AS350B2 Ecureuil, G-OROZ

AAIB Bulletin No: 12/2001	**Ref: EW/C2001/1/2**	**Category: 2.3**
Aircraft Type and Registration:	AS350B2 Ecureuil, G-OROZ	
No & Type of Engines:	1 Turbomeca Arriel 1D1 turboshaft engine	
Year of Manufacture:	1992	
Date & Time (UTC):	21 January 2001 at approximately 1521hrs	
Location:	6 miles northwest of Enniskillen, Northern Ireland	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 4
Injuries:	1 Fatal	2 Fatal 2 Serious
Nature of Damage:	Aircraft destroyed	
Commander's Licence:	Private Pilots Licence (Helicopter)	
Commander's Age:	50 years	
Commander's Flying Experience:	Fixed Wing: 146 hours Helicopter: 317 hours Last 90 days - 35 hours Helicopter Last 28 days - 13 hours Helicopter	
Information Source:	AAIB Field Investigation	

Synopsis

This accident occurred when the pilot lost control of the helicopter probably as a result of inadvertent entry into cloud. Witness evidence indicating that a hydraulic failure or rotor RPM warning horn was sounding during the last seconds of the flight pointed to some kind of technical failure, but after extensive examination and testing of relevant systems, no technical fault could be found. However, the hydraulic test switch was found selected to the 'Test' position and the investigation concluded that this could have caused the reported warning. Whether the horn caused the pilot to become distracted and enter cloud inadvertently or whether the horn came on later cannot be known, but it would have significantly increased the pilot's stress level. If the horn was accompanied by flight in manual control, in IMC conditions close to the ground the workload would have been extremely high and the chances of successful recovery by a relatively inexperienced pilot would have been remote.

History of the flight

The pilot, a business owner, planned a surprise trip for his wife and family from their home on the northern shores of Lough Erne, County Fermanagh, Northern Ireland to an hotel near Cong in County Mayo, Republic of Ireland. The plan involved flying the company helicopter, an AS350 B2 Squirrel, to the hotel in the early afternoon of Saturday 20 January 2001 and returning the following afternoon. Fuel was not available at the hotel and the helicopter, which was kept in a hangar at the pilot's home, was refuelled to 88% full fuel load (475 litres) on the night before departure giving the aircraft an endurance of approximately 2 hours 45 minutes. The flight to the hotel proceeded uneventfully and the aircraft landed at approximately 1430 hrs after a 50 minute flight.

The weather for the return leg was fine at the point of departure, and the return flight departed the hotel on 21 January at approximately 1430 hrs. The pilot was seated in the right seat, his wife in the front left seat and his two sons and daughter occupied the rear seats. At 1450 hrs one of the passengers telephoned St Angelo Airport (about four miles south of destination) stating that the aircraft had 'run into some bad weather in the midlands' and 'requesting the weather at St Angelo'. He was told that the local weather was poor with a low cloudbase and cloud covering the hills to the west.

A VFR flight plan had been filed with Shannon ATC, and the pilot contacted Shannon after departure giving an estimated time of arrival at Enniskillen of 1510 hrs. At 1504 hrs the pilot cancelled the VFR flight plan with Shannon and was told to call Enniskillen (St Angelo Airport) when within radio range. At approximately 1510 hrs the pilot called St Angelo ATC and advised that '9 MILES SOUTH OF ENNISKILLEN AT 1000 FEET'. The ATC controller provided the latest weather conditions at St Angelo including the information that the weather appeared better to the east and north.

After some minutes, the ATC controller became concerned that he had heard nothing further from the helicopter; he made a transmission asking if the aircraft was still on frequency. In response, the pilot replied that he was 'WE ARE OUT HERE TO THE WEST PICKING OUR WAY THROUGH'. About two minutes later two open microphone transmissions were heard in St Angelo ATC; the first seemed to last for about four seconds, there was then a short break of about two seconds and the second transmission lasted about 10 seconds. There was no voice message but cockpit background sounds could be heard together with the sound of increasingly laboured breathing. In addition, throughout both transmissions there was the sound of a continuous warning horn. The St Angelo ATC controller, who was a qualified AS 350 instructor immediately identified the horn as being that of the low rotor speed/hydraulic failure warning horn.

