Aircraft Type and Registration:	Agusta A109E, G-PWER
No & Type of Engines:	2 PW206C turboshaft engines
Year of Manufacture:	2000
Date & Time (UTC):	3 March 2004 at 1939 hrs
Location:	1 mile east of Bournemouth (Hurn) Airport, Dorset
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Fatal) Passenger - 1 (Fatal)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	35 years
Commander's Flying Experience:	3,094 hours (of which 78 were on type) Last 90 days - 54 hours Last 28 days - 11 hours
Information Source:	AAIB Field Investigation

Synopsis

The pilot was flying a visual approach to Bournemouth Airport in poor weather at night; radar data indicated that the aircraft was tracking the extended centreline of Runway 26 at between 800 to 1,000 feet amsl. The pilot declared that he was visual with the airport but, shortly afterwards, the radar data indicated that the aircraft had entered a turn to the left. The aircraft turned through about 540° before striking the ground, fatally injuring both the pilot and the passenger. The pilot had probably become disorientated, and his limited instrument flying background did not equip him to cope with degraded visual environment. There was no evidence from the wreckage recovered of any mechanical failure or unauthorised interference with the aircraft or its systems that may have contributed to the accident.

History of the flight

The pilot had planned to collect the owner of the aircraft from Battersea Heliport and fly him back to Bournemouth Airport. He was familiar with the route to be flown and was notified of the task on the day of the accident. Prior to the flight he was seen accessing meteorological data from a computer terminal at the company premises; this was the normal method used for meteorological briefing but there was no record of the weather information that he obtained. At 1819 hrs the aircraft departed Bournemouth Airport on a Special VFR[1] clearance to transit to Battersea Heliport where it landed at 1856 hrs; the pilot was the sole occupant of the aircraft on this flight. The owner walked to the aircraft accompanied by a member of the ground staff and occupied the rear left seat in the passenger cabin; his three pieces of hand luggage, which he had brought with him, were placed onto the seat opposite him. Having seen the passenger secure his seat belt the ground handler closed the cabin door and indicated to the pilot that the aircraft was secure. No other bags or freight were loaded onto the aircraft.

The aircraft departed from Battersea Heliport at 1859 hrs. The reported meteorological conditions at 1820 hrs had included a visibility of 7 km, broken cloud at 3,800 feet with no significant weather. Recorded radar data indicates that the helicopter followed a direct track towards Bournemouth. The helicopter was initially cleared to an altitude of 1,400 feet and, when clear of the London Control Zone, received further clearance to an altitude of 1,700 feet.

At 1920 hrs the pilot contacted Solent Radar, who provided a Flight Information Service. Because of traffic departing from Southampton, Solent Radar cleared G-PWER to fly not above 1,500 feet on a route via Romsey. Recorded radar data indicates that the aircraft descended to an altitude of 1,400 feet and followed the required routing. A professional pilot at Whitenap, on the south-east outskirts of Romsey, heard a helicopter pass overhead at what he estimated to be approximately 1,500 feet. He stated that the weather was cold and misty and that he could see the cloud reflecting the ground illumination, he estimated the cloud base to be at about 500 to 600 feet. He did not see the helicopter and considered that it was in or above the cloud.

After a hand-over from Solent Radar, Bournemouth Approach control cleared the aircraft "TO ENTER BOURNEMOUTH CONTROLLED AIRSPACE SPECIAL VFR VIA STONEY CROSS NOT ABOVE 2,000 FEET QNH IS ONE ZERO TWO THREE MILLIBARS": (Stoney Cross is a visual reference point (VRP) to the northeast of Bournemouth Airport). After acknowledging this clearance the pilot was instructed to change to the Tower frequency and to "REPORT VISUAL WITH THE FIELD". Having changed to the Tower frequency the pilot requested permission to "POSITION STRAIGHT IN FOR 26": this was approved and he was instructed to report the airfield in sight. The most expeditious route to comply with this clearance, and one with which the pilot was familiar, would have been direct from Stoney Cross to the airfield. This route transits large areas of poor cultural lighting but at Stoney Cross any low cloud should have been visible silhouetted against or obscuring well illuminated areas such as

[1] Special VFR: Clearance for Special Visual Flight Rules is an authorisation by ATC for a pilot to fly within a Control Zone although he is unable to comply with Instrument Flight Rules.

Ringwood. The weather at Bournemouth Airport, recorded at 1920 hrs was: surface wind 180°/10 kt, visibility 2,700 metres in light rain with a few clouds at 1,200 feet, scattered cloud at 1,700 feet and broken cloud at 2,500 feet.

The last recorded radar position was at Stoney Cross VRP, when the aircraft was tracking parallel to the M27/A31 which, with the vehicle lights, would have been a well defined line feature at night. The subsequent track of the aircraft was not recorded on radar due to terrain screening. Progress along the A31 and then down the A338 would have provided a simple routing to follow, with the lights of Ringwood giving good references and an easily identifiable position. If however low cloud and poor visibility prevented that option then using the ILS localiser would have provided an accurate track along the extended runway centre line and the best opportunity to acquire the runway and approach lights.

The Tower Controller and the Radar Controller were both in the visual control room of the ATC tower at Bournemouth Airport but were unable to see the helicopter which was observed on a remote radar monitor to be tracking the extended centreline of Runway 26. The pilot acknowledged his clearance to land and the tower controller asked, "ECHO ROMEO JUST CHECK YOU ARE VISUAL WITH THE FIELD". The pilot stated "ER NEGATIVE NOT THIS TIME ECHO ROMEO". The controller confirmed that they could not see the aircraft either and turned the runway and approach lighting up to the maximum intensity. Shortly afterwards the pilot transmitted, "ER JUST BECOMING VISUAL THIS TIME". The controller recalled that just as that transmission was made the aircraft, which was about 1 to 1·5 nm from the airport, commenced a descending turn to the left. The controller transmitted "GOLF ECHO ROMEO DO YOU REQUIRE RADAR AT ALL" to which the pilot responded "YEAH", eleven times in quick succession. Having acknowledged that response, the controller asked "GOLF ECHO ROMEO EVERYTHING OK"; the pilot responded "NEGATIVE NEGATIVE". The radar returns indicated that the height of the aircraft reduced from about 1,000 feet to 400 feet during the first 180° of the turn and, as the aircraft continued the left turn, it climbed back towards 1,000 feet. Having completed a turn of approximately 360° the left turn continued through a further 180°, continually descending before the height readout was lost on the radar. During these manoeuvres, the pilot twice maintained an 'open mike' with continuous transmissions, initially for 29 seconds followed nine seconds later by a further 18 second transmission. During these transmissions the pilot confirmed that he had a problem but did not describe what it was, but stated "YEAH WE'VE GOT POWER". Shortly before impact he transmitted "OKAY IT'S OKAY I NEED A CLIMB I NEED A CLIMB".

The controller had been unable to locate the aircraft visually but saw the fireball created by the impact with the ground. The aircraft had struck the surface of a grass field at high speed whilst in a nose down attitude banked to the left. Both persons on board were fatally injured.

Pathological information

Post mortem examinations of the occupants revealed that both persons had died from multiple injuries. No evidence was found in the pilot of any disease, alcohol, drugs or any toxic substance which could have caused or contributed to the cause of the accident.

