Aircraft Type and Registration:	Hughes 369HS, G-CSPJ
No & Type of Engines:	1 Allison 250-C20 turboshaft engine
Year of Manufacture:	1976
Date & Time (UTC):	19 July 2003 at 0849 hrs
Location:	Cudham Lane South, Knockholt, Sevenoaks, Kent
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 2
Injuries:	Crew - 1 (Fatal) Passengers - 2 (Fatal)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence
Commander's Age:	39 years
Commander's Flying Experience:	112 hours (of which 8 were on type) Last 90 days - 12 hours Last 28 days - 3 hours
Information Source:	AAIB Field Investigation

Synopsis

The helicopter was seen to depart normally in good weather conditions. Shortly after takeoff, as the pilot acknowledged a frequency change instruction, the helicopter was seen to enter a descending left turn from which it did not recover. Eye witnesses reported seeing the helicopter 'fishtailing' and emitting unusual noises, cyclical in nature, which they thought consistent with changes in engine power. The pilot made one more RTF transmission just before ground impact but this message did not declare the nature of any problem. The machine struck the ground in a 30° nose-down pitch attitude at about 80 kt forward speed, severely disrupting the structure and imparting fatal injuries to the family on board. There was no evidence of any pre-impact technical failure and the engine was running at impact. The reasons for the accident could not be determined. However, information recovered from a Cockpit Voice Recorder (CVR) or Flight Data Recorder (FDR) could have enabled the investigators to determine the likely cause but there was no requirement for either on this rented public-transport category helicopter and none was fitted. Two safety recommendations were made concerning the installation of new technology cockpit voice recorders to all public transport category aircraft.

History of the flight

The pilot had hired the aircraft to take his wife and 14-month-old son for a local flight from Biggin Hill Airport. He had intended to fly out to the Canterbury area (40 nm to the east) and back to the airport. This was in preparation for a flight which the family was planning to make to the Isle of Wight the next day in the same helicopter. The pilot's son had flown with his father once before in a Bell 206 Jet Ranger but not in a Hughes 369HS (often referred to as the Hughes 500C). This latter helicopter presents a noisier environment for passengers, particularly those sitting in the rear seat, and the pilot and his wife wanted to ensure that their son would be comfortable in the aircraft before they embarked on a longer flight.

The family had arrived at the helicopter operator's offices at about 0745 hrs. The pilot discussed his intentions for the flight with the company's Chief Pilot and Operations Manager and confirmed his booking of G-CSPJ for the following day. The Chief Pilot was concerned that the pilot's son should have suitable protection for his ears because of the relatively high noise levels inside the aircraft. The pilot said that he had bought a headset specifically designed for a young child and it was agreed that that would be sufficient. The family, who all appeared to be in good humour, then drove to the hangar which was about one mile away on another part of the airfield.

The helicopter had already been refuelled and repositioned outside the hangar by one of the helicopter operator's own pilots to make room for a Jet Ranger that was in the hangar, in which he and another pilot were about to depart. The pilot of the Hughes was seen by the crew of the Jet Ranger to carry out a pre-flight inspection on his aircraft before strapping his son into a child's car seat which had been secured in the rear left seat of the helicopter. The Jet Ranger then took off and departed before the pilot and his wife had boarded the Hughes. Subsequent evidence showed that the pilot flew the Hughes from the front left seat, as is normal for this type, and his wife sat in the rear right seat. From his position, the pilot would have had difficulty in seeing his wife, and vice versa because of the central pillar behind and between the two front seats which contained the main rotor control runs (see Figure 1). Also, he would have had at least as much difficulty in seeing his son who was sat directly behind him.

Both collective levers and sets of yaw pedals were fitted in the helicopter but only the left seat cyclic was in place. The left collective lever was fitted with a friction control, which enabled the pilot to leave the collective in any required position if he had to take his hand off the lever, for instance while changing the radio frequency.

Having started the helicopter outside the hangar, the pilot called Biggin Hill ATC on the Tower frequency at 0843 hrs to request a Visual Flight Rules (VFR) flight "locally" to the east. He was given clearance to hover taxi to 'Pad One', which is an area of grass located on the north side of the threshold for Runway 29, and having arrived there was seen to bring the helicopter to the hover. The pilot then called to say that he was ready for departure and at 0846:20 hrs he was given clearance by ATC to take off to the east. He was advised that the surface wind was 180°/10 kt and that another aircraft, which was joining the circuit, was just passing abeam Sevenoaks (a town 6 nm to the south-east). The helicopter took off towards the south-east climbing to an estimated height of 500 feet above aerodrome level (aal), as observed by the two Air Traffic Controllers on duty in Biggin Hill ATC Visual Control Room (VCR). It was normal for helicopters to track south-east towards Sevenoaks before continuing to the east and the height at which G-CSPJ departed ensured adequate separation from the inbound fixed wing traffic, which would typically be at a height of 1,000 feet aal. The helicopter's height also kept it below the base of Gatwick's Control Area, which was further to the south.

At 0848:02 hrs the Biggin Hill ATC Tower Controller repeated the information about the inbound traffic and instructed the pilot of the Hughes to change to the Approach Controller's radio frequency. The pilot did not respond to this radio call and the Tower Controller called again 10 seconds later, reiterating the instruction to change to the Approach Controller's radio frequency. The pilot acknowledged this call but did not indicate whether he had seen the other aircraft, a Cherokee, and the pilot of that aeroplane stated later that he did not see the helicopter. The pilot of the Hughes 369 completed his radio transmission at 0848:16 hrs and to do so would have used the press-to-transmit switch located on the top of the cyclic control.

It was the helicopter pilot's normal custom to pre-set the Biggin Hill Approach frequency in the standby position on the radio frequency selector, with the Tower frequency selected in the active position, before lifting into the hover at the airfield. This meant that he only had to press the button that would move the Approach frequency to the active position when it was required. A radar recording subsequently showed that when the pilot transmitted his reply, acknowledging the frequency change, the helicopter was 2.4 nm from Biggin Hill Airport on the 139°M radial and had been tracking approximately 135°M since it had first been detected by the radar one minute earlier. The radar recording also indicated that, at or just before the pilot's radio call, the helicopter entered a turn to the left which seemed to continue until the aircraft disappeared from the radar screen at 0848:26 hrs, just 10 seconds after the pilot completed his acknowledgement of the frequency change instruction.

