Air Accidents Investigation Branch

Department of Transport

Report on the Accident to the Sikorsky S61N helicopter G-BDII near Handa Island off the north-west coast of Scotland on 17 October 1988

LONDON

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Department of Transport
Air Accidents Investigation Branch
Royal Aerospace Establishment
Farnborough
Hants GU14 6TD

2 June 1989

The Right Honourable Paul Channon
Secretary of State for Transport

Sir,

I have the honour to submit the report by Mr R C McKinlay, an Inspector of Accidents, on the circumstances of the accident to Sikorsky S61N helicopter G-BDII, which occurred near Handa island, off the northwest coast of Scotland on 17 October 1988.

I have the honour to be
Sir
Your obedient servant

D A COOPER
Chief Inspector of Accidents

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Air Accidents Investigation Branch

Aircraft Accident Report No 3/89
(EW/C1087)

Registered Owner and Operator:		Bristow Helicopters Limited
Charterer:		Her Majesty's Coastguard
Aircraft:	*Type*:	Sikorsky
	Model:	S61N
	Nationality:	British
	Registration:	G-BDII
Place of Accident:		NNE of Handa island, opposite Loch Laxford off the NW coast of Scotland.
		Latitude: 58° 26' North
		Longitude: 005° 08' West
Date and Time:		17 October 1988 at 2040 hrs
		All times in this report are UTC

SYNOPSIS

The accident occurred during a Search and Rescue (SAR) mission, centred off the northwest coast of Scotland and it was reported to the Air Accidents Investigation Branch at 2310 hrs on the same day. The investigation was started the following day. The AAIB team comprised Mr R C McKinlay (Investigator in Charge), Mr P F Sheppard (Search), Mr R G Matthew (Operations), Mr R Parkinson (Engineering) and Miss A Evans (Flight Recorder).

The duty SAR crew were called out from their base at Stornoway to conduct a Search and Rescue flight for the two occupants of a small fishing boat, which had capsized somewhere in the area of Handa island. Towards the end of the search, whilst performing a hover manoeuvre, a crew member commented that the helicopter was travelling backwards very fast.

The commander's attempted recovery from this manoeuvre resulted in the aircraft striking the sea and immediately rolling over. All four crew members eventually boarded the liferaft and were later rescued by a Sea King SAR helicopter from RAF Lossiemouth which returned them to Stornoway.

The report concludes that the causal factors to the accident were:

(i) The commander failed to anticipate the effect of the loss of visual references in uncoupled* low speed flight at night.

(ii) The commander suffered a degree of spatial disorientation which led to unintended and undetected backward descending flight.

(iii) Following the crewman's warning, there was insufficient height remaining for the recovery to forward climbing flight which was attempted by the commander.

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* **Uncoupled** refers to flight undertaken with only stabilisation being provided by the Automatic Flight Control System.

1. Factual Information

1.1 History of the flight

Bristow Helicopters is contracted by H M Coastguard to provide an SAR helicopter, to operate from the Outer Hebrides, for Civil Maritime and Aeronautical Search and Rescue tasks off northwestern Scotland. Whilst the prime commitment is to provide maritime, coastal and island rescue services, there is also a requirement to provide a limited role in mountain rescue and to provide back-up to other SAR helicopters so engaged.

The duty crew, which comprised a commander, a co-pilot, a winch operator and a winchman, had been on standby for a call-out since 1200 hrs. At 1900 hrs, they were alerted by HM Coastguard that a small fishing boat had been reported overdue and that an SAR operation was necessary. The first reference point which was given was the southwest corner of Handa island. The specially equipped SAR helicopter lifted off from Stornoway, where it was based, at 1911 hrs. The Lochinver lifeboat had also been launched, but was unable to reach the search area until 2200 hrs.

The SAR dedicated equipment fitted to the helicopter comprised a Forward Looking Infrared (FLIR) system, an Area Navigation (R/Nav) system, an automatic Flight Path Controller (FPC) and directable search lights (See para 1.6). The R/Nav, the FLIR and all the lights were in use at the time of the accident.

It is standard practice and recommended in the Operations Manual that the aircraft commander should delegate the transit flying (towards the search area) to the co-pilot. However, on the accident flight, because it was a night departure and involved an immediate and tight low-level turn over an area of ground obstructions, to starboard, on the co-pilot's blind side of the helicopter, the commander elected to fly the take-off and he continued as handling pilot for the remainder of the flight. He instructed the co-pilot to *operate* the radar and the R/Nav and, during the search, frequently requested of him the data so provided. The winch operator and the winchman assisted with navigation from maps and visual reference. On arrival in the search area the winchman operated the FLIR which, as well as being an aid to navigation, identifies "warm" spots, as might be produced by survivors.

Arriving at Handa at 1931 hrs, the crew found the southwest coastline obscured by occasional patches of mist and so, rather than concentrate on this area, they decided to extend the search area so as to cover the entire periphery of the island. They orbited the island three times in a clockwise direction. Throughout this search, the height of the aircraft was varied, reportedly, between 80 and 200 feet above the surface and the speed was varied between 45 kt and the hover. The intricacy of the manoeuvres in height, airspeed and heading needed to achieve the task and the environment in which it was to be carried out were, in the commander's experience, beyond the capabilities of the FPC. He therefore decided to fly the helicopter uncoupled throughout this phase of the task.

On completion of the three circuits of Handa, having not found anything significant, they returned to the southwest corner and engaged the R/Nav and FPC to set up a "creeping-line ahead" search of the sea to the southwest of that point. This form of search is achieved by flying a series of evenly spaced reciprocal tracks at right angles to the intended direction of advance, so as to search a wide area whilst slowly advancing in the intended direction, in this case southwest. At 2020 hrs, the crew had completed only one leg of this pattern when the Coastguard informed them that one of the survivors had been picked up and that the new search datum was at Latitude 58° 23.34'N and Longitude 005° 09.76'W. This was set into the R/Nav and it placed the datum on the western end of a small island called Aigeich, immediately off the northeast coast of Handa. The Coastguard also reported that the capsize had occurred at 1430 hrs and that the rescued survivor had seen his colleague, who was not wearing any personal flotation aid, sink twice.

