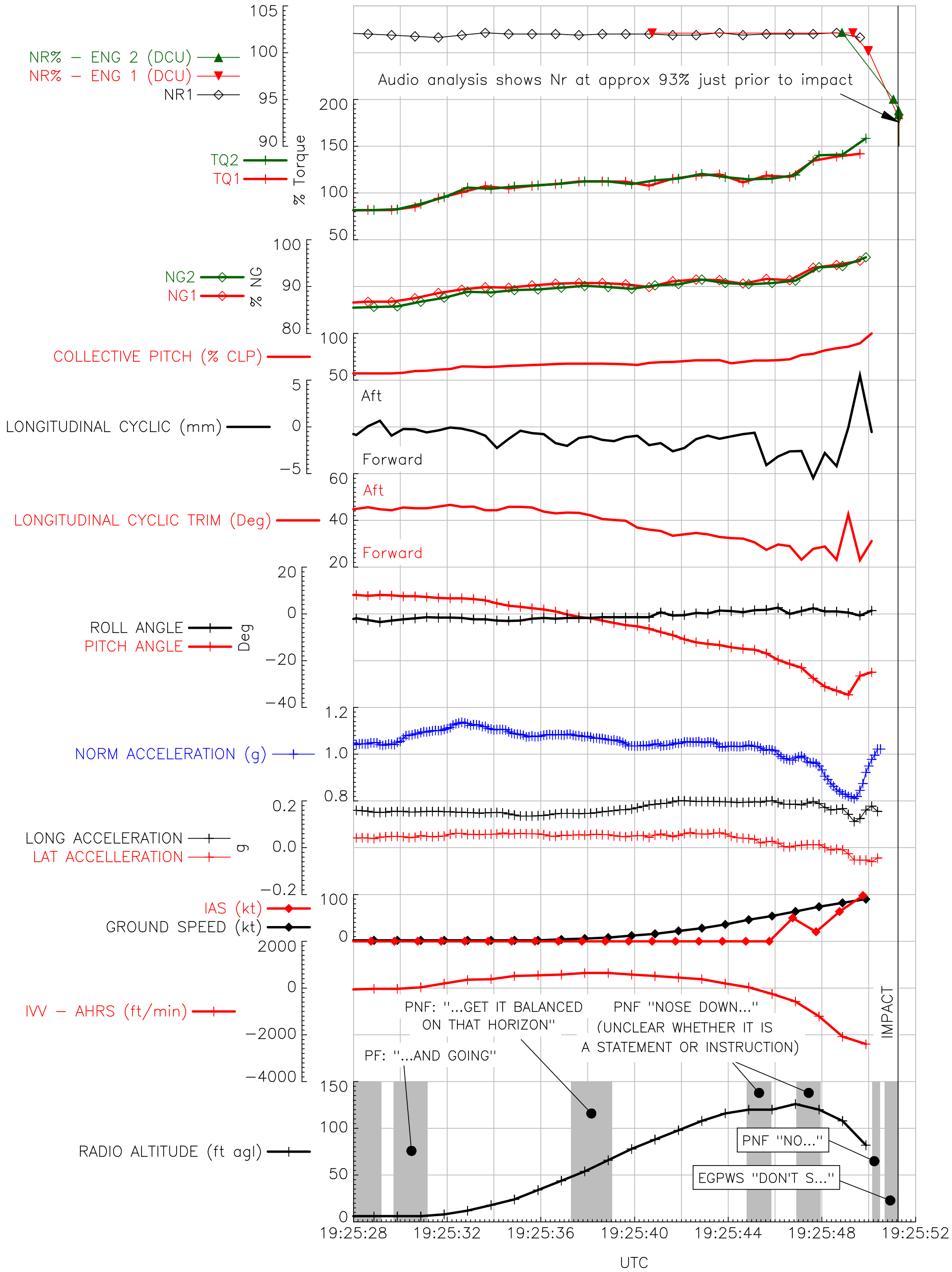

Figure 2

Pertinent engine DCU data parameters and CVFDR recorded data and transcript extracts. The commander was the Pilot Flying (PF) the co-pilot was the Pilot Not Flying (PNF)

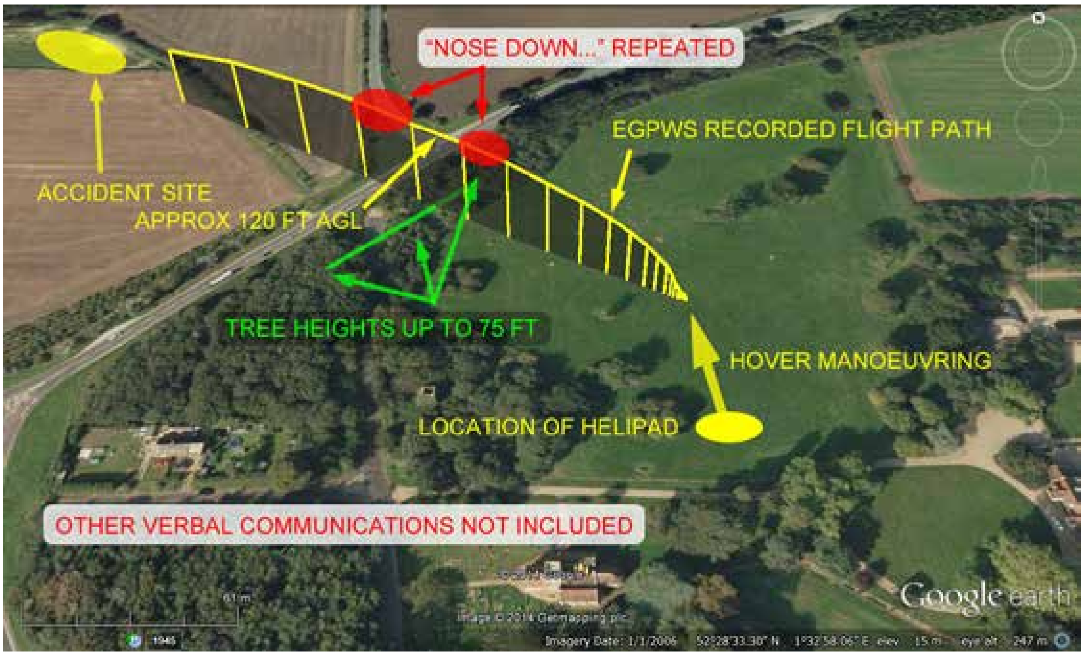

Figure 3
Flight path

The recorded data included parameters relating to cautions, warnings and system status. A gearbox torque caution was recorded by the CVFDR in the last moments of the accident flight. No other CVFDR warnings or cautions were recorded in the air. System status records were all attributed to normal operations for the given aircraft configuration.

The Autopilot Attitude Mode and Yaw Heading Hold were ACTIVE throughout the recorded flight. The data showed that trim release switches on the cyclic and collective controls, on which force must be applied against springs to achieve manual flight, were active throughout the flight.

The cyclic parameters were recorded twice a second. The sawtooth pattern of the parameter at the end of the flight indicates that a higher sampling rate would have been needed to capture accurately the dynamic behaviour of these parameters.

Previous flights

The CVFDR contained a recording of the previous flight and part of the one before that, in which the accident commander was also pilot flying and the co-pilot, pilot not flying. Briefings were absent or very short, and the habitual use of checklists and 'standard call-outs' were not in evidence.

Flight dynamics

The helicopter manufacturer declared that, based on their analysis of the recorded data, the helicopter responded appropriately to the crew inputs.

Excessive pitch

A comparison of the pitch attitude recorded during the accident flight with the previous flights recorded by the CVFDR is given in Figure 4. The maximum nose-down pitch attitude is not plotted as this graph uses a lower sample rate than the FDR data plot in Figure 2.