A witness who was standing in a friend's garden 3 nm to the south-south-east of Biggin Hill Airport had seen the helicopter approaching from the north-west. He recognised the aircraft as being G-CSPJ from his time spent at the flying club whose premises are next door to those occupied by the helicopter operator. The helicopter was observed to be flying straight and level, or possibly in a slight climb, at an estimated height of 400 to 500 feet. At about the position that the helicopter would have been when the pilot acknowledged the frequency change, this witness stated that he heard the engine noise changing from a high note to a low note and back to a high note over a three second period. He remarked to his friend that it did not "sound right" and at that point he saw the helicopter yaw to the left, possibly as much as 30°, and, seemingly, start a shallow descent at a forward speed which was considered to be slower than would be normal in the cruise. Tall pine trees on the eastern side of the garden then obscured the helicopter and "within a split second" the witness heard the 'engine' noise from the aircraft cease abruptly. He considered that this might have been a result of the blocking effect of the trees and the distance and orientation of the helicopter, as much as for any other reason.

Another witness, also a helicopter pilot, was standing in a nearby property and heard G-CSPJ approaching from the north-north-west. He saw the aircraft yaw left and right two or three times over a period of five seconds and then enter a turn to the left and start to descend. It straightened up and descended at a greater rate, pitching nose down about 45° as it flew away from his position towards the north-east. This witness concluded that the helicopter was "in trouble" when he saw it descending. He estimated that its forward speed was about 80 kt.

In the final stages of its flight the helicopter flew low over a private house on the east side of Cudham Frith (a wooded area 2.5 nm to the south-east of Biggin Hill Airport) at an estimated height of 150 feet, travelling in an east-north-easterly direction. Four witnesses in the garden of the property described the noise of the helicopter as being very loud and one of the four remembered hearing the noise "revving up and down" about two times. They all thought that the helicopter had a nose down attitude as it flew over, with one witness recalling that it pitched down 30° when it was directly above the house. It flew over Cudham Lane South, which is adjacent to the property, and just before disappearing behind the trees alongside the lane, the helicopter was seen to roll left gradually to about 15° angle of bank. Two witnesses in the garden of the property immediately to the north and two more at the stables next door to that were aware that the noise from the helicopter sounded loud but remembered it being constant.

When the helicopter was approaching and flying over the house adjacent to Cudham Frith, other witnesses half a mile to the east and north-east of the aircraft were alerted by its unusual sound. They variously recalled it sounding similar to a lawn mower engine "hunting", the engine noise from an aerobatic aircraft changing from low to high power and back again (repeated three times) or, thirdly, as if the engine power was surging (about six times over a 15 second timespan). Another witness heard a mechanical, grating noise coming from the aircraft and saw it rocking from side to side, although not violently. By all accounts, the helicopter was finally seen to enter a left turn and pitch nose down between 30° and 45° with one witness estimating the angle of descent at 40°. G-CSPJ then disappeared out of sight behind trees and a "thud" was heard. A brief transmission made at 0848:30 hrs on the Biggin Hill Approach frequency has been identified as coming from the Hughes 369. The voice is considered to be that of the pilot and the two words heard are a distressed utterance rather than recognised RTF language. This transmission coincided with the time that the helicopter is believed to have struck the ground in a field on the east side of Cudham Lane South (see Figure 2).

Many people in the vicinity heard the noise from the impact and went to render assistance but it was immediately apparent to the first witnesses on the scene that the three occupants of the helicopter had not survived the accident. Although there was a strong smell of fuel, no fire ensued despite the helicopter being very seriously disrupted.

Personnel information

The pilot started flying in September 2001 and all of his experience was gained in helicopters. He obtained his Private Pilot's Licence (Helicopters) in April 2002 and was issued with a rating for the Bell 206 Jet Ranger at the same time. That rating was renewed a year later in April 2003 and in the same month the pilot added the Hughes 369 rating to his licence, having started his training for that type in January 2003. He had further plans to continue his training in the future and gain a commercial licence. Having experienced no problems previously, he had been encouraged to pursue this idea.

The pilot had accrued a total of 112 hours on helicopters, of which eight hours had been gained in the Hughes 369. The remainder, apart from two initial lessons in a small piston-engine helicopter, had been flown in the Bell Jet Ranger. Of those eight hours in the Hughes 369, the pilot had flown as pilot-in-command (PIC) for a total of 1 hour and 40 minutes. His last flight in the Hughes was on 29 June 2003 when he flew, with a passenger, to Lydd Airport. Having landed, he shut the helicopter down for an hour and a half before returning to Biggin Hill. His previous and only other flight as PIC in the Hughes was on 6 May 2003. His last previous flight in any aircraft took place on 6 July 2003 when he flew a Bell Jet Ranger.

On a number of occasions the pilot had taken friends and family for flights in a Jet Ranger. All of them remarked on his safety consciousness, discipline and thoughtfulness towards his passengers as well as his calm attitude and ability to concentrate on what he was doing. He would habitually brief his passengers not to talk to him after takeoff until he spoke to them. Moreover, he was not reluctant to carry out a precautionary landing if he was concerned about his aircraft's serviceability. Once, when the pilot was concerned about an unusual high-pitched noise, he advised ATC that he intended to land in a field. Having done so, he contacted the aircraft operator and the problem, which was temporary, was resolved and he continued the flight.

Similarly, the pilot's wife was regarded as being calm and capable and both she and the pilot were judged to have the necessary temperament and ability to cope with any distress that their son might have experienced during the flight, even if this meant that they had to make an unplanned landing.