The commander therefore tracked round the north coast of Handa island towards the new datum, arriving there at 2023 hrs. For the same reasons as before, and because the FPC tends to "unlock" when flying over outcrops of rock, the commander decided to conduct the search in uncoupled flight. With the aid of the various aircraft lights, the commander was able to keep sufficient visual contact with the rocky outcrops and inlets to conduct the search and maintain visual flight. The search of these islands was continued until it was apparent that no survivor was at the prescribed location and so, at about 2025 hrs, another sweep to the south and west of Handa island was carried out.

During the search phase of the task, crew members were engaged in advising the commander of the aircraft's proximity to obstacles and maintaining the visual and electronic search. On arrival at the designated location the search progressed and widened and knowledge of the aircraft's precise geographical location became of secondary importance to the crew. They were, therefore, subsequently unable to describe the exact flight path flown between 2025 hrs and 2040 hrs, the time at which the accident occurred. However, the transcript of the Cockpit Voice Recorder (CVR) indicates that they were again rounding the southwest corner of Handa at 2031 hrs and, at this time, the Coastguard suggested that they should carry out a search "North of the datum". This, together with such information as the crew are able to supply, makes it likely that the aircraft was flown towards a group of small islands called Dubh Sgeirean 3 nm to the north of Handa.

At 2040 hrs, when the crew considered that they had searched the area thoroughly, the commander climbed to about 200 feet and came to a near hover into wind, whilst deciding where to search next. The commander states that it had not been his intention to come to a hover, but rather to restrict his progress towards the cliffs, of unknown height, which he could see ahead on the radar. However, as a result of this climb manoeuvre, he lost visual contact with the surface and was attempting to fly uncoupled, by reference to the flight instruments only. A few seconds later, the winch operator announced "WE'RE GOING BACKWARDS VERY FAST", to which the commander immediately replied that he was "PUTTING THE NOSE DOWN". Less than one second later, the Automatic Voice Alerting Device (AVAD) announced that the aircraft was descending through 100 feet.

The commander stated that, when he then looked out at the sea surface, he realised that a rapid rate of descent had built up and impact with the sea was inevitable. He therefore attempted to level the helicopter and cushion the impact by application of the collective lever. The lever, however, was already close to the top of its travel and so no further power was available. He later recalled that, just as he brought the aircraft to the near hover, the Attitude Director Indicator (ADI) showed a 2° nose-down attitude, consistent with the level flight he had been performing earlier, and did not show the subsequent nose-down pitch input which he made. Furthermore, upon cross reference, the standby Artificial Horizon instrument showed several degrees of nose-up attitude. However, neither pilot recalls any vertical gyro comparator caption illuminating.

The read-out of the Cockpit Voice Recorder shows that, less than 3 seconds after the AVAD warning, the helicopter struck the water. It struck in a slightly nose-down attitude, rolling to the right and with a small amount of forward movement. The fuselage immediately rolled over to the right and began to sink, nose first, stabilising with only a few feet of the underside of the tail unit sticking out of the water. The helicopter subsequently sank.

Immediate escape was effected by three of the crew: The commander via his sliding window, the co-pilot out of his emergency exit and the winch operator from the starboard cargo door at which he had been positioned. It was only by good fortune that the winchman, who was surviving in a pocket of air inside the fuselage, was subsequently released when the commander and the winch operator opened the rear port emergency exit, from the outside, in order to retrieve the liferaft.

Having located and inflated the liferaft, which the winchman had unstrapped from its mounting on the inside of the emergency exit in his efforts to escape, the whole crew boarded it, to await rescue. This was provided by an RAF Sea King SAR helicopter from RAF Lossiemouth, which recovered the S 61 crew at 2213 hrs and returned them to Stornoway.

The crew were taken to Lewis Hospital, where they were examined and found to have sustained no serious injury.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	-	-	-
Serious	-	-	-
Minor	2	-	-
None	2		

1.3 Damage to aircraft

During the impact with the sea, the starboard side of the boat hull was badly creased and there were ruptures in the skin in the areas below the cockpit, the starboard cargo door and the starboard rear (main) door. The starboard sponson was torn away and the starboard cargo door, together with the winch fixtures mounted above it, was disrupted. The tailboom, just to the rear of its attachment to the fuselage, was severely disrupted by impact inertia. A rotor blade or blades had struck the area of the upper starboard cockpit, causing minor damage.

Major damage had been caused to the main rotor blades, the main rotor head, the tailboom and the tail rotor blades by movement on the sea bed and by the salvage operation.

1.4 Other damage

There was no other damage.

1.5 Personnel information

1.5.1 *Commander* Male, aged 48 years.

Licence: Airline Transport Pilot's Licence (Helicopters) valid until May 1990.

Aircraft ratings: Bell 47, Wessex 60, Bell 212, S 61 N.

Instrument rating: Valid to 29 October 1988.

Medical examination: Valid until February 1989. No waivers or limitations.

Flying experience:

Total hours:	7200
Helicopter hours	6800

	Hours on type	2000
	Hours on SAR:	1700
	Hours in last 90 days:	50
	Hours in last 28 days:	20
	Hours in last 24 hours:	2
	Previous rest period:	24 hrs

Last Base Check: 11 August 1988, valid for 6 months.

Safety and Survival Check: 25 January 1988, valid for 1 year.

Last "wet" liferaft drills: 30 September 1987, valid for 2 years.

1.5.2 *Co-pilot:* Male, aged 26 years.

Licence: Commercial Pilot's Licence (Helicopters), valid until March 1997.

