Eurocopter AS355N Ecureuil II, G-EMAU, 9 Oct 1998 at approximately 2305 hours

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Aircraft Type and Registration:	Eurocopter AS355N Ecureuil II, G-EMAU
No & Type of Engines:	2 Turbomeca Arrius lA turboshaft engines
Year of Manufacture:	1993
Date & Time (UTC):	9 October 1998 at approximately 2305 hours
Location:	Sulby, Near Welford, Northamptonshire
Type of Flight:	Public Transport (Police Air Support)
Persons on Board:	Crew - 1 - Passengers -2
Injuries:	Crew - 1 serious - Passengers -1 fatal
Nature of Damage:	Helicopter destroyed
Commander's Licence:	Airline Transport Pilot's Licence
	(Helicopters and Gyroplanes)
Commander's Age:	39 years
Commander's Flying Experience:	3,364 hours total (of which 998 hours were on type)
	Last 90 days - 44 hours
	Last 28 days - 15 hours
Information Source:	AAIB Field Investigation

History of the flight

The pilot and the two observers of a police air support unit (ASU) reported for duty at about 1600 hrs for a shift that was due to run from 1630 hrs until 0230 hrs. During the handover briefing from the previous crew the helicopter was declared to be serviceable. The pilot and observers then conducted their own operations and meteorological briefing before the pilot checked the helicopter to ensure that all systems were set correctly to allow for a rapid response.

During the early evening the pilot rejected two tasks, one for operational reasons and the other because the weather at the helicopter base was unsuitable with prolonged heavy rain and a low cloud base. The weather improved at about 2000 hrs. The crew responded to a subsequent task and were airborne at 2030 hrs. When they returned to base at 2100 hrs the visibility was assessed as excellent and there was no noticeable cloud.

The crew responded to a further task just before 2300 hrs. The pilot and one of the observers went to prepare the helicopter, which was parked on its pad adjacent to the crew accommodation. Once outside, the pilot noted that there was some light mist over the adjacent fields. However, he could see clearly the lights of a village 3 km away and there was no 'blooming' from any of the helicopter pad lighting which may have indicated excessive moisture in the air. Furthermore, he could see stars directly above. The pilot was therefore confident that conditions were satisfactory for a visual surface contact flight. He then joined the observer at the helicopter and strapped in. When the second observer arrived at the helicopter he was also aware of the light mist and a feeling of dampness in the air but confirmed that he could see the lights of the nearby village quite clearly.

Once everybody was strapped in the pilot started the engines, selected the autostabilser system ON, uncaged the Attitude Indicator (AI), confirmed that the OFF flags had retracted from both the main and the standby AI and selected the landing lights to ON. He then applied power and lifted the helicopter into a low hover where he checked the engine instruments. Once satisfied that all indications were normal he commenced the transition to forward flight and a visual departure.

The helicopter had been parked on a heading of approximately 220°M and the pilot began a gentle turn to the right as he commenced the transition. This was the standard procedure for a visual departure from this site since it took the helicopter over open agricultural ground. It was also the general direction for the particular task to which they were responding. The helicopter crossed the southwest corner of the helipad on a track of approximately 230°M in a gentle turn to the right. At this stage the landing lights were still illuminated and there were no reflections from any cloud or fog. At a height estimated by the pilot to be about 25 to 30 feet, and with an associated airspeed of about 15 to 20 kt, the helicopter suddenly entered a bank of fog. The pilot immediately selected the landing lights to OFF in order to reduce the glare from the reflected illumination; this was accomplished by a single switch located on the collective pitch lever and both lights extinguished immediately. The pilot then checked his flight instruments and realised that the AI indicated about 15° bank to the right. The pilot corrected this with an application of left cyclic control. He also applied left yaw pedal in order to centre the slip ball. The pilot reported that he had some difficulty in seeing the ball clearly since the internal lighting for the AI (the base of which contains the slip ball) was not serviceable and the instrument was illuminated by an external pillar light located above the AI. The pilot does not remember using the standby AI. He then told his observers that they were in fog and that he was now flying by sole reference to the flight instruments. He applied full power and remembers that the torque limit light illuminated indicating that maximum take off torque had been achieved. When he checked the Airspeed Indicator (ASI) it was indicating zero, however, it should be noted that this instrument does not provide a positive indication of airspeed below approximately 40 kt. The pilot made further control inputs to the left using both the cyclic control and the pedals in an attempt to maintain wings level flight as indicated by the AI. At this stage he remembers that he felt 'out of balance'.