Pilot's background and flying experience

The pilot had recorded his flying hours in three separate log books from which the information set out below was collated.

He commenced flying on 26 July 1993 and then went to the United States where he gained an FAA commercial licence, with an instructor rating, and spent some four years as a flight instructor accumulating flying hours. He was issued a UK Private Pilot's Licence (Helicopters) with an instructor rating on 19 June 1998. Since then he had continued flying as an instructor, mainly on the Robinson R22 helicopter but he also did some instructing on the Robinson R44. Having completed the necessary requirements he was issued with a UK Airline Transport Pilot's Licence (Helicopters), (ATPL/H), on 20 January 2000. A type rating for the Agusta A109C was issued on 21 March 2001 after the pilot had completed a conversion course between 23 May 2000 and 7 March 2001. A differences course for the more complex Agusta A109E was undertaken on 22 and 23 December 2003; since the successful completion of that training he had recorded 78 hours of flying on the type of which 15 hours 27 minutes were at night. He had demonstrated to colleagues a working knowledge of the autopilot, which he had accrued as a result of experience on the aircraft. He had operated the aircraft mainly between Bournemouth, Battersea Heliport and the owner's private residence in Dorset. The pilot did not hold a UK Instrument Rating.

As far as could be established, prior to 6 December 1999 the pilot had recorded a total of 44 hours night flying, of which 33 hours and 20 minutes was as pilot in command and 10 hours and 40 minutes were dual. A total of 30 hours and 40 minutes of instrument flying was also recorded up to that date. From 6 December 1999 until the date of the accident there was no further record of any instrument flying and only 40 minutes of night flying had been recorded until the pilot commenced flying G-PWER on 1 January 2004; since that date he had recorded 15 hrs and 30 mins of night flying in G-PWER.

Brief description of G-PWER

The Agusta 109E helicopter G-PWER had been purchased by the owner in December 2003 and was used for private and business purposes. It was fully equipped for operation under the Instrument Flight Rules (IFR) with an Electronic Flight Information System (EFIS), an autopilot and standby flight instrumentation.

The owner had previously owned a Robinson R44 helicopter which was used for the same purposes but as he intended to carry out more night and overwater flights, he decided to procure a twin engine, IFR capable helicopter. He was satisfied with the service provided by the pilot who flew him on a regular basis in the R44 and when he took delivery of the Agusta 109E he arranged for that pilot to complete the differences course in order to qualify him to fly it.

Meteorological information

An aftercast provided by the Meteorological Office showed a moist south-westerly airflow covering the route from Battersea to Bournemouth. The leading edge of an occluded warm front lying north/south had moved east into the Bournemouth area at the time of the accident. The weather associated with this front was overcast and misty with outbreaks of light rain and drizzle; the surface visibility was generally 5 to 6 km deteriorating to 1,500 to 2,500 metres in any precipitation. There were areas of broken stratus cloud with a base of 600 to 1,000 feet and a further layer of strato-cumulus cloud which was broken to overcast with a base at 1,700 feet. The mean sea level pressure was 1023 hPa.

The latest Bournemouth Airport Terminal Approach Forecast (TAF) was available from 1516 hrs on 3 March and covered the period from 1600 hrs on 3 March to 0100 hrs on 4 March. It forecast a surface wind from 180° at 12 kt with a visibility greater than 10 km and broken cloud at 3,500 feet. Temporarily the visibility was forecast reduce to 7,000 metres in rain with broken cloud at 1,200 feet. There was a 30% probability, between 1700 hrs and 2200 hrs, of a temporary increase in the surface wind from 180° to 15 kt with gusts to 25 kt, together with a reduction in visibility to 3,000 metres in heavy rain with associated broken cloud at 800 feet and broken cumulo-nimbus cloud at 1,800 feet. In the period between 2000 hrs and 2200 hrs the surface wind was forecast to change direction to 240° at 10 kt as the front moved across the area to the east.

Relevant elements of the weather recorded at Bournemouth Airport covering the period after the aircraft's departure for Battersea at 1819 hrs are presented in the table below.

Time of Observation	Surface wind	Visibility (metres)	Weather	Cloud
1820 hrs	190º/ 09 kt	4,000	Light drizzle	Overcast at 2,100 ft
1850 hrs	180º/ 11 kt	2,900	Light rain	Overcast at 1,700 ft
1920 hrs	180º/ 10 kt	2,700	Light rain	Few at 1,200 ft Scattered at 1,700 ft Broken at 2,300 ft
2020 hrs	190º/ 10 kt	3,000	Light rain	Few at 600 ft

Note: No observation was made at 1950 hrs because ATC were dealing with the accident.

The reported meteorological conditions were available on the Automatic Terminal Information Service (ATIS), which the pilot would be expected to use. Other airports nearby, such as Southampton and Boscombe Down, showed a similar rapid deterioration in visibility and cloud base as the occluded front passed over them. A professional pilot, who heard the helicopter pass overhead on its approach to Bournemouth, reported that the weather over the south-east of Romsey at the time was cold and misty and he estimated that the cloud base was about 500 to 600 feet.

Bournemouth Airport

Bournemouth Airport Air Traffic Control Zone (ATCZ) is class D airspace and extends to a radius of 5 nm from the airport reference point, which is the centre of Runway 26, and has a vertical extent from the surface to a height of 2,000 feet.

Runway 26 at Bournemouth is 2,271 metres long, 46 metres wide and has an asphalt surface. The airfield elevation is 38 feet and the threshold elevation for Runway 26 is 30 feet. Runway and approach lighting consists of white High Intensity Runway Edge Lighting, Precision Approach Path Indicators located to the left of the touch down zone and set to 3°, and a Calvert, five bar, High Intensity Approach Lighting System. Prior to the accident the runway and approach lighting were set to the maximum intensity. In addition there was concentrated and scattered lighting within the airfield boundary, both from the internal lights of buildings and external lighting gantries, which lighting illuminated parking and maintenance areas.

The aircraft's track from Stoney Cross took it over the area to the north-east and east of the airfield. This area is sparsely populated with only one major road near the airport, the A338, running north/south 1 km east of the runway threshold: a wood containing tall, mature trees bordered the eastern edge of this road. The small, dispersed village of Avon is located on the extended runway centreline at a distance of 2 km from the runway threshold. The area surrounding Avon for a radius of approximately 2 km has only isolated properties and minor roads. The lights from these isolated buildings and the headlights of passing vehicles would have provided only very limited sources for external visual reference.

Whilst the approach lights and airfield lighting would have provided good visual references the area to the east and northeast of the airfield was dark and featureless with virtually no external visual references discernible in the prevailing visibility. In addition, the reported surface visibility of 2,700 metres was probably further reduced by rain on the cockpit windows. There would also have been no discernable horizon and the only lights visible would have appeared well below the true horizon giving false visual cues to the pilot. The pilot would thus have been operating in a seriously degraded visual environment during the later stages of his approach to Runway 26.

