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REPORT ON THE ACCIDENT TO

SIKORSKY S-76B G-HAUG

AT OMEATH, CO. LOUTH

12 DECEMBER 1996

AIRCRAFT ACCIDENT REPORT 01/98

Notification of Accidents or Incidents should be made on the 24 hour reporting line

(01) 604 1293

In accordance with Annex 13 of the International Civil Aviation Organisation Convention, European Union Council Directive 94/56/EC and Statutory Instrument SI 205 of 1997, the sole purpose of this investigation is to prevent aircraft accidents. It is not the purpose of the accident investigation nor the investigation report to apportion blame or liability.

CONTENTS

AAIU Reference No: ***19960076***
Category: ACCID

Name of Operator:	Norbrook Industries
Manufacturer:	Sikorsky
Model:	S-76B
Nationality:	British
Registration:	G-HAUG
Place of Accident:	2 nm SE of Omeath, Co. Louth, Ireland
No. & Type of Engines:	2 PT6B-36A
Year of Manufacture:	1989
Date :	12 December 1996

0. Synopsis

0.1 Summary

G-HAUG departed Belfast International - Aldergrove Airport on 12 December at 18.03 hrs, to return to its home base at Ballyedmond, Co. Down, Northern Ireland. This would normally be a flight of some 20 minutes duration. The approach to the home base was executed using a locally produced GPS-based approach procedure. Having commenced its descent, in preparation for landing at Ballyedmond, the helicopter struck the north face of the Carlingford Mountains at 960 feet above sea level, approximately 2 miles SE of the village of Omeath, Co. Louth, at 18.16 hrs. All three occupants suffered fatal injuries.

The investigation found that the circumstances of the accident were consistent with controlled flight into terrain.

0.2 Investigation

The accident was notified to the Air Accident Investigation Unit (AAIU) by the Irish Marine Emergency Service (IMES) at 16.30 hrs on 13 December 1996, and the investigation commenced that day. The Air Accident Investigation Unit team consisted of Mr. G. Liddy, Investigator-in-Charge, and Mr. J. Whyte. In addition, inspectors from the UK Air Accidents Investigation Branch (AAIB) took part in the investigation, including Mr. R. Shimmons (Operations), Accredited Representative, and Mr. S. Culling (Engineering), Advisor to the Accredited Representative. The Cockpit Voice Recorder was transcribed by Mr. R. James of the Flight Recorder Section of the AAIB.

The manufacturer of the aircraft, Sikorsky, actively assisted in the investigation, and Racal Avionics decoded the memory of the RNAV-2 computer.

Note 1: The pilot designations used for the two flights in this report are:

	(1) Training Flight	(2) Final Flight
Second pilot of the operation	Pilot under Instruction	PNF
Visiting Pilot	Instructor	PF
Chief Pilot of the operation	-------	Passenger

Note 2: All timings relating to the final flight of G-HAUG are harmonised with GPS - derived UTC.

Acknowledgements

The map extract shown in Annex C which is taken from Sheet 29 of the 1:50,000 Series, is used with the permission of the Ordnance Survey Office, Phoenix Park, Dublin, given under Permit No. 6687.

The map extract shown in Annex D, which is taken from Sheet 29 of the 1:50,000 Series, is used with the permission of the Ordnance Survey Office of Northern Ireland, given under Permit No. 1017.

1 FACTUAL INFORMATION

1.1 History of the Flight

1.1.1 Background to the Flight

The helicopter was operated as a private aircraft by Norbrook Laboratories, mainly to transport the Chairman of that company. Two pilots were employed by the company to fly the aircraft. The Chief Pilot had been employed by the operator for two years. The Second Pilot of the operation had been employed by the operator for nine months. This pilot did not possess an Instrument Rating. He had undergone a flight test for the award of an Instrument Rating in November 1996, but he was unsuccessful. It had been arranged that he would retake the Instrument Rating Flight test with a UK Civil Aviation Authority (CAA) examiner in G-HAUG on the morning of 13 December 1996.

To assist in the preparation for this Flight Test, the services of the Visiting Pilot, an experienced instructor, were engaged. This visiting pilot was also engaged to act as the safety pilot for the test on 13 December. He had also performed the duties of safety pilot on the unsuccessful Instrument Flight Test in November. This pilot was a CAA approved Instrument Rating Examiner (IRE), but he was not authorised to conduct initial Instrument Flight Tests.

A routine flight from Ballyedmond to a helipad in south Dublin was flown on the morning of 12 December, taking off at 10.00 hrs with the Chief Pilot as P1 and the Second Pilot of the operation as P2. G-HAUG then departed Dublin at 14.50 hrs with the Second Pilot of the operation as P1 and the Chief pilot as P2. A running stop was made at Ballyedmond where a passenger disembarked, and the helicopter continued to Aldergrove, where it landed at 15.55 hrs. The helicopter was refuelled, and the crew met with the Visiting Pilot, and a pre-flight briefing took place. The helicopter then took off at 17.00 hrs for instrument flying training of approximately one hour's duration, in the Aldergrove Airport area, with the Second Pilot of the operation in the right hand cockpit seat, and Visiting Pilot in the left hand cockpit seat, as instructor. The Chief Pilot remained on the ground for the duration of this training flight.

The Cockpit Voice Recorder (CVR) recorded the last 5 minutes of this training flight. No approach or landing checks were heard on the CVR during this period.

At 17.55 hrs the helicopter landed at Aldergrove Airport, and picked up the Chief Pilot, without closing down the engines or rotors.

1.1.2 Final flight

For the final flight to Ballyedmond, the Chief Pilot sat in the passenger cabin. During the running pick-up of the Chief Pilot, the Visiting Pilot clearly indicated that he had expected the Chief Pilot to take over his front seat. The Second Pilot of the operation said to the Visiting Pilot that the Chief Pilot would not want to fly the leg back to Ballyedmond. The two pilots then remained in the seats flown on the training flight.

The Second Pilot of the operation decided that the Visiting Pilot should be the handling pilot (PF) and that he, the Second Pilot of the operation, would be the non-flying pilot (PNF) for the return trip to Ballyedmond. This decision was accepted by the PF. The PNF then filed a flight plan with Aldergrove ATC for Ballyedmond (Kilkeel) by radio. G-HAUG was cleared by ATC to fly to Kilkeel, using Special Visual Flight Rules (SVFR), not above 2000 feet, to take them to the Aldergrove Zone boundary. No pre-departure cockpit checks were heard on the CVR.

As the aircraft lifted off initially, a warning chime sounded, followed by a low pitched beep. The PF accepted responsibility for this event, and there was some banter from the PNF and the Chief Pilot. At 18.01 hrs the helicopter departed Aldergrove Airport and routed initially to a reporting point, Moira, at the Aldergrove Zone Boundary. At 18.02 hrs a radio frequency change was made from Aldergrove Tower to Aldergrove Approach Control. At 18.04.01 hrs, the PF expressed concern with the situation and his lack of knowledge of the area, and stated that he was relying on the PNF for navigational guidance. The PNF replied that he had set up the navigational system to route them to Moira and thence to Warrenpoint. Analysis of the RNAV-2 system subsequently showed that the selected route was from Moira to Warrenpoint, thence to a waypoint MAP, located 1 mile south of Ballyedmund, and finally to Ballyedmund. Details of the route are given in Para 1.12.5.5.

The crew discussed climbing the aircraft to 2,500 feet, but stopped somewhat short of that altitude because the outside temperature was below 0°C. At this point the PF commented that they were on top of a cloud layer. The PF then requested the Flight Director to be displayed on his side. The PNF noted that the PF did not have the Flight Management System (FMS) selected, and he then set it up for the PF.

At 18.05.30 hrs, the PF again expressed his concern, specifically with regard to high ground to the left of track. The PNF reassured him and pointed out the motorway at the zone boundary.

At 18.06 hrs the PF called ATC to report leaving the Zone, and was instructed to call when approaching the Mourne Mountains. At 18.07.15 hrs the PF asked the PNF to check the external temperature. The PNF replied that the temperature was zero, but there was no ice. At 18.07.42 hrs the PNF advised the PF that it was now safe to descend to 2,000 feet. ATC requested the aircraft to report its maximum height. The PF replied *"not above 2,500 feet"*.

At 18.10 hrs, the PNF stated that they had twelve miles to run to waypoint WARRN, that a descent to 1,500 ft could be started 5 miles before WARRN, and that the rest of the let down would be done after passing WARRN.

At 18.12.06 hrs the PNF instructed the PF to start a gentle descent; the PNF called Aldergrove to inform them that they were starting their descent and that they were leaving their frequency. Aldergrove acknowledged this call.

The PNF remarked to the Chief Pilot *"Quite claggy out there"*, to which the Chief Pilot replied "*Yes, just a bit"*. The PNF then advised the PF to slow down, and the PF confirmed that Nav Capture was achieved, indicating the aircraft was now flying a pre-programmed route, using the inputs from the autopilot.

At 18.14.17 hrs, the PNF advised the PF that they were crossing a small ridge north of Warrenpoint and that this could be observed on the movement of the Radar Altimeter Indicator (Rad-alt).

As the helicopter approached waypoint WARRN, beside Warrenpoint, at 18.14.40 hrs, the PNF advised the PF *"Okay, don't let it turn you early. In fact I'd go on heading for a bit"*. The PF replied *"Well, about south? That about right?"* and the PNF responded *"Just maintain south for a while, yes please.....,cos it's turning you inside the........"*. but did not complete the sentence. The PF acknowledged this instruction.

At 18.14.50 hrs the PNF said *"Okay. Now there's WARRN so you can begin your turn and descend all the way down to 500 feet"*. There was no response from the PF. Four seconds later the PNF added *"And you've got five miles to run"*. The response of the PF was *"Two miles a minute, that should be about right"*.

At 18.15.23 hrs the PNF commented that they should break out into clear air shortly if, based on his expressed assumption, the weather was the same as when they had departed Ballyedmond at 15.30 hrs. The PF then requested the undercarriage to be lowered. The PNF lowered the undercarriage and confirmed the Engine Air Particle Separator (EAPS) and passenger sign were on. The PF then requested the PNF to "*run through the checks*". The PNF then started to call out the standard checklist. At 18.16.03 hrs, as the checks were in progress, the PNF advised the PF to turn onto a heading of 130º. The PNF then said *"I'll just go off that for a moment, yeah."*

At 18.16.20.3 hrs the alarm of the Automatic Voice Alerting Device (AVAD) started to sound and the aircraft simultaneously struck the mountain. The CVR stopped at 18.16.21.8 hrs.

The ground speed at impact was 124 kts, as indicated by the navigation computer. The location of the impact was at:-

Latitude :-	54º 03.675'N
Longitude:-	006º 13.954'W
Elevation :-	960 ft. above sea level

The alarm was raised the following morning, 13 December, and the wreckage was located later the same day.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	2	1*	Nil
Serious	--	--	--
Minor/None	--	--	--

* The Chief Pilot is considered a passenger in the final flight.

1.3 Damage to Aircraft

G-HAUG was totally destroyed in the accident.

1.4 Other Damage

Approximately 675 litres of JET A1aviation fuel were scattered over the crash site.