The pilot and the surviving observer remember seeing some trees just before the helicopter struck them. They both described a number of impacts before the helicopter came to rest. They undid their seat belts and vacated the wreckage. Very shortly afterwards a fire started. After an initial attempt to locate their colleague the observer returned to the helipad to raise the alarm whilst the pilot continued the search but to no avail.

The observer made a telephone call from the helipad to the Leicester police control room to inform them of the accident and to request assistance; this call was logged at 2310 hrs. The first police assistance arrived on the site and made an initial report at 2323 hrs. The fire services were called at 2314 hrs and arrived on site at 2330 hrs.

Flight notification

Tasking of the helicopter can be either by telephone, radio or self activation and, due to the long distances that the helicopter may have to cover to reach the task area, an expeditious reaction and aircraft start is required. Prior to any take off the helicopter crew are required to notify the Leicestershire police operations room that they are about to get airborne. This can be done either by telephone or VHF radio. Once airborne confirmation of a safe take off is made by VHF radio. If the crew do not make contact within five minutes then the police operations room will take appropriate action. On this occasion the police operations staff were notified by VHF radio that the helicopter was about to get airborne but they received the telephone call from the surviving observer about the accident before they were required to take any further action.

Medical and survival aspects

The helicopter came to rest in an inverted attitude and the observer in the left front seat sustained fatal injuries. Shortly after the impact a fire started which destroyed the helicopter structure. The two other crew members confirmed that their colleague had been wearing a safety helmet prior to take off and thus the accident must be regarded as not survivable, given the fatal injuries which were sustained. The pilot sustained serious injuries to his lower back and the observer in the rear seat had a fractured leg and other serious injuries.

Earlier in the week the pilot had suffered from a sore throat and had taken 16 Paracetamol tablets over the previous four days. He had taken the last tablet 24 hours before the accident and had felt well thereafter. It is not believed that the Paracetamol played any part in the cause of the accident. However, it is possible that ascending infection to his semi-circular canals made him more susceptible to disorientation when deprived of external visual cues.

Meteorological conditions

The synoptic situation for the evening of 9 October 1998 indicated that a cold front was crossing the area from the north west. The weather associated with this cold front included a reduced visibility in heavy rain with a low cloud base. The pilot reported that these conditions improved markedly at about 2000 hrs as the cold front passed through and at 2030 hrs he accepted a task to fly. When he returned to his base at 2100 hrs he described the visibility as greater than 10 km with no noticeable cloud.

This account of the meteorological conditions is fully supported by reports from nearby airfields. The cold front cleared East Midlands airport at 1920 hrs and Birmingham airport at 2120 hrs. After the passage of the front both airfields reported similar conditions. At 2120 hrs Birmingham recorded a surface wind of 240°/05 kt, visibility in excess of 10 km with a few clouds at 900 feet, the temperature was +12°C and the dewpoint was +11°C. At 2250 hrs (the report closest to the time of the accident) the conditions at Birmingham were recorded as a surface wind of 270°/05 kt, visibility in excess of 10 km with no reported clouds, the temperature was +10°C and the dewpoint was +8°C. The cold front did not clear London (Luton) airport until 2350 hrs.

The helicopter base is situated amongst agricultural land which had been subjected to heavy and prolonged rain. After the passage of the cold front the presence of light surface winds over saturated ground, coupled with a temperature and dew point that were nearly coincident, provided the requisite conditions for the formation of mist and fog.

The air support unit is equipped with a cloud base indicator to allow for constant monitoring of the cloud base directly above the crew accommodation area. This equipment was unserviceable on the night of the accident but, since the commander had reported that he could see the stars above the helicopter pad, it is unlikely that this instrument would have detected the fog bank over the adjacent agricultural land.

Engineering investigation

The helicopter had entered a wood to the east of the helipad on a track of 075°M, and had come to rest inverted 50 metres beyond the entry point. The first significant rotor blade strike, at a height of 11.5 metres above the ground, was from a retreating blade on the right hand side of the flight path which had severed a 280 mm diameter tree trunk. Three lighter impact marks on a more substantial tree on the left hand side showed that the helicopter had then rolled to the right before hitting the ground and burning out. The length of the helicopter's path through the wood appeared incompatible with its probable entry speed, which was estimated to be between 20 to 40 kt. It is possible that some rotor energy was converted into forward speed during the early tree impacts, and that the cushioning effect of the intervening smaller trees may have extended the penetration of the wood beyond that solely attributable to the helicopter's initial entry speed.