Spatial disorientation

Three senses interact to orientate ourselves in our daily lives: vision, proprioception (pressure sensing organs in the skin and joints) and vestibular (balance apparatus in the inner ear). In the airborne environment the proprioception and vestibular senses are fallible and may even generate false cues; the pilot must now rely on vision alone. This is not a problem for the pilot if he is flying in daylight and clear of cloud; however, when flying at night or in cloud the external visual references are either degraded or non-existent. In order to achieve the desired flight path the pilot must now monitor closely his attitude and performance instruments and interpret them correctly. Such flying requires specific training and constant practice to remain proficient and safe. Procedural instrument flying, which enables a pilot to carry out an instrument approach, is a particularly demanding skill. Furthermore, the transition from instrument to visual flight, or from visual to instrument conditions, produces its own problems, and unusual attitudes or rapid changes in flight path can be especially difficult to resolve. Any inability to correctly apply the skills specific to instrument flying can lead to spatial disorientation and potential loss of control of the aircraft when flying in an environment where the external visual cues are degraded.

Flying regulations

The regulations which relate to the circumstances of the accident are contained within Civil Aviation Publication (CAP) 393, Section 2: these are based on *The Rules of the Air Regulations 1996*. The definition of 'Special VFR flight' is in Rule 1 and further information can be found in the UK Aeronautical Information Package (AIP) at ENR 1.2. The practical application of these rules, which cover the Special VFR flight being undertaken by the pilot of G-PWER, are contained in Rule 25 *Flight within controlled airspace* and Rule 26 *Flight outside controlled airspace.* The relevant text within the rules states:

> *Rule 25 (2):*
>
> *"…an aircraft flying within Class D 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;"*

This requirement is deemed to be complied with if:

> *"the aircraft is a helicopter flying below 3000 feet above mean sea level and remains clear of cloud and in sight of the surface."*

Rule 26 (2:)

"…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."

This requirement is deemed to be complied with if:

"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 for visibility is reasonable, and remains clear of cloud and in sight of the surface."

The alleviation to remain 'clear of cloud and in site of the surface' does not differentiate between flight at night and by day.

Flight recorders

The aircraft was not equipped with a flight data recorder or a cockpit voice recorder as neither was required by regulation.

Global positioning system

A GARMIN Global Positioning System (GPS) model 295, was recovered from the crash site. This model stores GPS track in a non-volatile memory (NVM) which is attached to the main circuit board within the unit. Both the front and rear of the unit had sustained impact damage and the front panel display was cracked. The unit was taken to GARMIN's UK site where the unit was examined, under the supervision of an AAIB inspector. A number of electronic components were found to have sustained damage and the unit could not be powered. The unit was then taken to the GARMIN facility in the United States where they had the capability to recover data from a damaged unit. The NVM was removed from the damaged circuit board, installed into a new unit and the NVM was successfully downloaded. GARMIN were able to confirm that the unit had not been in operation at the time of the accident.

Maintenance history of the aircraft

The aircraft, Serial No 11092, was manufactured by Agusta SPA in October 2000. At the time of the accident it was in possession of a Certificate of Airworthiness in the Transport Category (Passenger) which was current until 16 January 2005. The 'Maintenance Statement And Scheduled Maintenance Inspection Certificate Of Release For Service' was current until 4 December 2004, or until completion of 664.5 airframe hours, whichever occurred first. At the time of the accident the aircraft had completed 654 hours and all relevant Out of Phase Inspections/Component Changes listed in the above document were annotated as having been completed at the correct times. The Certificate of Maintenance Review was current until 8 April 2004 and was thus in force at the time of the accident.

Certain maintenance actions carried out shortly before the accident having potential relevance to the condition of the aircraft during flight are detailed under Manufacturer's Modification Actions (see below).

Significant features of the aircraft

This aircraft type is equipped with an Electronic Flight Information System (EFIS) consisting of two Electronic Attitude Director Indicators (EADIs) and two Electronic Horizontal Situation Indicators (EHSIs). An EADI is positioned above an EHSI on each pilot's instrument panel. The EADI and the EHSI are the primary flight displays used by the pilot to achieve the desired flight path. In certain failure modes loss of the pilot's EADI results in automatic transfer of the main display function to the EHSI below it, with the 'compass' display displaced to the bottom of the screen and reduced to the upper sector of the relevant arc (ie a presentation of the forward 180° of heading).

Engine, aircraft and systems parameters are displayed by means of two Electronic Display Units (EDUs) positioned side by side to the left of the commander's EADI. During normal operation parameter displays are distributed between the two EDU screens. Information from the EDUs is not necessary to achieve the desired flight path. In certain failure modes a screen may become blank; in that event pre-determined parameters normally visible on that screen will automatically be transferred and concentrated on the remaining screen thus ensuring that sufficient data for aircraft operation remains available to the pilot. Data on less critical parameters then cease to be displayed.

The electrical system incorporates two generators, one driven by each engine. During normal operation, the two generators charge the battery and supply two DC bus bars which in turn directly power a variety of services. The battery bus bar supplies a number of services directly. At the time of the accident a 35A circuit breaker, positioned behind a panel above the pilot's foot-well, protected the battery bus bar on G-PWER.

Aircraft configured in the same manner as G-PWER incorporate an emergency relay designed to reduce pilot workload in a generator bus failed condition by automatically transferring flight critical services to a direct supply from the battery bus bar. In such a generator bus failed condition the emergency relay is energised automatically, causing its contacts to be switched such that the battery bus bar now supplies both emergency and both essential bus bars, whilst continuing to supply those services permanently connected to it. In this failure condition the generators are thus isolated from direct connection to the emergency and essential bus bars, which nonetheless remain powered. No cockpit indication of the position of the emergency relay is provided.

An inverter for the 26V and 115V AC bus bars is supplied via the emergency relay from the generators in the normal condition and via the battery bus should a generator bus have a fault. A further inverter feeds these services and is directly powered from the generator supplies so is not affected by the relay but becomes inoperative in a No 2 generator bus failed condition.

The engines on this type are each controlled via a fuel management module (FMM) which, in the automatic mode, receives signals from the Electronic Engine Control units (EEC), but may be controlled manually via switches on the collective control lever in certain failure modes.

The flight controls on this type are powered via hydraulic servos. Two hydraulic pumps are each driven from the main rotor gearbox; each pump supplies a self-contained hydraulic system. Each of the three servos controlling the main rotor is a tandem unit, each section of which is powered from a different hydraulic system; redundancy is thus provided to enable pitch and roll control to be retained in the event of a single hydraulic system failure.

The automatic flight control system (AFCS) imparts movement to the mechanical pitch and roll inputs of the main rotor servos via linear electrical actuators. Two of these actuators are joined in series and formed a part of each roll input rod, whilst two further units perform a corresponding function on the pitch control inputs. Each of the AFCS computers operate one of the two roll and one of the two pitch linear actuators respectively; each computer is independently powered and each received signals from one of a pair of gyros, each in turn powered from separate inverters.

Accident site

The accident site was an area of flat pasture with a slight downward slope towards a water course. The wreckage was spread over a trail having a length of approximately 100 metres, terminating at the watercourse. The direction of the wreckage trail was approximately 120° magnetic. The structure of the aircraft was largely destroyed by fire.