Eyewitnesses in the village of Monea, about five miles to the west of St Angelo airport, described seeing a helicopter flying very low and slow beneath a low cloudbase at about 1515 hrs. The helicopter seemed to be trying to head in an easterly direction but low cloud over the hills to the east prevented this and the helicopter was seen to complete a 180° turn and head back in a west north westerly direction. One eyewitness to the west of Monea saw the helicopter disappear in the direction of Monea and a few minutes later heard, but could not see, the helicopter returning. A short time later eyewitnesses who were about a mile northwest of Monea saw the helicopter descend out of cloud in a nose down attitude turning to the right. The helicopter was seen to pitch further nose down and turn rapidly to the right before plunging into a copse of trees.

Several of the eyewitnesses made their way to the accident scene and found the helicopter upright but leaning forward and to the right among trees that formed the boundary of a steeply sloping field. The roof of the passenger cabin had collapsed trapping the two front seat occupants and the two passengers seated in the right rear seats. The passenger in the left rear seat was conscious and rescuers soon released him from the wreckage. When the cabin roof was lifted the two passengers in the right rear seats showed no signs of life; the front seat occupants were taken to hospital with serious injuries but the pilot died 24 hours later.

Only one of the surviving passengers could recall the last moments of the flight. He had been dozing for most of the return flight, but was roused by noises of anxiety over the cockpit interphone. He was aware of the pilot and one of the other passengers speaking and when he looked out he could see 'white all around'. He could feel that the aircraft was descending and rotating in a clockwise direction. Just before impact he noticed the ground out of the forward right window and this confirmed the rotation to the right. Throughout the period from being aroused to impact he could recall hearing a horn which he described as 'intermittent like a vehicle reversing'. The survivor estimated the time lapse between awakening and hitting the ground to be about 10 seconds. This was the survivor's second flight in the helicopter.

Pilot's background and training

The pilot began fixed wing training for a PPL (A) in May 1985 which he successfully completed in May 1986. Thereafter his fixed wing flying was sporadic, but by the time of the accident he had acquired 149 hours with his last fixed wing flight recorded in April 1999.

In March 1999 he began a rotary wing conversion on the Robinson R22B, but after about 11 hours dual training his company purchased G-OROZ and the remainder of his rotary wing training was conducted on the AS350. A PPL(H) was issued in October 1999. In the following months, he flew regularly amassing up to 20 hours every month. By the time of the accident the pilot had 317 rotary wing hours of which 306 hours were on type. Most of the flying was cross country flights in connection with the pilot's business.

In September 2000 the pilot underwent two days of refresher training at Oxford with the manufacturer's UK agent. The refresher consisted of groundschool training, a training flight and a skill test for renewal of the Licence Proficiency Check. In the course of the flight training and skill test, engine-out landings, a simulated hydraulic failure and 30° bank instrument turns were practised.

The pilot had flown almost exclusively with the same instructor from St Angelo during his PPL(H) training and, once qualified, he continued to fly frequently with the same instructor. The instructor pilot considered the accident pilot to be a good manipulator of the controls. He recalls counselling the accident pilot on the dangers of entering IMC both during and after training.

Medical and pathological information

Post mortem examination of the pilot did not reveal any condition that may have impaired his ability to conduct the flight.

Meteorological information

The Meteorological Office provided the following weather information for the period around 1500 hrs on 21 January 2001. An occluded front lay to the east of Ireland leaving a light southerly airstream covering the area. Cloud was generally 6 oktas stratocumulus base 5,000 ft amsl and 7 oktas stratus base 400 ft amsl with hill fog over high ground. Winds between the surface and 1000 feet amsl were generally light south to south easterly at about 5 to 12kt.

Actual weather conditions recorded between 1500 hrs and 1600 hrs at St Angelo Airport (about 5 miles east of the accident site) indicated a southeasterly surface wind at 5 kt, good visibility with 7 to 8 oktas of stratus at 3 to 400 feet above airfield level. Temperature was 6° C and dewpoint 5°C.

Witnesses near the crash location described dry but overcast conditions with low cloud covering the hills. In the valleys visibility under the cloud was good, but conditions were changing rapidly and clear conditions became mist and fog in a matter of minutes. The pilot of a military helicopter dispatched to assist the rescue services at the accident site estimated the cloud base in the general area of Enniskillen as 500 feet agl with the cloud base at the accident site at 150 feet agl.