The tail unit and main rotor and gearbox were torn away during the early impacts and this caused the power turbines of both engines to overspeed, resulting in the release of their turbine blades.

There was no evidence to indicate that fuel had been released from the aircraft's integral fuel tanks before it struck the ground. The ground fire totally destroyed the helicopter structure, as well as most of the avionics and equipment. A small part of the instrument panel containing the main and standby AIs survived the worst of the fire. The pilot's main AI had heat damage on its casing, but the casing had not been penetrated and showed no evidence of having received a direct impact during the accident. The standby AI showed less external heat damage than the main AI, and was also free from obvious impact damage.

Main and standby attitude indicators

The main AI used an electrically driven, two axis of freedom, vertical gyroscope assembly. It was designed to be maintained on an 'on condition' basis, not requiring scheduled maintenance or scheduled overhaul. The maintenance philosophy required that the instrument be left in service until an unserviceability was reported by the pilot.

An external caging knob provided simultaneous erection of the pitch and roll axes, through mechanical coupling, for a fast erect capability. Gyroscope verticality was maintained by a mechanical erection system; errors of less than 7° would automatically be corrected at a nominal rate of 2.5° per minute. When the spin axis displacement from the local vertical exceeded 7° automatic erection rates in both axes were reduced. Errors of greater than 10° must be eliminated by caging the indicator to reduce the error to less than 7°, after which the self erection system would align with the local vertical. The gyroscope wheel speed and the nature of the erection system combined to provide a minimum of nine minutes of usable attitude information after total loss of power.

A power warning system monitored the 28 Vdc indicator input power. Upon initial application of power, the power warning OFF flag remained in view. After approximately two minutes, the warning flag would be removed from view. The power warning OFF flag would appear if any of the following circumstances applied:

- Interruption of input power to the indicator,
- Placing the PULL TO CAGE knob in the caged position,
- Inadequate wheel speed,
- The absence of internal power to the gyroscope.

An inverter converted 28 Vdc input power to three-phase, 400 Hz, AC power required by the vertical gyroscope.

Attitude information was displayed by a sphere which was mechanically driven by the pitch gimbal and directly attached to the roll gimbal of the vertical gyroscope. Movement of the roll and pitch gimbals registered roll and pitch axis sphere movement in relation to a miniature airplane symbol. A roll index, attached to the roll gimbal, indicated the roll displacement angle relative to a frame mounted roll scale. Pitch displacement angles were displayed on the sphere.

The main AI had been returned to an overhaul agency once in 1995 for a lighting defect, and twice in 1998 for operating and lighting faults as follows:

25 February 1998:	Topples in flight requires setting every 15 to 20 minutes.
7 July 1998:	Gyro wanders, internal light u/s.

Neither operating fault was confirmed on test, and consequently no rectification was carried out. The internal light defect, reported on 7 July, was not repaired because no spares were available; the AI was therefore returned to the ASU in the 'as received' condition.

The normal lighting for the main AI comprised two bulbs fitted into a wedge of clear plastic behind the instrument glass, but in front of the instrument face; and two further bulbs fitted inside the sphere representing the earth to eliminate any shadows. The primary illumination came from the wedge and the lighting inside the sphere was considered by the manufacturer to be secondary. Due to the lack of lighting spares available when the AI was returned to service following its removal on 7 July 1998, a single 'pea' bulb was installed at the '12 o'clock' position on the instrument panel above the AI.

Both the main and standby AIs were stripped by the manufacturer in the presence of an AAIB Inspector. The main AI display mechanism was jammed by solidified plastic from the caging mechanism, lighting wedge and the sphere, which had been melted in the ground fire. The plastic would have melted at around 200°C. The mechanism position had stopped at a position indicating a vertical dive and right wing down: this was considered not relevant as the mechanism would have toppled during the impact with trees and ground.

Friction in the pitch axis, typically caused by brinelling of the bearings, would cause precession errors to be displayed in roll. However, unless there was a serious fault (which was not apparent) such friction would have less effect than that of the self erection system. The self erection system was functioned statically and revealed nothing out of the ordinary.

The strip examination of the standby AI did not show any melting or heat damage inside the case except for some paint discoloration on alloy items in contact with outer casing. The gimbals were free in roll, but the pitch display mechanism had come off its fulcrum, possibly through severe gimbal lock during tumbling, or shock in that plane. One side of the pitch scale had moved from behind the display rim to in front of it; this could also have been caused by gimbal lock. The rotor was found to be seized, but it broke free easily and thereafter ran smoothly; it was considered that the problem had probably been caused by lubrication oil which had dried out during the ground fire. The caging system and the power failure flag were satisfactory.