Aircraft ratings: Bell 47, Hughes 369, S 61 N.
Instrument rating: None. Company rated.

Medical examination: Valid until 26 October 1988. No waivers or limitations.

Flying experience:	Total hours	610
	Helicopter hours:	530
	Hours on type:	365
	Hours of SAR:	300
	Hours in last 90 days:	119
	Hours in last 28 days:	49
	Hours in last 24 hours:	2
	Previous rest period:	24 hours

Last Base Check: 27 April 1988, valid for 6 months.

Safety and Survival Check: 7April1988, valid for 1 year.

Last "wet" liferaft drills: 30 September 1987, valid for 2 years.

1.5.3 *Winch Operator:* Male, aged 46 years.

Ratings: Company Crew Trainer. Qualified as both winch operator and winchman.

Medical Certificate:	13 October 1988, valid for 1 year.	
Flying experience:	Total hours:	6200
	Helicopter hours:	2600
	Hours on type:	150
	Hours of SAR:	2600
	Hours in last 90 days:	58
	Hours in last 28 days:	16
	Hours in last 24 hours:	2
	Previous rest period:	48 hours
Last Base Check:	13 August 1988, valid for 1 year.	
Safety and Survival Check	19 August 1988, valid for 1 year.	
Last "wet" liferaft drills:	30 September 1987, valid for 2 years.	

1.5.4. *Winchman:* Male, aged 41 years.

Ratings:	Qualified as both winch operator and winchman.	
Medical Certificate:	18 May 1989, valid for 1 year.	
Flying experience:	Total hours:	6268
	Helicopter hours:	2890
	Hours on type:	304
	Hours of SAR:	300
	Hours in last 90 days:	49
	Hours in last 28 days:	18
	Hours in last 24 hours:	2
	Previous rest period:	48 hours
Last Base Check:	30 May 1988, valid for 1 year.	
Safety and Survival Check:	30 May 1988, valid for 1 year.	
Last "wet" liferaft drills:	1 May 1987, valid for 2 years.	

1.6 Aircraft information

1.6 1 Leading particulars

Aircraft type:	Sikorsky S61N
Serial number:	61750
Date of manufacture:	1975

Certificate of Airworthiness: (C of A)	Renewed in April 1988 in the Transport Category (Passenger) and valid for 12 months.
Certificate of Registration:	Valid. Issued to Bristow Helicopters in November 1985.
Total airframe hours:	16881
Hours since C of A:	409
Engines:	General Electric CT-58-140-2
Hours since overhaul:	No 1: 213 (Total 3547 cycles) No 2: 952 (Total 7015 cycles)

1.6.2 *Weight and balance data*

Basic APS weight:	15408 lb
Fuel weight:	4200 lb
Operating weight:	19608 lb
Restricted T/O weight:	20500 lb
Estimated weight at time of accident:	18208 lb
C of G range at aciident weight (inches aft of datum)	256.8-277.2
C of G at accident weight:	262 ins

1.6.3 *SAR dedicated equipment*

A Louis Newmark LN 450 Flight Path Controller (FPC), when coupled to the LN 400 Autostabiliser Equipment, enables the aircraft to maintain an automatic hover at a pre-selected height and datum point, whilst allowing either the commander or the winch operator to make small fore-aft or sideways adjustments to that datum. This latter capability is enabled by the selection of "HOVER TRIM" on the control console. An area navigation (R/Nav) system on the aircraft provides, by alternative selections, a display of the present wind vector, the ground speed, or range and bearing information from any chosen geographical datum position. A forward looking mapping radar is displayed to the two pilots and a 180° Forward Looking Infrared (FLIR) scanner is operated by the winchman at a console half way down the fuselage on the port side. Finally, apart from the normal landing lights, there is a forward looking adjustable searchlight controlled from the cockpit and a sideways scanning searchlight manually controlled by the winch operator from the open starboard cargo door.

The FPC, when coupled to the R/Nav, provides five modes specifically dedicated to the SAR role of the helicopter. However, the only two relevant to this accident are the "HOVER" and "HOVER TRIM" modes. These differ only in that in HOVER mode, the aircraft maintains a fixed datum into wind hover, whereas in HOVER TRIM the datum can be moved fore/aft and sideways by either the pilot or the winch operator. The pilot achieves this by using the cyclic stick trim switch and the winch operator by means of an Auxiliary Manoeuvre Controller (AMC) mounted just forward of the starboard cargo door.

When operating in THE HOVER TRIM mode, the system is subject to limitations of manoeuvre capability. The groundspeeds achievable are:

Cyclic:	20 kt forward	AMC:	10 kt forward
	15 kt aft		5 kt aft
	15 kt laterally		7 kt laterally.

As the system relies upon radio altimeter and Doppler signals for its reference, it is also subject to the normal environmental limitations of each:

a. At groundspeeds of less than 4 kt, precipitation may produce anomalous FPC guidance and, unless adequate visual references are available, a fly-out should be initiated.

b. Doppler and radio altimeter information will be erroneous if any substantial vessel, structure, coastal cliffs or outcrops of rocks fall within the relevant beam. A minimum horizontal separation of 100 metres from these obstructions must be maintained during coupled operation of the FPC, unless adequate visual references are available.

1.6.4 *Area navigational equipment*

The equipment fitted is a Racal R/Nav (AO3) which can provide range and bearing information from entered positions. It also provides present wind vectors and the aircraft's position. The system derives its raw data from the aircraft's air data sensors, the Decca Chains, available VOR/DME stations and Doppler information.

1.6.5 *Airborne weather/mapping radar*

A Bendix 1400C radar system is fitted which, apart from the normal weather and mapping displays, can be used in conjunction with the R/Nav to provide a variety of navigational capabilities. These are described in paragraph 1.8.