It could not be determined if the pilot or any member of the family had obtained meteorological information prior to departure from Cong, and none of the normal sources had any record of an enquiry from the helicopter's occupants.

Flight data

The helicopter was not required to be equipped with a flight data recorder or a cockpit voice recorder and neither was fitted. High terrain along the route screened the helicopter from ATC radar coverage. However, the aircraft's Global Positioning System (GPS) had retained a recording of the aircraft's track and groundspeed on the flights to and from Cong and this data was successfully retrieved.

On the outbound leg, the GPS data showed an almost straight line soutwesterly route from the east shore of Lough Erne to Cong. The return route was a reciprocal of the outbound route until about 5 miles East of Connaught airport. At this point the route diverged to the east and at a position about 9 miles to the east of Connaught Airport speed was reduced from a cruise groundspeed of about 130 kt to 40 kt for a period of about five minutes. During this period the helicopter carried out one anti-clockwise orbit. Following this orbit the helicopter resumed a northeasterly track, parallel and about 5 miles to the southeast of the outbound track, until a point about 9 miles south of Enniskillen. Here the aircraft turned on to a northwesterly track taking it to the west of Enniskillen and speed was again reduced to groundspeed 30 kt or less.

The last 5 minutes of GPS data showed the aircraft flying toward Monea from the south at groundspeeds down to 14 kt. In the area of Monea the helicopter carried out two 360° orbits before departing to the west of Monea and then to the north over Killyveagh Glebe. The GPS data then shows the helicopter crossing the B81 Monea to Derrygonnelly road and accelerating back up to 80kt. There is then a discontinuity of data between the penultimate GPS data point located 800 metres north of the crash site and the final GPS data point which shows the helicopter on a westerly track about 150 metres north of the crash site at a groundspeed of 22 kt.

The GPS data is consistent with eyewitness data until the helicopter crosses the B81. The police made enquires at houses north of the B81, but although people had been present at about the time

of the accident no-one could be found who had seen or heard the helicopter in the area. An eyewitness at a farm just south of Killyveagh Glebe who heard the aircraft pass over the farm and then saw it descend out of cloud about half a kilometre to the northwest reported that she heard the aircraft throughout. She also considered that the time between the over flight of the farm and impact seemed consistent with direct flight between the farm and the impact point.

GPS Installation

The GPS system fitted to the aircraft comprised a panel-mounted GPS receiver coupled to a colour moving map display. The GPS receiver was capable of computing the position of the aircraft on a continuous basis and displaying that position, together with other navigation information, on a small screen on the front of the equipment

Analysis of the moving map data snapshots and the last position computed by the receiver showed anomalies during the final stages of the accident flight. Out of the last three snapshots recorded in the moving map equipment, the first two showed unusual variations in groundspeed. This may have been due to an inability of the GPS receiver to compute accurate positions thus propagating errors into the calculations of speed during the thirty seconds that separated these two, recorded points. There was a discontinuity in the recording between the penultimate and final recorded points. The moving map equipment was designed to insert a discontinuity in the record whenever a positional fix was not available or when the end of a flight (based on groundspeed values) had been detected. Evidence in favour of a loss of satellite fix may be inferred from the error in the last recorded position retained by the GPS receiver. This position was calculated to be approximately 1.2 km north-east of the accident site.

Aircraft information

Systems Control Console (SCC)

Many of the systems on the helicopter are controlled via the Systems Control Console which is located centrally below the instrument panel, within easy reach of the pilot's left hand. The SCC contains push-button type switches which operate various systems such as the fuel pumps, windscreen wipers and external lights. The switches are located in individual recesses within the console and are colour coded and clearly identified with legends. The switches are flush with the surface of the console when in the off position and are recessed when in the on position. To select a switch on, it must be depressed in its recess until it latches in the on position. Pressing the switch again causes it to unlatch and return to the off position.