The initial impact crater was approximately ½ metre deep, in firm ground, becoming shallower and then deepening once more. The first section contained the nose-wheel, various fragmented flying control tubes, wiring and numerous general fragments, all of which were totally burnt. The second deeply indented section, offset to the left of the trail axis, contained very little but was clearly made by the impact of the main rotor gearbox which was the next major item in the wreckage trail and was complete with some blade sections. This was followed by the equipment bay with the main landing gear, luggage bay, the No 2 engine and the tail-boom; all of which appeared to have initially come to rest as a unit with its axis near the vertical. The aft section of this unit had subsided onto the ground as a result of fire damage in the area of the rear cabin bulkhead and equipment bay. Numerous printed circuit boards from items of electronic equipment were spread over the accident site and a GPS unit, which was not part of the basic aircraft equipment, had been thrown the full length of the trail, coming to rest beyond the water course. To the left of the initial impact crater were ground penetration markings consistent with rotating contact of the main rotor blades in the field surface occurring at a steep angle of inclination.

The overall evidence indicated that the aircraft had struck the ground with a steep nose-down attitude and flight path, banked to the left at an angle in excess of 60° and was complete with all main and tail rotor blades attached. The undercarriage was down and the speed at impact was estimated as being in excess of 130 kt. The impact point was 1.5 km approximately east of the threshold of Runway 26 and 200 metres south of the runway extended centreline.

On-site examination of the wreckage

The full spans of the main load bearing structures of all four main rotor blades were present at the accident site. The blade roots remained attached to the rotor head and the head remained attached to the output shaft from the main rotor gearbox. Sections of trailing edge structure were not individually identified, but as these areas were highly fragmented and much of the wreckage was reduced to ash, there was every reason to believe that all this material was present at impact. Three of the four blade tip fairings were present; most of the material of the fourth tip fairing had been separated by impact forces and was not recovered. In view of the high level of destruction and the intensity of the ground fire this absence was not unexpected. The tip fairing performs its major function at high aircraft speeds and at low speed its loss would not have compromised control of the helicopter; furthermore its low mass would not cause its absence to result in a major imbalance. All pitch change links were in place connecting the pitch change horns to the swash plate and the rotating scissors links were connected and intact. All three hydraulic rams remained attached to the swash plate. The lower ends of the three actuator bodies had all separated from their attachments to the gearbox in a manner consistent with overload occurring in the impact.

Both tail rotor blades were almost undamaged but the drive trunnion was absent from its normal position, although the blades still rotated when the tail rotor drive shaft was turned. Under such movement, rotating motion was transmitted from the output shaft of the tail rotor gearbox to the tail rotor via its undamaged pitch-change mechanism. The two ends of the drive trunnion were subsequently identified in the wreckage and were found to have separated from the mid section as a result of overload.

The hydraulic pumps were both absent from their locations on the main rotor gearbox; they were, however, recovered amongst the items of loose wreckage in the trail. The No 1 engine was lying in two separate sections in the wreckage trail, having separated from the structure. All four cabin doors were also identified in the wreckage trail, together with the outer skin of the baggage door.

Wreckage examination process

The wreckage was transported to the Farnborough facility of the AAIB where detailed examination was carried out. Fractured sections of the transfer gear train of the main rotor gearbox, which had separated from the main casing of the latter, were identified and examined. The main reduction gear casing was initially examined before being transported to the UK facility of the agents for the manufacturer, where it was strip examined under AAIB supervision.

The following items were transported to the respective manufacturers, where they were examined under AAIB supervision and functionally tested where possible: both engines, both hydraulic pumps, the hydraulic power flying control units, the auto-stabilisation linear actuators, the four blade dampers, both fuel management modules and the flow divider units.

Examination of the remainder of the wreckage at the AAIB facility confirmed that no extremities of the aircraft were absent from the accident site. All four groups of bolts and nuts securing the brackets attaching the main rotor gearbox struts to the structure above the cabin were identified, still correctly secured to fragments of the latter. Certain items of the control system linking the cyclic stick and collective lever to the hydraulic actuators were recovered in a burnt, melted and/or fragmented state. Much of the remainder of that mechanical system could not be identified. Little more than fragments of the cockpit instrumentation and the electronic systems were recovered and identified.

Findings of detailed component examination

Examination of the gearing in the main rotor gearbox and in the transfer gear train revealed that all components were free from pre-impact damage. Similarly the surviving length of the tail rotor drive shaft was intact and able to transmit torque.

Strip examination of the engines revealed that the gas generator and power sections of both units were rotating with considerable speed at impact and were free from evidence of pre-impact failure. The output drive coupling of the No 1 engine exhibited torsional failure indicating that considerable power was being transmitted at impact. The gearbox of the No 2 engine showed heat damage to roller bearings consistent with high rotational energy at the time the impact occurred. The degree of impact damage to the FMM of the No 2 engine rendered a comprehensive examination impossible; it was established, however, that the position of internal components in both FMM units was consistent with both engines operating in automatic mode.

All main and tail rotor blades were present, although some sections of the main blades (one tip fairing and areas of composite skin and honeycomb core trailing edge fairing) were either not recovered or the original locations of the recovered portions not identified. The amount of blade material not recovered or fully identified was consistent with the impact features and the extent and location of the fire.

All the upper mechanical elements of the main rotor control system from the hydraulic servos to the blades remained connected confirming that, given correct control response of the actuators, normal blade control would have occurred. The tests carried out on the surviving main rotor blade servos, together with testing of the valve assembly carried out to the one severely damaged unit, in conjunction with examination of its partly destroyed main ram body, indicated that all units would have been capable of correct functioning with either or both hydraulic systems supplying power.

The tail rotor servo, which had been seriously damaged by heat, was tested; major external leakage and absence of function was revealed. Strip examination of all actuators confirmed no evidence of pre impact mechanical defect which could contribute to active or dormant failure and in the case of the tail rotor actuator confirmed that heat deterioration of the rubber seals fully accounted for lack of function and both internal and external leakage. Testing of the main rotor dampers confirmed their correct functioning.

The hydraulic pumps were both found separated from their mountings on the main rotor gearbox in a manner consistent with impact effects. Consequently their input drives were destroyed and functional testing was not possible. Strip examination revealed no evidence of mechanical failure.

The two auto-pilot/auto-stabilisation servos were partly dismantled and examined with a view to establishing whether they were performing a controlling function at the time of the impact. The examination was inconclusive.

Previous incident

Immediately after the accident it was reported that some weeks earlier the aircraft had suffered a double EDU failure during a night landing at the owner's residence. Information was received that the pilot was then not able to shut-down the engines by the normal electrical means after landing. The electrical system design and the aircraft maintenance documentation relating to this failure were reviewed after the accident.

On the 12 February 2004 the pilot made an entry in the Technical Log for 'Double EDU failure'. This followed a flight during which the aircraft had landed at both Battersea Heliport and at the owner's residence. Landings at these locations are recorded as occurring at 1715 hrs and 1840 hrs respectively, which would have been at night time and would probably have required the use of the landing light. Thereafter the aircraft was recorded as flying on 14 February from the owner's residence to Bournemouth Airport landing at1608 hrs, and then on 16 February from Bournemouth Airport to its maintenance facility where it landed at 1200 hrs. The landings on these flights would have been in daylight and would not have required the use of the landing light.