1.5 Personnel Information

1.5.1 **PNF**: Male, aged 50 years

Licence:	Airline Transport Pilot's Licence (Helicopters and Gyroplanes) First issued 11 May 1989 Valid until 10 May 1999
Aircraft Ratings:	Aerospatiale AS350B, Bell 206 series, Sikorsky S76A, B & C
Instrument Rating:	None
Medical Certificate:	Class 1 valid to 28 February 1997 With the requirement to have available spectacles to correct for near vision whilst exercising the privileges of the licence.
Last Base Check:	20 April 1996
Flying Experience:	Total all types: 4,150 hours On type: 160 hours Last 90 days: 60 hours Last 28 days 20 hours

1.5.2 **PF**: Male, aged 43 years

Licence:	Airline Transport Pilot's Licence (Helicopters and Gyroplanes) First issued 25 November 1987 Valid until 24 November 1997 Airline Transport Pilot's Licence (Aeroplanes) First issued 14 December 1990 Valid until 13 December 2000
Aircraft Ratings:	ATPL(H): Bell 222, Bell 206 series, Sikorsky S61N & M Sikorsky S76A & B ATPL(A): Boeing 757, Boeing 767 Boeing 777, PA 23, 34 & 44 series

	Instrument Rating:	Valid from 9 May 1996 (renewal)
	Medical Certificate:	Class 1 valid to 21 February 1997
	Last Base Check:	21 May 1996
	Flying Experience:	Total all types: 12,042 hours On type: 438 hours Last 90 days: 12 hours Last 28 days 3 hours (data valid to 23 November 1996)
1.5.3	**Chief Pilot**: (passenger)	Male, aged 45 years
	Licence:	Airline Transport Pilot's Licence (Helicopters and Gyroplanes) First issued 03 July 1990 Valid until 02 July 2000
		Private Pilot's Licence (Aeroplanes) First issued 09 June 1976
	Aircraft Ratings: ATPL:	 Aerospatiale AS355F, Bell 212, Bell 206 series, Sikorsky S61N & M Sikorsky S76A, B & C, Westland S55 series 3
	PPL:	Single engine Aeroplanes up to 5700 kg.
	Instrument Rating:	Valid from 8 May 1996 (renewal)
	Medical Certificate:	Class 1 valid to 31 December 1996 With the requirement to have available spectacles which correct for near vision whilst exercising the privileges of the licence.
	Last Base Check:	15 November 1996
	Flying Experience:	Total all types: 11,990 hours On type: 490 hours Last 90 days: 37 hours Last 28 days 18 hours

1.6 Aircraft Information

1.6.1 General Information

Leading Particulars

Type:	Sikorsky S76 B
Constructor's Number:	760358
Date of Manufacture:	1989
Certificate of Registration:	Registered in the name of Norbrook Laboratories Ltd., Newry, Co. Down.
Certificate of Airworthiness:	Issued 3 January 1996, valid until 2 January 1997, in the Transport Category (Passengers).
Total Airframe Hours:	2,511 hrs
Engines (2):	P & W PT6B-36A Free Turbine turboshaft engines: No. 1: Serial No. 36111 No. 2 : Serial No. 36077
Maximum Weight Authorised for take-off:	11,700 lbs
Actual Take-off Weight:	10,556 lbs
Estimated Weight at time of Accident:	10,316 lbs
Estimated Fuel Remaining at time of Accident:	1,230 lbs
Centre of Gravity (CG) Limits at Accident Weight:	195.6 to 207.4 aft of Datum
Centre of Gravity at time of Accident:	206.3 aft of Datum

1.6.2 Aircraft description

The S-76B registered as G-HAUG was constructed by Sikorsky Aircraft in 1989. It was previously registered in the UK as G-HPLC. On 26 September 1994, the registration was changed to G-HAUG and ownership was transferred to the current owner. The S-76B has a conventional semi-monocoque fuselage and tail boom, and retractable tricycle undercarriage. There is a four bladed main rotor and a four bladed tail rotor. Power to the rotors is supplied by two Pratt and Whitney PT6B-36A free turbine engines.

1.6.3 Cockpit Equipment

G-HAUG was fitted with a comprehensive avionic suite and was certified for single pilot operations in IFR conditions and at night. Central to the avionic system was a Honeywell FZ-700 dual Digital Automatic Flight Control System (DAFCS). The DAFCS was effectively an autopilot specifically designed for use in helicopters. The prime instrument display was a Honeywell EDZ-705 Electronic Flight Instrument System (EFIS) consisting of four Visual Display Units (VDUs), located in vertical pairs in front of each pilot. The upper VDU was normally used as a Attitude Director Indicator (ADI), which basically provided artificial horizon information required to fly the aircraft. The lower VDU was normally used as a Horizontal Situation Indicator (HSI), which was effectively a compass display used to navigate the aircraft.

1.6.4 Aircraft Navigation Equipment

The aircraft was fitted with a Racal Avionics RNAV-2, an Area Navigation System which could provide navigation information from up to four independent sources. In the event of loss of signal from a source, the system would continue to compute the aircraft's position, based on the last known position from the source, and updated by Dead Reckoning (DR), using TAS and aircraft compass heading. The system was used to control a course indicator on the HSI display. The crew could select which navigation source, or combination of sources, they wished to use as the primary navigation reference.

Three navigation sources were fitted to G-HAUG; one based on the Global Positioning System (GPS) using satellites, a second on the Decca navigation system, and a third on VOR/DME. The RNAV-2 had a Navigation Computer Unit (NCU) and a Control & Display Unit (CDU). The NCU received inputs from various sensors and provided outputs to the cockpit display units and the DAFCS.

Control of the NCU was provided by the CDU, using function keys and an alpha/numeric keyboard. The GPS receiver fitted to the aircraft was a Trimble TNL 8000.

The system maintained a databank of waypoints. These waypoints included the position of selected points on the earth's surface, such as navaids (NDBs, VORs and DMEs) and airways, together with major airfields, runway ends and outer markers and prominent ground features which could be used as an aids to navigation. The databank could also be programmed to include route structures for a particular operator. On G-HAUG, a database of waypoints particular to this operation was supplied by Racal. The expiry date of this database had lapsed at the time of the accident, but this did not affect the operation of the system on this flight. The database was supplemented by further local waypoints inputted by the operator's pilots. The date when these local waypoints were generated was not determined.

1.6.5 Navigation Control System

The DAFCS had the facility to be coupled to the Flight Director (FD). When this facility was engaged, the DAFCS controlled the aircraft using the same commands as those displayed on the ADI and HSI. These instruments acted as a means of monitoring the performance of the DAFCS or autopilot. When the DAFCS was not coupled, the same modes of operation were available for Flight Director only. The pilot could then manoeuvre the aircraft to satisfy the FD commands.

'Coupled' is the term given to the configuration of the navigation system and DAFCS which enabled radio beacons and/or waypoints to be navigated automatically.

The crew could select an number of different DAFCS modes. The following three modes are pertinent to this report:

<u>Route Steer Mode</u>

In Route Steer Mode, which was selected by pressing the NAV button, the RNAV-2 provided steering guidance to maintain the aircraft on track between pre-defined waypoints along a selected route. As the aircraft approached a waypoint, a turn alert arrow flashed approximately one minute before the start of the anticipated turn. When the anticipated turn point was reached, the turn alert arrow was extinguished, and the course pointer on the HSI turned to the course for the next leg of the flight. The distance of the anticipated turn point from the waypoint was dependent on a number of factors, including the magnitude of the course change, the aircraft speed, wind speed and wind direction.

While the display indications changed to the new leg at the anticipated turn point, the RNAV-2 computer recorded the time of leg change as the moment the aircraft was abeam the waypoint.

Heading Select Mode (HDG)

In this mode, which was selected by depressing the HDG button, the flight control computer provided input to the command cue to command a turn to the heading indicated by the heading bug on the HSI. When HDG was selected, it overrode other navigation modes.

Direct-to Select Mode (D)

This mode was selected by depressing the -D- button, and Direct page was displayed which showed a list of Flight Plan waypoints, commencing with the next 'To' waypoint. Procedurally, this resulted in guidance being output to the DAFCS to steer the aircraft, from its present position, directly to the waypoint (as selected) in the route plan.

The switching for virtually all of the navigation, DAFCS and VDU functions and displays was performed by toggle type press activation switches. One press activated the required function and the selected switch was illuminated by an internal light bulb, to indicate that the function was activated. When the switch was pressed again the function was cancelled and the indicator light extinguished.

1.6.6 HSI Display

The HSI in G-HAUG had three principal display presentation options. In the Full Compass Display presentation, a full 360° compass card was displayed, with a helicopter symbol at the centre of the display. While this display could show course deviation information, it could not display route information in the form of waypoint or route display. The Arc Display showed information essentially similar to that of the Full Compass Display, except that only a 90º segment of the compass card was displayed, showing 45º on either side of the aircraft's current heading. The final display option was Map Display which was similar in layout to Arc Display, but showed route information, including waypoints and VOR/DME stations, instead of the course bar shown in Arc Display. The weather radar display could also be superimposed on the Map Display. Because this presentation could display the route, the extent of the display in terms of range could be varied. When the radar was on and superimposed, the range on the HSI was set from the radar. When the radar was off, the range was set on the display controller.

When the display was in Arc or Map presentation, it would only display information in a 45° arc on either side of the aircraft's heading. Information outside this arc was not displayed, but continued to be processed by the navigation system. All the screen information was displayed on a black background. There was no line to denote the lateral limits of the Arc or Map Display.

It was not possible to determine from the wreckage which display option was selected by either pilot. Each pilot had the facility to select the HSI display of his choice on his screen. Pilots who flew similarly equipped helicopters in the UK stated that the Arc or Map Displays were nearly always used.

The HSI in G-HAUG provided information regarding the extent to which the aircraft was left or right of a selected course. This indication is known as track deviation. The method of presenting the deviation information was dependent on the HSI display used. In Full Compass Display and in Arc Display, the centre of the course bar moved left or right of the axis of the course bar, and the extent of the movement was proportional to the deviation off track. The scale of the movement off centre was indicated by dots on the display. There were 2 dots on each side of centre and full scale deflection was 2½ dots. The significance of a track deviation of 1 dot was dependent on the navigation mode in use. For example, in VOR and ILS modes 1 dot represented an angular deviation off track. In VOR mode, 1 dot represented an off-track deviation of 5º, while in ILS mode the same indication represents 1º. However if the VOR was in Approach Mode, with a suitable DME station selected, the significance of a 1 dot deviation was again varied. The angular deviation produced by VOR and ILS modes resulted in a given course deviation distance producing a larger deviation indication as the aircraft approached the VOR or ILS. However when GPS was used as the navigation source, the deviation displayed was directly proportional to the distance that the aircraft was off track, and 1 dot represented an off-track deviation of 2.5 nm. In GPS Enroute Mode the deviation indication, for a given off track distance, remained constant as the aircraft approached a waypoint, irrespective of the remaining distance to run to that waypoint. In GPS Approach Mode, the sensitivity was also constant, but with a sensitivity of .5 nm per dot. It should be noted the dot sensitivities of the HSI display in G-HAUG were a function of the Trimble GPS and RNAV-2 system used in this aircraft, and may well be different in other equipment combinations.

When the HSI was selected in Map Display, off-track information was at the bottom of the HSI screen as a direct distance off track in nautical miles, with a precision of one decimal place, followed by the letter L or R, indicating left or right of track.

1.6.7 Radar Altimeter

G-HAUG was equipped with one Honeywell Radar Altimeter, type AA300. The indicator was fitted on the lower right hand corner of the PNF's (right hand cockpit seat) console. This altimeter was equipped with an AVAD audio alarm that produced a triple chime, followed by a verbal warning, when the aircraft descended to 100 feet above ground. This signal was fed directly into the pilots' headsets. The verbal warning stated "One hundred feet". This altimeter was also fitted with a pilot adjustable bug. When the bug was set to above 100 feet, and when the helicopter descended to the bug height, a yellow warning light in the top LH corner of the altimeter indicator was illuminated. The height output of the Radar Altimeter was also displayed on the HSI and the colour of this display changed when the aircraft descended below the set bug height.

1.6.8 Weather Radar

G-HAUG was equipped with a Primus 870 weather radar. This radar was designed specifically for the detection of adverse weather, and is not optimised for the detection of ground features or for navigational purposes. This type of radar does not clearly distinguish between returns from rain and cloud and those from high ground. The performance in this regard is particularly poor when the aircraft is actually in cloud or rain. In discussions after the accident, some pilots familiar with this installation on the S76 stated that the radar was very limited in its use as a navigation aid, and that considerable pilot effort was required to achieve even minimal results for navigation purposes. These pilots further stated that they rarely used the radar for navigation purposes because of these performance limitations. However another pilot stated that he had found the radar to be useful for coastal mapping, when operating close to the coast.

The weather radar had the facility to display route information, using the current route information generated by the RNAV-2. In addition the radar could be used to display aircraft checklists.

1.6.9 Automatically Deployable Emergency Locator Transmitter (ADELT)

The ADELT system is a distress beacon that can be either manually or automatically ejected from the aircraft. Automatic ejection is accomplished by impact sensitive switches mounted in the aircraft. The ADELT fitted to G-HAUG was a Series CPT-600 manufactured by Caledonia Airborne Systems. This item of equipment was fitted as an option on G-HAUG; there was no regulatory requirement to fit this item to the aircraft.

When ejected, the beacon is only automatically activated when it is immersed in water. The buoyant beacon then transmits on 121.50 MHz and 243 MHz, which are international distress frequencies. The beacon is also equipped with a transponder, which transmits an encoded signal between 9.3 and 9.5 GHz.

On G-HAUG, the ADELT beacon was housed in a special fairing underneath the tail boom, and was configured to be ejected rearward on receipt of a signal from the crew or from the crash switches.