Fuel Control

A Fuel Control Lever (FCL) located on the floor to the left of the pilot is used to control the fuel supply to the engine for engine starting. Once the engine has started, the FCL is moved forward into the flight detent where the main rotor speed is automatically governed to 390 RPM by the hydro-mechanical governor in the Fuel Control Unit. This reduces the pilot's workload by removing the need for him to operate the throttle in flight. Should the governor fail, moving the Fuel Control Lever forward from the flight detent into the emergency range bypasses the governor, enabling the pilot to directly control the engine power manually to maintain the correct rotor RPM. If the main rotor RPM drops below 360 RPM a continuous horn tone alerts the pilot of low rotor RPM. An intermittent tone from the same horn warns the pilot if the rotor RPM increases above 410 RPM. Main and tail rotor RPM are indicated on a gauge on the instrument panel. Advice from the

manufacturer and pilots experienced on type is that, with a serviceable governor, a droop or increase in rotor RPM due to harsh manoeuvring would be likely only to cause a brief sounding of the warning horn before RPM recovered automatically to within limits.

Hydraulic system

Hydraulic pressure to drive the main and tail rotor servos is provided by a gear-type pump which is belt-driven from the main gearbox. A hydraulic low pressure switch and the hydraulic test solenoid valve are integral with the pressure regulator.

A toggle switch on the collective lever allows the hydraulic system to be selected on and off. Selecting the switch to 'off' dissipates the hydraulic pressure in the main rotor servos, providing a manual reversion capability to allow the pilot to retain control of the helicopter in the event of a servo jam.

Nitrogen-filled accumulators on the main rotor servos provide hydraulic assistance for a short time if hydraulic pressure is lost, allowing the pilot to slow the helicopter and land. When the accumulators are exhausted, the control forces become significantly higher, though not unmanageable.

A hydraulic test ('HYDR TEST') push button switch in the Systems Control Console allows the main rotor servo accumulators to be tested. The accumulators are tested during the pre-flight checks by selecting the 'HYDR TEST'switch on and moving the cyclic stick to verify that the accumulators are providing assistance. It is not normal practice to operate the hydraulic test button in flight and the AS350B2 Flight Manual cautions against this, as operation of the test switch depressurises the accumulator in the yaw compensator servo, resulting in high yaw pedal forces. The 'HYDR TEST' switch is a distinctive orange colour, which distinguishes it from the other switches within the console.

The hydraulic low pressure switch activates when the hydraulic pressure drops below approximately 35 bar. This illuminates the red 'HYD' warning light on the WCAP and produces a continuous tone from the warning horn. The same horn provides warning of low main rotor RPM. The horn remains on until the failure condition is removed or the horn is cancelled by the pilot. The horn may be cancelled by pressing the horn cancel button on the Systems Control Console. The amber 'HORN' light on the Warning Caution Advisory Panel (WCAP) illuminates as a reminder that the horn has been cancelled.

Accident site information

The helicopter crashed in a copse of trees bordering a field on the south slope of a ridge near the south shore of Lough Erne, approximately 7 miles west of Enniskillen. The crash site was located 200 feet amsl. Boggy conditions and steeply sloping fields made rescue and wreckage recovery activities difficult.

Main rotor blade damage to surrounding trees indicated that the helicopter was in a slightly nose down attitude and banked approximately 30° to the right on impact. Crash site and wreckage examination indicated that the helicopter had a high rate of descent and relatively low speed forward and to the right on impact. The helicopter remained upright and came to rest leaning against a tree which had struck the right side of the fuselage.

The wreckage was intact and all parts of the helicopter could be accounted for at the crash site. No evidence of bird strike, mid-air collision or in-flight structural failure was found. There was no post-impact fire. Fuel from a small leak in the fuel tank had contaminated a large area of the slope below the crash site and fuel continued to leak from the wreckage for several hours after the accident. The hydraulic fluid reservoir was ruptured and the right side of the fuselage was stained by hydraulic fluid.

The main rotor blades had cleanly cut through several trees trunks up to 25 centimetres in diameter. Both the main rotor blades and main rotor head were severely damaged, but the blades had remained attached. The main rotor blades had split open at several locations on their trailing edges due to the shock load from impact with the trees. The outer portion of one main rotor blade had shattered and small pieces of the foam core and fibreglass sheath were found scattered around the crash site. By comparison the tail rotor and tail boom, including the horizontal and vertical stabilisers, were undamaged, except for minor scuff marks from small tree branches.