1.6 6 *Forward Looking Infrared equipment*

Forward Looking Infrared (FLIR) equipment, "Infravision FLIR thermal imaging system 1000A", is able to detect infrared radiation and process the images so derived into a TV compatible picture at the console operated by the winchman.

The camera, mounted on a motorised gimbal beneath the nose of the helicopter, is controlled by a joystick control on the console. It is able to detect objects such as a man in the sea at distances up to 160 m and an object as large as a liferaft considerably further. These ranges are also dependent upon the angular width of the sweep, which is variable between fixed ahead and 90° left and right.

This equipment can also be used for close-range navigation.

1.6.7 *Automatic Voice Alerting Device*

An Automatic Voice Alerting Device (AVAD) was fitted to the helicopter and received its information from the radio altimeter. When the helicopter descends through a preselected height, a series of attensons (chimes) are followed by the verbal message "CHECK HEIGHT". Also, as the helicopter descends through 100 feet, the attensons are followed by the message "100 FEET".

1.6.8 *Automatically Deployable Emergency Locator Transmitter*

An ADELT, capable of transmitting on the emergency frequency or transponding on a radar frequency, was fitted to the helicopter. The ADELT after being ARMED could then be DEPLOYED, from its housing on the rear starboard side of the helicopter, by an electrically detonated squib releasing a large spring. The squib could be fired by a manually operated switch in the cockpit, a saline (immersion) switch or one of three frangible switches mounted in the lower hull.

This equipment did not function during the accident sequence.

1.6.9 *Other relevant equipment*

The helicopter emergency exits were fitted with EXIS lights on their corners and sides to facilitate their location in the dark or under water.

Two RFD Type 14 Helirafts (liferafts) were positioned in the helicopter, one fastened to the forward cabin bulkhead and one to the inside of the rear port emergency exit. The forward one must be released and launched manually, the rear is released automatically with the emergency exit.

A Burndept BE 369 emergency locator beacons (ELB) is located beside each of the liferafts.

1.7 Meteorological information

1.7.1 *Forecasts*

Airmet Scottish issued an area forecast at 1000 hrs on 17 October 1988, valid for the period 1100-1900 hrs. Relevant extracts are quoted below:

> Weak front affecting extreme NW with moist airstream over remainder of the region.

Coastal fog near windward coasts.
Outlook to 18/0100 hrs: Increasing low level winds, coastal stratus spreading inland.
Wind at 1000 feet: 150° at 25 kt.

At 1530 hrs, Airmet Scottish issued another forecast covering the period 17/1700-18/0100 hrs. The only relevant change from the previous issue was:

Local moderate turbulence below 5000 feet over land with surface wind exceeding 25 kt in places.

1.7.2 *Reported weather*

There is no weather reporting station close enough to the search area to take into account the local variations of weather likely to be provided by the extreme northwest Scottish coastline, exposed to the Atlantic Ocean.

However, on the CVR the co-pilot can be heard stating that the wind varied between 120°/ 7 kt and 160°/ 13 kt and the crew report that, whilst the direction remained fairly steady from the southeast, the strength and the turbulence varied considerably according to their proximity to the various funnel effects and ground obstructions. They further report that when they were in the water, the wind was virtually calm. The only other comments of significance were that the night was moonless with no horizon visible and other than in the mist patches the visibility was good.

1.8 Aids to navigation

1.8.1 *Horizontal navigation*

The FPC provides, as well as SAR dedicated 3 axis modes, single axis modes comprising, in the horizontal plane, IAS hold, heading hold and R/Nav coupling

For the purpose of navigation, the R/Nav allows keyboard entry of Lat/Long positions as either waypoints or destinations or, when coupled with the FPC it will fly the aircraft to or from them.

The radar system display can be used, together with the R/Nav, to provide a SEARCH mode which, by selection, allows full-scale display ranges from 20 nm down to 0.5 nm. This capability was in use for the precise navigation of the helicopter, whilst conducting the search around the bays and islets.

The airspeed indicator (ASI) is calibrated for all speeds within the capability of the helicopter and is used as a true indication of the airspeed during the take-off profile. However when the helicopter is being decelerated, error, induced by the position of the pitot sensor relative to the ambient airflow, renders the information so derived unreliable at speeds below 45 kt. The Flight Manual defines that the minimum speed for *uncoupled* flight under Instrument Meteorological Conditions (IMC) shall be 45 kt.

1.8.2 *Vertical navigation*

The single axis modes of the FPC provide the capability of both barometric and radio altimeter height hold.

The barometric altimeter height hold has operating limitations as follows:

Minimum speed: 45 kt;
Operating height: Between 500 feet and FL 100.

The radio altimeter height hold has limitations as follows:

Maximum speed for engagement below 100 feet: 70 kt;
Operating height: Between 40 and 999 feet.

The AVAD also provides vertical navigation information. During the helicopter's final descent, the attensons, followed by the message, occurred as the helicopter descended through 100 feet. These are shown on the CVR graph at Appendix 1.

1.9 Communications

All communications between the Coastguard and G-BDII, using the radio callsign "Rescue 119", on VHF FM marine frequencies 156.0 MHz ("Channel 0") and 156.8 MHz ("Channel 16") were satisfactory and were available for transcription. To ensure the safety of the flight, a mandatory radio check call was required at 15 minute intervals.

During the search, difficulty with the communications between the Coastguard and the Lochinver lifeboat had caused an increase in the normal radio traffic and had involved some relaying of messages by Rescue 119. At 2044 hrs, the lack of response from Rescue 119 to a request that they should relay a message to the lifeboat, caused the Coastguard, suspecting that their helicopter might be in trouble, to initiate SAR action with the Rescue Co-ordination Centre (RCC) at Pitrievie Castle, Edinburgh.

1.10 Aerodrome information

None relevant.

1.11 Flight recorders

A Flight Data Recorder was not required and none was fitted.