Technical documentation

The pilots carried out their own refuelling and minor fault rectification such as bulb changes. The ASU did not have technical support on site, but relied on a maintenance organisation at Kidlington, Oxfordshire some 70 miles away. The technical log maintained by the unit did not contain any defect entries on the AIs, although the work sheets showed that four defects had been raised during scheduled servicing.

The Minimum Equipment List which defined the minimum equipment serviceability requirement, allowed flight with an unserviceable main AI 'for VMC, or provided the standby AI is fitted and serviceable'.

The main AI was certificated for use a primary instrument with internal lighting; the manufacturer considered the pillar lighting unsatisfactory in that it was less efficient than that originally provided. The technical documentation did not contain an Acceptable Deferred Defect, associated with pillar light, to limit the period of its use.

Crashworthiness

The AS 350 Squirrel is a single engine helicopter with a similar structure to its twin engine counterpart the AS 355 Twin Squirrel. Since 1985 the AAIB has investigated 11 accidents involving AS 350 helicopters and 19 involving AS 355 helicopters. A survey of these accidents gave the following information:

	AS 350	AS 355
Total	11	19
Aircraft destroyed		

4

5

Accidents resulting in a fuel fire

0

5

A significant difference between the two helicopters lies in the fuel tank design. The AS 350 fuel tank comprises a discrete fuel cell manufactured from a material which provides enhanced crashworthiness. The AS 355 fuel tank comprises two unlined structural tanks which are liable to rupture if aircraft structure suffers serious deformation. Self-sealing fuel tank liners are offered as an optional extra for some military purposes and these have the properties necessary to provide additional protection in the event of a crash or other damage to the fuel tanks. This option was not available for G-EMAU, or for the other four AS355s which were destroyed by fire. Although the AS 355 is no longer manufactured, its derivative models are now available with crashworthy fuel tanks.

Pilot experience and training

The pilot qualified as a helicopter pilot with the Royal Navy in 1986 and his subsequent flying has been exclusively on helicopters. His naval operational flying included flights overland at low level and at night. He joined the Manchester Police Support Unit in October 1994 where he flew the AS 355 helicopter. In August 1997 he joined the East Midlands Air Support Unit (ASU) as chief pilot. His total flying of 3,364 hours included 731 hours at night, 998 hours on the AS 355 helicopter and 143 hours of instrument flying. At the time of the accident he held a valid pilot's licence and his training records indicated that all training had been completed correctly.

The nature of the police support tasks ensures that such flying is conducted primarily in visual conditions and the pilots are not therefore required to maintain an instrument rating. The pilots do, however, maintain an instrument capability to allow for sudden and inadvertent flight into instrument conditions. The pilots are checked every 6 months on their flying competence and 30 minutes of every such check is dedicated to training for flight by sole reference to the flight instruments. For this exercise they wear an instrument flying hood which fits onto their flying helmets and deprives them of external visual references. This instrument training is designed to improve their ability to conduct: climbing and descending turns, recovery from unusual attitudes and a recovery to an airfield using a runway approach aid such as an Instrument Landing System. The unusual attitude training includes exposure to and recovery from a high power/low speed situation such as could be experienced during the transition to or from the hover.

Instrument flight in helicopters

In considering instrument flight by IFR approved twin engine helicopters it is noteworthy that their flight manual limitations include a minimum speed below which flight by sole reference to the flight instruments is prohibited; this speed is 55 kt for the AS 355N. Below this speed the inherent instability of a helicopter is increased as a direct consequence of the decreased airflow over the aerodynamic surfaces and the tail rotor. Furthermore, at low speeds the pilot's attention is directed increasingly to the cues provided outside the helicopter such that, in the hover, reliance is place completely on external cues. These combined factors of increased instability and a greater reliance on external visual cues make the task of flying any helicopter by sole reference to the flight instruments at a low speed extremely difficult. This problem is compounded during the transition between visual flight and flight on instruments.

Disorientation

After take off the helicopter turned through approximately 155° in the estimated 10 to 12 seconds that it took to travel from the southwest corner of the helicopter pad to the trees. Assuming that this change of direction was relatively smooth, this implies a yaw acceleration of about 2° to 3°/sec^2. Laboratory thresholds for the detection of yaw (without visual cues) are about 1°/sec^2. Given the other demands on his attention it is unlikely that this pilot would have had a positive impression of the direction of the turn, although some sensation of turning was a possibility. This suggestion is consistent with the feelings of unease reported by the pilot. In addition, the number of control inputs (roll, rudder, possible pitch inputs and an increase in power) made during the critical period when he was deprived of visual cues would have contributed to the uncertainty in the pilot's appreciation of the aircraft motion.