Detailed wreckage examination

General aircraft damage

The helicopter sustained moderately severe damage on impact, including detachment of the cabin side and roof panels. With the exception of the right side of the rear cabin, the cabin area and cabin floor were relatively undamaged. The lower front fuselage of the helicopter had struck a small bank, badly damaging the nose of the helicopter and the pilot's footwell. The fairing panels and structure under the cabin floor were crushed and had trapped the flight control rods. Both front seats had broken away from their attachments to the cabin floor. The right side of the fuselage behind the cabin was severely damaged by impact with the tree against which the helicopter came to rest. The tail boom had partially separated from the fuselage due to the vertical impact loads.

The engine

The engine manufacturer, under AAIB supervision, tested the engine. After a preliminary visual examination the engine was run at various power settings up to 95% before power turbine blade tip rub resulting from the impact required the engine to be shut down. The Fuel Control Unit was bench tested and correct operation of the governor was verified. The alignment marks on the power turbine pinion gear and its securing nut were found to be out of alignment by 1 millimetre, indicating that the engine had been exposed to a torque approximately twice the allowable normal maximum operating torque, which according to the engine manufacturer cannot be generated in flight even with very rapid collective control inputs.

Main Gearbox/Rotor Head

The main gearbox input drive pinion flexible (Thomas) coupling had failed due to torsional overload. The flexible coupling between the engine shaft and the short tail rotor driveshaft had failed in a similar manner. Internal inspection of the main gearbox did not reveal any damage and the gearbox turned freely. The pitch control mechanisms on the main rotor head were intact and operated correctly. The 'Starflex' rotor hub arms were sheared at an angle consistent with the main rotor blades having been driven at the time of impact. The main gearbox had torn from its mountings and had collapsed on top of the fuel tank below. The energy absorbing characteristics of its polyamide construction prevented the fuel tank from rupturing. At the same time the main gearbox was thrown forward and to the right, causing the right-hand front gearbox suspension bar

to strike the cabin rear bulkhead, causing significant intrusion into the right-hand side of the rear cabin.

Primary controls

Continuity of the cyclic, collective and yaw controls was confirmed. After freeing the trapped collective and cyclic control rods, these controls could be operated satisfactorily. The yaw pedals could not be freed due to the extent of the damage in the pilot's footwell. It was not possible to establish the position of the controls at the time of impact due to the dynamic effects that the impact would have had on the control positions.

The Fuel Control Lever was found in the fully forward position, corresponding to the emergency range.

Instruments

The engine torque meter was at full scale deflection, indicating a torque reading of 130%. The method of construction of this instrument is such that it will retain the reading if power is removed and the needle cannot be backdriven. The torque meter reading was therefore taken to be a reliable indication that a high collective control demand was being input at the time of impact and that the engine was producing significant power.

Hydraulic System

There was no evidence of an in-flight hydraulic failure. The hydraulic pump drive belt was intact but had been pulled off the drive pulley most likely due to the impact. Residual hydraulic fluid was found in the hydraulic servos and hydraulic pipes and the hydraulic filter was free of debris. Evidence at the crash site indicated that there was hydraulic fluid in the reservoir at the time of impact. The hydraulic selector switch on the collective lever was in the 'ON' position. The hydraulic test 'HYD TEST' push button switch on the Systems Control Console was in the 'test' position (depressed). The warning horn cancel button was not selected.

The hydraulic pump, pressure regulator, low pressure switch and main and tail rotor servos were tested by the helicopter manufacturer in the presence of an AAIB Inspector and found to operate satisfactorily.

Front Seats

Both front seats had detached from the floor in the impact. Rescuers found the pilot still in his seat, lying across the rear seat occupants. It was evident that both front occupants had been thrown forward and to the right when their seats became detached. There was evidence that the pilot had been thrown against the cyclic stick and the instrument panel and his head had struck the door frame.

The front seats were the standard, original fit AS350 high-backed seat which is entirely of a moulded fibreglass construction. The seats were identified with part number 77125805 on the seat back. The shoulder harness inertia reel unit is attached at the bottom of the seat back. Longitudinal steel strips located on either side of the base of the seat pan allow the seat to be bolted to the 'C' section seat rails. The seat rails are locked in place in the cabin floor by turnbuckles which locate in slots in the bottom flange of the seat rails.