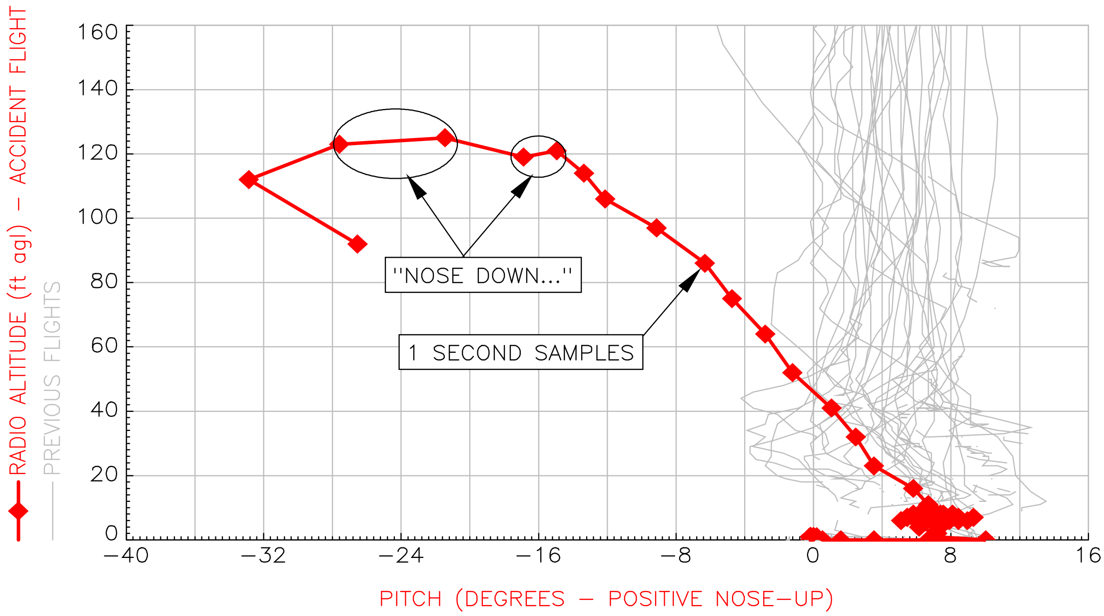

Figure 4

Radio altitude compared to pitch for the accident flight, compared with the previously recorded climb profiles

This shows that from approximately 50 ft agl in the climb the pitch attitude was becoming abnormally nose-down.

Somatogravic illusion

In the absence of visual cues, the "down" direction is sensed from accelerations experienced. This sensation can be compromised when gravity is no longer the only force being sensed, for example when an individual is within an accelerating body such as an aircraft. This somatogravic illusion is illustrated in Figure 5.

During the accident flight the helicopter had little movement in roll and so the recorded normal (vertical relative to the helicopter body) and longitudinal accelerations can be used to derive a model of "force vector pitch", ie, the pitch attitude perceived by an individual in the absence of visual cues.

The tri-axial accelerometers, located near the centre of gravity of the helicopter, are the primary source of acceleration data recorded by the CVFDR. However, smoothing of the data before recording causes the data to reflect the underlying acceleration trend and not the dynamic accelerations.

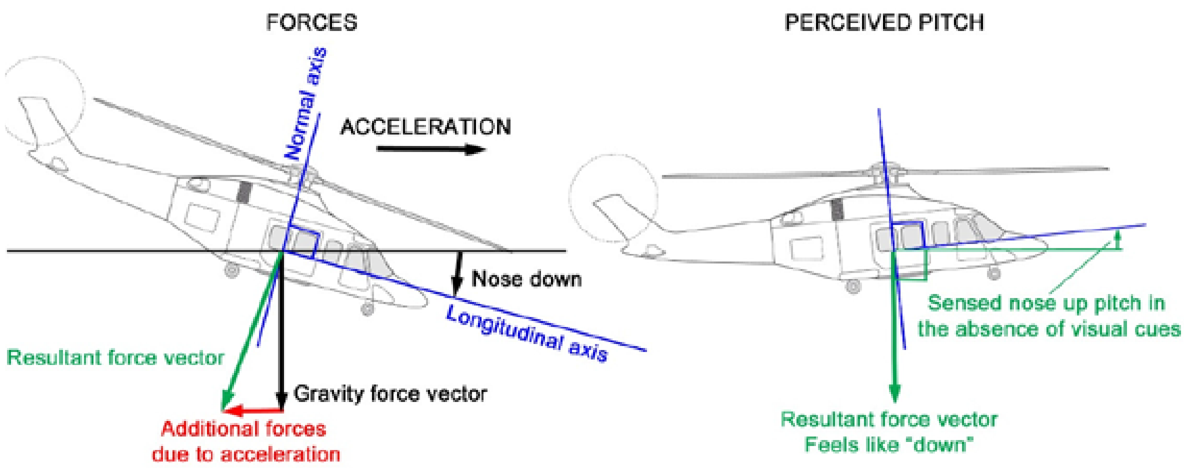

Figure 5

Effect of acceleration on perceived pitch in the absence of visual cues

The Attitude Heading Reference System (AHRS) also provides accelerometer parameters which are recorded in the CVFDR. These are not filtered to the same extent as the tri-axial accelerometers. These sensors are fitted in the nose of the helicopter, away from the centre of gravity, and therefore are affected by rotational motion. The attitude changes of the helicopter are not recorded at the same rate as the accelerations and so accurate correction for rotational motion during dynamic events, using the recorded data, is not practical. Neither data set is ideal but, given some of the dynamic pitch motion, the smoothed tri-axial data is the only set that can be used reasonably in this instance.

Figure 6 plots the radio altitude against the force vector pitch derived from the tri-axial accelerometer data and compares the plot with those of previous flights.

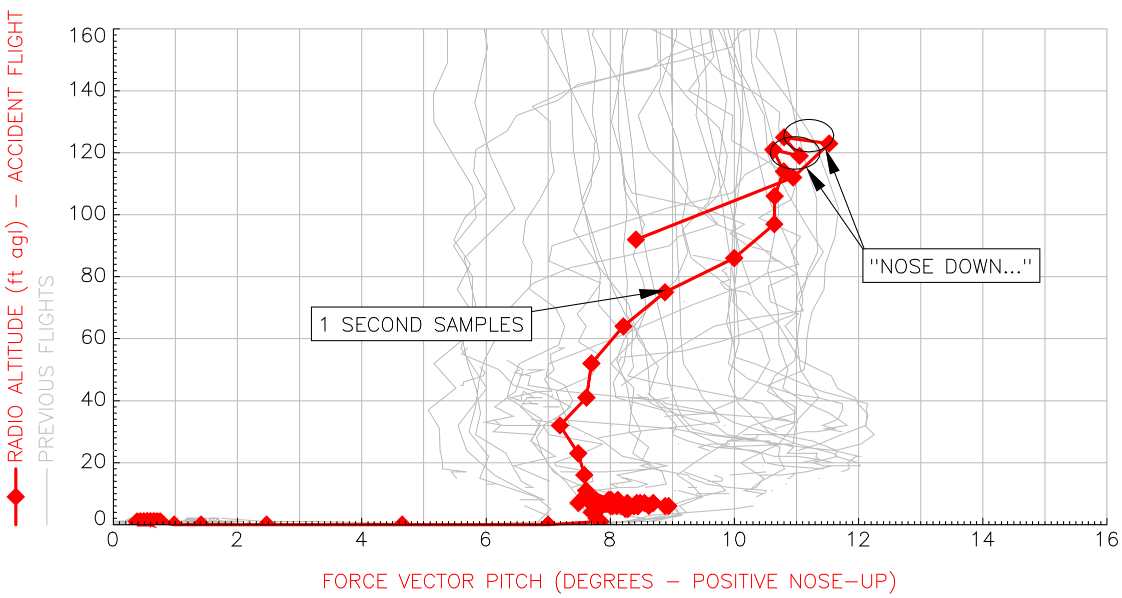

Figure 6

Radio altitude plotted against force vector pitch for the accident flight compared to previously recorded climb profiles

During the accident flight, the calculated force vector pitch remained comparable with previous flights for the first part of the flight. The first crew communication referencing the pitch of the helicopter was at a point in the flight where the calculated force vector pitch was more nose-up than the majority of previous flights for the given height.

Indicated Airspeed

Airspeed information is presented to the pilots by speed tapes on the left side of the primary flight displays. These are immediately adjacent to the electronic attitude display indicators which incorporate artificial horizon displays. The IAS parameter did not register until late in the flight. On the previous flights IAS began to register with lower ground speeds than on the accident flight. However, the data also showed that very early in the accident flight, the helicopter had more nose-down pitch for the given groundspeed than the previously recorded flights and this would have affected the sensing of IAS.