Radio communications

The aircraft was fitted with the Garmin GNS 430, which combines VHF communications, navigation functions and moving map graphics on a single colour display (see Figure 3). The communications and navigation frequencies are both altered by means of the same co-located rotary knobs (one inner and one outer) situated on the bottom left hand corner of the combined control panel and display. Rotating the outer knob changes the MHz frequencies and the inner knob similarly changes the kHz frequencies. Momentarily pressing the inner knob toggles the tuning cursor between the communications and navigation standby frequency displays. It is possible to do this accidentally while changing the kHz part of the communications or navigation standby frequency. Both the communications and navigation displays show their respective active and standby frequencies. Pressing separate buttons for each facility moves the standby frequency to the active position.

Fuel shut off valve

The fuel shut off valve is operated by a push-pull control on the left side of the instrument panel. The control, which is pulled out to close the valve, is in a similar but opposite position to the ventilation control on the right side of the panel (see Figure 4). In the Jet Ranger there are two ventilation controls and they are situated in comparable positions to the fuel shut off valve and the ventilation control in the Hughes (see Figure 5). Further, the shapes of the fuel shut off valve and the ventilation control in the Hughes are similar although the fuel shut off control is red in colour whereas the air vent control is black.

Meteorological information

The Terminal Area Forecast (TAF) for Biggin Hill for the period between 0700 hrs and 1600 hrs on 19 July 2003 gave a surface wind of 190°/10 kt with visibility in excess of 10 km and scattered cloud at 3,000 feet agl. At 0820 hrs an actual weather observation at Biggin Hill Airport recorded a surface wind of 160°/08 kt, varying in direction between 130° and 210°, with visibility in excess of 10 km and no cloud below 5,000 feet agl. The temperature was 22°C and the dew point was 16°C. In, general the weather was fine, typical of a good summer's day, and it remained so for the duration of G-CSPJ's flight.

Recorded data

The recorded data that was recovered was limited to the RTF tape recordings and a recording of Thames Radar (data from a radar head at Heathrow) for the period covering the flight. Analysis of the radar recording, which includes a 'contact' for G-CSPJ up to four seconds before the aircraft is believed to have struck the ground, indicates that the helicopter's average ground speed in the last 10 seconds of recorded flight was 72 kt.

Analysis of the radio transmissions from G-CSPJ indicates that the main rotor speed was a constant 490 RPM at the time of each radio call made by the pilot, with the exception that during his last brief transmission the main rotor speed had increased to 500 RPM. The normal power-on limits are 484 to 489 RPM and the power off limits, during autorotation, are 400 to 523 RPM.

Rate of descent analysis

At 0848:16 hrs the pilot acknowledged the frequency change from Biggin Hill Airport's Tower Controller. He made no mention of any problem, so it is reasonable to believe that the aircraft was at a height of approximately 500 feet agl. At the time, G-CSPJ was flying over a small valley so the aircraft may well have been maintaining 500 feet above the airfield's level (1,100 feet on the QNH pressure setting). However, the field in which the aircraft crashed has an elevation of 730 feet compared with Biggin Hill Airport's 600 feet. Taking account of that difference, it is possible that G-CSPJ descended no more than 370 feet in the last 14 seconds before striking the ground. That would give an average rate of descent (ROD) of 1,585 fpm. This compares with the helicopter operator's Training Manual figure for the ROD during autorotation, at 70 kt, of 1,800 fpm.

Description of the Hughes 369 (MD-500) helicopter

The Hughes 369 series arose from a US military requirement for a light observation Helicopter, where it was known as the OH-6. In its initial form (including the civilian version known as the Model 369HS) it had a four-bladed main rotor and V-shaped empennage. Later versions had a five-bladed rotor and T-shaped empennage, but all models used manual flying controls without hydraulic assistance. Handling is generally considered to be more responsive compared with other helicopters in the same category.

Although, as stated, there is no hydraulic assistance to the flight controls, a device known as 'the one-way lock' is fitted in the longitudinal pitch control circuit. According to the aircraft's manuals, the lock was found to be necessary to offset high stick forces which could be fed back from the main rotor into the longitudinal pitch circuit in the aft-cyclic sense at high forward speeds. The one-way lock is a self-contained hydraulic device which allows inputs from the cyclic control stick to be transmitted to the swashplate but locks if any loads are fed back by the rotor disc into the cyclic stick in an aft sense: these loads are transmitted into the structure. There are two failure modes of the one-way lock – one in which the aft loads are fed-back into the cyclic (translating as about 40 lbs stick pressure) and the other in which the same 40 lbs could be required to move the stick in either longitudinal direction every time a change is required.

All models of this helicopter are equipped with electrical actuators for longitudinal and lateral trim. Trim control is via a conventional 'coolie hat' switch on the top of the cyclic control column.

On-site examination

The wreckage of the helicopter lay spread across a field of short grass. From the initial impact mark to the furthest pieces of wreckage was a distance of 60 metres, forming a debris trail on a heading of 360°. The initial impact marks comprised a heavy depression created by the nose fuselage underside and two marks associated with the front of the landing skids. About four metres further on and to the right of the depression, a series of three main rotor blade marks could be discerned, each partly overlaying the other. After this very heavy impact, which completely disrupted the helicopter forward of the engine firewall, smaller items from the fuselage and the cabin continued to the end of the trail, where the engine, main rotor gearbox, tailboom and empennage came to rest. There had been no fire, although a strong smell of fuel persisted around the initial impact area and along the wreckage trail.

Remnants of two of the four main rotor blades had remained attached to the rotor head, another was found about one-third of the way along the wreckage trail. The fourth had been flung out to the right of the debris trail and lay in the boundary hedge of the field and was the least damaged. One of the tail rotor blades was found 35 metres before the first impact whilst the other was located about the same distance beyond it. Examination of the collective lever friction control (a rotating collar) revealed that the friction was 'off'.