1.6.10 Cabin Layout

G-HAUG was configured with two pilots' seats in the cockpit. However the aircraft could be, and on occasion was, operated as a single pilot aircraft. The passenger area consisted of an executive type layout, with a bench seat along the rear cabin bulkhead, facing forward, and two swivel seats, one on each side of the cabin, located behind the pilots' seats. The window glazing in the passenger area of G-HAUG was tinted.

1.6.11 Aircraft Flight Manual

Both the USA FAA and the UK CAA have issued flight manuals for the Sikorsky S76 B. The manuals are largely similar. The major difference is that the CAA version includes an additional supplement on the navigation system. The CAA version was applicable to G-HAUG, as it was a UK registered aircraft. The FAA version contains little information on the function of the navigation system, and the CAA supplement, while covering many aspects of the navigation system, does not cover the GPS system. In particular, there is no reference in either flight manual to the calibration of the dots on the HSI when the navigation system is in GPS mode.

1.6.12 Maintenance Records

At the time of the accident, G-HAUG had accumulated 2511 total flying hours. Although the aircraft was operated as a private aircraft, it was maintained to Public Transport Standards.

A Certificate of Maintenance Review was issued by an approved maintenance facility in England, on 30 September 1996. The next review was due on 30 January 1997.

On 22 October 1996, at 2,447 total flying hours, the aircraft had undergone a servicing at this facility, comprising of Checks 1, 2, 3 and 4. Among the items accomplished on this inspection, the following are of interest:

- The CVR was removed for cleaning, playback check and maintenance. It was re-fitted and function checked.

- A 3-month inspection of the ADELT was carried out, the ADELT beacon was tested and its battery was replaced.

On 21 November 1996, a Check 1 (50 hour Inspection) was accomplished at 2,489.45 hours, and the next scheduled inspection due was at 2,539.45 hours, on 2 January 1997. This would have coincided with the C of A renewal.

The Technical Log was recovered from the accident site. It had been completed up to, and including, the flight from Dublin to Aldergrove, via Ballyedmond, on the day of the accident. No defects were noted in the Technical Log, and there were no outstanding items.

Most maintenance on G-HAUG was accomplished at the approved facility in England. However, sometimes Check 1 was performed, by personnel from this facility, in the hangar at Ballyedmond.

1.6.13 Weight and Balance

The aircraft was loaded within the prescribed limits. Weight and balance was not a factor in this accident.

1.7 Meteorological Information

1.7.1 An after-cast of the actual weather conditions was provided by the Meteorological Office at Shannon. The details were:

General weather situation: a slow moving cold front, with minor waves, had cleared the area south of Carlingford by about 18.00 hrs. This was replaced by a cold north easterly airstream with occasional outbreaks of light rain or showers. Some of the showers had turned to sleet by 20.00 hrs.

The estimate of the enroute weather conditions was:

Cloud:	Scattered to broken stratus, bases varying between 700 ft and 1,000 ft; locally broken at 500 ft near hills and high ground.
Visibility:	10 km, occasionally 3 km to 7 km in precipitation.
Temp/Dew point:	04º/02º C
Height of zero degree isotherm:	1,800 to 2,000 ft Moderate, locally severe, icing likely in cloud, above the freezing level.
Winds:	2,500 ft 060º/25 kts 2,000 ft 060º/25 kts 1,500 ft 060º/20 kts 1,000 ft 050º/18 kts 500 ft 050º/15 kts

1.7.2 The Actual Weather at Aldergrove at 18.00 hrs:

Wind:	030º/13 kts
Visibility:	10 km or more
Weather:	Light rain shower
Cloud:	Few at 700 ft, scattered at 1,100 ft, broken at 2,000 ft
Temperature:	+5ºC

Dew point:	+2ºC
QNH:	1011 hPa
Trend:	Tempo 8 km broken cloud at 1,200 ft
Sunset:	16.06 hrs
Moon:	2 days after new moon

The above weather information refers to Aldergrove Airport, which was the nearest meteorological station to the accident site. Aldergrove is located inland, approximately fifteen miles from the sea. The area of the accident, in Carlingford Lough, is in a mountainous coastal area and can have its own micro-climate, particularly in winter.

1.7.3 A number of comments were made on the CVR relating to the weather encountered during the flight:

- At 18.03 hrs, before reaching Moira, the PF asked *"Can we get rid of this landing light"*, and 50 seconds later he asked for the wipers to be switched on.

- At 18.04.24 hrs the PF asked *"What do you want to go up to? Two five?"* The PNF replied *"Two five. Well no, if you stop here 'cos otherwise we're getting pretty cold. It's already below zero, so stop where you are."* The PF then stated "*We're actually on top of it at the moment"*. This would normally indicate that they were on top of a layer of cloud somewhere between 2,000 and 2,500 ft.

- Ten minutes into the flight, at 18.12.54 hrs, the PNF said to the Chief Pilot, *"Bit claggy out there"*. The Chief Pilot agreed with this statement.

- 60 seconds before impact, at an altitude of approximately 1,250 ft the PNF said, *"Should break out shortly anyway I think, if it is like it was when we left, of course"*.

1.7.4 A member of the local Garda Siochana (Irish Police) drove over the Windy Gap, a pass through the Cooley Mountains, 1 nm west of the crash site, at approximately 18.40 hrs. The high point of this pass is 630 ft above sea level. He reported moderate rain in the area.

1.7.5 A witness at Omeath, Co. Louth reported that he briefly observed the lights of an aircraft flying overhead and saw them disappearing into cloud about the time of the accident.

1.8 Aids to Navigation

In the area of the accident, there were no ground aids to aerial navigation. The high ground to north, east and south of Carlingford Lough effectively blocked out any of the aids such as DME, VOR, and ADF located at Aldergrove and Dublin airports. For the same reason ATC radar coverage was non-existent below 2,500 ft in the general area.

There is a VOR/DME station at the Isle of Man, approximately 35 nm east of Ballyedmond, which was used on occasion when approaching Ballyedmond from the east. However, due to the distance and blocking terrain, this facility was not available when approaching Ballyedmond at low level from a westerly direction, as on the final flight of G-HAUG.

In Carlingford Lough there are a number of small maritime navigational lights. The only substantial light is the Haulbowline Rock situated at the eastern entrance to the Lough, 8 nm SE of Warrenpoint.

1.9 Communications

Due to the high ground surrounding Carlingford Lough, it was not possible to communicate with Aldergrove or Dublin ATC when below 2,000 ft. in this area. There were no other aeronautical communication facilities available in the Carlingford area. The ground facility at Ballyedmond was not manned, nor was any listening watch or operational flight following maintained at Ballyedmond, when G-HAUG was on its final flight.

1.10 Aerodrome Information

1.10.1 Aldergrove

Not applicable to this investigation

1.10.2 Home Base (Ballyedmond)

The intended landing site at Ballyedmond consisted of two helicopter landing pads. One of these pads was immediately beside a substantial hangar which was used by G-HAUG.

There was also a JET A1 refuelling facility. Lighting of the pad area was available, and could be turned on from an approaching helicopter by means of a sequence of blips on the aircraft's radio transmitter, using an appropriate frequency.

1.11 Flight Recorders

1.11.1 Flight Data Recorder (FDR)

G-HAUG was not equipped with an FDR, nor was it a requirement that it should be so equipped.

1.11.2 Cockpit Voice Recorder (CVR)

G-HAUG was equipped with an Universal A100 cockpit voice recorder, as an item of optional equipment. There was no requirement that it should be so equipped, as the aircraft weighed under 5,700 kg and operated in the Private Category. This CVR was of the usual 30-minute duration, endless tape loop type. It was configured to record on four tracks, which were allocated as follows:

Track 1	PNF live microphone and headset signals,
Track 2	PF live microphone and headset signals,
Track 3	Flight deck area microphone,
Track 4	Encoded main rotor speed.

The recorder was recovered from the aircraft at the accident site, and was found to have suffered external damage. It was transported to the UK in the custody of an AAIU Inspector. A satisfactory replay was obtained using the replay equipment of the UK AAIB. The quality of the CVR on Tracks 1 and 2 was satisfactory. The sound quality on Track 3, the area microphone, was found to be muffled and required enhancement to be understood. Track 4, which should have contained the encoded signal giving main rotor RPM, was found to be blank.

A transcript of the full recording was produced, which covered the period from the later stages of the training flight until the end of recording, at the point of impact. Relevant extracts of the tape are included in this Report. All such extracts are shown in italics. A more complete extract is given in Annex A. The CVR information was essential in determining the events leading up to the accident.

1.12 Wreckage and Impact Information

1.12.1 On Site

The wreckage was located 1,000 ft above sea level at 15.25 hrs on 13 December 1996. The AAIU on-site inspection of the wreckage started at 10.00 hrs on 14 December 1997. The recovery of the major components commenced on the morning of 15 December 1996, and was completed later that day.

The disruption in the cockpit area was very severe. Where possible, the positions of switches and controls in the cockpit were noted.

Those relevant to the investigation were:

Undercarriage Selector	-	DOWN
Radar	-	OFF
Radar Altimeter Decision Height Bug	-	160 feet
Altimeter setting	-	1011 hPa

The hydraulic jacks of the main undercarriage indicated that the undercarriage was in the "Down" position at the time of impact.

1.12.2 Impact Information

The first ground contact was made just before a large rock outcrop. Short impact marks, approximately 0.6m long, created by the helicopter's undercarriage, indicated that the helicopter was in approximately level flight, with left bank. These marks indicated an aircraft heading of approximately 140º T (True) at impact.

Immediately after this initial contact, the nose of the helicopter struck a large rock outcrop. The face of the outcrop was inclined at approximately 45º to the horizontal. The helicopter disintegrated on impact with the outcrop, and the major sections were deflected upwards, missing a large standing rock behind the outcrop. The heavier sections of wreckage travelled the furthest distance up the slope, along the direction of flight, while lighter components came to rest closer to the initial impact point. Many smaller pieces of debris were found to the left and right of the impact point, all beyond the initial impact point.

The general wreckage was contained within an area approximately 200 metres long and 75 metres wide. Some blade tip components were found approximately 400 metres beyond the impact point. The crash site featured a strong smell of kerosene, and there was evidence of fuel on rock outcrops throughout the crash site.

1.12.3 Aircraft Structural Damage

The helicopter broke, on impact, into 6 major sections. These sections were found in the following order, from the initial impact point:

- Tail boom complete with tail rotor gearbox, tail rotor head and blades;
- Helicopter centre section, including main undercarriage bay;
- Forward cabin floor area;
- Instrument panel and nose area;
- Engine platform including engines;
- Main rotor gearbox, including rotor head and main blade stubs.

The engine output shafts and tail rotor shafts all failed in torsional shear. Rotation marks were found on these shafts. Various other rotating assemblies, such as oil cooler fans, bore marks consistent with rotation at impact.

The stubs of the four main blades were still attached to the main rotor head. Three of the four tail rotor blades were still attached to the head by strands of carbon fibre, but had fractured close to the hub. The fourth blade was found at the crash site.

The cabin area had largely disintegrated.

1.12.4 **Radar Switch**

In the wreckage of G-HAUG, the radar control switch was found in the 'off' position. Post crash analysis of the radar display tube could not determine if it was turned off shortly before impact or if it had been off for the entire flight. The CVR shows that during the final cockpit checks, the radar was checked and reported as *"is off",* 24 seconds before impact. This was the only reference to radar on the CVR tape.

1.12.5 **RNAV-2 Memory**

1.12.5.1 The GPS receiver was functioning up to the time of impact, and passed position data to the RNAV-2 navigation computer. The memory of this computer, which was retained by an internal battery, gave a last processed (once per second) RNAV-2 position of N 54º 03.834', W 006º 14.218'. The raw GPS-ARINC input data, yet to be processed by the RNAV-2, gave a position of N 54° 03.813', W 006° 14.177', using WGS 72 as reference datum. The impact position was N 54° 03.675', W 006° 13.954', using the UK Ordnance Survey datum. The RNAV-2 recorded that the GPS receiver was functioning normally at the time of impact.

1.12.5.2 The RNAV-2 also recorded the final Decca position as N 54º 03.72' W 006º 14.46'

1.12.5.3 The following pertinent information was recovered from the RNAV-2 computer memory, and all recovered data was consistent with the correct operation of the navigation system:

- The RNAV-2 was functioning throughout the flight until loss of power at 18.17.30.9 hrs on 12 December 1996. This time base is pilot-inputted GMT and was 69 seconds ahead of GPS derived UTC. The impact time therefore corresponds to a GPS time of 18.16.21.9 hrs.

- GPS was selected as the primary navigation sensor.

- The QNH setting on the NAV system was 1021 hPa.