Central Maintenance Computer (CMC)

The CMC is a Modular Avionics Unit (MAU) card housed in the nose of the helicopter. It stores fault codes relating to the helicopter avionic systems in non-volatile memory (NVM). The MAU suffered impact damage but a full data download was achieved. The data was supplied to the MAU manufacturer for decoding.

The faults recorded on the CMC did not reflect any system issues relevant to the accident.

Engineering

Initial examination

The helicopter struck the ground in a gently rising field immediately ahead of a row of rolled hay bales (see Figure 7). These formed a boundary between the body of the field and a recently ploughed section, approximately 420 metres from the takeoff point. Inspection of the terrain under the flight path of the helicopter did not find any evidence that the helicopter had struck any of the trees or any other object during the flight.

The first ground marks, made by the lower nose of the helicopter and the nosewheels, indicated that the landing gear was DOWN and that the helicopter had struck the ground with approximately 25º of nose-down pitch on an approximate heading of 304º. Items recovered from the initial impact point included elements of the lower nose structure, forward fuselage and both cockpit entry steps. The helicopter then passed through the hay bales into the ploughed field. Four of the five main rotor blade tips were embedded in the ground to the right of the helicopter's flight path approximately nine metres beyond the initial impact point. Measurements indicated that the rotor blades had struck the ground between 50 and 60º 'nose-down'.

A second impact mark, which contained elements of the forward fuselage and passenger cabin structure, was identified 45 m beyond the first ground mark. Several items from the nose avionics bay, including both batteries, had been released between the first and second impact marks. The fuselage came to rest 18 metres beyond the second impact point facing

180º to its direction of travel. The ground markings and distribution of wreckage between the second impact point and the fuselage's resting place indicated that the helicopter had become airborne again after the second ground impact. During the impact sequence three of the five main rotor blades had detached from the rotor head.

Figure 7
General view of the accident site

The helicopter suffered significant disruption to the fuselage which had resulted in the failure of all the major structural elements of the cockpit and passenger cabin. The right fuel tank was intact, but the left tank and several fuel lines were found to be damaged. Approximately 400 litres of fuel were recovered from the fuel tanks and, based on tests carried out at the accident site, it is estimated that up to 1,000 litres of fuel may have leaked from the damaged fuel system.

Initial examination confirmed that both engines had been operating during the impact sequence and that the rotor head could be turned. The rotor head had suffered significant damage, consistent with the rotors turning under high power at impact. The damage observed to all of the main rotor blades was also indicative of rotation under power at impact.

Impact damage resulted in the failure of the tail fin and the tail rotor drive shaft at the base of the fin. Witness marks indicated that the tail rotor drive shaft had been rotating during the impact sequence. The tail rotor drive shaft was also found to rotate freely when the main rotor head was turned.

The CVFDR was removed from the fuselage and transported to AAIB headquarters for analysis prior to the recovery of the wreckage of the helicopter.

Aircraft information

The helicopter was a long-nosed variant of the Agusta Westland AW139 fitted with two Pratt and Whitney Canada PT6C-67C engines each rated at 1,100 hp and a maximum torque limit of 160%. Electrical power was provided by two engine driven generators and two batteries mounted in the nose of the helicopter.

Each engine was controlled by an Electronic Engine Control (EEC). Each engine was also fitted with a Data Collection Unit (DCU), designed to record a snapshot of engine parameters when the EEC detects an exceedence of engine parameters. When a recording snapshot is triggered, the relevant DCU records data relating to the engine, comparative data from the other engine and the position of the collective pitch control. Each snapshot is time-stamped against EEC running time and stored in one of three buffers; the Fault Buffer, the Event Buffer and the One Engine Inoperative (OEI) Buffer, depending on the triggering event. The EEC's and DCU's are powered by an engine-mounted generator and will record data while the gas generator module of the engine is operating at, or above, 40% rpm.

The helicopter was equipped with the Honeywell Primus EPIC integrated avionic system. The EPIC system comprises two MAUs, installed in the nose of the helicopter, consisting of a cabinet that contains a number of Line Replaceable Modules (LRMs). The MAU's function is to integrate the systems and sub-systems that supply the helicopter with navigation, communication, automatic flight, indicating, recording and maintenance capabilities. Operation is via cockpit controls, sensors, displays and integrated computers.

Engine parameters are acquired by the MAUs from the EECs. Each EEC collects data from sensors installed on its respective engine and digitises it. This data is then transmitted to both MAUs. Therefore, in the event of a MAU failure (caused, for example, by a power supply problem or a self-diagnosed shutdown), the data from both engines remains available. Data received from the EECs is referred to as 'digital' engine data. For redundancy purposes, some sensors are wired directly from the engine sensors to each MAU, bypassing the EECs. These parameters are referred to as 'analogue' engine parameters as they are acquired by the MAUs directly from the sensor. No 1 engine analogue parameters are only connected to MAU 1 and No 2 engine to MAU 2.

FLIR

The helicopter was fitted with a Forward-Looking Infra-Red (FLIR) system; live imagery from an IR camera mounted beneath the helicopter's nose could be selected on one of the displays in the cockpit. The status of the system was not recorded and the CVFDR contained no reference to the system by the pilots. It was not possible to determine whether it was active during the accident flight.

Maintenance information

Examination of the helicopter's maintenance records confirmed that it had been maintained in accordance with current airworthiness requirements. The final entry in the airframe log book, 4 March 2014, stated that it had accumulated 488.07 flying hours since manufacture. The last routine maintenance inspection was completed on 3 March 2014 at which time a main rotor blade damper was replaced. On 11 February 2014 a tail rotor damper was replaced during scheduled maintenance and the last annual inspection was completed on 13 October 2013 at 375.20 flying hours. No defects were identified in the helicopter's records which could have affected the outcome of the accident.

Detailed examination

Inspection of the rotor drive train confirmed that there was no evidence of a failure with either engine or any of the elements of the main and tail rotor drive trains. Reconstruction of the flying control circuits and examination of the main and tail rotor hydraulic actuators confirmed that all the damage was consistent with the impact forces and that there was no evidence of a pre impact defect or restriction within any of the flying controls.

Both engine DCU's were downloaded by representatives of the engine manufacturer at the AAIB. Initial analysis of the data showed that both DCU's had recorded a number of exceedence snapshots initially triggered by both engines exceeding the peak torque limit of 160%. A detailed analysis of the data was carried out by the engine manufacturer which confirmed that the left engine EEC had not recorded any defects in the 140 hours prior to the accident and the right engine EEC had no stored faults for 83 hours prior to the accident. Data recovered from both DCU OEI buffers showed that a snapshot was recorded 14.4 seconds prior to impact. This was triggered by both engines reaching the lower boundary of continuous OEI operation (111% torque). At 3.6 seconds before impact both engines were recorded reaching the lower boundary for 2.5 minute OEI operation (141% torque). Prior to impact both engines appear to have been performing normally with no EEC faults recorded. The analysis identified that at the point of impact both engines were delivering power, with torques above 160% and the collective pitch lever was above 98% of its travel. After impact a number of faults were recorded which were similar on both engines and were the result of the impact with the ground.

Meteorology

The investigation did not identify meterological reports or forecasts which the pilots had consulted before the flight, but it is possible that they used smart-phones or tablet devices (both were found on the accident site) to obtain this information, without carrying printed copies with them.

The Met Office chart of forecast weather below 10,000 ft valid at 1800 hrs for an area which included all of England, south of the Humber Estuary, was presented as follows:

AREA	SURFACE VIS AND WX	CLOUD	0 C
D	ISOL 12 KM NIL WDSPR 7 KM HZ OCNL (ISOL LAN TL 21 Z) 3000 M BR ISOL (OCNL W) 600 M FG SEA COT ISOL 200 M FG LAN FM20 Z OCNL HILL FG	OCNL BKN ST 000-005 / 015 SEA COT ISOL (OCNL FM21 Z) BKN/OVC ST ... ...004-008 / 010 LAN (BASE 000 FG)	070-XXX

The Met Office explained that the term 'COT' is defined by the World Meteorological Organisation to mean 'at the coast', and has no more detailed definition.

The nearest locations for which aviation forecasts were available were North Denes Heliport, 11 nm NNE of Gillingham Hall, and Norwich Airport, 15 nm to the NW.