Both front seats had failed in a different manner on each side of the seat. The seat rails had torn out of the base of the pilot's seat, leaving the seat rails still attached to the cabin floor. The right side of the seat base had failed extensively due to vertical compression loading. The left side of the seat base was largely undamaged, except where the fibreglass had sheared around the periphery of the seat rail attachment due to tension loading.

The right side of the front passenger's seat base had failed the same manner as the right side of the pilot's seat base. On the left side, the entire seat rail had pulled out of the cabin floor due to the slots in the seat rail having been distorted sufficiently to allow the seat rail to become released from the turnbuckles. The outer section of the rear slot had failed in overloading and was missing. The seat rails were fitted with 'L' shaped brackets which overlapped the outer edges of the slots and were designed to limit the extent to which the slots could open up, but this proved ineffective due to the slots having experienced significant vertical as well as lateral distortion.

The failure of the front seat bases was inconsistent with the relative lack of damage to the cabin and in particular the cabin floor. Similar failures of the seat rail attachments at the seat base and the cabin floor attachment were seen in a previous fatal accident to an AS350 helicopter with the same type of seats (AAIB Accident Report 4/96 refers). The seats have also been known to fail even under fairly gentle impact loads, as reported in AAIB Bulletin 1/2001 in which an AS355 helicopter made a forced landing on the roof of a house and in which the occupants sustained no injuries.

Although the AS350 fibreglass front seats met the crashworthiness testing requirements applicable at the time that the helicopter was certificated in 1978, subsequent experience proved these requirements to be inadequate. Accordingly in 1989 the FAR Amendment 25 regulations revised the certification loading requirements upwards considerably. The same requirements are reflected in JAR 27.561:-

	Static Load Factor (g)	
Load Direction	**FARs Amdt 10**	**FARs Amdt 25/JAR 27.561**
Down	4	20
Up	1.5	4
Sideways	2	8
Forwards	4	16

Seats designed to the latest specifications which are installed on the current generation of new helicopters by necessity have a substantial metal frame to enable them to meet the new design criteria. These seats are available as a customer-specified option on the AS350B3 which is the latest variant of the AS350. Eurocopter Lettre Service No. 1424-25-99 was issued in November 1999 to advise operators that the new crashworthy seats could be retrofitted to earlier variants of the AS350 under an optional Service Bulletin (SB No. 25.00.57) issued in May 1999. In view of the cost and time involved (6 man-weeks) to perform this modification, it is unlikely that many operators would have opted for the improvement, particularly if they had been unaware of the deficiencies of the fibreglass seats.

Lettre Service No. 1424-25-99 also recommended that operators who opted not to install the new crashworthy seats should modify their fibreglass seats in accordance with Eurocopter SB No. 25.00.63. issued in 1999. This SB was issued in response to the Safety Recommendations made in previously mentioned AAIB Formal Report 4/96. The SB adds 4 additional plies of fibreglass to the lower seat pan and introduces new 'T' section seat rails. The SB is recommended by Eurocopter but has not been made mandatory by the DGAC or CAA.

Harnesses

The front and rear passengers' harnesses had remained intact and showed evidence of having been cut by rescuers to free the occupants. The pilot's shoulder straps were intact, but his left lap strap had released from its floor attachment shackle due to failure of the stitching. The lap strap appeared to be in good condition and there was no evidence of distress to any of the harness components.

Additional information

The helicopter was not equipped or certified for flight under Instrument Flight Rules and the pilot was not qualified to fly in Instrument Meteorological Conditions. The flight therefore had to be conducted under Visual Flight Rules. The Air Navigation Order Section 2, Rules of the Air, Rule 26 (2) specifies the following for VFR flights:

> (a) .....an aircraft flying outside controlled airspace below flight level 100 shall remain at least 1500 metres horizontally and 1000 feet vertically away from cloud and in a flight visibility of at least 5 km.
>
> (b) Sub-paragraph (a) shall be deemed to be complied with if:
>
> > (iii) in the case of a helicopter the helicopter is flying at or below 3000 feet above mean sea level flying at a speed, which having regard to the visibility is reasonable, and remains clear of cloud and in sight of the surface.

However, sub-paragraph b (iii) is subject to the overriding requirement of Rules of the Air, Rule 5 (1) (e) which specifies that:

> (e) An aircraft shall not fly closer than 500 feet to any person, vessel, vehicle or structure.