1.12.5.4 The RNAV-2 recorded that at the time of impact:

- The altitude input from the Digital Air Data System (DADS) was recorded at 1328 ft, with a rate of descent of 396 ft/min. This related to a fixed pressure setting of 1013 hPa.

- The calculated rate of change of heading was 3º per second to the left, which is a standard rate 1 turn.

- RNAV-2 was commanding a steer left turn towards the waypoint MAP, and that the required heading to fly direct to MAP was 20° left of the actual heading of the aircraft.

- The indicated cross track error was 1.4 nm right of track, with a distance to go of 2.5 nm, measured along track, to waypoint MAP.

- The VOR/DME was tuned to Aldergrove VOR/DME. The system had reverted to DR (Dead Recording) approximately 35 seconds before impact, indicating a loss of signal from that station at that time. The loss of signal would have been caused by high ground between the VOR/DME station and the aircraft. The last position of the aircraft, as recorded by the VOR/DME, including the DR update, was N 54º03.72', W 006º12.90'.

1.12.5.5 The RNAV-2 memory showed that the route, which was selected in the system, was set up to take the aircraft from a waypoint MOIRA, at N 54° 29.50', W 006° 15.90', located at Moira, Co. Down, to a waypoint WARRN, at N 54° 06.35', W 006° 15.39', beside Warrenpoint, Co. Down, on a course of 180° T, and then turning to the next waypoint, on a new course of 132° T, which was known as MAP, at N54° 03.26', W 006° 09.60', which was located in the centre of Carlingford Lough, approximately 1 mile south of the heli-pad at Ballyedmond, and thence to the destination, waypoint B, at N 54° 03.91', W 006° 09.66', located just south of Ballyedmond. From the RNAV-2 memory it was not possible to determine if this route information was being fed to the auto-pilot system, or simply to the Flight Director (FD).

1.12.5.6 The last leg change at WARRN had taken place at 18.16.13.6 hrs, and at impact the system was computing the leg WARRN to MAP, and the next leg was to be MAP to B.

1.12.5.7 The RNAV-2 memory contained a circular buffer of key press inputs to the system. The timing of these key presses are not retained by the system. The keypress buffer indicated that two 'GO TO' selections were made before the last leg change, i.e. before WARRN.

1.12.6 Instrument Panel Switches

As previously noted, most of the switches relating to the selected navigation functions were back lit toggle-type switches. The only method to determine the state, i.e. 'on' or 'off' of such switches at impact was by examination of the condition of the indicating bulbs. Unfortunately, in many cases the destruction of the instrument panel made this impossible. Furthermore, in some cases, such as the HSI Display Controller switches, the illumination for the 'on' condition was provided by electronic solid state devices, not by incandescent light bulb filaments, thereby rendering determination of the switch position impossible.

However, analysis of the bulbs in the MS 700 Navigation Mode Controller indicated that both pilots had selected heading mode at the time of impact.

1.13 Medical and Pathological Information

1.13.1 General

The victims were removed to the County Morgue in Dundalk, Co. Louth, on Saturday 14 December. Due to the pressure of other work, the State Pathologist was unable to make a preliminary examination of the bodies until late that evening. A full post-mortem was completed the next day, which was three days after the accident. Various fluid samples were subjected to pathological examination at Beaumont Hospital, Dublin, on Tuesday 17 December. These and other fixed tissue samples were sent to the Royal Air Force Institute of Pathology and Tropical Medicine, in Buckinghamshire, on 13 February 1997, for further examination. The results of these tests were also sent to the Federal Aviation Administration Toxicology and Accident Research Laboratory, and also to the Department of Microbiology in Dublin University for further analysis.

1.13.2 Injuries

All three persons on board suffered major injuries in the accident impact. The nature and extent of these injuries, particularly those to the head and upper body of all three victims, caused immediate death on impact, and precluded survival. The pathologist concluded that in each case the cause of death was severe trauma due to high speed impact.

1.13.3 Toxicology Tests

Considerable difficulty was experienced in obtaining suitable samples for toxicology tests, due to the trauma suffered by the bodies. The results of the toxicology tests are noted in Annex B. Although ethanol was found in all three bodies, a high level of Ethanol was found in the PF. The opinions of the sources listed in para 1.13.1 above were sought on the possibility of post-accident fermentation causing these results.

All sources agreed that post-accident fermentation had occurred. Specifically, the alcohol found in the PNF was agreed to be solely due to fermentation, and slightly higher alcohol level found in the Chief Pilot was either very largely or even completely due to post-accident fermentation. However, a discrepancy of opinion arose with regard to the PF. One authority stated that the presence of Hafnia Alvei in the PF's samples, which was not found in the Chief Pilot's samples, could lead to high levels of post-mortem alcohol production. The same source stated that the analysis of the PF's blood samples demonstrated the presence of higher alcohols, all of which are associated with bacterial production of Ethanol, and are not seen in ingested alcohol.

Another authority accepted that given the time delay and storage environment prior to the Beaumont toxicology tests, Ethanol production of the order of 60 to 80 mg per 100 ml would be the level normally expected, but that the readings of 196 mg per 100 ml could not preclude the possibility of the presence of some imbibed alcohol.

1.13.4 Other information

The spouse of the PF stated that he had spend a quiet night at home the evening prior to the accident. Before the training flight, the PF met the Operations Manager of the ground handling agency and a meteorologist at Aldergrove. Both witnesses stated that they did not believe that the PF was under the influence of alcohol. The CVR did not show any indication of behaviour associated with high levels of alcohol consumption.

1.14 Fire

There was no fire.

1.15 Survival Aspects

1.15.1 General

The nature of the impact dynamics were such that the accident was considered to have been non-survivable. As a result, the investigation of the survival aspects of the accident was limited to the notification and response of the emergency services, and the discovery of the location of the helicopter after the crash.

1.15.2 Emergency Services Response

The ATC flight plan gave a clearance for a Special VFR flight to clear the Zone to the southwest. This flight plan was closed by the crew at 18.12 hrs as the helicopter started its descent towards Warrenpoint.

At 08.20 hrs on the next day, 13 December 1996, the CAA Examiner, who was to perform the Instrument Rating Test with the PNF, arrived at the handling agent's facility at Aldergrove and found that the helicopter had not arrived. Initially ATC were unable to contact the company of the operator, and checks were made at local hotels and other airfields to see if they had knowledge of the helicopter. At 09.00 hrs the owner's company was contacted and they stated that the helicopter was on its way to Aldergrove. When it had not arrived by 09.35 hrs, the Examiner contacted Aldergrove ATC who replied that their last contact with G-HAUG was the previous evening at approximately 18.13 hrs; due to the previous report that the helicopter was on its way to Aldergrove, they had ceased to be concerned. At this point the owner's company reported that the pilots' beds had not been slept in and over-due action was initiated.

The distress phase was activated at 10.30 hrs. Two RAF Wessex helicopters were dispatched and the Royal Ulster Constabulary (RUC) were alerted. An RUC aircraft also took part in the search. At 11.26 hrs the Irish Marine Emergency Services (IMES) in Dublin were informed of the search by Rescue Co-ordination Centre at Kinloss, and at 11.28 hrs IMES was requested by Belfast Coastguard to search the south side of Carlingford Lough.

IMES requested their Greenore Coastal Rescue Team to search the area between Greenore and Omeath and at 12.04 hrs IMES, following a request from the UK Authorities, requested the Irish Air Corps (IAC) to search the south shore of Carlingford Lough.

At 12.26 hrs Rescue 111, an IAC Alouette 3, arrived in the area and commenced a search of the Carlingford Lough south shore. In the meantime two RAF Nimrod aircraft were also requested to search the north Irish Sea area. Rescue 111 was then instructed to search Dundalk Bay, and at 14.15 hrs routed to Bessbrook to refuel. It rejoined the search at 15.15 hrs and was then requested by IMES to search the Carlingford Mountains area. At 15.25 hrs Rescue 111 located wreckage and bodies. Initially it reported seeing two victims. After landing beside the accident site, the crew found all three victims, and confirmed they were deceased. Due to the onset of nightfall, it was decided not to recover the bodies until the next day.

Gardaí and Mountain Rescue Teams then assembled at Omeath and reached the accident site at 23.00 hrs.

The next day, 14 December, following an initial examination of the site, the bodies were removed to Omeath by Gardaí and Mountain Rescue Teams, and thence to Dundalk Mortuary.

1.15.3 Emergency Location Beacon (ADELT)

G-HAUG was equipped with an ADELT Emergency Location Transmitter as described in para 1.6.9. This unit did not eject from the aircraft in the accident. The aerial of the beacon had become detached from the beacon during the impact. After the accident, the beacon assembly was returned to the UK for testing and was found to function correctly.

1.16 <u>Tests and Research</u>

Research has shown that some GPS-NAV systems do feature a selection between a lateral distance deviation and an angular deviation on the HSI display. In the angular deviation display the waypoint behaves as a pseudo VOR, and a given lateral deviation from track produces a larger deviation indication as the aircraft approaches a waypoint. The navigation system on G-HAUG did not have this angular display feature.

1.17 Organisational and Management Information

1.17.1 Operation of the Aircraft

The operation was initiated by the owner, but it was organised by the Chief Pilot, who advised the owner on matters relating to the operation, and effectively managed it on a daily basis. Apart from the two professional pilots, no other aviation professionals were employed by the owner in the conduct of the operation.

The aircraft was operated in the private category. As the aircraft was not used for any consideration, or hire and reward, it was consistent with UK Regulations to operate such an aircraft in the private category.

1.18 Additional Information

1.18.1 Location of Accident

The accident occurred in County Louth, in the territory of the Republic of Ireland. However the border in this area does not coincide with the boundary of the Scottish (UK) FIR and the Shannon (Republic of Ireland) FIR.

The FIR Boundary in this area is a straight line, for ease of navigation control. Consequently part of Co. Louth lies within the Scottish FIR. The accident occurred 200 metres north of the FIR Boundary, on the Scottish side.

1.18.2 Applicable Rules of the Air

1.18.2.1 Applicable regulations

Because the flight was planned to take place entirely in UK airspace, the flight will be assessed in this report using UK Air Navigation Order (ANO) as laid down in CAP 393.

1.18.2.2 Categories of operation

The UK ANO recognises only two broad categories of aviation operation. These are the private category and the public transport category. The operation of corporate aircraft, that is carrying non-fare-paying passengers, is regulated by the rules pertaining to the private category. Where pilots are remunerated, as is the norm in corporate aviation, they are required to hold a commercial pilots licence.

G-HAUG was operated in the private category, and flown by professional pilots holding Airline Transport Pilot's Licence (Helicopters and Gyroplanes). The fact that the aircraft was registered and maintained to Transport (Passenger) standards did not affect its operations category.

1.18.2.3 Use of GPS

UK Regulations in force at the time, as explained in AIC 16/1996, did not permit the use of GPS as the primary navigation system in IMC. However, the fitting of GPS in aircraft, including helicopters, is permitted. Furthermore, there is no prohibition on integrating GPS into the navigation and AP system. G-HAUG was fitted with GPS, and this was fully integrated into the RNAV-2 system.

In G-HAUG, the flight crew had the capability to select GPS as the prime navigation input to the RNAV-2. Post-accident analysis of the navigation computer showed that GPS was selected as the prime navigation source at the time of the accident.

1.18.2.4 IFR Flight Rules

Rule 22 of the UK ANO specifies that outside controlled airspace, at night, a flight will be flown in accordance with the Instrument Flight Rules.

With regard to minimum height, Rule 29 of the UK ANO states:

"Without prejudice to the provisions of rule 5, in order to comply with the Instrument Flight Rules an aircraft shall not fly at a height of less than 1000 feet above the highest obstacle within a distance of 5 nautical miles of the aircraft unless:

(a) it is necessary for the aircraft to do so in order to take-off or land;

(b) the aircraft is flying on a route notified for the purposes of this rule;

(c) the aircraft has been otherwise authorised by the competent authority; or

(d) the aircraft is flying at an altitude not exceeding 3000 feet above mean sea level and remains clear of cloud and in sight of the surface."

1.18.2.5 Approval of approach procedures

Apart from the generic Article 55, which states:

"A person shall not recklessly or negligently act in a manner likely to endanger an aircraft, or any person therein",

there is no specific prohibition, in UK Regulations, on descending below IFR Safe Sector Altitudes, for aircraft including helicopters which are operated in the private category, once an approach has been initiated. There is no definition of what constitutes the start of an approach.

Again under UK Regulations, for aircraft including helicopters, which are operated in the private category, there is no requirement to have approach procedures, into airfields or landing areas outside controlled airspace, approved by the UK CAA.