The North Denes forecast at 1702 hrs predicted light winds and a visibility of 200 metres in fog and broken cloud at 100 ft temporarily improving, between 1800 hrs and 2100 hrs, to 1500 metres in mist with scattered cloud at 100 ft.

The forecast for Norwich at 1702 hrs predicted light winds and a visibility of 6,000 metres with no significant cloud with the visibility reducing to 4,000 metres in mist between 1800 hrs and 2100 hrs and a 30% probability of a visibility of 200 metres in fog with broken cloud at 100 ft between 1800 hrs and 2100 hrs.

The actual observations at Norwich at 1920 hrs (six minutes before the accident) described 3 kt of wind from 070º, a visibility of 3,000 metres in haze, no significant cloud, temperature +5C, dewpoint +4C, a QNH of 1030 HPa with a temporary reduction in visibility to 200 metres in fog.

Additionally, the Met Office provided an aftercast of the conditions around Gillingham:

> *'…an area of high pressure was centred over the UK with very light winds affecting the area. It was a rather hazy afternoon with visibilities generally between 5000 M and 8 KM. Conditions deteriorated further through the late afternoon with much of Norfolk affected by mist, and in coastal areas, such as North Denes, dense fog developed between 1620 and 1650 UTC. On light east to northeasterly winds this dense fog gradually crept further inland reaching Norwich Airfield by 2020 UTC. This would suggest that visibility in the Gillingham area would have deteriorated in to fog prior to this time.'*

Eyewitness reports and CCTV recordings reinforced the findings in the aftercast that the area around the accident site was affected by dense fog which formed in the early evening.

The operator

The helicopter was owned and operated under the auspices of a limited company, incorporated in 1993, and ultimately owned by the principal passenger. For some years, the company had held an Air Operator's Certificate issued by the UK CAA. During the AOC-holding period, the company demonstrated that it met various regulatory requirements in excess of the requirements applicable to private flying. The owner was the accountable manager of the AOC operation. Under JAR-OPS 3, accountable managers were required to satisfy the CAA of their suitability to hold the post, and the owner had done so.

Since the cancellation of the AOC in 2008, operation of the company's helicopter was the responsibility of the senior pilot employed by the company; at the time of the accident this was the commander. A similar arrangement had existed prior to the AOC being granted. In the absence of an AOC, there was no regulatory requirement for an operations manual or safety management system for private flying. Some evidence suggested that an operations manual, including type-specific matters, procedures to be employed by pilots flying together, such as briefings and standard calls, and a safety management system had existed, at least in draft form, in recent years, but none was in use at the time of the accident.

The helipad at Gillingham Hall was one of the helicopter's regular destinations, and both pilots had flown to and from of it previously, by day and night.

Previous accident

In the 1990s, the operator used an S-76 helicopter in the same role as that in which the accident helicopter was engaged. The Irish Air Accident Investigation Unit (AAIU) investigated a fatal accident involving the loss of that helicopter in 1996, and published an 85-page report[4].

The report explained that the helicopter flew into terrain during an arrival to the helicopter's base in Northern Ireland. The helicopter's three occupants were fatally injured.

The report found that the primary cause was *'loss of situational awareness'* on the part of the pilot flying, and that secondary causes included:

'
- *The Commander of the Aircraft, the PNF, failed to make adequate preparation and take precautions to ensure the safety of the flight*
- *The crew embarked on the flight without proper planning or briefing*
- *The use of a locally produced GPS-based approach procedure which gave little margin for error, and which was inadequate to alert the crew to terrain dangers.*
- *The operation of this aircraft, in a corporate aviation role, in the private aviation category, in a demanding environment, without the benefit of external monitoring of the operation.'*

The report noted that:

> *'The flight used a navigation approach procedure that would not meet the standards required by the UK Authorities for public transport operations. However, this was not illegal because the flight was operated under private category rules'.*

An annex to the report contained a facsimile of the approach procedure found in the wreckage. A chart recovered from GLBAL depicted a similar approach to the same geographical area

Footnote

4 Aircraft Accident Report 01/98: Report on the accident to Sikorsky S-76B G-HAUG at Omeath, Co. Louth 12 December 1996.

The AAIU report also noted:

'Operation of the Aircraft

The operation was initiated by the owner, but it was organised by the Chief Pilot, who advised the owner on matters relating to the operation, and effectively managed it on a daily basis. Apart from the two professional pilots, no other aviation professionals were employed by the owner in the conduct of the operation.

The aircraft was operated in the private category. As the aircraft was not used for any consideration, or hire and reward, it was consistent with UK Regulations to operate such an aircraft in the private category.'

And:

'Operations Under Private Category Rules

In the UK, corporate aviation is regulated under the rules pertaining to private aviation. Therefore the rules that applied to the operation of G-HAUG were those that apply to normal private category aviation. These rules govern, in the main, the operation of private pilots, largely in simple single-engined aircraft, with fairly basic instrumentation. Typical general aviation activity of this kind is owner flown and operated, and the owner is usually intimately involved with the operation and flying of the aircraft.

The operation of G-HAUG was markedly different from these general aviation norms. The owner was not a pilot, and his prime requirement was that the operation should provide effective transportation in most weather conditions prevailing in the area. To achieve this he purchased a state-of-the-art aircraft and hired professional pilots to manage the operation. The evolving procedures generated by the pilots indicated a strong commitment to meeting the owner's requirements.

This eventually led to use of an approach procedure… that relied heavily, and almost exclusively on GPS and fully exploited the potential of the aircraft's systems, with very little margin for error. It is not known what weather minima were in use at the time, but the lack of concern on the part of the PNF and the chief pilot when still in cloud, in the final stages of the flight, while below the height of mountains on both sides of a relatively narrow lough, indicates that the situation was not unusual and that the aircraft was still above the minima being used in the operation when it collided with the mountain.

As a consequence of the fact that the operation was conducted under general aviation rules, there was very little external examination of the operation. In particular, this led to the use of approach procedures which would not satisfy the standards set by the CAA. Because the aircraft was operated in the private category, it was not illegal to use such approach procedures.

> *It appears anomalous that the rules pertaining to general private aviation should also apply to the all-weather operation, by day and by night, of a very sophisticated twin-engine helicopter equipped with a very capable avionics fit, which was engaged in the professional transportation of passengers, albeit of a limited number of persons.*
>
> *It may be noted that some countries do legislate for corporate aviation, to a standard between the private category and full public transport category. There are some difficulties in determining the transition point between corporate and private aviation, but a definition of corporate aviation could use criteria such as the employment of professional pilots and the seating capacity of the aircraft.'*

The Irish AAIU made nine Safety Recommendations including:

> '• *The UK CAA should consider the establishment of a special category for the operation of corporate aviation. (SR 7 of 1998)'*

This recommendation was accepted by the UK CAA, which supported work by the Joint Aviation Authorities (JAA) towards proposed regulation of corporate operations. That regulation did not materialise during the life of the JAA.

> '• *The JAA Joint Working Group for JAR OPS 2, which reviews operation standards for aircraft operation in the JAA States, including the UK and Ireland, should consider the establishment of a special category for the operation of corporate aviation, to encompass the operation of aircraft such as G-HAUG. (SR 8 of 1998)'*

There was no response to this recommendation from the JAA. The UK CAA provided comment to the AAIU.

> '• *The Irish Aviation Authority (IAA) and the UK CAA should bring to the attention of operators of corporate aircraft the safety benefits that would result from external vetting of their operations, pending the establishment of a suitable regulatory framework for corporate aviation activities. (SR 10 of 1998)'*

The UK CAA accepted this recommendation.

Personnel information

The commander held a CPL(H), with IR, issued by the UK CAA. It contained ratings on the A109 series, AB139 (sic), AS355, Bell 206 series, Hughes 269, R22, R44, and SK76 helicopters. His last proficiency check on the AW139 was conducted in G-LBAL on 7 May 2013. His flying experience is given in the header of this bulletin. His Class One medical certificate was valid. In the 14 days prior to the day of the accident, he had flown on a total of five days accumulating a total of 14 hrs 12 mins flying time.

The co-pilot held a CPL(H), with IR, issued by the UK CAA. It contained ratings on the A139 (sic), AS355, R22, and R44 helicopters. His previous licence contained a rating on the A109 series of helicopters. His last AW139 proficiency check was carried out in a simulator at the manufacturer's facility in Italy on 22 February 2014. The last completed page of his log book, dated 7 March 2014 showed a total flying time of 1,187 hours of which approximately 367 was on the AW139. His Class One medical certificate was valid. In the 14 days prior to the day of the accident, he had flown on two days accumulating a total of 8 hrs 36 mins flying time.