A Fairchild A100 Cockpit Voice Recorder (CVR), with a recording duration of thirty minutes, using an endless loop of plastic based magnetic tape, was fitted. The track allocation was as follows:

Track 1	Co-pilot's microphone and headset signals
Track 2	Cockpit area microphone
Track 3	Main rotor rpm
Track 4	Captains microphone and headset signals

The recorder was removed from the helicopter and a satisfactory replay was obtained. A graphic representation of the rotor rpm, the AVAD ("100 FEET") and the last two relevant remarks made by the crew, is shown at Appendix 1.

The graph shows that the rotor rpm remained constant at 102-103 % until impact and that the AVAD attensons and 100 FEET message occurred just under three seconds before impact.

1.12 Wreckage and impact information

1.12.1 Recovery of the helicopter

The wreckage was located and then lifted aboard the salvage vessel, North Sea Commander, at 2200 hrs on 25 October. The location and the recovery are described in detail in paragraph 1.17.

1.12.2 Initial examination of the wreckage

From examination of the wreckage on the sea bed and on board the salvage vessel it was assessed that the helicopter impacted the water pitched approximately 5° nose-down, banked 15° to the right and slipping to the right. It had also been moving with a forward speed of no more than 5 kt and descending at a speed in excess of 1000 fpm.

To facilitate the transportation of the wreckage to AAIB at Farnborough, the main rotor head, the port sponson and the rear landing gear were removed.

1.12.3 *Detailed examination of the wreckage*

1.12.3.1 *Aircraft general*

The helicopter as a whole was examined for any evidence of abnormality or other features which may have had bearing on the accident and none were found. Specific areas were then examined in detail and the results are shown in the following paragraphs.

1.12.3.2 *Flight instruments*

The two Attitude Director Indicators (ADI), part numbers 111303-4, were taken to the manufacturers, the Astronautics Corporation in Milwaukee, for a calibration audit and strip examination. Both instruments had been washed free of sea water, dried and soaked in PX 24, a water displacing compound and lubricant, before transit to the USA. Having ensured that the instruments were free of internal damage, corrosion or salt deposit, they were then tested.

The commander's instrument was found to function to specification except for the pitch and roll trim knobs. Detailed examination revealed that salt water had penetrated the variable resistances causing corrosion and salt deposits on the moving parts. The unit was subsequently cycled in ±10° pitch for about 11 hours and found to function normally.

The co-pilot's instrument was also examined. The instrument case had been damaged in the impact and the internal mechanism showed signs of corrosion forming. The impact damage interfered with the roll cage and the roll brushes were very badly fouled. The pitch and roll trim knobs did not function properly, due to similar problems to those which affected the commander's instrument. A functional check of the unit revealed no faults other than those which could be attributed to either the impact or the subsequent immersion in salt water.

The two Sperry VG-14H vertical gyros were also checked. Although neither functioned properly, the faults, which were all identified, were consistent with salt water immersion.

The electrical continuity of the power source and the wiring between the instruments and the vertical gyros was found to be satisfactory. Overall, therefore, nothing was found which might have caused a failure of the commander's ADI whilst the helicopter was airborne.

The standby artificial horizon was examined in detail and no fault was found other than that which could be attributed to immersion in sea water. It was not possible to run the unit because corrosion, resulting from its immersion, had caused the rotor and gearbox of the unit to seize. Electrical continuity and resistance checks revealed no faults.

1.12.3.3 *Hydraulic system*

After the sea water had been drained from the helicopter's hydraulic reservoirs, a ground rig was connected to the system which was then functioned. No fault which could have contributed to the accident was found.

1.12.3.4 *Automatically Deployed Emergency Locator Transmitter (ADELT)*

When examined, the ADELT was found to be in the ARMED condition but the squib had not fired. Tests showed that the squib fired correctly when 24 volts DC was applied to it. The manual deployment switch had not been used and the impact had been insufficiently severe to operate the frangible switches. The continuity of the saline switch electrical circuit was checked and found to be open and it was for this reason that the saline switch failed to fire the squib.
Investigation into the reason for this open circuit revealed that it had been caused by incorrect *completion of the* installation of the ADELT, by the operator, in 1987.

1.12.3.5 *Pitch change rod fracture*

Following the recovery of the helicopter to AAIB at Farnborough, examination of the flying control circuits revealed a fracture of the eye-end of the left cyclic pitch control rod, at the hydraulic primary servo end. Microscopic examination subsequently showed this to be an overload fracture consistent with damage caused during the recovery of the helicopter. During normal aircraft operations, it would not be possible to generate the magnitude of load required to fracture the eye-end.

1.13 Medical and pathological information

All four members of the crew survived and were fit to carry out their flying duties. They were subsequently medically examined and nothing was found to suggest that any medical factor had influenced the course of the accident.

1.14 Fire

There was no fire.

1.15 Survival aspects

The commander escaped via his sliding window, the co-pilot by jettisoning his emergency exit and the winch operator, though considerably hampered by the inrush of water, through the open forward starboard cargo door. They did not have time, nor in the winch operator's case the opportunity because of the inrush of water, to pull the forward jettison handle for the rear port emergency exit (see paragraph 1.15.2). The winchman, who was trapped in the rear fuselage, would not have escaped from the sinking aircraft without subsequent assistance from the crew members who had already escaped.

1.15.1 Immersion suits

Two crew members were wearing bellows neck-seal immersion suits and these were totally satisfactory. The other two, because their bellows neck-seal suits were being overhauled, were wearing the split neck-seal variety. Of these two, the co-pilot, finding it uncomfortable to fly with the suit zipper closed right up to the neck, found himself in the water with his neck-seal partially unfastened. The water therefore entered his immersion suit, causing him to suffer considerably from the cold.