Following rectification the Certificate of Release to Service was issued on 16 February. The 'Action' section relating to the 'Double EDU failure' entered in the Technical Log on 12 February was dated 16 February and states, 'Fault traced to Bat Bus C/B. The corresponding Additional/Defects Sheet contained the comment 'Pilot reports both EDUs failed in flt.' The Rectification section states; 'Fault confirmed as No 1 EDU failure in flt, Loss of P1 I/C Fault traced to No 1 Batt Bus C/B popped. Unable to reproduce fault after C/B Reset'.[1] A further 'A' check was also carried out at the maintenance facility on the same date, together with two items not affecting the electrical system.

Thereafter, no further defects were reported up to the date of the accident; although the aircraft conducted landings at night which would have required the use of the landing lights. The only work carried out in the intervening period was on 23 February at the maintenance facility, when firstly, implementation of a service bulletin on the rotor system and regular programmed lubrication took place and secondly, Bollitino BT 109 EP-39 was implemented, (see below).

Manufacturer's modification actions

Two Bollitinos were issued by Agusta SPA at about the time of the incident on 12 February described above. These were the result of analysis of a single in-service problem on another aircraft which had been notified to the Italian Certification Authority.

Bollitino BT 109 EP-41 required the emergency relay to be tested in-situ to ensure that the generators supplied services directly during normal operation; evidence from operator experience suggested that on occasions the relay was remaining in the 'ground' position despite both generators functioning correctly.

Analysis by the manufacturer had indicated that an incident reported by an operator could be explained if the emergency relay remained incorrectly in the position corresponding with the

[1] The abbreviations used in these technical records are as follows. C/B: circuit breaker. P1: aircraft commander's position. I/C: intercommunication system.

energised condition (ie the position to be expected during flight in a generator bus fault condition) and the landing search light was deployed along with the normal services used in night operation. Under such circumstances the current, calculated by the manufacturer as passing through the battery bus-bar circuit breaker, would exceed the latter's 25A rating. As a consequence, the breaker would be expected to trip and a number of important services, including both EDUs, the commander's EADI display and the electrical signals between the engine control panel and the two Engine Control Units (also known as the Electronic Engine Controls) would be lost. These electrical signals control the engine shut-down function; signals from the fuel control panel would similarly be lost.

Details of the incident of 12 February 2004 and the associated maintenance action carried out immediately afterwards, were supplied to the aircraft manufacturer after the accident involving G-PWER. Their electrical specialists concluded that the improper operation of the emergency relay, allowing it to remain in the 'ground' position, followed by tripping of the 25A battery bus circuit breaker when the load of the landing light came on, explained the incident. It was noted that replacement of the battery bus circuit-breaker by a 35A unit, in compliance with BT 109 EP-39, would have eliminated the possibility of a repeat of the former event.

The aircraft Technical Log and associated documentation indicates that this replacement had been carried out by the maintenance company on 23 February 2004. The removed 25A circuit breaker was recovered from the premises of the operating company after the accident. The documentation also indicates that the other Bollittino, BT 109 EP-41(in situ test), had been implemented before the incident of 12 February and revealed no evidence of a sticking relay at that time.

Possibilities of unauthorised interference

The possibilities of unauthorised interference were considered. An improvised explosive device could have been positioned in the cabin or the baggage hold. All cabin doors and the undamaged skin of the baggage door were, however, recovered from the accident site. No evidence of damage other than that consistent with ground impact was found on any of them. In particular no high velocity particle impacts were noted in any of these door components. The tail-boom area of the aircraft was also free from any damage other than that inflicted by fire. Placing a device in any other location would have required unauthorised opening of cowlings, a time consuming activity likely to have attracted suspicion. In addition, explosions in these areas would result in separation of cowlings and probable incapacitation of the pilot. No evidence of any in-flight separation of any parts was found and the pilot was known to have been conscious immediately prior to the impact.

Tests and Research

Tests on a similar aircraft

Another Agusta 109E aircraft, serial number 11162, having a similar instrument screen layout to G-PWER and incorporating the same wiring configuration, including the automatic generator failure change over via the emergency relay as installed on G-PWER, was utilised for tests. These were carried out in conjunction with AAIB to simulate the effects of the improper operation of the emergency relay.

The emergency relay was replaced by an assembly which bridged the terminals feeding the contacts in such a way that the battery bus supplied both emergency and both essential bus bars. This simulated the failure of a generator in flight. In this configuration, the relay, although not energised was in other respects acting as would an energised relay. External ground power was supplied and the squat switch connection was disabled. The electrical system thus configured to represent a non design flight condition with both generators functioning, but with the emergency relay remaining in the ground position. The 35A battery bus bar circuit breaker was then manually tripped. This produced the following results:

> The EADI and EHSI displays, on the left side of the cockpit, continued to function normally. The Commander's EADI, on the right side of the cockpit, became blank whilst his attitude display appeared on the right EHSI instrument together with the heading display in compressed, partial compass, forward sector mode. Both EDUs were blank and all external communications from the commander's position became inoperative, regardless of the selection on his station box (used to control communications selection). In addition the landing searchlight would not deploy. This is presumed to replicate the conditions encountered on 12 February 2004 and shows that under such circumstances VHF communication cannot be made via the commander's station box. This contrasts with the known situation immediately before impact when VHF transmission from the aircraft was being both received and recorded.

The emergency relay was re-installed, thus simulating its normal operation. Ground power was made available to the generator systems. The battery bus bar circuit breaker remained switched off. This is assumed to be the condition of the aircraft on arrival at the maintenance facility on 16 February 2004. The results were as follows:

> The Commander's EDU display was now blank whilst all other displays were normal. No transmissions could be made from the No 1 VHF, in either the normal or fail mode on the station box. This concurs with the observations noted in the technical log following receipt of the aircraft at the maintenance facility on 16 February 2004.

With no external power supply and the generators not operating, both overhead Gen Bus switches were selected ON, the 35A battery bus circuit breaker remained OFF. This situation was intended to simulate the actions taken and subsequently reported to AAIB following the incident on 12 February 2004. The results were as follows:-

> The right EDU display was now blank whilst all other displays were normal. VHF Communications were available from the captain's position.

AAIB analysis of the electrical supply distribution arrangements for the wiring of G-PWER showed that the electrical control of the EEC (including the engine shut-down function) would not be possible in the defect mode postulated as occurring on 12 February 2004, ie with the emergency relay incorrectly positioned and the battery circuit breaker tripped. Shut-down would, however, be possible by means of the engine mechanical power levers which link directly to the two FMM units. This appears consistent with reports of events immediately following the incident on 12 February 2004.

Flight Assessments

Two flights were conducted in order to understand the problems which appear to have been experienced by the pilot.

The first flight was flown in daylight, in good weather, and in an Agusta A109E with an experienced instructor. The purpose of the flight was to identify the track and vertical profile of the aircraft involved in the accident as described by the witnesses. Manoeuvres were also flown in order to understand the aircraft behaviour, firstly with the stabilisation system engaged and then with it disengaged. In addition, the loss of elements of the electrical system and their effect on the stabilisation, cockpit displays and ability of the pilot to transmit on the aircraft radios were simulated in the air and on the ground.