The combination of the above two paragraphs results in a situation where it is not illegal for a private operator to produce and fly approach procedures generated by themselves, to a helicopter pad outside controlled airspace, which result in descending below the normal IFR Safe Sector Altitude during the approach phase. Furthermore there is no requirement to submit such approach procedures to the UK CAA for approval.

1.18.2.6 Qualification for Flight at Night

UK ANO Rule 22.2 states:

"In the United Kingdom an aircraft flying at night:

(a) outside a control zone shall be flown in accordance with the Instrument Flight Rules; or

(b) in a control zone shall be flown in accordance with the Instrument Flight Rules unless it is flying on a special VFR flight."

To fly an aircraft under IFR, the pilot-in-command should be in possession of a valid Instrument Rating. However, under Schedule 8 of the UK ANO, a holder of a Commercial Pilot's Licence (Helicopters and Gyroplanes) may have a night rating. Such a night rating permits a pilot to fly at night, under IFR, outside controlled airspace.

A night rating must be kept current by having completed not less than 5 flights at night in the preceding 13 months. The PNF, while not holding a Instrument Rating, was legally entitled to fly as pilot-in-command at night outside controlled airspace, as he satisfied the above night rating requirements.

Within controlled airspace, an Instrument Rating was not required, as clearance for a Special VFR flight plan had been granted, for the portion of the flight to the control Zone boundary.

1.18.2.7 Designation of a Responsible Person

UK AIP RAC 3-1-5 Para 3.1.11 states:

"Flight plans can only be delivered to destination aerodromes which are either on the AFTN or linked to it by a Parent Unit. A pilot flying to any other destination should, before departure, advise a Responsible Person at destination of his ETA. The responsible person will notify the Parent ATSU if the aircraft fails to arrive within 30 minutes of the ETA......"

1.18.3 Irish Regulations

With regard to regulations pertinent to this accident, the only significant difference in Irish Regulations is the non-existence of a night rating category. To fly in Ireland at night a pilot must possess an Instrument Rating.

1.18.4 Approach Procedure

1.18.4.1 The S-76B was purchased 2 years before the accident to replace a lighter helicopter. Part of the reason of this change was to improve the poor weather access to Ballyedmond.

In the wreckage, a sketch of an approach procedure was found. An enhanced reproduction of this sketch, overlaid on a map of the area, is shown in Annex C. Discussions with a previous Chief Pilot of the operation, and also with a frequent passenger in the aircraft, indicates that the original poor weather approach procedure was to fly at altitude to a waypoint SLDA which was 2.75 nm east of the Haulbowline lighthouse, using GPS, but cross checked by the VOR Station in the Isle of Man. The aircraft would descend in this area until visual contact was made with the sea.
The aircraft would then route, under the cloud base, to Carlingford Lough, using the GPS waypoint OMSE, which corresponded to Haulbowline lighthouse, and thence to waypoint MAP, which was

directly 1 mile south of the base at Ballyedmond, on the centreline of the Lough, and then to Ballyedmond which was then known as waypoint BAL1. If ground was not clearly visible at 500 ft at MAP, a missed approach procedure was initiated, whereby the aircraft would continue on the same heading, but climbing to achieve 1500 ft by waypoint OMNW, just beside the town of Warrenpoint, at the head of the Lough. The flight would then continue, via waypoints NLDA and NLDB, to Aldergrove.

At some point the designation of the waypoint at Ballyedmond was changed from BAL1 to B.

1.18.4.2 As the above procedure required a lengthy detour to the north and east of the Mourne Mountains, when routing from Aldergrove, a revised procedure for marginal conditions evolved. Initially, this was to approach a new waypoint near Warrenpoint, called WARRN, coming from Aldergrove, and passing over WARRN at 1,800 ft. If the ground was not in sight at this point and altitude, the aircraft would route directly to waypoint SLDA to start the over-sea descent procedure described above. However if the ground was visible at WARRN, the descent to MAP would continue.

1.18.4.3 The CVR indicates that the desired target altitude for WARRN on the final flight was 1,500 ft.

1.18.4.4 No physical evidence was found as to what cloud-base minima were in use for the Ballyedmond approach at the time of the accident. A minima of 500 ft was used for approaches from the sea. The CVR transcript at 18.15.13 hrs, when the aircraft had just reached WARRN, shows that the PNF informed the PF that he could then descend to 500 ft.

1.18.5 Other Information

1.18.5.1 It is known that the PF checked the weather for the Aldergrove area before the training flight on the day of the accident. This was the only flight he expected to perform that day. No record could be found of a further weather check by any of the crew prior to the final flight to Ballyedmond.

1.18.5.2 G-HAUG's Technical Log shows that the PNF had conducted a number of flights at night when he was the only pilot on board. These flights included approaches and landings at Ballyedmond at night.

1.18.5.3 Discussion with UK IRE examiners indicated that the FMS would normally be in the raw data mode during an Instrument Rating Test.

1.18.5.4 Enquiries were made of the UK CAA regarding the use of weather radar on IRT flight tests. They stated that it would be used in conditions of thunderstorm activity. However, there were no rules laid down with regard to the use of weather radar in other conditions, but it was normal to leave the radar switched off.

1.18.5.5 The Chief Pilot, seated in the back of the aircraft, remained in contact with the crew during the final flight. When comments were made to him, he responded immediately, in particular with regard to a comment by the PNF about the poor weather. The PNF offered to disconnect the Chief Pilot from the intercom system and to turn on the cabin light, but the Chief Pilot declined in both cases.

1.19 Useful or Effective Investigation Techniques

The successful decoding of the information retained in the memory of the RNAV-2 computer was of significant assistance to this investigation. The retained GPS and route information was particularly useful.

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2. ANALYSIS

2.1 The Training Flight

The purpose of this flight was to prepare the PNF of the final flight for his Instrument Rating Test (IRT) the following day. On this flight, the PF of the final flight, was sitting in the left hand seat, and was obviously in charge of the training flight. The final portion of this flight was recorded by the CVR. The cockpit environment appears to have been reasonably relaxed. While it was a training flight the instructor was clearly in command and there is no evidence of a discordant atmosphere in the cockpit.

2.2 Planning for the Final Flight

2.2.1 At the end of the training flight, during the running pick-up of the Chief Pilot, the PF clearly indicated that he had expected the Chief Pilot to take over his front seat. The PNF informed the PF that he, the PF, should fly the leg to Ballyedmond. The response of the PF clearly shows that he had not expected to fly this leg. Two comments by the PF before the final take-off indicate that he was unfamiliar with the location of the their destination. By implication he was not aware of all local hazards, in particular those on the southern side of Carlingford Lough.

2.2.2 The PNF clearly assumed command of the aircraft immediately after the completion of the training flight. He determined who would fly the aircraft, and he took total responsibility for the navigation of the aircraft, particularly after the PF expressed his reservations about the flight. The PNF set up the route on the navigation system, and he continued to give the PF instructions with regard to course, heading, altitude and speed throughout the flight.

2.2.3 There is no evidence that any attempt was made to check the weather conditions en route or at Ballyedmond. A comment by the PNF just before impact, indicates that the only knowledge of the weather at Ballyedmond was based on his observation of the weather there when he departed Ballyedmond at approximately 15.30 hrs, almost three hours before the accident.

2.3 Take-off Event

The chime and low pitch beep heard on the take-off were identified as the warnings associated with the lack of auto-pilot engagement on lift-off.

In addition to the normal AP functions, the auto-pilot on the S76, in common with most helicopters of this size, uses the lower auto-pilot modes to provide aircraft stability. After landing, it is necessary to turn off the auto-pilot, as it will attempt to bank the helicopter during turns while taxiing. The auto pilot must then be re-engaged before lift-off. Failure to do so results in an unstable helicopter, which is difficult to control. This appears to have occurred in this case, and the normal rectification, i.e. touch back on to the ground and re-engage the auto-pilot, was performed. The fact that this event occurred is consistent with the CVR evidence of a failure to perform the normal pre-takeoff checks.

2.4 En route Events

2.4.1 As the aircraft was climbing towards 2,500 ft, the PNF instructed the PF to stop climbing before 2,500 ft was reached because the temperature had fallen below zero. The PNF's concern would probably have been due to the possibility of ice forming on the aircraft; this indicates that the aircraft was probably in cloud at this time, as icing is generally not a concern in clear air. Comments regarding turning off the landing light and that the aircraft was on top of a layer of cloud would indicate that the aircraft had been flown through cloud during this period.

2.4.2 The PF then again expressed anxiety about the situation, particularly with regard to high ground on the left. The PNF reassured him by pointing out the motorway below. The fact that the motorway became visible probably indicated that the aircraft was in and out of cloud at this time. The high ground mentioned here referred to the Mourne Mountains. The Mourne Mountains include peaks up to 2,763 ft, with one peak of 2,056 ft just 5½ nm east of track.

However, it should be noted that, in the later stage of the flight, the consistently higher ground within the 'safe IFR sector', i.e. within 5 nm of the flight path, was to the right of the proposed flight path.

2.4.3 From this stage onwards, the PF appears to have accepted all navigation directions without further questioning or comment, and he performed the role of handling pilot, under the navigational direction of the PNF. The previous training flight, and the Instrument Rating Test the previous month, where he acted as safety pilot, would have made him aware of the major obstacle in the general area, i.e. the Mourne Mountains. However there is no evidence that he had knowledge of the Carlingford Lough area or the approach procedures used by the operator.

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2.4.4 The keypress buffer of the RNAV-2 indicated that two 'GO TO' selections were made before the last leg change, i.e. before the aircraft arrived at WARRN. These were probably instructions to the system to Go Direct to MOIRA and then Go Direct to WARRN. Nav capture was achieved as the aircraft approached WARRN, and the navigation remained in route mode until impact.

2.5 The Turn at WARRN

2.5.1 As the aircraft approached WARRN, it was in heading mode, being flown either manually or in automatic mode. Then, at 2½ nm from WARRN, the PF stated that Nav Capture was achieved. In this configuration the navigation system would maintain the current navigation leg to a point approximately 1½ nm north of WARRN, i.e. the anticipated turn point, when the navigation system would indicate that a turn on to the next leg, WARRN - MAP, was required. If the aircraft was being manually flown, a pilot would normally initiate a left turn to comply with the indications of the HSI. If the autopilot was fully coupled, the aircraft would start to turn on to the new leg automatically.

2.5.2 It is estimated that the aircraft reached the anticipated turn point, 1½ nm before WARRN, at approximately 18.14.24 hrs. Just 5 seconds later the PNF told the PF not to allow the aircraft to turn early, which would indicate that the aircraft was in coupled mode at this point. He further advised the PF, *"in fact I'd go on a heading for a bit"*. This instruction probably meant that the PF should select Heading Mode, which would maintain the aircraft on a selected compass heading. Putting the aircraft into Heading Mode effectively disconnected the navigation system inputs from the automatic pilot, so that the aircraft was no longer automatically flying the selected route. The PF then had to query if the required heading should be about south, which the PNF confirmed. The PNF started to explain why he wanted to delay the turn, but did not complete his explanation. It is probable that the PF selected Heading Mode at this point, and the aircraft would consequently have continued in straight flight, on a course of approximately 180°, passing the waypoint WARRN.

2.5.3 There is no obvious explanation as to why the PNF was concerned about the aircraft turning too early at waypoint WARRN, and his consequent instruction to maintain a heading of south. A number of possibilities are considered. Firstly, it is possible that the PNF may have perceived some external visual reference that may have led him to believe that the aircraft was further from WARRN than it was in reality. A sighting of distant lights through a break in cloud, or lights glowing through cloud could have been the basis of such a perception.

It is also possible that he decided to delay the turn until he had a visual fix on Warrenpoint, or at least until he was able to perceive the glow of the lights of Warrenpoint through the cloud cover. Alternatively he may have been concerned that the automatic system had started to turn the aircraft too early. In general, automatic systems initiate a course change with a very gradual increase in bank in the direction of the required turn, and are programmed not to exceed 20º angle of bank during a course change. Consequently such systems generally initiate a course change earlier than a pilot would in a manually flown aircraft. In this particular case the tail wind component would have caused the system to initiate the turn earlier than normal, to avoid being blown south of track during the turn. The system would have displayed the distance to WARRN until the anticipated turn point, and the PNF may have been concerned that the turn was initiated further out than usual. It is noteworthy that he instructed the PF to maintain the heading only 5 seconds after the system initiated the turn. Immediately prior to the anticipated turn point, the system would have indicated the remaining distance to WARRN. However, when the system had initiated the turn, the distance-to-run display in the top right hand corner of the HSI would then have changed to show the distance to run to the next waypoint, MAP, which was 5.5 nm at that point. Thus, once the system initiated the turn, the distance to run to WARRN was no longer displayed to the crew.