1.15.2 The rear port emergency exit

The rear port emergency exit, to the inside face of which is attached one of the two liferafts and an ELB, can be jettisoned in one of two ways:

a Pulling the toggle positioned on the ceiling of the cabin, immediately aft of the forward cabin bulkhead, or;

b. Pulling the toggle mounted at the top of the cabin sidewall, 3 feet forward of the exit.

There is a third jettison handle, located in the middle of the door, but this is rendered unuseable by the rear liferaft and the ELB, which are strapped to the door's inner surface.

1.15.3 The winchman

The winchman, sitting at the FLIR console half way down the fuselage on the port side, attempted to remain seated until the aircraft came to rest, in accordance with his training. However, he was forced out of his seat by the rapid ingress of water and gradually slipped down the sidewall as the aircraft rolled around him.

He was then washed by a succession of waves, emanating from the open forward exits, towards the rear of the aircraft. When the aircraft eventually stopped moving, it was upside down and the winchman in the rear cabin was in a fairly large air-pocket contained by the floor of the aircraft above his head. The aircraft had settled, temporarily, about 10° nose-down and inverted. He attempted to reach the emergency exit jettison operating mechanism, now well below the water and several feet in front of him, but was frustrated by his own natural buoyancy and the small amount of air trapped in his immersion suit.

The water then began to rise as the aircraft settled to around 15° nose-down, confining him in the extreme tail section of the cabin, in a small wedge shaped air-pocket about 4 feet long by a maximum of 10 inches deep. He tried unsuccessfully three more times to reach the jettison handle but failed for two reasons. The handle was by now 6-8 feet in front of him and even deeper below the water. Also, he was now unable to locate it visually because it was totally obscured by a curtain of bubbles, rising from the soundproofing in the roof and illuminated by the light from the emergency and the Exis lights.

In extreme desperation, he released the liferaft and the ELB from the door and attempted to locate and reach the door release mechanism itself, now made available by the absence of the liferaft and ELB. By now thoroughly exhausted, he was again frustrated by the same problems as before and managed only to rip some of the trim from the door. He stated that, at this point, some quarter of an hour after the accident, he had lost his will to survive.

The commander and the winch operator were together in the water. The co-pilot, who was wet and very cold, had climbed up onto the inverted tail section of the aircraft. Because of the condition of the co-pilot, it was decided to board the liferaft which they imagined would be already inflated with the winchman aboard. Not finding it, they realised that the emergency exit to which it should be fastened was still closed so the commander reached below the water and opened it.

The winchman, seeing a square of dark grey light appear in the position of the exit, made a final effort and duck-diving out of it found himself on the surface. As he was the only crew member who knew where the liferaft was now located, he reached down and retrieved it.

1.15.4 *Emergency locator beacons*

The Burndept BE 369 ELB positioned beside the rear liferaft was deployed and functioned correctly, transmitting on 121.5 MHz and 243 MHz. The ELB stowed in the forward passenger cabin functioned correctly when subsequently checked. The two personal Sarbes of the crew members who operated them transmitted on 121.5 MHz.

1.15.5 The liferaft (RFD type 14 Heliraft)

The liferaft inflated in the approved manner, but the crew reported that the boarding ramp was very slow to inflate, rendering it useless during the time it was needed, and also that it was entangled in various strings and webbing.

It is a design feature of the liferaft that the boarding ramps have the lowest priority for the supply of gas, such that they are presented for use only when the raft itself is fully inflated and ready for boarding. It has been noted, even during daylight wet drills in a heated swimming pool, that this can seem a disproportionately long time.

Once aboard, it needed the combined efforts of the crew to free the canopy from its stowage, in the 'V' slot between the two main buoyancy chambers on the outside of the liferaft. The crew therefore believed that either the main bouyancy chambers or the canopy arches had over-inflated. However, over-inflation is unlikely to have been the cause of the difficulty as the system is protected by several over-inflation relief valves.

The crew have since realised that the difficulty of freeing the canopy was mostly due to incorrect drill procedure in failing to cut the painter attachment line. In a double sided liferaft, the painter attachment line , at the liferaft end, is a "Y" lead, with one branch attached to the top buoyancy chamber and one to the bottom. This, of necessity, passes outside of the stowed canopy arch and the top branch must be severed before attempting to free the arch. Furthermore, they did not use the three tapes provided on the canopy arch for its extraction, but tried to get their hands between the buoyancy chambers and the arch.

It is worth noting, however, that this type of Heliraft had only recently been introduced into service and of the 4 crew members, only the commander had carried out more than one "wet drill" on this type at the time of the accident. It is considered by the operator that the complicated deployment drill of the canopy is a small price to pay for the ability to enter the liferaft immediately that it is inflated. The company have now introduced an Heliraft drill video ,for all UK units, which is shown to the aircrew every six months.

1.16 Tests and research

1.16.1 Flight trials

The AAIB requested Bristow Helicopters Limited to provide another S61 helicopter, together with an experienced SAR crew, for the purpose of establishing whether it was possible to repeat the flight profile of the subject aircraft, without there having been an aircraft malfunction. A series of manoeuvres was carried out in the low velocity regime.

The helicopter used for the tests had an All Up Weight of 17238 lb, about 1000 lb lighter than the accident aircraft, and it was found that the twin-torque (T/TQ) required in the (out of ground effect) hover was 58%.

The OAT was +9° C and the tests were conducted in an 18 kt headwind.

SERIAL 1

The aircraft was flown progressively rearwards to a ground speed of 10 kt, maintaining height by increasing power to 70% T/TQ. Recovery to forward flight needed only a gentle forward cyclic input plus a small increase in power (5% T/TQ). The aircraft recovered smoothly into forward flight with no height loss.

SERIAL 2

The aircraft was flown progressively rearwards to a ground speed of 20 kt, maintaining height by increasing to 70% T/TQ. Similar gentle correction to that used in Serial 1 was applied and. after a short delay, the aircraft recovered smoothly into forward flight with no height loss.