Both pilots had completed training for their initial instrument ratings at the same flying school. The chief flying instructor there gave an account of the training they had received for a type rating on a multi-engine helicopter, followed by the instrument rating. The CAA confirmed that the training provided was in keeping with the relevant requirements and reflected normal practice in the training community. The type rating was conducted entirely under visual flight rules. Screens were positioned inside the cockpit transparencies for the instrument rating to deprive the pilot under training or test of a view of the external environment. The instructor or examiner carried out the takeoffs and landings, with the student only having control of the helicopter at a safe height and at or above Vmini (the minimum airspeed for flight under IFR).

No evidence was found to show that either pilot had received training in vertical departures in low visibility.

Both pilots maintained single-pilot qualifications to operate the helicopter; they were not trained or tested as a crew of two. The helicopter was operated privately, therefore no flight crew duty limitations applied.

Pathology

A specialist aviation pathologist carried out post-mortem examinations of both pilots. These found no pre-existing conditions which could have accounted for the accident, and toxicological tests returned negative results.

Vertical departures with limited visual references

Discussions with British military helicopter pilots revealed that procedures exist in military aviation for vertical departures, flown with very limited external visual references, and military pilots are trained and tested in these techniques. In these circumstances, flight by sole reference to the instruments is permitted at speeds below Vmini. There was no evidence that either of the pilots of GLBAL had received training in these procedures.

Vmini

The AW139 flight manual limitations section stated:

> *'Minimum airspeed for flight under IFR (Vmini) .... 50 KIAS'*

The CAA advised that Vmini was defined in FAA and EASA documents. The FAA stated that Vmini (Minimum IFR Speed) is *'The minimum speed for which compliance with the IFR handling qualities requirements has been demonstrated'* and that it *'should be established as a limit for IFR operations'*.

EASA Certification Standard (CS) 29 Book 1 Appendix B stated:

> *'Vmini means the instrument flight minimum speed, utilised in complying with the minimum limit speed requirements for instrument flight.'*

Discussions identified that Vmini should be interpreted as the minimum speed for flight by sole reference to the flight instruments, rather than under IFR, as this provision might otherwise appear to prohibit normal departure and arrival under IFR even in VMC. Practically-speaking, Vmini is the speed below which the helicopter should be flown with reference to external visual cues. During departure, the helicopter should be flown visually until Vmini is attained, after which flight by sole reference to the instruments may continue at or above that speed until the speed reduces below Vmini, when visual flight must be resumed.

Regulations

The CAA was asked to confirm the minimum visibility requirements relevant to private helicopter operations under IFR at private landing sites. It was established that no minimum visibility is set down for private helicopter operations at landing sites which do not have published IFR procedures. For commercial air transport operations the minimum visibility is 800 m; no cloud base is specified.

For private departures under IFR from aerodromes, the minimum RVR or visibility is 800 m.

CAA paper 2007/03 *'Helicopter Flight in Degraded Visual Conditions'*

In September 2007, the CAA published its paper 2007/03 'Helicopter Flight in Degraded Visual Conditions'(DVE). The *'Overall findings'* of the report included:

> *'d) During the period 2000-2004 there were 4 fatal accidents involving private flights, representing 50% of the relevant private cases identified and resulting in 8 fatalities. They all involved spatial disorientation as a probable causal factor...*
>
> *e) Serious consideration must be given to the measures that need to be taken to reverse this trend, taking into account improvements to regulations, operating procedures and requirements or pilot training requirements.'*

The report noted that:

> *'When addressing requirements for visibility minima, factors such as the height that the aircraft should be permitted to fly at versus the available view over the nose of the aircraft should be taken into consideration. For a given cockpit view, the pilot's forward view diminishes with increasing aircraft height…'*

Under *'Pilot training issues'* the report noted:

> *'Pilots should be better trained to make informed decisions on whether 'to fly or not' in marginal conditions, or when IMC conditions are developing enroute. This might be achieved by developing a probability index based on factors that contribute to a high risk accident scenario (e.g. meteorological conditions, visual conditions, visual range, acuity of the visual horizon, aircraft configuration, aircraft handling qualities).'*

The report's concluding remarks included:

> *'Helicopters are difficult to fly at the best of times, i.e. in good visual conditions with plenty of outside world references and with stability augmentation… As visual conditions degrade, control becomes complicated (workload increases) by the interaction between stabilisation and guidance functions, and it becomes more difficult for the pilot to utilise tau cues coherently.*
>
> *The results [of the simulator investigations carried out] have highlighted just how precarious the balance between performance and safety is, and how small the safety margin can get, as visual conditions degrade. The accidents reviewed [7] also reflect this precariousness and the vulnerability of the 'average' pilot to the consequences of loss of spatial awareness. Hence, it is of concern that analysis of the data shows that the number of accidents resulting from spatial disorientation in a DVE is increasing… As noted previously, it is clear that timely consideration must be given to the measures that need to be taken to reverse this trend, including the recommendations given in the following section.'*

The report made eight recommendations, including:

> - *'Specification and adoption of FODCOM[5] training requirements for all civil helicopter operations that fall into the DVE[6] category.*
> - *Appropriate steps should be taken to raise pilot awareness of the problems associated with operations in the DVE, i.e. the interaction between vehicle handling qualities and visual cueing conditions.*
> - *Address the probability of pilots encountering DVE conditions by providing guidance on whether 'to fly or not' in marginal conditions with the potential for DVE encounters. This could be achieved using a simple probability index based on consideration of those factors that contribute to a high risk accident scenario, including:*

5 Flight operations department communication.
6 Degraded visual environment.

> i) *meteorological conditions (precipitation, cloud base etc.),*
>
> ii) *visual conditions (time of day, fog/mist/haze conditions, visual range, acuity of the visual horizon etc.),*
>
> iii) *aircraft configuration (navigation aids, flight instruments, cockpit view and layout etc.),*
>
> iv) *aircraft handling qualities (SAS, FCMCs).'*

The CAA published an Aeronautical Information Circular based on this paper in 2007 (P100/2007) which was updated in 2013 as P067/2013.

CAP686 Corporate Code of Practice (Helicopters)

In 1998 the CAA published a code of practice for helicopter operators. This was republished in 2009. The preface to the 2009 edition stated, among other things:

> *'The aim of the Code of Practice is to give guidance on owning and operating a helicopter for corporate purposes to those companies whose principle place of business is in the United Kingdom and the Channel Islands.*
>
> *The Code of Practice is mainly intended to apply to the operation of multi-engine IFR equipped helicopters operating with less than nineteen passengers and normally flown by a single pilot: it has also been structured to be easily adjusted to cover any corporate or aerial work flight.'*

The code offered guidance on compilation of an operations manual, safety management systems and risk assessments, and training. Application of the code was optional for operators.

CAA action

On 23 May 2014, the CAA published a safety notice entitled *'Private and Aerial Work Helicopter Operations – Guidance On Aerodrome Operating Minima For IFR Departures'* which stated:

> *'Any helicopter pilot landing or departing at an aerodrome needs to ensure that the site is suitable and that the prevailing weather conditions at the site are adequate to carry out all normal and emergency procedures. Whether a field site or a licensed facility, the aerodrome of departure will need to provide an environment where the flight can be commenced and safely continued into the en-route phase. In relation to this, the commander of the aircraft has certain legal and airmanship obligations to fulfil in relation to ensuring that the flight can be safely made whether day or night, under the Visual Flight Rules (VFR) or the Instrument Flight Rules (IFR).*
>
> *In contrast to helicopter Public Transport operations, private and aerial work flights are allowed more operational flexibility including a greater possible choice*

> *of take-off and landing sites. With that flexibility, however, comes the potential for increased risk and a need to exercise high standards of airmanship, decision-making and hazard assessment. This is of particular importance when planning to depart IFR, in Instrument Meteorological Conditions (IMC) or at night, from a site where instrument procedures and aids are not available or established.'*

It acknowledged the absence of a legal minimum visibility requirement for some operations, and continued:

> *'Where no IFR departure procedures have been established, it is recommended that private and aerial work flights apply the VFR night visibility minima of 3,000 metres for take-off'.*

EASA Part NCC

A series of EASA implementing rules will bring new regulation into force, and operations such as that of G-LBAL will fall under Part NCC, which covers non-commercial, complex, aircraft. Operators will be required to produce, and operate in accordance with, a suitable operations manual, and to have an appropriate safety management system.