The skill test for initial issue and renewal of a helicopter PPL(H) rating requires that the pilot demonstrate the ability to conduct a 180° level turn solely by reference to instruments. However, the helicopter is basically an unstable machine and the general view amongst helicopter instructor pilots is that even such a basic manoeuvre in cloud is likely to be beyond the ability of a low experience holder of a PPL(H). Indeed this view is reflected in the advice provided in the CAA General Aviation Safety Sense Leaflet 17B, Helicopter Airmanship. Paragraph 4.7 states:

> b If you encounter deteriorating weather **turn back or divert before you are caught in cloud.** A 180° turn in cloud can easily become a death spiral.

Sub-paragraph d states further:

d If conditions get worse e.g. 1000 foot cloud base and 3 km or less visibility turn back, divert or make a precautionary landing before entering cloud. **Don't PRESS ON - LAND ON!**

Analysis

General

Evidence from eyewitnesses on the ground and the surviving occupant of the helicopter indicates that the helicopter descended from cloud out of control. It is possible that the pilot suffered some incapacitation between his last deliberate RTF transmission to St Angelo Tower and impact, but evidence from the survivor that the pilot was talking in the last moments of flight and the lack of any post mortem evidence makes this unlikely. The main possibilities are therefore some sort of technical failure that caused a loss of control, pilot disorientation as a result of being inadvertently in IMC or a combination of these two factors. These possibilities are examined in light of the evidence available.

Helicopter serviceability

The helicopter had flown satisfactorily the previous day and for some 40 minutes prior to the accident with no reports of any problems.

At the crash site there was evidence of significant fuel having been available and damage to the trees, main rotor blades and engine and drive train components indicated that the engine was producing power at the time of impact. Subsequent testing of the engine confirmed that it was capable of producing power. No evidence of failure of the flying controls or hydraulic system was found. No technical reason could be found which could account for the hydraulic test switch being in the test position. The Fuel Control Lever position being found in the emergency range might have indicated a governor failure, however testing of the FCU proved the governor operation to be satisfactory. The location of the lever on the cockpit floor between the front seats is such that it could easily have been moved during the rescue activities, and therefore cannot be taken in isolation to be definitive evidence of a technical failure.

In summary, despite extensive testing no evidence was found of any failure of the helicopter or any of its flight critical systems which might explain the circumstances of the accident.

Weather conditions

Meteorological Office data and evidence from witnesses indicates that the weather around the time of the accident in the Monea area was very poor. Conditions were changing rapidly but could be generally characterised as a very low cloudbase with cloud covering the high ground, but good visibility below cloud.

The investigation found no evidence to indicate that the pilot obtained meteorological information before departure from Cong, and it is therefore possible that the pilot was caught unawares by the deterioration in the weather around Enniskillen. However, given the information provided by St Angelo Tower during the mobile phone call at 1450 and the poor weather in the 'midlands' to the South of Enniskillen it is reasonable to assume that the pilot would have expected some deterioration in the weather by the time he reached Enniskillen. Moreover the GPS data showing that the pilot started to reduce speed about 5 miles south of Enniskillen tends to indicate that the

weather was deteriorating in that area and that the pilot was taking the precaution of reducing speed as he had done when encountering poor weather earlier.

On encountering deteriorating weather conditions a pilot must determine the point at which he can no longer comply with VFR. The evidence from witnesses around the village of Monea indicates that the aircraft was flying at very low speed and well below 500 feet AGL. It is therefore unlikely that the pilot was operating in compliance with the Rules of the Air at this stage and certainly the conditions were considerably below the point at which the CAAs General Aviation Safety Sense Leaflet 17B recommends a turn back. In these circumstances with the helicopter being flown at low speed below a very low cloud base in rapidly changing weather conditions it is highly likely that the pilot inadvertently entered IMC

The warning horn

The investigation was unable to discover any mechanical reason why the warning horn should have been sounding in the helicopter's last few seconds of flight. All hydraulic components were found to be serviceable, hydraulic fluid was available and although the pump drive belt was detached at the crash site this probably occurred at impact. Moreover the rotor RPM governor was found to be serviceable. Advice from the manufacturer and pilots experienced on type is that, with a serviceable governor, a droop or increase in rotor RPM due to harsh manoeuvring would be likely only to cause a brief sounding of the warning horn before RPM recovered to within limits.