SERIAL 3

The aircraft was rapidly accelerated rearwards to a ground speed of 20/25 kt, requiring 85/90% T/TQ to maintain height. On this occasion, the rapidity of the rearwards travel caused the pilot to make a much sharper, but still quite small, forward cyclic input. The result was a very rapid pitch-down to an attitude of 35°, in an accelerating descent. Recovery required the use of 100% T/TQ, and the (approximately) 30 feet height loss was regained as forward flight speed increased.

SERIALS 4 & 5

It was the intention to make these two serials, as nearly as possible, indentical.and the results were very similar.

The aircraft was allowed to progress rearwards to a ground speed of 15/20 kt without increasing power. This manoeuvre allowed a rate of descent to build up to the order of 250-300 fpm and a little over 100 feet was lost. Full power, 103% T/TQ, was applied in order to recover. Any forward cyclic application tended to pitch the aircraft towards the ground in a nose-down attitude with an increased rate of descent. Rather than accept this consequence, it was decided to recover to rearwards flight. Recovery was then made with very little correction to the already established rearwards speed.

1.16.2 *Computer comparison*

The helicopter aerodynamics department at RAE Farnborough devised a computer programme, using aircraft characteristis provided by the manufacturer, which is able to define flight profiles for a given set of parameters. The parameters used to represent the accident sequence were:

(a) AUW: 18208 lb (b) Wind: 20 kt at 200 feet--0 kt at sea level.
(c) Maximum groundspeed: -(minus) 13 kt.
(d) Cyclic displacement: 3° in 0.2 seconds for 1 second.

The results derived were:

(a) Rate of descent: at 100 feet: 1290 fpm. at 0 feet: 1475 fpm.
(b) Initial pitch-down angle achieved by attempted recovery: 26.7°.

These were used to generate the likely flight profile of G-BDII. It can be seen from the graph, given at Appendix 2, that this profile very closely follows that reported by the crew. The impact parameters of the computer flight profile are also very similar to those found by the post-impact examination of the wreckage.

1.17 Additional information

1.17 1 *The search, salvage and recovery of G-BDII*

Evidence taken from the crew and witnesses, together with the relative position at which the crew had been lifted from their liferaft, suggested several possible positions for the wreckage. All of them were within the entrance to Loch Inchard.
Search operations began using a locally based trawler, the "Integrity R". This departed for the site at 1400 hrs on 20 October 1988. An initial search was conducted using the AAIB's hand held Dukane beacon detector equipment. This is capable of homing onto the sonar signals emitted from the two beacons fitted to the aircraft. By 1500 hrs an approximate position had been determined. A short sidescan sonar run was carried out and a possible target was detected at a depth of 58 metres. The ship's Decca position was then noted.

The following day, Trisponder shore based navigation stations were set up and the position of the Dukane beacon confirmed. A thorough sidescan survey of the area was then carried out, revealing that the only sensible contact was at the position previously identified, 58° 27.6'N and 005° 08.4'W. The position was marked by a buoy and the initial search stood down.

The salvage was carried out using the survey vessel "North Sea Commander". This departed from Peterhead at 1740 hrs on 24 October and was equipped with accurate positioning systems, lifting gear and a diving team which operated WASP one-atmosphere diving suits. The vessel arrived at the buoyed position at 1200 hrs on 25th and, after the required system checks, the WASP was deployed at 1515 hrs and the wreckage positively identified at 1520 hrs. A video camera and visual survey was carried out and it was seen that G-BDII was mainly in one piece but the rear of the tail section had broken off, the starboard sponson was missing and the rotor blades were broken oft. It was lying inverted slightly on its starboard side against an outcrop of rocks.

Lifting strops were attached to the rotor head, using the WASP, and the main fuselage was on the surface by 2200 hrs on the 25th. Some damage was done to the starboard side, blister window and radome during the lift onto the deck and one of the cockpit upper windows had to be broken in order to attach a steadying line. The tail section was subsequently recovered along with some main and tail rotor blade sections and other small items. Operations were ceased at 0514 hrs on the 26th.

During the lifting operation, although the wind had been gusting to force 8, the seas at the recovery site were moderate due to being in the lee of the land. However, the start of the return voyage was delayed by the sea conditions until 1015 hrs. The North Sea Commander berthed at Aberdeen at 0900 hrs on 27 October 1988.

1.17.2 Previous instances of temporary loss of control close to the hover

A task similar in some aspects to the SAR role is that performed by the Royal Navy helicopter pilots, when "sonar dunking" in the anti-submarine role.

A survey of the occurrences of departure from a stable hover, covering the period January 1977 to July 1986, was made by the Royal Navy. Although the instances investigated were all flown by Sea King helicopters, the relevant flight characteristics of this helicopter and those of the S 61 are virtually identical.

In their report, it was determined that there had been six incidents which:

a. All occurred at night.
b. All originated with late detection of departure from a steady hover, usually backwards.
c. All attempted to recover to the hover.
d. All had the potential to deteriorate very rapidly.

2. Analysis

2.1 Conduct of the flight

2.1.1 Systems and instrument failures

The nature of the accident provided a possibility that a failure in the flying control circuits or a decrease of engine power available could have been contributory, if not causal, to the accident. The engineering investigation therefore concentrated upon the particular aspects of these systems likely to have promoted the events which led to the accident. However, examination of the wreckage revealed nothing to suggest a pre-impact failure of the flying control systems and the CVR showed no significant decrease in main rotor rpm at the time when the commander had applied full collective lever. The flight instruments, including the ADIs were also examined and no evidence was found to suggest a pre-impact failure, although a transitory failure of the commander's ADI could not be ruled out,

2.1.2 Rearwards drift

In all modes of helicopter flight, constant reference to pitch attitude, height and speed is needed. Whilst flying on instruments in forward flight above 45 kt, this is provided by the ADI, the altimeter and the airspeed indicator, whereas in visual flight the three parameters are maintained primarily by reference to external cues. However, where full visual references are not available, careful monitoring of the instruments is required to avoid deviations of altitude and height.