Conclusions from on-site examination

The length of the wreckage trail suggested that the helicopter had been travelling at a relatively high speed (subjectively in the order of 80 kt) on a northerly heading at impact. The depth and relative aspects of the initial impact fuselage, skid and rotor marks indicated a nose-down attitude in the order of 30 degrees, this leading to immediate and complete disruption of the forward fuselage and cabin. The heavier parts of the helicopter were thrown to the furthest extent of the wreckage trail, as is common in this type of impact.

The multiple main rotor blade strikes at a single location were indicative of substantial main rotor RPM with the steep nose-down attitude causing blades to impact successively close together. The fourth blade detached and was thrown to the right before it struck the ground. Similarly, the disposition of the tail rotor blades was consistent with significant rotational speed at the time of their separation.

Thus it was concluded that the helicopter had been structurally intact at the time of ground impact and that there was evidence of high-speed rotation of the main and tail rotors. The aircraft had been travelling at considerable forward speed but descending relatively steeply (compared to normal helicopter operations) with a correspondingly steep nose-down attitude. The impact was not survivable.

Detailed examination of the helicopter

The wreckage was removed from the site and transported to the AAIB hangar at Farnborough for further examination. The airframe was examined first, in conjunction with a representative of the manufacturer. The components of the flight control system, in particular, were separated out and checked for pre-impact continuity and any signs of anomalies. The 'one-way lock' device was taken to the manufacturer's facility in the USA for testing and strip inspection, with no pre-impact defects being found as a result.

The two cyclic trim actuators were identified. Being electric motors rotating an extending screw-jack arrangement via gearing, their extensions were unlikely to have moved during the impact and it was found in both cases that they were in a position corresponding approximately to neutral trim.

The engine was removed from the airframe and despatched to an overhaul facility for strip inspection under AAIB supervision and in the presence of a representative of the manufacturer. This examination concluded that there was no evidence of any pre-impact failures or anomalies and that the engine was operating at the moment of impact. Despite the massive damage to the airframe, the engine itself was relatively intact and it was possible to test most of the associated accessories to a greater or lesser extent. Particular attention was paid to the Power Turbine Governor (PTG) which controls the power turbine (and hence main rotor) RPM. The PTG was mounted on a test rig and put through a manufacturer's test schedule. With one or two minor exceedences of limits, which were not considered to be detrimental to its operation, the unit was considered to have been capable of satisfactory function, although it was acknowledged that the test schedule may not have been effective in detecting any tendency by the PTG to 'hunt' around the selected RPM. It was advised that the best way to check for this phenomenon would be to install and run the unit on a test engine. The condition of the unit precluded this option.

The light bulb filaments from the central warning panel were examined under a microscope to determine whether they showed any signs of hot stretching, indicative of being illuminated at impact. No signs of such were found on any of the filaments.

Finally, some attempts were made to verify that all four entry doors of the helicopter were closed and latched at impact, as the operator advised that accidental in-flight opening of the doors was not unknown, albeit with no catastrophic consequences beyond the possible distraction of the pilot and/or alarming effects on passengers. The earlier models of this helicopter employed a method of latching the doors which was improved on later models, but without the ability to retrospectively embody on the earlier versions. This same lack of positive latching which could lead to incomplete closure and inadvertent opening also leads to difficulty in establishing that the doors are closed and latched prior to impact. This is because structural flexing or handle movement can allow the doors to spring out from their latch plates without leaving distinctive witness marks on either the plates or the lock plungers. The only door which appeared to yield clear evidence of being shut at impact was the pilot's (left) door, where damage and distortion could be matched to similar effects on adjacent frame and fuselage structure. Evidence of the status of the other doors was inconclusive.

Pathological information

The pathology report stated that all three occupants had died from severe multiple injuries which were received during the accident. There was no evidence of any disease or toxicological factor which could have caused or contributed to the accident.

Tests and research

A flight was carried out in a Hughes 500E helicopter, under the command of one of the aircraft manufacturer's instructors/test pilots, to establish what handling characteristics this type of aircraft possesses. Although this was a different variant of the helicopter type from that involved in the accident, the manufacturer advised that its flying characteristics were the same. The most notable differences between the two variants are that the 500E model has five main rotor blades, which is one more than the 369HS, and it has a T tail as opposed to the V shaped tail on the accident aircraft. The opportunity was also taken to try and reproduce the noises which the witnesses recalled G-CSPJ making shortly before it struck the ground. The test conditions were clear sky, light wind, 1,000 feet agl and essentially level flight at the start of each test point.

The most notable feature of the aircraft was its behaviour when the collective was lowered promptly to enter autorotation and the cyclic control was kept in the same position as it had been for straight and level flight at 70 kt. Within three seconds of lowering the collective to its full extent the helicopter had pitched down approximately 30° and rolled about 10° to the left.

The test aircraft was flown past an observer on the ground while regular variations were made, separately, on the collective, cyclic, yaw pedal and throttle controls. The results were recorded on a video camera for qualitative assessment. The inputs which gave the greatest fluctuations in audible pitch and volume were those involving the collective and throttle. Of these two, the throttle variations were most apparent to the ear. It was considered that the noise being heard was that of the rotor blades rather than the engine.

The aircraft manufacturer confirmed that the collective control would remain where it has been set, without friction applied, if the 'collective bungee' had been correctly adjusted. The 'collective bungee' is designed to render collective lever loads relatively constant throughout the full range of travel. Should the adjustment of the collective bungee alter then the collective lever could either tend to 'throw off' or 'throw on' pitch depending on whether it was above or below its midpoint of travel.

Another flight was also conducted in a Jet Ranger helicopter, the other type that the pilot was qualified to fly. This flight retraced, as much as possible, the track flown by G-CSPJ.

Analysis

When, at 0848:16, the pilot completed his radio transmission acknowledging the instruction from the Biggin Hill ATC Tower Controller to change to the Approach frequency, 129.4 MHz, there was no sign that there was a problem with the helicopter or the pilot's ability to control it. He had not responded to the first instruction to change radio frequency and this could have been because he was talking to his wife or son, or vice versa and had not heard the radio call. Possibly there was some other distraction but whatever it was that distracted him, he was not prompted to mention it to ATC and he sounded content to change frequency and continue with the flight in the good weather that existed.