2.5.4 The tail wind of 13 kts, experienced in this flight, would be somewhat unusual in this area, which is normally subject to south westerly winds, frequently of high wind speed. It can be calculated that wind on the night of the accident would cause the navigation system to initiate the course change approximately 30 seconds earlier than would be the case if the wind was at 25 kts from the south west.

2.5.5 The PF had previously expressed his concern about the high ground to the left of track, and he may have interpreted the instruction to delay the turn as a warning to avoid high ground to the left of waypoint.

2.5.6 At 18.14.50 hrs, just 20 seconds after the instruction to go on heading, and 14 seconds before reaching WARRN, the PNF stated *"Now there's WARRN"* and instructed the PF to begin the turn and to descend down to 500 feet. However he did not give any heading information for the PF to follow. The PF did not acknowledge this instruction.

2.5.7 When the PNF stated *"Now there's WARRN",* it is unclear if he was referring to an abbreviation for Warrenpoint, or the waypoint WARRN. In or around this time, no significant changes would have occurred on the navigation display. The last change would have been at the anticipated turn point some 25 seconds earlier.

It is therefore probable that the PNF was referring to the lights of Warrenpoint, which he may have been able to see through a break in the cloud. Warrenpoint was in the lee of the Mourne Mountains, and this could have produced a break in the clouds. It is also possible that the lights of Warrenpoint, which is a sizeable town, could have been perceived as a glow through the clouds. The probability is that the PNF had some visual fix on the lights

of Warrenpoint at this point. It is therefore quite probable that the decision to turn, as discussed in para. 2.5.3 above, was the PNF's desire to have a visual fix on Warrenpoint before changing course to MAP.

2.5.8 At 18.15.04.5 hrs the PNF commented that they had 5 nm to run, which would have been the distance to the waypoint MAP. This information would have been displayed on the HSI. At exactly the same time, the RNAV-2 recorded that the leg had changed, indicating that the aircraft was overhead or abeam the waypoint WARRN.

The PF made a mental calculation regarding their ground speed and descent rate, and mumbled *"Two miles per minute that should be about right"*. The PNF made a brief remark about breaking out shortly, clearly indicating that the aircraft was in cloud at this time. At this stage the PF, being aware that they had less than 5 nm to run, performed the normal action of a handling pilot at this point of an approach, which was to call for the start of the standard checks. He requested the undercarriage to be lowered. The PNF responded by lowering the undercarriage and checked off two items that would normally be done as part of the checklist. These items were called off rapidly, indicating that the checks were performed from memory and without the use of the cockpit checklist. After a pause of approximately 3 seconds, the PF asked the PNF to *"run through the checks"*. The PNF then started to call out the formal cockpit checklist. These checks were still in progress at 18.16.03 hrs when the PNF asked the PF to turn to a heading of 130º.

2.5.9 In considering the human factors aspects, it is distinctly possible that the PF, at this time, was mindful of his error at Aldergrove only thirteen minutes earlier, when he took off without the autopilot engaged. That error could be attributed to the failure to perform the required checks before take-off. It is therefore possible that he opted not to accept the initial mental checks performed by the PNF, but decided that the formal checklist should be completed. Such a decision would have been consistent with his training and experience as an airline pilot.

2.5.10 While it was appropriate for the PF to commence the checks at this point, this may well have distracted the PNF from monitoring the navigation of the aircraft at a critical time.

2.5.11 The direct track from WARRN to MAP was 132º True or 140° Magnetic. When the PNF asked the PF to turn to 130º, the aircraft was 1.1 nm south of track, and approximately 3.1 nm, measured along track, from MAP. The track to steer, at this time, to go directly to MAP, should have been approximately 118º T. The RNAV-2, at the point of impact, 20 seconds later, was calling for a course of 20º to the left of the then heading of 139º M, which would give a correct course to steer to MAP of 119º M. It would therefore appear that the PNF was working from memory, or using the information from the course indicator on the HSI. when he gave the course of 130º to the PF. The RNAV-2 memory shows that the navigation system was still computing the leg WARRN - MAP, and therefore the course indication, in both needle and digital display, would have indicated a course of 132°. If the course of 130° had been executed immediately at this point, the aircraft would have flown parallel to the WARRN-MAP track, but 1.1 nm south of that track.

When the PNF called for 130°, the deviation from track, and the extent of the deviation, would have been shown on the HSI displays on both sides of the cockpit. However because the HSI was displaying GPS data from the RNAV-2, the extent of the deviation shown on the HSI, in either Compass Rose or ARC modes, would have been less than half a dot when this instruction was given. In an approach to an airfield, using a VOR or ILS approach, an deviation of this magnitude would not be a cause for alarm. Given the PF's airline experience, where VOR or ILS approaches are the norm, and his previously expressed concern regarding high ground to the left of track, he possibly would not have been unduly concerned by a small deviation indication to the right of track.

2.5.12 A number of factors may have caused some difficulty for the PF during the final phase of the flight. The initial instruction given by the PNF *"go on heading"* was vague in that it did not specify the required heading. The PF had to enquire what heading was required, when he asked *"Well, about south? That about right?"*. The PNF confirmed this heading and started to explain the reason for this instruction, but stopped before completing the explanation. This instruction was given just after the change of displayed leg. Consequently, after this instruction was given, the only change in the display would have been a gradual reduction of the course deviation until the aircraft passed WARRN. At WARRN the deviation indication would have been zero.

Thereafter, as the aircraft continued south, the only change would have been a gradual increase in the deviation indication. The principal features of the probable HSI display, in the various modes, is shown in Annex E. The loss of displayed information in the Arc and Map modes, once the aircraft passed WARRN, due to the 45° angle display limit, is particularly noteworthy. The relatively small deflection of the deviation indicator in Compass Rose and Arc modes, even when 1 nm south of track is also noteworthy. This small indication may not have alerted either pilot as to the extent of the geographical deviation south of track.

2.5.13 When the PNF called, just before WARRN, to begin the turn, the PF may have responded with a very slow rate of turn. The probable resultant flight path is indicated by the green line in Annex D.

However, there is an alternative hypothesis which merits consideration. The aircraft would have started to turn slightly at the anticipated turn point before the PF reacted to the PNF instruction to go on heading, which was given 5 seconds after the anticipated turn point. The PF may then have selected the heading bug on the then heading of the aircraft, which could have been a few degrees left of south. If this track was 170º, as a result of a 10º left turn, the predicted flight path would have been a straight line, as indicated by the black line in Annex D, until the PNF called for a turn on to 130º. In this scenario, the PF would not have responded to the PNF's call to turn, just before the aircraft reached WARRN. The full text of the PNF's call at this point was, *"Now there's WARRN, so you can begin your turn and descend all the way down to 500 feet"*. The PF did not acknowledge this instruction. As the instruction to begin the turn was embedded between two other significant items of information, i.e. a fix on Warrenpoint, and an instruction to start a descent, it is possible that the instruction to turn did not register with the PF. Furthermore, this was one of the rare occasions on this flight when he made no response or acknowledgement to an instruction from the PNF.

2.6 Aircraft Configuration

Shortly after take-off, the PF requested to have the flight director displayed on his side, probably because he was not able to select course information on his HSI. The PNF indicated that the reason he, the PF, could not select the required display was because the FMS control was configured to the RH seat. This RH configuration would have been the normal selection during the training flight, when the PNF had been the handling pilot, seated in the RH seat.

As the normal setting for the FMS during an instrument rating test flight would be raw data, this would indicate that the FMS had not been re-configured since the training flight, which was in effect an 'dry run' for an instrument rating test. The probability that the FMS was still configured for the training flight, and the absence of any checks at the end of the training flight or at the start of the final flight, would indicate that the aircraft configuration on the final flight was the same as that on the training flight. As there is a significant possibility that the radar was off for the training flight, it is probable that it was off for the entire duration of the final flight. The absence of any reference to the radar display on the CVR, particularly to point out ground features to the PF, would reinforce this probability.

The CVR indicates that the Radar was checked *"is off"*, by the PNF, twelve seconds before impact. It is distinctly possible that this check merely verified that the radar was already 'off' and that this check was to verify that it was not in stand-by mode. The foregoing would indicate that the radar was not used on the final flight.

2.7 Reconstruction of Flight Track

Using the data from the RNAV-2 memory and the CVR, the final phase of the flight has been plotted, and the probable track is shown in Annex D. Relevant truncated extracts from the CVR are superimposed on this plot.

2.8 Weather Factors

2.8.1 Cloud and rain were encountered in the flight, as evidenced by the discussions regarding turning off the landing light, the use of wipers and concern regarding airframe icing. Such items would only be a matter of concern if the aircraft was in cloud or rain.

The evidence of the witness in the Omeath area, who saw aircraft lights disappearing into cloud about the time of the accident, indicates that the aircraft was probably flying in and out of cloud prior to the accident.

The comment of the PNF, 1 minute before impact, at an altitude of approximately 1,250 ft, that they should break out shortly clearly indicated that the aircraft was in cloud immediately before the collision with the mountain. The evidence of the witness at Windy Gap would indicate that there were rain clouds in the accident area at the time of the crash.

The information provided by the Meteorological Service indicates that, in the vicinity of hills and high ground, such as the area surrounding Carlingford Lough, the cloud base may have been as low as 500 ft and up to 7/8 of the sky may have been obscured by cloud coverage.

There was no moonlight on the night of the accident, due to the phase of the moon.

2.8.2 The foregoing indicates that the flight was conducted with the aircraft moving in and out of cloud and/or rain, in an area where high ground was obscured by cloud. The CVR indicates that these conditions did not cause significant concern to either of the two pilots normally involved in the operation.

2.9 The Use of GPS

2.9.1 The analysis of the aircraft's navigation computer indicated the GPS had been selected as the prime input to the FMS. Therefore, at any point of the flight when the ground was not in sight, the GPS-derived FMS data was the primary navigation aid being used by the pilots.

2.9.2 To make this approach technically possible in conditions where the ground was not visible, the crew would have to use GPS, as this was the only system available to them that was technically capable of achieving the precision for such an approach.

In the final phases of the flight, i.e. the descent from Warrenpoint to MAP, the external navigational systems such as VOR and DME, could not have been used due to surrounding high ground. Furthermore, due to ground above 1,000 ft within 1.25 nm on either side of the flight path to the 500 ft waypoint MAP, Decca could not give the required accuracy to make such an approach technically possible.

2.9.3 The displays in the cockpit did not give the crew any direct indication of their proximity to adjacent topographical features. While the GPS indicated their position, in terms of latitude and longitude, and also their position in relation to the selected route and waypoints, it would require a tedious operation, difficult to achieve in a cockpit at night, to plot the ongoing position of the aircraft on a map. The speed at which the aircraft was flown, allied with the restricted nature of the planned approach down Carlingford Lough, exacerbated the crew's difficulty of ascertaining their position in relation to nearby mountains.

2.9.4 While GPS, as employed in the approach from WARRN to MAP, would give the pilot an approach aid that is similar in function and accuracy to a VOR or ILS localisor approach, there are fundamental differences. A VOR or ILS approach is produced by a qualified agency, and is designed and approved in accordance with internationally agreed standards, particularly with regard to obstacle clearance limitations. Independent verification is always a feature of such approved approaches. The locally-produced GPS approach procedure that was used for the approach to Ballyedmond by G-HAUG was a simple sketch of the local area with the route and waypoints marked. It did not apparently contain any waypoint altitude minima or weather minima data, and only very limited obstacle information. There is no evidence that any personnel qualified in the design of approach procedures were involved in producing this procedure.

2.9.5 As G-HAUG was in GPS navigation mode, the deviation sensitivity would have been 1 dot on the deviation indicator per 2½ nm deviation off track. When the PNF called for a turn on to 130º, G-HAUG was 1.1 nm off course, so the deviation indication would have been less than a half dot.

The lack of information in the aircraft's Flight Manual concerning the functioning and calibration of the HSI track deviation display in GPS navigation mode, may well have resulted in a situation where both pilots were unaware of the true significance of the deviation indication. Furthermore the lack of an accepted standard for displaying GPS-derived deviation information on an integrated HSI display would not have assisted either pilot's understanding of the significance of the displayed information.

2.9.6 An anomaly appears to exist whereby the fitting of a fully integrated GPS system to the G-HAUG was certified, yet the use of GPS as the primary means of navigation was not permitted. This may have resulted in the full functioning of the GPS, especially when used with multifunctional displays such as the HSI, not being detailed in the Flight Manual.