A normal transition from visual to instrument flight takes at least a few seconds. The sudden and unexpected loss of external visual cues, any consequent alarm felt by the pilot and the presence of confusing sensations of motion would all tend to extend this period. Poor illumination of the instruments could also further extend the transition and compromise the speed and accuracy of the control inputs. It is impossible to determine exactly how long this transition took. Indeed, the fact that his evidence contains no reference to the compass rotation that must have occurred during the critical period suggests that he never became fully established on instruments. During the period of transition to instrument flight and afterwards he would also have been uncertain of the helicopter's position until external visual cues (the trees) became visible just prior to impact.

Instrument lighting

The internal lighting for the AI was unserviceable, instead the instrument was illuminated from above by a pillar lamp. The likely effects of this arrangement were examined by investigators in a blacked out helicopter configured with the same instrumentation as G-EMAU and with the illumination set to a moderate level. The most noticeable effect was to produce a disc of shadow covering the lower two thirds of the attitude ball and tending to obscure the horizon reference. The distinction on the instrument between earth and sky was, nevertheless, reasonably clear. However, depending on the angle of bank, it is likely that the curved shadow edge across the upper half of the display would make the precise assessment of roll more demanding. Increasing the illumination did not improve this situation. A positive effect of using the pillar lamp alone was to improve the illumination of the slip indicator, thus making it easier to interpret. Overall this instrument appeared useable with the pillar light only, but would probably have demanded closer than normal attention to gain a reliable impression of aircraft attitude.

Operational changes resulting from the accident

After the initial stages of the investigation the ASU, with assistance from the CAA, considered possible alternatives that would improve the safety of departures and arrivals at the helicopter base in the hours of darkness. It was decided that an illuminated strip would be constructed on adjacent farmland. The strip, which will be grassed but hardened, will be 400 metres long and 10 metres wide. It will be equipped with recessed amber runway edge lights spaced at 30 metre intervals on each side of the strip. The ends of the strip will be marked by conventional red/green threshold lighting. The path from the helicopter pad to this strip will be 25 metres long and 10 metres wide and will be illuminated four recessed blue taxiway lights. This taxiway will intercept the strip at its mid point so that the helicopter can then take off to the southwest or northeast, over open land, with 200 metres of illuminated strip ahead. This will provide the pilots with a defined visual reference during departures and arrivals at night, it should also allow them to identify any fog or mist in the take off path.

Summary

Prior to the accident the pilot was in current flying practice both by day and at night. He also met the recency requirements of the ASU for IF training in that he had completed further training, including recovery from unusual attitudes, within the last six months. He was adequately rested before the flight. His recent self medication with Paracetamol is not believed to have played any part in the cause of the accident. However, it is possible that ascending infection to his semi-circular canals made him more susceptible to disorientation when deprived of visual cues.

With his perception of the meteorological conditions at the time of the take off the pilot expected that he would be able to complete a visual transition and departure to the south west. Prior to taking off he was satisfied that the main AI was erect and that there was no OFF flag displayed. During the transition, at an estimated height of about 30 to 35 feet and with an associated airspeed of about 20 to 25 kt, the helicopter suddenly entered a bank of fog. This sudden and completely unexpected loss of external visual cues probably extended the period normally required for an orderly transition to flight by sole reference to instruments. This period may have been further extended by the closer attention required to interpret correctly the main AI display, which was illuminated from above by a pillar lamp since the internal lighting was unserviceable. The evidence suggests that the pilot never became fully established on the flight instruments. During this period of intense mental activity the commander did not detect changes to the aircraft motion, and in particular, the yaw acceleration. He would thus have been unsure of the aircraft's position until just prior to impact with the trees.

No evidence was found of any malfunction in the AI and, given the short duration of the flight, it is considered to be unlikely that any subtle malfunction would have manifested itself. Furthermore, the attitude indications noted by the pilot once in the fog were consistent with the gentle turn to the right initiated by him immediately after take off. It is therefore considered unlikely that a malfunction of the AI contributed to the accident.

The evidence indicates that the pilot became disorientated after he lost external visual attitude references. He was then unable to control the helicopter by sole reference to the flight instruments, and the helicopter crashed into trees adjacent to its operating base.