The CAA issued Information Notice IN-2013/087 *'Future Flight Operations Other than for the Purpose of Commercial Air Transport'* on 7 June 2013, explaining that there is a transitional 'opt-out', and that the CAA has taken advantage of the full opt-out term. On 6 September 2013 the CAA published a further Information Notice on the same subject, IN-2013/143, to provide an:

> *'update on the progress of rule development which will lead to the introduction of European implementing rules affecting aircraft operations other than those for the purpose of commercial air transport.'*

The CAA has confirmed that Part NCC will come into effect within the UK on 25 August 2016.

Decision making

In its report of the accident involving a commercially operated complex helicopter[7] the AAIB noted that:

> *'…pilots will often be subject to pressures – real or perceived – to complete a task. These pressures might lead pilots to continue with flights in circumstances where otherwise they would not…'*

Discussion with industry participants during the investigation of the accident involving G-LBAL indicates that increased regulation is not a complete solution if these pressures cause pilots to operate a flight in violation of the regulations, and that mitigating the pressures themselves is necessary to improve safety.

Footnote

[7] Report on the accident to Agusta A109E, G-CRST, near Vauxhall Bridge, Central London on 16 January 2013.

Analysis

Engineering

The ground marks and distribution of wreckage on the accident site indicate that the helicopter struck the ground approximately 25º nose-down with considerable forward speed. The nose-down attitude of the fuselage then increased rapidly to the point where the main rotor blades struck the ground. The process was probably accelerated by the fuselage passing through the rolled hay bales. The items recovered from the initial impact point indicated that the forward section of the fuselage had suffered significant damage during the initial impact which resulted in the release of the aircraft batteries and loss of power to the flight recorder.

The distribution of wreckage indicated that, immediately after the main rotor blades struck the ground, the helicopter continued on its heading but became airborne again and began to rotate clockwise about its main rotor head before striking the ground for a second time, 43 metres beyond the initial impact point. The debris recovered from the second impact site indicated that the lower fuselage structure had been severely compromised. After the second impact the fuselage became airborne for a second time before coming to rest 18 metres beyond the second impact point. It was estimated that the fuselage had rotated through approximately 540º before coming to rest.

The helicopter's records confirmed that it had been maintained in accordance with current airworthiness requirements and that there were no apparent defects which had a bearing on the accident flight. No evidence was found of any pre-accident defects or restrictions in the flying control systems or the main and tail rotor drive trains. The helicopter appeared to respond appropriately to control inputs. The analysis of the downloaded DCU data confirmed that both engines were operating at impact and performing in accordance with flight crew control inputs. The engine EECs had recorded no faults during the accident flight or in the 83 flying hours prior to the accident.

Operations

The accident flight

The helicopter was serviceable prior to the accident flight. The pilots were suitably qualified for their duties and were in current practice. They had experience of the helicopter and the site from which they were to depart, and no evidence suggested that they were not fit to fly. In the context of the operation, the proposed flight was routine.

Forecasters had correctly predicted deteriorating visibility and the onset of mist and fog through the afternoon and evening, and the co-pilot's questions to the commander during the previous sector, and the commander's responses, demonstrate that the pilots were aware of the forecasts and that the copilot was concerned that a plan to deal with the possibility of conditions too inclement for flight had not been made. Although the investigation did not establish what forecast information the pilots had accessed, it is clear from their dialogue that they were aware of the foggy conditions both before and after their onset.

The visibility deteriorated significantly in the time before departure, and departure at the original planned time might have been into less difficult conditions. For pilots, rapidly deteriorating weather, as a departure is delayed, presents challenges. In particular, it creates an unpredictable and dynamic environment in which a decision that flight is no longer an appropriate option may have to be taken promptly.

The CVFDR recorded the following pre-flight conversation between the pilots: "[unintelligible] I DON'T MIND TELLING YOU I'M NOT **** VERY HAPPY ABOUT LIFTING OUT OF HERE"; "IT SHOULD BE OK IT'S... I DON'T THINK IT IS BECAUSE YOU CAN STILL SEE THE MOON". The pilots had operated this helicopter from this helipad routinely, by day and night. The helicopter was serviceable, the load and planned flight were not unusual, and the wind was very light. The only novel aspect of the departure identified during the investigation was the fog. It is logical, then, that this exchange illustrates that one of the pilots remained concerned about the conditions into which the helicopter would depart, very shortly before it was due to do so. Whilst it was not possible to identify which pilot spoke which phrase, it is clear that both gave thought to the conditions.

The remark about the moon may suggest that, at that moment, the fog was not very deep. However, in foggy conditions, the difference between horizontal (surface), vertical, and slant visibility can be marked. This typically poses challenges for pilots when an airfield may be seen clearly from directly above in flight, but is not visible on a normal approach. The moon's elevation, 37°, clearly did not place it overhead, but nonetheless it was appreciably above the horizon. Moreover, fog is not always uniform, and visibility within it may vary significantly both with time and from one place to another, even over short distances.

The eyewitness remark, recorded on the video recording of the departure, that no stars were visible suggests that the fog may have been relatively thicker towards the north-west; the direction in which the eyewitness was looking.

Because the departure was from a private landing site, rather than an aerodrome at which meteorological observations were made, the pilots were not able to receive visibility and cloudbase information from an official source. It is possible that the availability of an official observation of the conditions might have prompted a decision not to depart.

The co-pilot's remark to the commander, that he had informed the owner and other passenger that they must now depart, suggests that the pilots had determined that further degradation in the visibility would render departure inappropriate.

Briefing

The CVFDR recording of earlier flights showed that the pilots did not conduct formal briefings, but occasionally made short statements of their intentions. The commander's brief: "RIGHT ALL I'M GOING TO DO, TAKE IT OVER TO THE CENTRE OF THE FIELD, AND THEN JUST PULL THE POWER, WE'LL GO VERTICALLY UP, I'LL GO FOR THE STROBE AND JUST MAKE SURE THE HEADING BUG IS CENTRAL FOR US IF YOU CAN" suggests that a vertical departure profile was the intention. However, no evidence of a briefed height to be attained, or value for the height of takeoff decision point (TDP) was discovered, so comparison between the intended profile, and the helicopter's actual profile, is difficult.

The commander may have intended to climb the helicopter vertically until it cleared the top of the fog layer, or attained a particular height, or simply until he felt comfortable to carry out a transition into forward flight. His brief that "WE'LL GO VERTICALLY UP" suggests that it was not his intention to begin a transition into forward flight promptly after climbing away from the hover. This short brief did not refer to any previous discussion or briefing on the technique or parameters to be used, but it is possible that the pilots had spoken about the departure procedure to be employed before they boarded the aircraft and the CVFDR was activated. In which case, their shared understanding of the plan would have been more comprehensive than the available evidence suggests.

Appropriate training in vertical departures in reduced visibility would have enabled the pilots to plan and execute the proposed manoeuvre with a greater chance of success, (notwithstanding that it would not have been a legitimate manoeuvre in this civilian operation). No evidence was found to show that either pilot had received training in vertical departures in low visibility.

Crew co-ordination

There were no procedures to dictate how the two pilots should co-ordinate as pilot flying and pilot not flying, in particular with regard to which pilot should maintain visual references outside the cockpit or monitor the instruments. Additionally, the pilots had not been formally trained or tested operating as a crew of two. It is probable that a formal division of tasks and responsibilities, with pre-planned means of identifying and communicating normal or abnormal progress, could have assisted in achieving and maintaining better situational awareness, and preventing the progressive change in the flight path to the point at which the accident was inevitable.