The evidence indicates that G-CSPJ struck the ground 14 seconds later, at 0848:30, in an approximately 30° nose-down attitude having descended 370 feet or more and turned left through about 130°. The aircraft's ground speed was estimated by radar to be 72 kt in the 10 seconds up to 4 seconds before impact. At impact the ground speed was assessed as being of the order of 80 kt. It follows that the aircraft descended at an average rate of 1,585 fpm or greater and at a mean angle of bank of about 30° (using simple formulae) during the last 14 seconds of flight. During that time the pilot changed the aircraft's active radio frequency from 'Biggin Tower', 134.8 MHz, to 'Biggin Approach', 129.4 MHz. At the moment when the helicopter was about to strike the ground, the pilot's voice was heard on the latter frequency indicating that the press-to-transmit switch on the cyclic stick had been depressed.

It is most likely that the pilot changed the radio frequency before or while the helicopter was starting its descent and left turn. To do so, it would have been normal for him to take his left hand off the collective lever and place it on the cyclic stick thus allowing him to use his other hand to operate the controls on the radio which was located on the console to his right. This would have felt unfamiliar by comparison with the Jet Ranger, in which he had gained most of his experience. In the Jet Ranger the single pilot operates the flying controls from the right seat and retains control of the cyclic with his right hand while changing the radio frequency with his left hand. In both cases the collective lever can be held in its cruise position by applying a degree of friction while the lever is untended. It is estimated that this simple act of switching the standby radio frequency to the active position in the Hughes would have taken a matter of about three to five seconds if the 'Biggin Approach' frequency had been pre-set in the standby position.

If, for some reason, the Biggin Approach frequency had not been pre-set in the standby position, the pilot would have had to change both the MHz and kHz elements of that frequency and then transfer it to the active position. This might have taken of the order of five to ten seconds and it is possible that during that process the pilot could have accidentally pressed the inner tuning rotary knob and toggled the tuning cursor to the navigation standby frequency. In that event the act of changing frequency would probably have taken even longer and could have concentrated the pilot's attention inside the aircraft and distracted him from seeing or feeling what the helicopter was doing. The fact that the aircraft descended and turned simultaneously might have masked the gravitational cues that the pilot would normally get if the aircraft was conducting those manoeuvres separately. However, that said, the aircraft would have been quite controllable during the period of the frequency change if the pilot had maintained a frequent lookout and monitored the positions of the flying controls.

If the pilot had not applied sufficient friction to the lever and if the collective bungee had moved out of adjustment since it was last inspected, it is possible that the collective lever could have risen or fallen while it was untended. In doing so the helicopter would have yawed right or left unless the change in torque was counteracted through the yaw pedals; G-CSPJ was seen to yaw both ways at about the time that the pilot acknowledged the frequency change but it could not be concluded with certainty what caused those manoeuvres. They might have been the result of a control input or inputs, instability in the PTG or other sources of variation in the power being delivered by the engine. Unfortunately it was not possible to test the PTG for any tendency to 'hunt' around the selected RPM.

The speed of the main rotor (Nr) was calculated to be 490 RPM during all but the last, very brief radio transmission when the Nr had increased to 500 RPM. These figures compare with the normal 'power on' limits of 484 to 489 RPM and the 'power off', autorotation limits of 400 to 523 RPM. The investigation concluded that the engine was producing power at the time the aircraft struck the ground but, because it was not possible to say with certainty that the PTG was operating correctly, the increased Nr could either have been the result of the engine speed hunting about a mean figure or the aircraft flaring rapidly and the Nr increasing above the governed speed due to autorotative forces. This latter situation could have been the result of the pilot instinctively trying to pitch the aircraft nose up, with rapidly applied aft cyclic, in an attempt to avoid the ground.

The investigation revealed no pre-impact defects in the flying controls, that the engine was operating at the time it struck the ground and that the rotors were rotating within the limits required to enable controlled flight. The average ROD of the aircraft during the final 14 seconds approached the 1,800 fpm expected during a stabilised autorotative descent at 70 kt. This indicates that the collective lever was lowered during that time, either voluntarily or involuntarily. If it had been a voluntary control input, that suggests that the pilot may have been intending to land. The subsequent reconstruction flight in a Jet Ranger revealed that there were other fields ahead and to either side of G-CSPJ's south-easterly track which were possible alternatives and would have provided a more into wind approach than was flown by the Hughes. Also, had it been the pilot's intention to land immediately, it is likely that he would have advised ATC on the radio.

The investigation has revealed no technical reason for the pilot to carry out a landing away from the airfield or any failure which would have impaired his ability to control the aircraft, as might be implied by the extreme pitch attitude of the helicopter when it struck the ground. In the absence of any such fault, the aircraft's responsiveness to control inputs should have enabled the pilot to correct the helicopter's flight path and avoid it striking the ground at such apparent high speed. The implication is that he was not aware of the impending danger as the aircraft departed from straight and level flight.

It is possible that the collective lever lowered without the pilot's knowledge after he had released it to change the radio frequency. Following the accident the collective friction on the left lever was found to be off, leaving both levers free to move. If it had lowered to its full extent, the aircraft would have yawed left unless the yaw pedals were moved to take account of the reduced torque reaction. Also, the aircraft would have pitched forward and rolled left, but less markedly, unless corrective inputs were made on the cyclic. These reflect some of the aircraft's manoeuvres witnessed by observers on the ground. However, they do not account for the fluctuating noises from the aircraft and the successive yawing manoeuvres. It is possible that the collective did drop and that the pilot repositioned it, thus explaining a successive yaw movement to the left and then to the right. That said, having noticed such corrective action, the pilot would probably have been wary of the potential for the aircraft to descend, or he could have applied sufficient collective friction to prevent it lowering.