2.9.7 GPS is probably unique among modern aid to air navigation, in that its initial use in aircraft was not at the instigation of aviation authorities. Because of the control of the GPS system by the US military authorities and the associated difficulty with selective availability, aviation regulatory authorities have been slow to sanction GPS as a primary navigation system.

Consequently there is a marked absence of an accepted international standard for the use and display of GPS information. In the absence of such standards, individual manufacturers are setting their own standards. A variety of display modes and options are now available, which can vary, in significant detail, from one aircraft installation to another. The behaviour of the deviation bar is one example. These variations give rise to the possibility of confusion in the minds of pilots as they move from one aircraft type to another. This possibility of confusion could be greater for pilots who normally fly EFIS equipped aircraft which are not fitted with GPS. Such pilots may not be aware of the significant difference in the representation of VOR and GPS deviation data when presented on an almost identical display. In the case of G-HAUG, the majority of the PF's experience in recent years was on EFIS aircraft which were not fitted with GPS.

2.10 The Planned Approach

The operation formerly used a procedure, detailed in para 1.18.4.1, which utilised a descent over the sea in poor weather. This procedure was later modified, as detailed in para 1.18.4.2, particularly for flights from Aldergrove to Ballyedmond, and used WARRN waypoint as an initial point for a direct descent to MAP from the west, with a target height of 1,800 ft at WARRN. The CVR indicates that the procedure was further modified to reduce the target height at Warrenpoint to 1,500 ft, without a declared weather minima.

No physical evidence has been found to indicate what weather minima were being used for such a descent at the time of the accident. However, at 18.14.50 the PNF stated *"Okay. Now there's WARRN so you can begin your turn and descend down to 500 ft."* which could have meant that once the aircraft had arrived at Warrenpoint, the SOP of the operation was to descend to 500 ft at MAP, even if the aircraft was in IMC conditions. Furthermore the PNF expressed no concern or anxiety when the aircraft had not broken out of cloud at 18.15.22 hrs, when he said, *"Should break out shortly ...."* It is calculated that the aircraft was at approximately 1,250 ft and 3.75 nm from MAP when this remark was made, albeit ¾ nm south of track. The foregoing indicates the minima in use were lower than 1,250 ft, and may have been 500 ft.

2.11 IFR Flight Rules

2.11.1 The PNF did not have an IFR rating, but the departure from Aldergrove to the Zone boundary (the limit of controlled airspace up to 2,000 ft) was made under Special VFR rules. It was therefore legal for the PNF to fly in the airport Zone, at night, provided the aircraft remained clear of cloud.

2.11.2 It could be reasoned that when G-HAUG first broke IFR Safe Sector Rules, i.e. when it came to be less than 1,000 ft clear of ground within 5 nm of the aircraft, which occurred near Newry some 6 nm before WARRN, it was already preparing to land and was therefore legally entitled to descend below the 1,000 ft clearance safety limit. Furthermore, when the aircraft later descended below the actual altitude of ground obstacles that were within 5 nm of the aircraft, in the descent to MAP, it could be argued that this again did not violate the requirements of Rule 29 with regard to altitude, if the derogation regarding making an approach were applied.

2.11.3 Comments made on the CVR during the flight, and the general weather situation indicate that the aircraft did not remain clear of cloud and in sight of the ground for much of the flight, even before reaching Moira, when the aircraft was subject to Special VFR Rules. If the descent is not considered to have started until the aircraft reached Warrenpoint, then Rule 29 of the UK ANO was contravened.

2.12 Operations Under Private Category Rules

In the UK, corporate aviation is regulated under the rules pertaining to private aviation. Therefore the rules that applied to the operation of G-HAUG were those that apply to normal private category aviation. These rules govern, in the main, the operation of private pilots, largely in simple single-engined aircraft, with fairly basic instrumentation. Typical general aviation activity of this kind is owner flown and operated, and the owner is usually intimately involved with the operation and flying of the aircraft.

The operation of G-HAUG was markedly different from these general aviation norms. The owner was not a pilot, and his prime requirement was that the operation should provide effective transportation in most weather conditions prevailing in the area. To achieve this he purchased a state-of-the-art aircraft and hired professional pilots to manage the operation. The evolving procedures generated by the pilots indicated a strong commitment to meeting the owner's requirements.

This eventually led to use of an approach procedure to Ballyedmond that relied heavily, and almost exclusively on GPS and fully exploited the potential of the aircraft's systems, with very little margin for error. It is not known what weather minima were in use at the time, but the lack of concern on the part of the PNF and the chief pilot when still in cloud, in the final stages of the flight, while below the height of mountains on both sides of a relatively narrow lough, indicates that the situation was not unusual and that the aircraft was still above the minima being used in the operation when it collided with the mountain.

As a consequence of the fact that the operation was conducted under general aviation rules, there was very little external examination of the operation. In particular, this led to the use of approach procedures which would not satisfy the standards set by the CAA. Because the aircraft was operated in the private category, it was not illegal to use such approach procedures.

It appears anomalous that the rules pertaining to general private aviation should also apply to the all-weather operation, by day and by night, of a very sophisticated twin-engine helicopter equipped with a very capable avionics fit, which was engaged in the professional transportation of passengers, albeit of a limited number of persons.

It may be noted that some countries do legislate for corporate aviation, to a standard between the private category and full public transport category. There are some difficulties in determining the transition point between corporate and private aviation, but a definition of corporate aviation could use criteria such as the employment of professional pilots and the seating capacity of the aircraft.

2.13 PNF's Experience

The PNF had joined the operation in the Spring before the accident. Consequently he had limited experience of the operation in Winter conditions, such as those that existed on the night of the accident.

2.14 The Chief Pilot

2.14.1 The Chief Pilot responded immediately to comments made to him during the flight. He also declined offers to be cut off from the cockpit intercom and to have the lights turned on in his area of the cabin. This would indicate that he remained in contact with the activity in the cockpit throughout the flight. He did not raise any comments on the conduct of the flight.

2.14.2 Having been P1 on the Dublin - Ballyedmond - Aldergrove flight earlier in the day, he would have been aware of the weather situation at Ballyedmond earlier in the day. Furthermore, he was appraised by the PNF on the final flight of the fact that conditions were claggy. His lack of intervention would indicate that the flight was being conducted within the norms of this operation.

2.15 Pathological Evidence

The Ethanol levels found in the PNF and Chief Pilot were, almost certainly, due exclusively to post-mortem micro-biological process. However, in the case of the PF, there is a conflict of professional opinion as to whether the levels found in his samples were due totally to post-mortem fermentation.

2.16 The Aircraft and Systems

No evidence was found that indicated any malfunction in the aircraft, or its systems, that might have related to the accident. In particular, on the CVR tape, there is no mention of any defects, and no alarms or

warnings were recorded during the flight, apart from that associated with the lift-off with the auto-pilot disengaged, and the final rad-alt alarm. The data recovered from the RNAV-2 memory indicates that the aircraft's navigation system was functioning correctly up to the time of impact. The aircraft's technical records indicate that it was clear of defects at the time of the accident.

2.17 Human Factors

2.17.1 From evidence on the CVR it is clear that the PF was not prepared for this flight and was unhappy during its execution. On the previous flight he was in clear command of the aircraft and the PNF of the final flight was acting under his instruction. Then, unexpectedly, and in reverse of their roles on the previous flight, the PF found himself flying the aircraft, now under the command of the PNF, into an area with which he was unfamiliar, in difficult weather conditions, and at night.

2.17.2 All three persons on the aircraft had roles and responsibilities in the conduct of the final flight.

The Chief Pilot (Passenger)

- He had a responsibility to ensure that all flights carried out in this operation were performed in a safe manner.

- He approved the modification of the approach procedure to Ballyedmond.

- He permitted a pilot unfamiliar with the area to fly the aircraft into a strange area in poor weather conditions.

- He would have been aware of the PNF's lack of experience in this operation in winter conditions.

The PF

- He was a very experienced pilot, with considerable command experience, on fixed wing aircraft and helicopters, and was a CAA approved IRE.

- He allowed himself to be nominated as the handling pilot for a flight into an unfamiliar area of difficult terrain, in poor weather conditions, without effective pre-briefing or planning.

- As the situation developed, he did express his anxiety, but he did not take a decisive stand.

- Thereafter, he appears to have resigned himself to the role of aircraft handler, and left all navigational decisions to the PNF.

The PNF

- He had failed his Instrument Rating Test the previous month, with the PF in the aircraft as a safety pilot. He had just completed a one-hour flight with the PF, effectively as a pupil of the PF. He was faced with the prospect of repeating the IFR Test Flight the next day, again with the PF acting as safety pilot. This may have placed him under pressure to prove his ability to the PF, and to demonstrate his ability to conduct 'real' flights in difficult conditions.

- Such pressure to prove his ability may have led to his dismissal of the concern of the more experienced PF, and may also have caused him to continue the flight into deteriorating weather conditions.

- Immediately after the instructional flight, he took command of the situation, and designated the crew for the final flight, and nominated the Visiting Pilot as PF.

- He did not give the PF any effective briefing for the flight, in spite of his knowledge that the PF was not familiar with the Ballyedmond area.

- In particular, he did not give the PF any briefing, at any point, on the procedure used for the approach descent into Carlingford Lough, or the terrain features in that area.

- In response to the expressed concerns of the PF, regarding his unease with the situation, the PNF's replies concentrated on his own knowledge of the situation, and his ability to successfully navigate the aircraft. He did not use the opportunity to give the PF an effective area and route briefing.

2.18 Visual Perception

It is possible that the aircraft may have broken cloud briefly before impact. However at this stage the mountain lay in the forward path of the aircraft, and it was devoid of any lights, houses or other such features. Furthermore, the higher portions of the mountain, which rose up 1000 feet above the height of the impact site, and which were directly in front of the aircraft, would have been obscured by cloud and rain. The absence of any visual clues would have made detection of the mountain mass in the dark very difficult, at best.

2.19 Location of Wreckage

2.19.1 It is probable that the ADELT was not armed, and for this reason did not deploy. However even it if had been armed and had deployed, it would not have transmitted, as the beacon must be immersed in water to activate the beacon battery. If the accident had been survivable, an ELT beacon which could have functioned without immersion in water may have facilitated the location of the aircraft. Some countries require ELT beacons to function in such on-land situations.

2.19.2 Nobody raised an alarm when the flight failed to arrive at Ballyedmond. No evidence was found that the crew had advised anybody of their estimated time of arrival (ETA) at Ballyedmond. The UK AIP requires the commander of an aircraft to ensure that a responsible person is aware of the ETA. The flight plan passed to Aldergrove ATC covered the flight only to the Zone Boundary. ATC had no role in monitoring the flight after this point, as the flight plan was closed while the aircraft was still airborne.

2.20 Cockpit Voice Recorder

While it was not a legal requirement to carry a CVR on G-HAUG, the availability of the recording was of major assistance to the investigation of the accident.

2.21 Terrain Warning

The only equipment fitted to G-HAUG that would give warning of rising terrain underneath the aircraft was the radar altimeter. As the aircraft approached the impact point, the probable flight path was over the sea, south of Warrenpoint, and then over terrain less than 100 ft above sea level. When within ½ nm of impact, the terrain started to rise, with increasing steepness, to the impact point at 960 ft. Beyond the impact point, on the extended flight path, the terrain continued to rise steeply to 1600 ft. At an estimated ground speed of 120 kts, the rapid decrease in altitude as indicated by the radar altimeter, would have started only 15 seconds before impact. The radar altimeter bug, set at 160 ft, would have caused the alarm light on the indicator to illuminate less than 2 seconds before impact. The radar altimeter audio alarm sounded less than 1 second before impact. Neither of these final warnings gave enough time for terrain avoidance action.

Due to the location of the radar altimeter in the lower right corner of the instrument panel in G-HAUG, the reduction in the radar altimeter indication would have been almost invisible to the PF. If the PNF was engaged in any activity located toward the centre of the instrument panel, his opportunity to detect the rapid lowering radar altimeter indication would have, at best, been limited. The situation was exacerbated by the descent of the aircraft, so that a decrease in the radar altimeter indication was to be expected at this point in the flight.

It was not a legal requirement to carry Ground Proximity Warning System (GPWS) on G-HAUG. Given the steepness of the terrain gradient, it is doubtful that such equipment could have given the crew a warning as they approached the mountain that would have resulted in successful avoiding action. However, Enhanced GPWS (EGPWS), if equipped with a suitable database, could possibly have given the crew sufficient warning of the terrain obstacle in front of the aircraft.