Automatic flight systems

The commander referred to the heading bug before beginning the departure climb and, after the hovering portion of the flight, the active Yaw Heading Hold mode of the AFCS maintained the helicopter's heading very close to the bugged value. This indicates that the AFCS was controlling the helicopter in yaw. The cyclic and collective controls were manipulated by the commander throughout the accident flight; the automatic flight modes, which could have maintained pitch and roll, were not active. In other words, the aircraft was flown manually in pitch and roll. Flight in degraded visual conditions places additional demands on pilots. The appropriate use of autopilot functions can assist in minimising workload and allowing maximum attention to be devoted to monitoring the aircraft's attitude and path and other parameters such as speed and groundspeed. Greater reliance on the automatic flight capabilities of the helicopter might have prevented the development of the abnormal pitch attitudes during the departure.

Intended versus achieved profile

Without precise knowledge of the intended flight path, it is difficult to comment on the way in which the aircraft's performance deviated from the commander's plan. However, it is unlikely that, in the dark and in fog, he intended to fly a departure that would involve close proximity to the ground. This is evidenced by his briefing and the vertical manoeuvre which followed. The fundamental difference apparent between what is considered to be his intended profile and the profile achieved concerns the helicopter's pitch attitude.

If the helicopter had not progressively pitched down as it did, the departure would more likely have been successful. The investigation did not identify any malfunction of the flight instrument and display systems, and given the error messages or abnormal parameters which would have been found in recorded data if they had malfunctioned, it is deduced that they were operating correctly throughout the accident flight. However, it is not possible to know where the pilots' visual attention was directed.

Pilots' visual attention

The pitch attitude deviated from the 'normal' regime of attitudes versus height (Figure 4) as the helicopter climbed through 78 ft agl, and reached a maximum 35° nose-down, after which the deviation began reducing. The duration of flight with an increasing unusual pitch attitude was just over nine seconds. It seems likely that a pilot whose attention was focussed on the flight instruments for this length of time would have noticed the abnormal pitch attitude and, if flying, corrected it, or if not flying, drawn his flying colleague's attention to it.

Pilots flying close to the ground and/or obstacles avoid contact with them by monitoring the helicopter's relative position visually. The lift-off and hovering portion of the flight will have been conducted with the commander's visual attention outside the cockpit. There was no briefing as to when attention would be transferred to the flight instruments, though this would normally occur once Vmini was achieved. This highlights that the achievement of Vmini is an important objective during departure and it may be that attention was not to be fully given to the flight instruments until this time.

For these reasons, it seems probable that the pilots' visual attention was directed outside the cockpit.

Visual cues

Visual cues may be very compelling. In the darkness, and fog, the available outside cues were restricted to the lighting in the paddock and any other visible cultural lighting. In the direction of flight, and to the north and west of the departure route, there was little nearby habitation. The commander's view, from the right seat, was of these areas. Neither the Hall, nor the moon, would have been visible to him. Thus, his visual environment lacked cues.

Although there were lights illuminating trees in the paddock, these would have been progressively lost to view in a vertical climb above the ground, as the line-of-sight between the pilots' eyes and the lights was obstructed by the helicopter's structure. In dense fog, they might have been lost to view before the structure obstructed their view.

Amongst the few cues available, once the climb commenced, the headlights of the car travelling towards the paddock along Raveningham Road may have been apparent. This leads to the possibility that the pilot(s) saw those lights, but did not recognise that they were on a moving vehicle. This is considered in the context of the gradual loss, from perception, of the lights illuminating trees in the paddock.

An assumption (perhaps, a subconscious one) that the car's lights were fixed would have led to an illusory effect. As the lights moved progressively down the pilots' field of view, the illusion of the helicopter pitching nose-up would have been created. This could explain a compensatory nose-down pitch input.

The car driver recalled that the helicopter passed over his vehicle once he had turned right onto Yarmouth Road. The co-pilot could have perceived the relative downward motion of the car's headlights as an indication that the helicopter was pitching nose-up, and it is possible that the "NOSE DOWN" calls were prompted by loss of sight of the car's lights beneath the helicopter's nose.

Pitching for speed

If the commander had intended to adopt an accelerative attitude in order to achieve forward speed, the late registering of airspeed on the flight displays may have been of significance in two ways. First, if he had intentionally selected an accelerative attitude, failure to achieve the expected speed might have led to further nose-down pitch inputs in an effort to achieve the desired acceleration. Secondly, the absence of the expected speed indication might have caused more attention to be given to the ASI than would otherwise have been the case, possibly to the detriment of monitoring of other parameters including attitude.

If the pilots had adopted a procedure by which the pilot not flying announced when the airspeed began indicating or achieved a nominal value, it would have enabled the pilot flying to concentrate his efforts on external cues until Vmini was, or was about to be, achieved. In the absence of this habit the pilot flying would need to cross-refer from external cues to the speed presentation, to determine when Vmini had been achieved.

The meteorological information suggests that a slight tailwind may have affected the helicopter during its departure; this would be one cause of a late registering of airspeed in comparison with other, into-wind, departures. A recognition of the easterly wind might have led to a decision to depart towards the east, into wind, rather than towards the west. However, the westerly departure was the usually favoured departure route on account of the relatively lower heights of tree-tops and the direction of the intended flight. Alternatively the late registering of airspeed in a downwind departure could have been anticipated and briefed by the pilots.

Another possible cause of the late registering of airspeed was identified as the nose-down attitude adopted, and its effect on the pitot-static system; thus the late registering could have been both a cause and a consequence of the pitch attitude profile of the flight.

Somatogravic illusion

Somatogravic illusion could have led to the progressively abnormal attitude of the helicopter 'feeling' normal to the occupants. It is notable that the point at which the co-pilot began prompting the commander about pitch attitude ("NOSE DOWN") corresponds with the points in Figure 6 when the value of force vector pitch for height is close to outlying the other plotted data. Until then, there was nothing abnormal about the value of force vector pitch, even though the pitch attitude itself had deviated substantially from its usual range of values.

Recognition of the abnormal progress of the flight

The helicopter's pitch attitude became progressively nose-down from shortly after the beginning of the climb from the hover. The longitudinal cyclic inputs were consistently in the nose-down sense and of small amplitude until the point at which the co-pilot stated "NOSE DOWN". The longitudinal cyclic input then showed a brief, but marked, nose-down input. This was followed by a further, similar input at the time the phrase was uttered for a second time. So, although analysis of the CVFDR did not establish whether the co-pilot meant that the pitch attitude was too nose-down, or was suggesting that it needed to be more nose-down, it is possible that the commander interpreted the latter and reacted to it. Alternatively, the same cues or reasoning which caused the co-pilot to make his prompt, may simultaneously have led the commander to make a nose-down correction.

Around this time, the amplitude of the cyclic inputs increased significantly. The collective was also brought up to its maximum position, commanding maximum available torque. This appears to reflect a recognition that the flight was not progressing as planned. The torque increased but was not sufficient to prevent a reduction in rotor rpm. The CVFDR did not record any exchange of control between the pilots, but even so, it is not possible to exclude the possibility that the co-pilot may have intervened on the cyclic or collective, or both.

Incapacitation

The post-mortem examinations showed no signs that incapacitation occurred or was likely to occur. The CVFDR recording contained nothing suggesting incapacitation. If the commander had become physically incapacitated (as opposed to disorientated), it is probable that he would have ceased making smooth control inputs and/or would have stopped applying pressure to the trim release switches. However, these were held in throughout the flight. The co-pilot's verbal prompt shortly before impact indicates against incapacitation in his case. Thus, it is unlikely that physical incapacitation was a factor.

EGPWS

The helicopter's EGPWS provided a warning immediately before impact, but not in sufficient time for the pilots to react. The limitations of EGPWS in rotary-wing operations are understood and work by the UK CAA and others is seeking to optimise the system's functionality. The rapid onset of the abnormal flight profile, such as in this case, may mean that sufficiently prompt alerting is not achievable without unacceptable rates of nuisance alerting during safe flights.

Operation of the helicopter

As the AAIU report into the 1996 accident acknowledged, the owner made habitual use of his helicopter. His acquisition of an IFR-capable helicopter, and the employment of two professional pilots, both with Instrument Ratings, demonstrated a commitment to benefitting from the flexibility and efficiency which a private helicopter offers, and the earlier works at the departure helipad, clearing trees and fitting lights, also reflected a desire to maximise the utility of the helicopter. Although the operator's procedures and documentation met the necessary standards during the time the AOC was held, it seems that since the end of AOC flying, the style of operation had returned to the private realm, without, for example, an operations manual.