Consideration was given to the possibility that the pilot could, accidentally, have pulled and closed the fuel shut off valve, mistaking it for a ventilation control which is in a similar position in the Jet Ranger. It was a warm day and, even at that early stage in the flight, the temperature may have been rising uncomfortably, particularly for the pilot's wife and son who were sitting on the back seat. If that was the case, the pilot must have re-opened the fuel shut-off valve because the engine was producing power when the aircraft struck the ground. In addition, following such an unintentional slip, it is likely that the pilot would have been very conscious of the aircraft's proximity to the ground and, as it approached, he would probably have flared the aircraft to reduce both its rate of descent and forward speed, either to execute a forced landing or to avoid the ground. By contrast, witnesses stated that the aircraft pitched down just before striking the ground and the wreckage trail indicated that it had a high forward speed.

The fluctuating noises recalled by a number of the witnesses were best reproduced on an aircraft flown by one of the aircraft manufacturer's test pilots/instructors by repeatedly raising and lowering the collective lever, or rolling the throttle on and off. It is difficult to determine why the pilot should need to 'pump' the collective lever with the aircraft descending under power. It is possible that when he released the collective lever to change the radio frequency, with the friction set too low, the lever dropped under the influence of the collective bungee and became jammed but still allowed a degree of movement. That, however, would not explain the pilot's apparent inability to control the aircraft in pitch, unless the temporary restriction affected both the cyclic and collective controls.

In the absence of any technical fault, there appears to be no reason for the pilot to alter the throttle setting. If he had, or the engine power had been fluctuating, it should still have been possible to control the aircraft in pitch and for the pilot to make an emergency radio call, as he had when carrying out an unplanned landing once before.

Finally, the helicopter was so severely disrupted, it is possible that the damage sustained has masked a problem, fault or control restriction which the pilot was attempting to overcome. It is known that the doors on this model of the Hughes 369 can open if not correctly latched shut before flight. However, in previous incidents it has been possible to close the door again in flight or make a controlled landing and then rectify the situation. Whether this or something else distressed the pilot's 14-month-old son cannot be discounted. Having said that, the pilot and his wife were regarded as being calm and capable people who would have been able to cope with such a distraction without it affecting the safety of the flight, even if it meant making an unplanned landing.

In summary, a large number of conceivable situations were examined during the investigation to try and establish the cause or causes of this accident. Each possibility was flawed because it did not fit all the known facts and witness evidence. This is unsatisfactory from two perspectives. It is not possible to state what measure or measures would prevent such an unusual accident from happening again and, secondly, those with a personal interest may never know why the accident occurred. It is extremely likely that the pilot would have taken the necessary action to prevent the aircraft striking the ground if he had been aware of its proximity. Therefore, it seems either that he may not have realised their predicament until the final moment or there was some obscure fault within the helicopter's power train or flight controls that left no post-impact evidence.

Conclusions

The investigation revealed no evidence of any pre-impact faults in the aircraft and the pilot did not make an emergency call on the radio, although he had successfully changed the frequency from the Biggin Hill ATC Tower frequency to the Approach frequency. A number of possible explanations were explored but each was flawed. As a result of insufficient information, the cause or causes of this accident, which happened in good weather and shortly after departure from Biggin Hill Airport, remain unresolved. This might not have been the case if the aircraft had been fitted with a Flight Data Recorder or Cockpit Voice Recorder or both. No such equipment was required or fitted on this aircraft.

International Standards and Recommended Practices - Flight Recorders

ICAO Annex 6, Operation of Aircraft[1] details the Standards and Recommended Practices for the carriage of flight recorders for rotary wing aircraft. The Standard[2] for International Commercial Air Transport helicopters is that a 30 minute CVR shall be fitted for weights in excess of 3,180 kg and with a first Certificate of Airworthiness dated 1 January 1987 or later. It is a Recommended Practice[3] that, for helicopters of that weight category with a first Certificate of Airworthiness dated 1 January 1990 or later, that a CVR with two hours duration should be fitted. Although the accident occurred on a private flight, G-CSPJ had a Certificate of Airworthiness in the Transport (Passenger) category but, due to the low weight and age of the helicopter, it was not required to carry any type of flight recorder.

The Air Accidents Investigation Branch in the UK has conducted, or assisted with, investigations into the circumstances of many helicopter accidents. All of the investigations concerning larger

[1] Annex 6, Part III, Section II is applicable to International Commercial Air Transport - Helicopters. Annex 6, Part III, Section III is applicable to International General Aviation - Helicopters.

[2] ICAO definition of Standard: Any specification for physical characteristics, configuration, materiel, performance, personnel or procedure, the uniform specification of which is recognised as *necessary* for the safety or regularity of international air navigation and to which Contracting States *will conform* in accordance with the Convention; in the event of impossibility of compliance, notification to the Council is compulsory under Article 38.

[3] ICAO definition of Recommended Practice: Any specification for physical characteristics, configuration, material, performance, personnel or procedure, the uniform specification of which is recognised as *desirable* for the safety or regularity of international air navigation and to which Contracting States *will endeavour to conform* in accordance with the Convention.

helicopters have benefitted from the information provided by the crash protected flight recorder(s) fitted at the time, whilst those without such devices, as in the case of G-CSPJ, have had to rely on witness and wreckage analysis only.

Before the UK requirement to fit both a CVR and a FDR to the larger categories of helicopter was introduced, a CVR was the sole source of information recorded onboard at the time of accidents and no dedicated parametric data, such as from a FDR, was available. In spite of this, valuable information was derived from analysis of audio recordings that assisted the investigations. The type of analysis performed then is still used in current investigations and falls broadly into two categories.

The first, and the most straightforward, is the reconstruction of the actions of the crew during the event. The method primarily concentrates on the provision of a time-related transcript of crew speech (including incoming and outgoing ATC communications). In some cases this may prove to be the *only* evidence of what the crew were attempting to do. In addition to crew speech the transcript includes reference to any audible warnings, alerts or discrete noises events such as 'sound of low rotor speed warning' or 'sound of touchdown'. Subjective analysis of the crew speech by qualified aviation psychologists is also used to provide some information regarding crew stress, workload and behavioural patterns. Combining this information gives the accident investigator a broad picture of the cockpit environment before the accident occurred.