The second flight was flown at night, in good weather, utilising a Bolkow BK117 helicopter with two experienced night rated pilots, both of whom were also instrument rated. The purpose of the flight was to evaluate the external visual references available at night during the approach to Runway 26 at Bournemouth. This aircraft was fitted with a video and thermal imaging camera in order to record the visual scene.

A summary of the conclusions drawn from the flights is set out below:

First flight

Estimated flight path

Using witness statements together with information from the ATC radio tape and other evidence it was possible to define a likely flight path, both horizontally and vertically, during the final stages of the approach. A flight was conducted to validate this profile.

The Air Traffic Controller recalled that the pilot transmitted "JUST BECOMING VISUAL THIS TIME" when the aircraft was about 1 to 1.5 nm from the airport. At about the same time the aircraft entered a descending turn to the left. It reached a minimum height of 400 feet after the first 180° of the turn and then climbed back towards 1,000 feet as the aircraft continued the left turn. Having completed a turn of approximately 360° the aircraft continued turning left through a further 180°, whilst continually descending until the height readout was lost on the radar. The aircraft then passed over a witness at a height estimated to be about 300 feet whilst descending and in a gentle turn towards the north. During the final moments of the flight the low rotor RPM warning was recorded. The aircraft manufacturer confirmed that this was symptomatic of a sustained, highly banked turn. The ground impact features indicate that the aircraft struck the ground whilst descending in a steeply banked turn to the left.

Effect of rapid lowering of the collective control

From the point at which the aircraft appears to have commenced the left descending turn, an approach angle of 7.5° was required to the runway threshold from a height of 800 feet, this increased to 9° from a height of 1,000 feet: the normal approach angle, as defined by the PAPIs, was 3°. Therefore, when the pilot became visual he would have recognised that he needed to lose height close in to the Runway 26 threshold. To achieve this he would have rapidly lowered the collective control.

In order to simulate this manoeuvre the aircraft was stabilised in level flight at 90 kt with the autopilot engaged; the cyclic trim release was then selected and the collective lever lowered rapidly to approximately 70% of its downward travel. No control inputs were made to counteract the reaction of the helicopter. The helicopter immediately yawed and rolled to the left and the nose dropped; the magnitude of the response directly correlated to the speed with which the collective was lowered. The yaw and roll were easily compensated for with cyclic and tail rotor control inputs given the good external visual references available on the assessment flight.

Loss of aircraft services

The loss of elements of the electrical system and their effect on the stabilisation, cockpit displays and ability of the pilot to transmit on the aircraft radios were simulated. The Agusta 109E is configured with all switches for the invertors, generator bus bars, generators and battery located on the left side of the overhead panel. The initiating speed for the loss of stabilisation was the 90 kt which approximates to the speed estimated by the Air Traffic Controller from the progress observed on the radar monitor screen in the visual control room of the ATC tower.

With both lanes of the autopilot engaged and the relevant modes selected, the aircraft accurately maintained the required flight path including a coupled ILS. Disengaging the autopilot caused the aircraft to turn left and descend but recovery was easily accomplished in visual conditions.

A coupled ILS was stabilised at 90 kt and both inverters were then switched OFF. This caused an instantaneous loss of the autopilot and all EFIS screens. The aircraft entered a descending turn to the left and accelerated but again recovery was easily accomplished in the visual conditions. A loss of both generators was not attempted in flight, nor was the loss of the generator bus bars, but either of these conditions would have resulted in the stability augmentation system remaining engaged. In the event of the loss of both inverters, both generators, or the generator bus bars, radio transmission would still have been possible.

A 'cut off' bar was fitted which, when operated, switched off both generators and the battery. If this were activated in flight all electrical power would be lost and all cockpit EFIS displays, the autopilot and all lighting would become inoperative. No radio transmission would then be possible.

Second flight

The BK 117 helicopter was flown on a clear night with no moon and with the visibility in excess of 10 km. The aircraft was operated out to a distance of four nm to the east of the threshold of Runway 26 and a number of approaches were flown maintaining the selected height until one nm from the threshold. Approaches commenced initially at 1,500 feet above the airfield elevation, later reducing to 800 feet. At a point adjacent to the accident site left orbits were flown, descending to 500 feet before climbing back to the initial height. With the visibility in excess of 10 km, the lights from the various conurbations provided a clearly defined horizon down to 500 feet which allowed the flight crew to maintain a safe visual orientation.

If the same visual scene was considered in a visibility of 2,700 metres very few lights would be available and no clearly defined horizon would have been visible. Car headlights on the A338 were obscured by the high trees on the eastern side of the road. If the aircraft was pitched nose down the available lights would offer no horizon and with the aircraft turning the apparent movement of individual lights would be highly disorientating. No depth perception would be possible to judge height and the aircraft instruments would be the only reliable source of aircraft flight path and attitude information.

Both pilots concluded that maintaining correct orientation in the vicinity of the accident site, at the heights flown, and using the available ground references in the conditions described on the night of the accident, would be extremely difficult and would require a high degree of competence in instrument flying.

Low RPM warning tone

The ATC recording of the Bournemouth Tower frequency contained an open microphone transmission from the pilot of G-PWER received within the final period of the accident flight and this recording was analysed by the AAIB. During the final 4 seconds a barely audible tone, which alternated in amplitude, was recorded. The signal was identified as a frequency of approximately 3,125 hertz with duration of approximately 0.05 to 0.08 seconds and a pulse period of approximately 0.14 to 0.16 seconds. A copy of the recording was then supplied to the aircraft manufacturer for further analyses. The manufacturer concluded that the frequency, sound duration and pulse period of the ATC recording were consistent with a LOW RPM warning horn. The manufacturer advised that the LOW RPM warning horn was activated at 95.5% NR power on or 89.5% NR power off.

Mobile telephones

Three mobile phones were recovered at the accident site. Two had evidence of heat and impact damage but were largely intact and the specific phones could be identified. The remaining phone had sustained significant fire damage and could not be identified.

In order to determine whether any of these phones may have provided a distraction to the pilot during the final moments of the flight they were taken to a computer forensics specialist to recover the data from each main circuit board memory and Subscriber Identity Module (SIM) card. No data could be recovered from the unidentified phone. The remaining two units were disassembled and the main circuit boards and SIM cards removed and downloaded. One SIM card had a Short Message Service (SMS) message stored, dated 8 February 2004. The second SIM card had 15 SMS messages stored, with the last message dated 17 February 2004. The main circuit board from both phones showed evidence of heat distortion and impact damage to electrical components. The circuit boards were installed into working models but neither could be powered and no data could be extracted from them.

The records for five mobile phone numbers relating to the pilot and passenger were requested from the service providers. Two phone calls were confirmed as having been made on the 3 March 2004. One phone number registered to the pilot had a call logged at 1348 hrs and a second number, with no subscriber details but believed to belong to the passenger, had a call logged at 1853 hrs. Of the three remaining numbers, two numbers had no logged calls for the accident date with the third number being disconnected, for which the service provider could not confirm if a call had been made on the date of the accident.