Evidence from the passenger that the horn was in fact *intermittent* rather than *continuous* casts further doubt on the reason for the horn's activation. However, given the highly stressful circumstances in which the horn was heard and the other noises that were occurring in the cockpit at the time, it seems more likely that the witnesses in the St Angelo tower, including an instructor qualified on type, were correct in identifying the horn as being continuous.

It has not been possible to determine why the hydraulic test switch was found in the wreckage in the activated position. The switch may have been depressed during impact or inadvertently by rescue crews, but there is a possibility that the switch had been pressed inadvertently in flight perhaps in an attempt to activate a light or more likely the windscreen wipers. In any event, if the switch had been depressed in flight the horn alone would have significantly increased stress levels in the cockpit and if the flight controls subsequently went into manual control (which would have happened automatically with the test switch activated once the accumulators were exhausted) the pilot workload would have been very high.

Whether the horn caused the pilot to become distracted and enter IMC inadvertently or whether the horn came on later and added to the cockpit stress levels after the aircraft had entered cloud cannot be known. However, if the horn was accompanied by flight in manual control in IMC close to the ground, the workload would have been extremely high and the chances of a successful recovery by a relatively inexperienced pilot would have been remote.

Survivability

Although the impact forces were moderately high, the cabin and cabin floor, with the exception of localised areas of damage, remained intact and the greater volume of the occupant space was unintruded. The fact that there were survivors from the crash indicates that the decelerations experienced by the occupants, although very high, were within the limits of human survivability. The lack of fire was also a major contributory factor for survival and this illustrates the improved

crashworthiness of the polyamide fuel tank fitted to the single-engined AS350 as compared to the metal fuel tank in the twin-engined AS355 helicopter.

The failure of the front seats to remain attached to the floor under moderate and survivable crash loads has once again highlighted the poor crashworthiness of the fibreglass front seats fitted to the AS350 helicopter. The attachment of the shoulder harness inertia reel to the seat back is an undesirable feature as it allows the inertia load of the occupant's upper torso to be transferred to the seat, contributing to the failure of the seat. Once the seat has detached from the cabin floor, the combined inertia loads of the occupant and the seat are transferred to the lap strap. The failure of the pilot's left lap strap appears consistent with the strap having been overloaded by the forces imparted as the pilot and his seat was thrown forwards and to the right. Once the lap strap had failed, the pilot would have been unrestrained. Evidence in the wreckage indicated that the pilot was thrown forward against the cyclic stick and the instrument panel and his head had struck the door frame. This accounts for the severe secondary injuries to the pilot's head and upper body which were identified in the pathology report. It was noted however, that even if the pilot's lap strap had remained intact, the shoulder straps would have tended to pivot the seat forwards around the pilot's lap strap and he would probably still have sustained severe upper body injuries. It is believed that the pilot's chances of survival would have been greatly improved had his seat remained attached to the floor.

Although the reinforcements to the seat pan and the new seat rail introduced in SB 25.00.63 are undoubtedly improvements, it is doubtful that they would have prevented the seats from detaching from the cabin floor in this accident, given the high impact loads and the inherent weakness of the seat pan as a whole.

The two rear passengers seated on the right side incurred fatal injuries as a result of a combination of impact forces, lack of upper torso restraint and the intrusion of the cabin rear bulkhead into their survival space. These passengers may have benefited from the use of shoulder harnesses had they been available, however it is highly likely that they would nonetheless have received fatal injuries due to the extent that the cabin rear bulkhead intruded into their survival space.

The CAA has been invited to publicise the availability of improved crashworthy seat for AS 350 helicopter variants.

Conclusions

The aircraft was seen to descend out of cloud and hit the ground. This was probably as the result of the pilot losing control due to his disorientation following an inadvertent entry into IMC conditions. The reason the aircraft entered cloud has not been determined but the aircraft was being flown in very poor, rapidly changing weather conditions in which there would have been a high risk of inadvertent IMC entry. The reason for the activation of the warning horn has not been determined and therefore its contribution to the accident cannot be certain, but it would probably have increased pilot stress levels and rendered more difficult any attempted recovery from IMC.