The second area of analysis cannot be achieved through simply listening to the audio recordings but requires more specialist audio equipment. It requires the analysis of the frequency content of the recorded signals and a detailed knowledge of the mechanical and electrical systems onboard an aircraft, in particular the power train construction and usual operating regime of the aircraft. In general terms, the audio signal is separated into the amplitudes of the various frequency components through the use of Fast Fourier Transform (FFT) analysis. A determination is then made as to the origin of the frequencies that are higher than the noise floor of the recording. This method is widely used by accident investigators and, in the main, is applied to the recording made from the cockpit area microphone. It should be noted however that analysis of the recordings from the remaining CVR channels has yielded information that has proved invaluable to the investigation in some circumstances. From analysis of the area microphone recording of a helicopter, a time history of some parametric data can be produced. Main rotor speed, engine gas generator speed and engine free turbine speed are examples of parameters which are usually derived in this manner. Other transmission related parameters might be derived depending on the circumstances of the accident and the quality of the audio recordings.

An assessment of change in amplitude of a particular frequency component over time can also provide the investigator with information regarding the degradation of the performance of an element of the power plant or transmission. This latter type of analysis, conducted by investigators after an accident, is the basis for the health monitoring systems that are now fitted to UK helicopters operating in the North Sea. Although the equipment fit for these helicopters includes a flight data recorder, it should be noted that the parametric time history derived from an audio recording is continuous whereas that from a FDR is a time-sampled history. Some of the sampled points are at intervals of up to one second apart and it is thus possible for the FDR recording to 'miss' some short period event whereas it may be detected by analysis of the CVR recording. In addition, fitting a flight data recording system to any aircraft is far more intrusive and hence likely to be more costly, than the fitting of a CVR system.

It is important to note that, even with a quiet cockpit such as may be found with single crew operation, the CVR will still provide valuable evidence to an investigation.

In accidents where there is extensive disruption of the aircraft due to the circumstances of the impact sequence, it may not be possible to determine cause and effect from wreckage analysis and witness evidence alone. This has proved to be the case in a number of the investigations, including that into the accident to G-CSPJ, which the AAIB has conducted. This is in contrast to the investigations into the circumstances of those accidents where CVR recordings were available; a selection of which are listed below:

AS332	Super Puma cracked tail rotor flapping hinge bearing – spectral analysis
S61N	Heavy vibration – ditched in sea – spectral analysis
S76	CFIT no FDR fitted – crew speech gave history of flight
S76	Crew perception of change in vibration due to failing main rotor blade
S61N	Hydraulic servo failure – spectral analysis
S61N	Search and rescue crew member fatal – crew speech gave history of flight
S61N	Practice search and rescue detail – crew speech gave history of flight
S61N	Tail rotor failure loss of control – crew speech and spectral analysis
SA365N2	Nearly ditched unintentionally – crew speech gave history of flight
AS332	Severe turbulence with tail rotor strike – crew speech and spectral analysis
S61N	Engine bearing failure followed by fire – crew speech and spectral analysis

The Air Accidents Investigation Branch has recognised the value of cockpit voice recordings since their introduction and has, as part of the certification process for new recorder/airframe combinations, provided an element of quality control by conducting assessments of flight test recordings for UK registered aircraft. The AAIB has also promoted the widening of the range of aircraft (initially fixed wing) to which CVRs are fitted. To this end it has recommended that CVRs be fitted to a wider range of aircraft in order to provide investigators with this valuable source of information should a tragedy occur. For fixed wing aircraft, this recommendation[1] has been accepted by, and is awaiting formal approval from, the JAA, which now advises the European Aviation Safety Agency (EASA).

As technology becomes more compact, lighter and cheaper, consideration should be given to encouraging owners, operators and manufacturers to fit recorders to as wide a range of aircraft, however small, with special emphasis initially on those that have a Certificate of Airworthiness in the Transport (Passenger) category. This would increase the proportion of air accidents which are solved and, thereby, improve the aviation community's knowledge of how to prevent accidents. While recommending consideration of such a measure, it is appreciated that the arguments against are financial, technical, and operational. However, it is envisaged that these arguments will diminish as technological progress reduces the commercial penalties of fitting a miniature CVR. It is therefore recommended that:

Safety Recommendation 2004-84

The Department for Transport should urge the International Civil Aviation Organisation (ICAO) to promote the safety benefits of fitting, as a minimum, cockpit voice recording equipment to all aircraft operating with a Certificate of Airworthiness in the Commercial Air Transport category, regardless of weight or age.

It is further recommended that:

Safety Recommendation 2004-85

The Department for Transport should urge the International Civil Aviation Organisation (ICAO) to promote research into the design and development of inexpensive, lightweight, airborne flight data and voice recording equipment.

In a letter to the AAIB dated 14 October 2004 the Department for Transport gave its full support to these two safety recommendations.

[1] AAIB Safety Recommendation 2001-38

Figure 1
(View from rear right seat – Hughes 369HS)