Previous accident, Safety Recommendations, regulation, and oversight

In its report on the previous accident involving the operator, the AAIU made a series of Safety Recommendations, several of which concerned additional oversight of private helicopter operations.

Similarities exist between the causal factors determined in that case and those around the loss of G-LBAL. The AAIU found that the primary cause of the accident to G-HAUG was *'loss of situational awareness'* on the part of the pilot flying, and it is apparent that the pilot or pilots of G-LBAL experienced a similar condition.

There are also similarities with the secondary causes identified by the AAIU including the use of a procedure not recognised for a civil helicopter pilot, which gave little margin for error, and in the course of which impact was inevitable by the time the pilots recognised that their trajectory was unsafe.

The AAIU report commented that:

> *'The flight used a navigation approach procedure that would not meet the standards required by the UK Authorities for public transport operations. However, this was not illegal because the flight was operated under private category rules.'*

With regard to G-LBAL, the departure would not have been permitted had it been from a licensed aerodrome. However, because it was from a private landing site, there was no requirement for a particular minimum visibility.

The AAIU report highlighted the difference between the majority of general aviation activity, concerning 'in the main, the operation of private pilots, largely in simple single-engined aircraft, with fairly basic instrumentation' and the operation then of the S-76 helicopter, which was, it stated, '*markedly different from these general aviation norms*'. The report explained that:

> *'The owner was not a pilot, and his prime requirement was that the operation should provide effective transportation in most weather conditions prevailing*

> *in the area. To achieve this he purchased a state-of-the-art aircraft and hired professional pilots to manage the operation. The evolving procedures generated by the pilots indicated a strong commitment to meeting the owner's requirements.'*

It also stated:

> *'The corporate environment of the operation of G-HAUG, particularly the type of flights flown, the use of such a sophisticated aircraft, the application of GPS to approaches in a very restricted area and the employment of professional pilots to manage the operation on behalf of an owner who was not a pilot, do not appear to be compatible with the norms of private category aviation, or with the spirit of the rules and regulations that apply to that category.'*

A similarity concerns the hazards and risk inherent in the particular manoeuvres being conducted at the time of the two accidents. The G-HAUG event occurred in IMC during execution:

> *'of a locally produced GPS-based approach procedure which gave little margin for error, and which was inadequate to alert the crew to terrain dangers.'*

while the G-LBAL event occurred during departure in inclement conditions, using a procedure not laid down in the flight manual or recognised as being compliant with the need to achieve Vmini before transition to instrument flight. Examination of the proposed vertical departure profile, into a dark foggy night with few (or, as the climb progressed, probably no) visual cues, should have identified that achieving Vmini by reference to the available visual cues was not certain. An AOC-holding organisation would have been required to consider this departure within its safety management system, and a good system might well have identified that the level of risk inherent was unsustainable.

These matters were addressed by the AAIU's recommendation (SR7 of 1998) that:

> '• *The UK CAA should consider the establishment of a special category for the operation of corporate aviation.'*

Although the UK CAA accepted this recommendation, no special category was established. CAP686 was issued after the G-HAUG accident, but provided guidance rather than regulation. Private operations of complex aircraft continue as before.

The same intent was also expressed in another recommendation (SR8 of 1998), which took account of the transition to regulation by the JAA:

> *'The JAA Joint Working Group for JAR OPS 2, which reviews operation standards for aircraft operation in the JAA States, including the UK and Ireland, should consider the establishment of a special category for the operation of corporate aviation, to encompass the operation of aircraft such as G-HAUG'*

The JAA (whose functions have largely been subsumed by the EASA) did not respond to this recommendation and no special category was established.

A further Safety Recommendation (SR10 of 1998) suggested that operators could act before regulations required them to do so:

> ‘• *The Irish Aviation Authority (IAA) and the UK CAA should bring to the attention of operators of corporate aircraft the safety benefits that would result from external vetting of their operations, pending the establishment of a suitable regulatory framework for corporate aviation activities.*
> *(SR 10 of 1998)’*

The UK CAA accepted this recommendation, but the operator of G-LBAL did not seek external vetting.

The CAA’s paper 2007/03 *‘Helicopter Flight in Degraded Visual Conditions’* described the circumstances of a number of accidents in the years up to 2004, and found that:

> *‘Serious consideration must be given to the measures that need to be taken to reverse this trend, taking into account improvements to regulations, operating procedures and requirements or pilot training requirements.’*

It addressed visibility versus height, taking into account the available view over the nose of a helicopter, and noted that:

> *‘Pilots should be better trained to make informed decisions on whether ‘to fly or not’ in marginal conditions.’*

Although the operator had a draft operations manual and safety management system, these appeared not to have progressed beyond the draft stage. Adoption of them might have brought about an accurate assessment of the risk inherent in the departure from Gillingham Hall in fog and better ways of evaluating the visibility at the time, the provision of procedures enabling the two pilots to benefit from potential synergy in multi-crew operations, and training in those procedures.

In conclusion, despite a previous fatal accident, a comprehensive investigation by the AAIU, the acceptance of safety recommendations by the CAA, and other work, including the CAA’s paper 2007/03 and CAP686, the causes of the G-HAUG accident were almost replicated in another fatal accident by the same operator some years later.

The AAIB has referred previously to the pressures – real or perceived – on pilots of aircraft operated in the corporate environment. These pressures remain when an aircraft is operated privately, but the private operation is also less comprehensively regulated. In particular, in the absence of minimum visibility requirements for operations at private sites, pilots of helicopters operating privately have no absolute criteria to support a decision whether or not to depart. A combination of appropriate regulation, and techniques for mitigating these pressures, may be required to improve the safety of non-commercial complex helicopter operations.

Safety action

Although the recommendations intended to prevent a recurrence of the accident involving G-HAUG were broadly accepted, no action resulted. The EASA has published Part NCC, covering non-commercial complex aircraft operations. The UK will adopt Part NCC in 2016. The AAIB asked the CAA to comment on how its implementation might answer the recommendations made in the AAIU report. The CAA did not respond directly but stated that, following this investigation and in connection with previous work by the AAIB[8], it considered that:

> *'A broader and deeper review of IFR flying outside controlled airspace in general is advised.'*

Accordingly the CAA has proposed the following safety action:

> *'The CAA intends that a multi-disciplined review be initiated, potentially involving industry participation, to review the whole subject and produce recommendations and suggested courses of action. Target date for completion of the review is 01 October 2015.'*

Vmini

The investigation established that the definition of Vmini promulgated by the FAA does not reflect the practical meaning of the term. It does not take account of IFR operations including hovering and accelerating flight after lift-off, until Vmini is achieved, and decelerating flight below Vmini prior to landing. The definition was carried across into the AW139 flight manual.

There is an opportunity for the meaning of Vmini to be clarified to reflect more accurately its meaning, and so the following Safety Recommendation is made:

> **Safety Recommendation 2015-024**
>
> The Federal Aviation Authority should amend its definition of Vmini, to reflect the legitimacy of flight under instrument flight rules by reference to external visual cues at speeds below Vmini.

The EASA definition of Vmini lacks clarity and, like the FAA definition, does not convey the practical application of the term. Therefore the following Safety Recommendation is made:

> **Safety Recommendation 2015-025**
>
> The European Aviation Safety Agency should amend its definition of Vmini, to provide a clear definition that reflects the legitimacy of flight under instrument flight rules by reference to external visual cues at speeds below Vmini.

Footnote

[8] FACTOR F1/2015 responding to AAIB Safety Recommendation 2014-035 regarding the serious incident to G-WIWI.

Conclusion

The helicopter departed the private site in fog and at night. Operation from the site in such conditions was permissible under existing regulation. Departure from a licensed aerodrome in such conditions would not have been permitted.

Evidence suggests that the flight crew may have been subject to somatogravic illusion caused by the helicopter's flight path and the lack of external visual cues.

The absence of procedures for two pilot operation, the pilots' lack of formal training in such procedures, and the limited use of the automatic flight control system, may have contributed to the accident.

Opportunities to reduce the likelihood of such an event, presented by the report into the operator's previous fatal accident, appeared not to have been taken.

The UK will adopt new regulations involving non-commercial complex aircraft operations in 2016 and, following the accident to G-LBAL and other occurrences investigated by the AAIB involving helicopters, the CAA intends to complete a review the subject of IFR flying outside controlled airspace by 1 October 2015.