Performance data

The Aircraft Manufacturer was provided with a figure for the approximate radius of the final turn estimated to have been executed by the aircraft. This was derived from ATC observations and the position of the ground impact.

They were asked to compute the power requirement and bank angle to execute a level turn to the left at two steady airspeeds. These were respectively 100 kt and 60 kt, selected to be representative of the probable extremities of the aircraft speed during the approach. The local ambient conditions were specified and sufficient data provided to enable the manufacturer to compute the aircraft mass. The results were as follows:

100 kt sustained turn:
Power required 1,196 Brake Horse Power (BHP), bank angle required 67·4°

60 kt sustained turn;
Power required 462 BHP, bank angle required 36·8°

Note 1: The power, per engine, factored for installation losses is:
Take-off power rating 593 BHP: Maximum continuous power rating 555 BHP

Note 2: The transmission limit is 900 BHP

Analysis

Operational elements

The pilot was qualified to conduct the flight under Special VFR permitted by Rule 25 and 26, and was familiar with the route being flown both by day and night. Although he had only been flying the A109E helicopter for two months he had already achieved 78 hours on the type. He had recent experience of flying at night, having achieved 15.5 hours in the previous two months. However, he did not hold an Instrument Rating, had no record of any instrument flying training and his last recorded instrument flying was in December 1999.

The available radar data indicates that the pilot had flown the transit from Battersea at constant altitudes and headings consistent with the clearances given. The regular nature of the flight path suggests that the altitude and heading hold modes of the autopilot were being used.

The meteorological conditions were generally as forecast with the approach of the occluded warm front affecting the Bournemouth area with associated low cloud and reduced visibility in rain. The weather to the north and east was considerably better with higher cloud base and improved visibility. The pilot did not request any updates of the Bournemouth weather at Battersea or whilst en-route to Bournemouth and his radio transmissions showed no signs of concern for the weather. It is not known if he listened to the Bournemouth ATIS but had he done so, the weather would have been that recorded at 1920 hrs which reported the visibility as 2,700 metres in light rain with the lowest cloud at 1,200 feet.

During the approach to Bournemouth Airport a witness at Whitenap could not see the aircraft as it passed over him and therefore at that point it was either in or above the cloud. Flying above the small amounts of stratus in the better weather to the northeast would have allowed the pilot to maintain reasonable levels of visual reference with the available ground illumination. This would also have met the legal requirement to '*remain clear of cloud and in sight of the surface'*. Had he been IMC it is probable that he would have requested an update for the weather at Bournemouth and therefore he was probably clear of cloud and in sight of the surface during the transit.

The lowering and increasing amounts of cloud accompanied by the light rain moving east led to a rapid deterioration of the weather at Bournemouth which would have seriously affected the ability of the pilot to maintain visual references. He would have been forced to refer to the flight instruments or rely on the autopilot for maintenance of aircraft attitude and flight path.

The heights recalled by the ATC controller of 800 to 1,000 feet at approximately 1 to 2 nm suggests that the pilot was not carrying out a coupled ILS although this possibility could not be excluded as he had previously demonstrated his knowledge and use of that capability. At 800 feet, on the runway extended centreline and at about 1 nm to 1.5 nm the approach lights, which had been turned up to maximum brilliance, would have been the first recognizable airport lights seen by the pilot

In order to continue his approach to the runway the pilot would have had to de-select the height and heading hold modes and initiate a positive descent. Normally he would hold down the force trim release button on the cyclic control to disconnect the autopilot thus allowing the pilot to fly the aircraft manually. As was demonstrated during the assessment flight, when lowering the collective lever rapidly to descend the aircraft yawed and rolled left and pitched nose down. This would normally be countered with a significant application of right tail rotor pedal and right cyclic. If this manoeuvre was not properly coordinated, the aircraft would yaw in an out of balance condition. If visual references were then lost due to an unmonitored turn left away from the approach lights or entry into cloud the pilot would find himself in a descending left turn in an out of balance aircraft. Effectively the pilot would then be in an unusual attitude, accompanied by disorientating sensations. He would then have to fly by sole reference to the flight instruments, or utilise the isolated ground lights which could produce confusing or conflicting visual cues. A deliberate descending turn to the left, in an attempt to avoid low cloud obscuring the approach lights, particularly if this was initiated in an aggressive manner would place the aircraft in a similar situation.

Consideration was given to the pilot having inadvertently switched off elements of the electrical system switches on the overhead panel. The loss of those systems that still allowed radio transmissions should not have caused the pilot to loose control of the aircraft. Moreover, the pilot did not identify any technical emergency affecting the aircraft.

In the first period of 'open mike' transmissions which lasted 29 seconds, the pilot can be heard experiencing considerable difficulties and was unable to communicate the nature of his problem. He stated "WE'VE GOT POWER" but did not say whether it was electrical or engine power. In the second period of 'open mike' transmissions which lasted 18 seconds, he recognised that the aircraft needed to climb. The noise of the main rotor blades can be heard in the background, which indicated that the aircraft was manoeuvring in tight turns or attempting to pull out of a dive. The transmissions ceased as either the aircraft impacted the ground or the pilot released the transmit switch.

From analysis of the transmissions, it is clear that the pilot was working hard to restore the aircraft to a safe flight path but he was overloaded and probably disorientated. Whilst he identified that the aircraft had power and that he needed to climb, insufficient time and height were available for him to translate that recognition into corrective action and prevent the accident.

The mobile phones recovered from the wreckage and the records for mobile phone numbers relating to the pilot and passenger were examined. There was no evidence of any phone calls during the flight and they would therefore not have provided a potential distraction for the pilot.

Engineering elements

The aircraft struck the ground at a relatively high speed, with a high rate of descent and a high bank angle, on a heading which was unexpected, given the proximity of the accident site to the runway threshold.

Although the forward section of the tail rotor drive shaft was destroyed by fire, the condition of the tail rotor trunnion was consistent with significant tail rotor RPM being present at the impact and torque being capable of being applied via a complete and coupled drive shaft. With no blade damage, the only viable explanation for the nature of the failure of the trunnion is that the tail rotor shaft speed was arrested by disruption in the region of the transfer gears at the rear of the main rotor gearbox or the sudden arresting of rotation of the main rotor at impact. The momentum of the tail rotor blades would then produce a high torque reaction in the splines of the trunnion resulting in a bending/bursting stress capable of failing the narrow cross section of the trunnion immediately adjacent to the splined hole in the centre. The presence of both ends of the fractured trunnion at the accident site, and absence of other significant tail rotor damage confirms that the rotation was present and that sudden arrest of that rotation occurred at impact. There was no evidence to suggest that the tail rotor servo had suffered any damage or failure prior to the impact and subsequent fire.

The outputs from the three rams of the main rotor pitch servo units remained connected to the swash plate, all pitch change links remained attached to both their respective blades and the swash plate, the two scissors link assemblies remained connected correctly and all fractures and other damage to the servo bodies and their mounts were consistent with the effects of impact forces. This leaves no doubt that the blade pitch angles would have responded correctly to control inputs to the servos.

Although the hydraulic piping constituting the distribution system of the flying controls was destroyed, the duplicated nature of those supplies and of the double ram actuators ensure that no single failure in the hydraulic piping could lead to loss of effectiveness of the main rotor control; a simultaneous double failure of hydraulic piping is considered a highly remote possibility.