The commander's decision to forego the use of the automatic systems of control during the low level search was based on his own experience of their limitations and was therefore justifiable at low level, provided that he remained in an environment where sufficient visual reference was available. This was the case when the helicopter was in a low hover above the rocky outcrops which provided him with adequate visual reference.

However, being uncertain of the height of the cliffs ahead, the commander elected to climb gently to 200 feet before deciding on his next course of action. Immediately before the climb, he had three options available to him:

(a) Maintain visual reference whilst turning the helicopter onto a heading suitable for a climb out;
(b) Attempt to engage automatic hover before turning onto a clear climb out heading;
(c) Perform a maximum rate climb without cyclic control input until clear of obstacles, and then resume forward flight .

By climbing, the commander had deprived himself of the references necessary for visual flight. However, he did not then resume a forward flight speed capable of registering on his ASI and, although he was then compelled to fly by reference to the flight instruments only, he did not engage the PFC.

In uncoupled flight with no visual references the lack of groundspeed information rendered the task of maintaining a hover, or near to it, extremely difficult and accidental drift was almost inevitable. This is supported by the number of previous instances, quoted by the Royal Navy, where positional control was lost. Furthermore, once the excessive drift back had developed, the option of engaging automatic flight was lost.

The commander later stated that a transient failure of his ADI may have been responsible for the initiation of the drift back. However, the previous instances of drift back quoted, none of which included reports of unserviceable ADIs, suggest that an occurrence of a transient failure of this instrument is neither necessary for, nor particularly pertinent to, drift from the hover datum.

It could be considered that an experienced SAR commander might reasonably be expected to monitor the indicated air speed in order to ensure that (what he believed to be) a continuing gentle acceleration was actually taking place. This however was not the case, and therefore was contributary to the commander allowing drift back to occur.

2.1.3 *The attempted recovery to forward flight*

When the commander was informed that the helicopter was travelling backwards very fast, he had only two options. He could either immediately initiate a climb with full power, in this case backwards, or he could attempt a recovery to forward flight.

It is apparent from both the flight trials described and the computer generated flight profile that, once a significant rearwards speed and rate of descent has been established, application of forward cyclic control causes further loss of height. The rate of its application also plays a part in the consequent loss of height. On the occasion of the accident, the commander's instinctive attempt to correct rapid rearwards travel *might* have naturally generated a high rate input of cyclic control, however small, and thus exacerbated the rate of descent already present when he applied it.

It can be seen on the CVR graph that by the time recovery had been implemented, at about 3 seconds to impact, the helicopter had already descended to 100 feet. However, being unaware of the rate of descent or, other than the comment that it was "very fast", the actual backwards speed attained, the commander's attempted method of recovery, by applying nose-down pitch and power, was reasonable.

Following his attempted recovery, any transient failure of the commander's ADI may have denied him knowledge of the degree of nose-down attitude attained and therefore the requirement to correct it. Nevertheless, once the descent rate and rearwards speed had been established, recovery to either level or climbing forward flight was almost certainly not possible within the 100 feet remaining.

It may therefore be concluded, with the benefit of hindsight, that the recovery most likely to succeed would have been to initiate a climb by full power application and then, once the climb had been established, gently transition into forwards flight.

2.2 The rear port emergency exit

The situation in which the winchman found himself appears to have been a direct result of his inability to locate or reach the release mechanism of this exit once the helicopter had inverted.

It is recorded that most helicopter uncontrolled ditchings, in other than ideal conditions, have resulted in a capsize. It is therefore necessary that emergency exit jettison mechanisms, whether on doors or hatches, should be as accessible when the helicopter is inverted as they are when it is upright. A recommendation has been made to the CAA that they should consider methods of implementing this.

3 CONCLUSIONS

(a) Findings

(i) The crew were properly licenced and medically fit to carry out their duties.

(ii) The crew were conducting an SAR flight in search of a possible survivor from a capsized fishing boat.

(iii) The helicopter had been maintained in accordance with an approved maintenance schedule and its Certificates of Airworthiness and Maintenenance were valid at the time of the accident..

(iv) Nothing was found to suggest that the helicopter was other than serviceable prior to the accident, however, a transitory fault may have occurred in the commander's ADI which, although possibly contributory, is not considered to be significant to the accident.

(v) Following a portion of the search which had been conducted without the use of the FPC, the helicopter was climbed gently and with little forward speed to 200 feet, with a consequent loss of external visual references. The difficulty of flying at low speed without visual references was not anticipated by the commander.

(vi) The helicopter developed a significant rearwards drift and rate of descent.

(vii) The attempted recovery to forward flight was a reasonable action, with the knowledge available to the commander at the time. However, subsequent tests have shown that a full power climb, with no attempt to regain forward flight until the climb had been established, would have been more likely to succeed.

(viii) The internal rear port emergency exit release mechanism was not readily accessible when the helicopter was inverted and partially flooded.

(ix) The crew did not use the correct liferaft canopy operating procedure.

(x) The ADELT electrical circuit had been incorrectly wired and consequently the saline switch did not operate the release mechanism.

(b) Causes

Causal factors of the accident were:

(i) The commander failed to anticipate the effect of the loss of visual references in uncoupled low speed flight at night.

(ii) The commander suffered a degree of spatial disorientation which led to unintended and undetected backward descending flight.

(iii) Following the crewman's warning, there was insufficient height remaining for the recovery to forward climbing flight which was attempted by the commander.

4 Safety Recommendation

It is recommended that the Civil Aviation Authority examine the requirement for the provision of a more accessible rear port emergency exit release mechanism for occasions when the helicopter is flooded whilst inverted, and illuminating it and the existing handles with Exis lights or other means.

R C McKINLAY
Inspector of Accidents
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