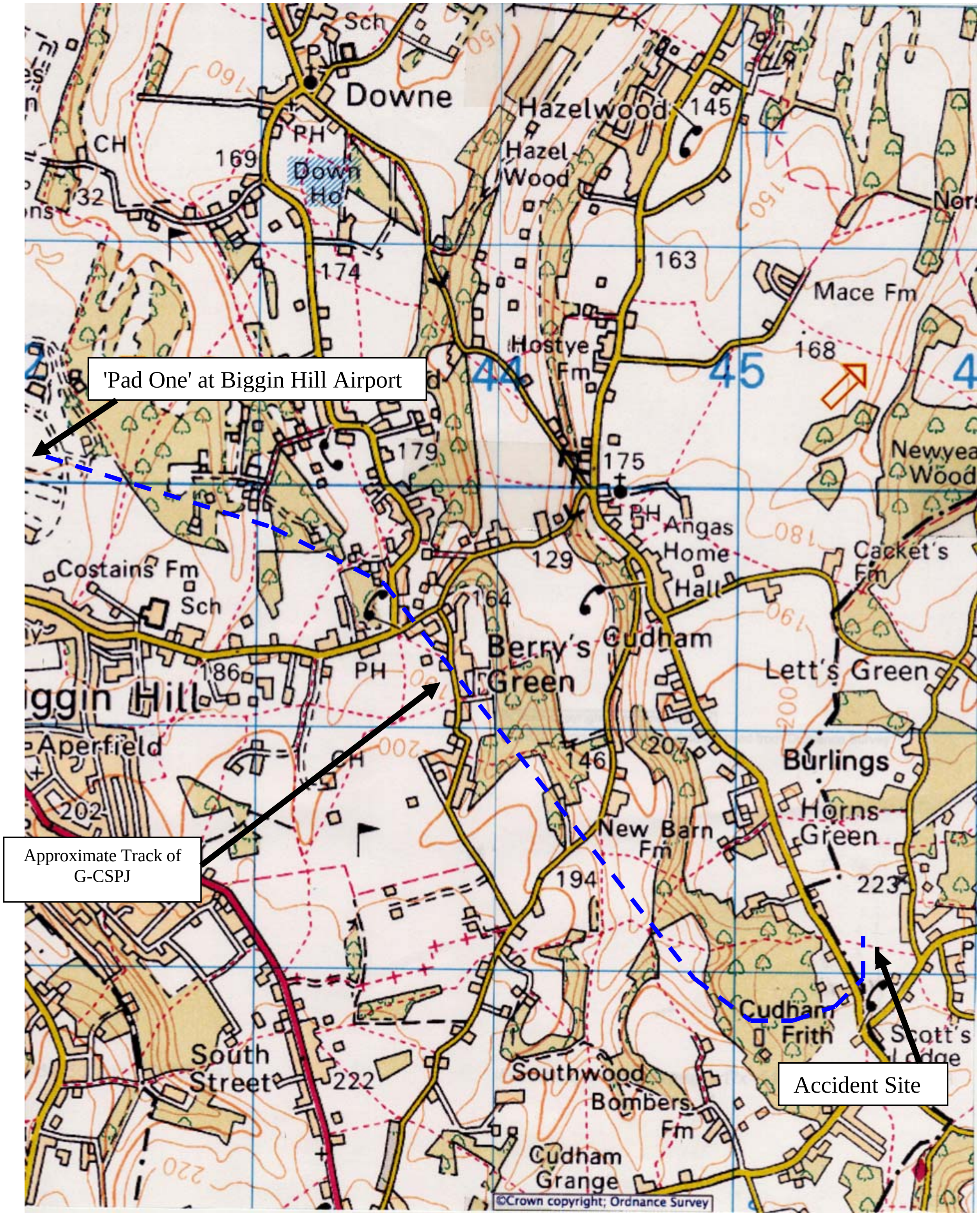

Figure 2

(Reproduced with the kind permission of Ordnance Survey)

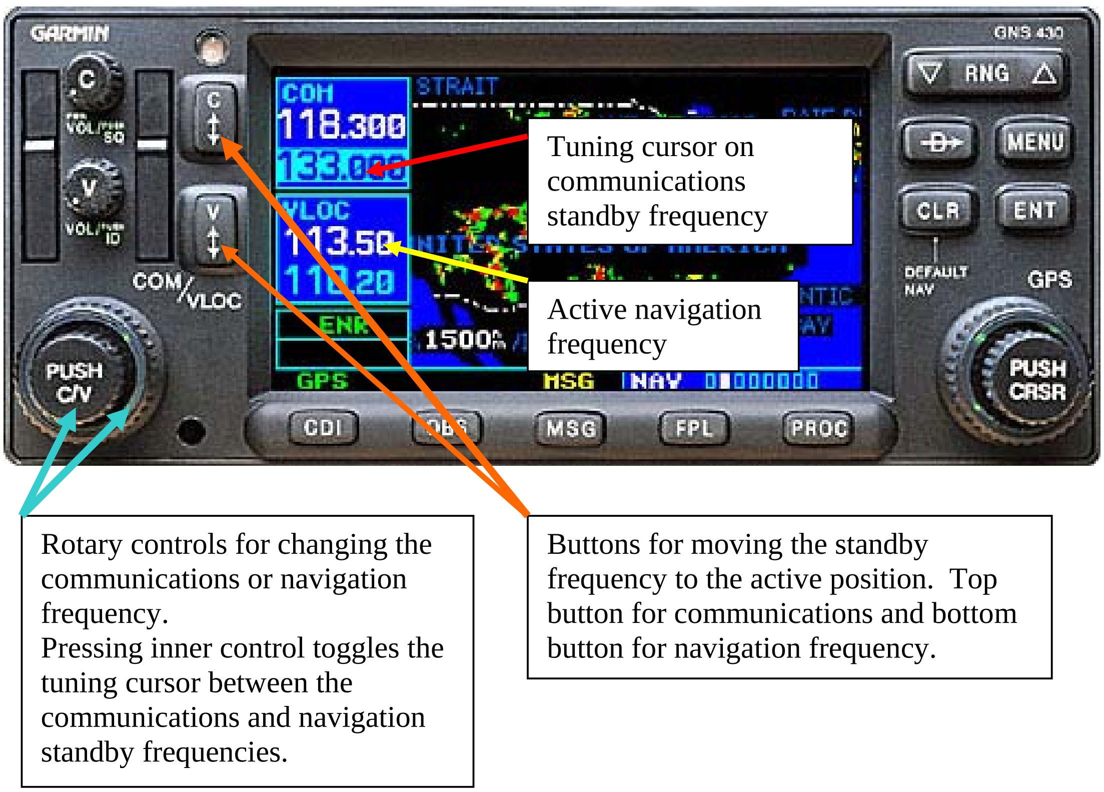

Figure 3
(Garmin GNS 430)

Figure 4
(Instrument console – Hughes 369HS)

Figure 5
(Instrument console – Bell 206 Jet Ranger)