The almost complete destruction of all the mechanical elements of the flying controls system between the cyclic and collective levers and the ram inputs precluded any useful comments on their pre-impact condition.

Both engines revealed evidence of either high output torque or high internal RPM at impact. The No 1 engine FMM was in a sufficiently undamaged condition and free from evidence of internal failure for one to be confident that it had operated correctly up to the impact. Both engine FMM units contained evidence consistent with them being in automatic mode at that time. The total evidence is thus consistent with the fact that both engines were producing power, were in automatic mode and therefore their FMMs were receiving approximately correct signals from the EEC which in turn was receiving correct sensor input signals. This suggests that both engines were responding correctly to EEC inputs and hence to pilot power demands.

The sound audible on the ATC recording of the final phase of the flight was identified as being consistent in frequency and modulation with that of the LOW RPM horn. The accident site examination revealed evidence consistent with the aircraft being banked at an angle in excess of that required to achieve the calculated 100 kt turn and the wreckage trail had the characteristics of a high speed impact. The performance calculations indicate that at an airspeed of 100 kt, a sustained turn having dimensions reasonably consistent with ATC observations together with the location and orientation of the wreckage trail, require an installed power exceeding that available. Under such circumstances, operation of the LOW RPM horn is a reasonable outcome even if both engines continue to function correctly.

No realistic assessment could be made of the pre-impact state of the instruments and avionics given their destruction during the impact and fire.

The reported multiple loss of services on G-PWER during a landing at night some weeks before the accident was studied. The analysis of the electrical design of the aircraft type, carried out by the manufacturer, to diagnose a suspected fault condition reported on another aircraft was described and made available to the AAIB. The results of the analysis were confirmed by tests conducted by the AAIB. The recorded information, entered by the pilot in the Technical Log, is consistent with both the theoretical and demonstrated effect if the aircraft carried out the flight of 12 February with the emergency relay malfunctioning. If the battery bus circuit breaker tripped under the load of the large current draw when the landing light was switched on, with most electrical systems already operating, then the two EDUs would become blank and certain other systems would cease to function normally. In addition, it would not be possible to turn off the engines by normal electrical means as was reported at the time. If, however, the emergency relay functioned correctly during the later flight to the maintenance facility and the battery bus circuit breaker remained in the tripped position, the theory predicts, and the tests demonstrated, that one EDU would function and the other would remain blank. This is consistent with the situation as noted at the maintenance facility in the Rectification section of the Additional/Defects Sheet raised on 16 February. The location of the battery bus circuit-breaker is not readily accessible and therefore it is not easily reset by the pilot. The action section of the Technical Log, detailing the rectification carried out confirms, however, that the circuit breaker was re-set by personnel at the maintenance facility. The analysis reveals that this action would return all services to an operable state and no further related problems appeared in the Technical Log thereafter, indicating that the immediate problems were successfully rectified.

The analysis of the electrical design of the aircraft by the manufacturer and the recorded work carried out by the maintenance company to address the immediate problem and subsequently to embody BT 109 EP-39 indicates that the nature of that problem was rectified by the maintenance company, was identified theoretically by the manufacturer and steps taken by them to prevent a repetition of it throughout the fleet. Those steps had been implemented on G-PWER before the accident. The general consistency of the results of the tests carried out on aircraft Serial Number 11162 with those predicted in the manufacturers' specialists' study, together with the presence of recorded VHF radio communications with the aircraft immediately prior to impact, indicates that the instrument system operating problems experienced some weeks before the accident were not present during the accident sequence.

Conclusions

The aircraft struck the ground with a high forward speed and a high rate of descent whilst banked steeply to the left; the main rotor was turning with considerable energy. The aircraft was judged to have been structurally complete with all major elements of the main rotor system and the tail rotor blades present. The main rotor gearbox and the transfer gearing were all free from pre-impact defects.

The aircraft would have been fully controllable in pitch and roll, given appropriate rotor RPM, provided correct inputs to the three main rotor servos were available and at least one hydraulic system was free from damage to, or failure of, its distribution piping. There was no evidence to indicate that normal yaw control was not available.

Both engines were free from evidence of pre-impact mechanical failure and were turning at high rotational speeds at impact. The evidence was consistent with both engines operating in automatic mode at impact. The above evidence is consistent with both engines producing demanded power or maximum normally available power at impact. There was no evidence of the detonation of an explosive device or of other unauthorised interference with the aircraft or its systems.

An earlier event, involving loss of cockpit displays, was explained by an analysis carried out by the manufacturer. The aircraft maintenance records indicate that the immediate problem was rectified solely by re-setting a circuit breaker; the success of this process was predicted by the manufacturer's analysis. Tests carried out by the AAIB on a similar aircraft produced results which agreed with those of the theoretical analysis carried out by the manufacturer. The test results were consistent with the entries in the aircraft Technical Log made by the pilot following the earlier event and with those made immediately afterwards by the aircraft operators' maintenance company. A subsequent modification carried out by the maintenance company, changing the battery bus circuit breaker to a higher rated 35A component in compliance with a manufacturer's mandatory Bollettino Tecnico and annotated in the aircraft maintenance records, was aimed at breaking the train of occurrences which led to the earlier event.

The AAIB tests confirm the manufacturer's electrical analysis showing that successful VHF transmissions received from the aircraft late in the flight and recorded by equipment at Bournemouth

Airport could not have been made had the previous mechanism of loss of cockpit display been present at the time those transmissions were made.

The frequency, duration and pulse period of the sound on the ATC recording were consistent with a LOW RPM warning horn. An analysis of the engine power requirements to perform certain manoeuvres showed that a flight consistent with observations and deductions of the pre-impact flight path could result in the operation of the LOW RPM warning on the aircraft despite both engines continuing to function normally.

The accident occurred when the pilot encountered a significant deterioration of the weather in the immediate area of Bournemouth Airport whilst operating SVFR on a visual approach to Runway 26. During the final stages of the approach the pilot probably became disorientated due to a loss of visual references when attempting to fly by sole reference to his flight instruments or limited ground lights or a combination of both. The pilot's limited instrument flying background did not equip him to cope with the difficult situation in which he found himself.

Recommendations

Whilst the aircraft was being operated at night, probably in accordance with Rules 25 (C) (ii) and 26 (b) (iii), it either entered an area of limited visual references or inadvertently entered IMC which prevented the pilot from maintaining external visual orientation. The freedom for helicopters to remain clear of cloud and in sight of the surface when operating below 3,000 feet, albeit in Rule 26 (b) (iii) "*at a speed which having regard for visibility is reasonable*", does not provide an adequate margin of safety for preventing inadvertent IMC or spatial disorientation, especially as there is no differentiation between day and night. It is therefore recommended that:

Safety Recommendation 2005-055

The Civil Aviation Authority should review the Rules of the Air and relevant regulations in their applicability to helicopters and should consider imposing minimum in-flight visibility requirements for day and night. These minima should afford an effective safety margin to prevent inadvertent flight in instrument meteorological condition or loss of adequate external visual references. The requirement for a clearly defined horizon, particularly over water or featureless terrain should also be considered.