2.22 Final Remark

The final remark of the PNF *"I'll just go off that for a moment, yeah"* is not clear. One possible explanation is a change of radio frequency to operate the remotely controlled lighting at Ballyedmond.

2.23 Designation of a Responsible Person

Because the base at Ballyedmond was not linked to the AFTN, the pilot in command of the aircraft was required to ensure, under UK AIP RAC, that a responsible person was nominated to maintain a flight watch for the final flight from Aldergrove to Ballyedmond. No evidence was found that such a person was nominated

2.24 European Standards

The Joint Aviation Authorities (JAA) are in the process of drawing up aviation standards and regulations for use in European States. Such standards are being adopted by member states. For this reason, some of the recommendations of this report are addressed to the JAA.

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3. CONCLUSIONS

3.1 Findings

3.1.1 The Aircraft had a valid Certificate of Airworthiness and had been maintained in accordance with an Approved Schedule.

3.1.2 No evidence was found of any technical problem on the aircraft, or its systems, that could have had any bearing on this accident.

3.1.3 The crew were properly licensed, in accordance with UK Regulations, to undertake this flight.

3.1.4 There was no proper planning for the final flight to Ballyedmond. In particular no check was made on the weather in the Ballyedmond area before the final flight. The PNF was aware that when the aircraft departed Ballyedmond three hours before the accident, the cloud base was approximately 1,000 ft in the Carlingford Lough area, where there were mountain peaks of 2,000 ft within the IFR Safe Sector.

3.1.5 The PNF was the commander of the final flight.

3.1.6 The PNF did not brief the PF adequately for the final flight.

3.1.7 The PF had not expected to fly the final flight to Ballyedmond at the end of the training flight. Consequently, he had not prepared for the flight, which was into an area with which he was not familiar, and which was to be flown at night and in poor weather. When offered, he accepted the flight, but he did not request a briefing.

3.1.8 The crew failed to complete standard checks at the end of the training flight, and again before the final departure. This probably resulted in the aircraft cockpit remaining in the configuration used in the training flight. For this reason the radar was probably off for the entire final flight.

3.1.9 The PNF, as commander of the aircraft, did not nominate a responsible person to maintain a flight watch, as required under UK regulations. Consequently the alarm was not raised until 14 hours after accident.

3.1.10 The PF expressed his unease with the situation. The PNF accepted full responsibility for the navigation of the flight and decided to continue the flight.

3.1.11 The flight did not remain clear of cloud while operating below IFR Safe Sector Altitude, or when operating under Special VMC in the Aldergrove Control Zone.

3.1.12 There is no definite explanation as to why the PNF instructed the PF to override the navigation system and to head due south, as the aircraft approached the leg change at waypoint WARRN, for a period of 20 seconds.

3.1.13 The PNF did not give the PF clear instructions for the turn at WARRN, and failed to monitor effectively the progress of this turn.

3.1.14 There is no definite explanation as to why the PF did not execute a normal turn at WARRN, when instructed to do so by the PNF. He may not have absorbed the instruction to turn, or he may have responded with a very slow rate of turn.

3.1.15 When the PNF repeated the instruction to turn, by requesting a turn on to the specific heading of 130º, he did not give the appropriate course to take the aircraft to waypoint MAP. A steer of 130º, even if executed immediately when the command was given, would still have led to a collision with the Carlingford Mountains. It is probable that the PNF derived the course of 130º either from memory or from the course indication on the HSI.

3.1.16 In calling for a heading of 130º, the PNF had failed to appreciate the extent to which the aircraft was south of track.

3.1.17 While the HSI, in either Compass Rose or Map mode, would indicate that the aircraft was south of track, the small extent of the indicated deviation would probably not have caused alarm to either pilot. If the HSI was in Map mode, where the track deviation distance would be indicated by a small digital display at the bottom of the HSI, it is possible that the pilots either missed the information, or did not appreciate the danger posed by the displayed information.

3.1.18 The absence of information in the aircraft's Flight Manual detailing the operation of the HSI deviation bar, while in GPS mode, may have led to a lack of appreciation by the pilots of the extent of the deviation south of track.

3.1.19 The lack of an internationally accepted standard for the display of GPS derived deviation information may have lead to a lack of understanding, by the pilots, of the significance of the displayed information.

3.1.20 No evidence was found that would indicate that the aircraft would have experienced any difficulty in following the selected route, MOIRA - WARRN - MAP - B, if the aircraft had been operated throughout in the fully coupled mode, with Nav Capture, and allowed to fly the selected route without manual intervention.

3.1.21 The type of approach to Ballyedmond flown on this flight, in the prevailing conditions, did not appear to cause concern to the resident pilots of the operation. This strongly indicated that flights of this nature, in such weather conditions, were not considered unusual.

3.1.22 Both handling pilots were in good health at the time of the accident. The ethanol levels found in the PNF and Chief Pilot were almost certainly due to post mortem micro-biological processes. In the case of the PF, it is not possible to come to a definite conclusion with regard to the ethanol content found in his body.

3.1.23 The flight used a navigation approach procedure that would not meet the standards required by the UK Authorities for public transport operations. However, this was not illegal because the flight was operated under private category rules.

3.1.24 The corporate environment of the operation of G-HAUG, particularly the type of flights flown, the use of such a sophisticated aircraft, the application of GPS to approaches in a very restricted area and the employment of professional pilots to manage the operation on behalf of an owner who was not a pilot, do not appear to be compatible with the norms of private category aviation, or with the spirit of the rules and regulations that apply to that category.

3.1.25 The regulation under the UK ANO that permits pilots without an Instrument Rating to fly at night, and in IMC, outside controlled airspace, while operating in the private category, appears anomalous, particularly when sophisticated aircraft are used in a corporate aviation environment.

3.1.26 In the case of this accident, because of the severity of the impact, the non-functioning of the ADELT had no effect on the survivability of those on board. However it did fail in its function to assist the SAR teams in their efforts to locate the accident site. If the impact had been less severe, the fact that the ADELT would not have functioned as it was not immersed in water, could have adversely affected the prospects for survival of those on board.

3.1.27 The flight was conducted using GPS as the prime navigation aid, and in the later portion used GPS as the sole approach aid, in violation of UK Regulations in force at the time of the accident.

3.1.28 The GPS system functioned correctly and accurately on the flight.

3.1.29 While GPS is a very effective and accurate aid, locally-produced GPS approach procedures do not have the quality assurance inherent with approved ground based aids and procedures. The use of such GPS procedures, produced without proper verification, should therefore be treated with the utmost caution.

3.1.30 The absence of an agreed international standard for the use and display of GPS information, with regard to the display of GPS derived data on the integrated HSI display, may have caused confusion in the minds of the pilots, particularly in the case of the PF.

3.1.31 The availability of CVR data significantly contributed to this accident investigation.

3.2 Causes

3.2.1 Primary Cause

The primary cause of the accident was the loss of situational awareness which prompted the PNF's decision to deviate from the programmed route when he instructed the PF to delay the turn on to the final segment of the approach to the missed approach point, waypoint MAP, by maintaining a heading of south at waypoint WARRN, and his subsequent failure to monitor the aircraft's rate of turn when he initially instructed the PF to execute the turn.

3.2.2 Secondary Causes

3.2.2.1 The Commander of the Aircraft, the PNF, failed to make adequate preparation and take precautions to ensure the safety of the flight.

3.2.2.2 The crew embarked on the flight without proper planning or briefing.

3.2.2.3 The use of GPS as a prime source of navigation, in violation of the then current UK Regulations.

3.2.2.4 The use of a locally produced GPS-based approach procedure which gave little margin for error, and which was inadequate to alert the crew to terrain dangers.

3.2.2.5 The failure, for whatever reason, of the PF to execute a normal turn just before waypoint WARRN, when instructed to turn by the PNF.

3.2.2.6 The incorrect and unsafe course of 130° that the PNF instructed the PF to fly shortly before impact.

3.2.2.7 The absence of information in the aircraft's Flight Manual regarding the functioning of the navigation system in GPS mode.

3.2.2.8 The absence of information in the aircraft's Flight Manual regarding the HSI display, regarding the calibration of the HSI dots in Full Compass or Arc Display.

3.2.2.9 The operation of this aircraft, in a corporate aviation role, in the private aviation category, in a demanding environment, without the benefit of external monitoring of the operation.

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4. SAFETY RECOMMENDATIONS (SR)

The following safety recommendations are made arising out of this investigation:

4.1 The UK CAA should consider the establishment of a special category for the operation of corporate aviation. **(SR 7 of 1998)**

4.2 The JAA Joint Working Group for JAR OPS 2, which reviews operation standards for aircraft operation in the JAA States, including the UK and Ireland, should consider the establishment of a special category for the operation of corporate aviation, to encompass the operation of aircraft such as G-HAUG. **(SR 8 of 1998)**

4.3 The UK CAA should review the regulation permitting operation, at night and in IMC, of flights by pilots who do not hold an Instrument Rating particularly those involved in professional operations.
(SR 9 of 1998)

4.4 The Irish Aviation Authority (IAA) and the UK CAA should bring to the attention of operators of corporate aircraft the safety benefits that would result from external vetting of their operations, pending the establishment of a suitable regulatory framework for corporate aviation activities. **(SR 10 of 1998)**

4.5 The UK CAA should bring to the attention of operators who evolve GPS approach procedures that are not subject to external validation, that over-reliance on the accuracy of GPS can produce procedures which do not allow pilots a reasonable margin of error. This is particularly so in low level operations. The UK CAA should also advise such operators that course deviation information, on a integrated EFIS display, can be very different from that encountered on a VOR or ILS approach.
(SR 11 of 1998)

4.6 The US FAA should ensure that the full functions of navigation systems in all modes are fully detailed in aircraft Flight Manual particularly in the case of fully integrated navigation systems, such as that fitted to G-HAUG. **(SR 12 of 1998)**

4.7 The US FAA should bring to the attention of designers of HSI displays the need to consider redesign of these displays with regard to the scaling of deviation bar information in various navigation modes, in order to clarify the data presented to the flight crew. **(SR 13 of 1998)**

4.8 The US FAA, representing the State of Manufacture, should, in international forums, pursue the adoption of an international standard for the display of GPS-derived deviation information.
(SR 14 of 1998)

4.9 The UK CAA should consider amending the certification specification for ADELT's to ensure that these devices are capable of functioning following overland accidents. **(SR 15 of 1998)**

ANNEX A

CVR Extracts

The following is a transcript of relevant extracts from the CVR recovered from the wreckage of G-HAUG.

Non-pertinent comments have been deleted from this transcript. " / ", indicates where such comments have been deleted.

**** denotes comments on the CVR tape which could not be deciphered.

Events are denoted in bold type.

GPS TIME		SOURCE	TRANSCRIPT
	/		
	/		
	/		
17.53.27		PF	Are we going to take it home and fuel it tomorrow?
17.53.33		PNF	Bags of fuel!
	/		
	/		
	/		
17.54.40		PF/RT	We're just parked in front of Eurojet, we just need to pick up another pilot and then we'll depart for Warrenpoint.
17.54.52		PF	What do you call where you're going?
17.54.54		PNF	Kilkeel.
17.54.56		PF	What?
17.54.56		PNF	Kilkeel.
17.54.57		PF	Kilkeel.
17.54.58		PNF	Yeah, and it's nowhere near where we're going.
	/		
	/		
	/		
17.55.36		PNF	Ever fly in here in other job?
17.55.40		PF	Used to in 75's. Don't any more.
17.56.55		PF	Does *(passenger's first name)* want to jump in here?
17.56.59		PNF	No, I shouldn't think so.

17.57.02		PF	Landing lights off please.
17.57.05		PNF	Yeah.
	/		
	/		
	/		
17.58.59		PNF	Better not shut down 'cos we can't move if they want us to.
17.59.30		PNF	You might as well fly me home then.
17.59.34		PF	What?
	/		
	/		
	/		
			Sound of rotors speeding up
18.00.18		PF/RT	Uniform Golf ready for taxiing......
18.00.21		PF	Where're we going?
18.00.22		PNF	Kilkeel.
18.00.24		PF/RT	...to Kilkeel
18.00.27		ATC	Uniform Golf Roger, you are going to Kilkeel and that's copied. And so are you ready for departure?
18.00.32		PF/RT	Affirm.
18.00.38		ATC	Golf Uniform Golf, cross r/w 25. Clear take-off. Surface wind is 030 degrees at 21 knots. Clear to leave the zone to the south, special VFR not above 2,000 feet.
18.00.49		PF/RT	(********) Uniform Golf. Good day.
18.00.53		ATC	Not sure if the QNH is a new one now but it's now 1011.
18.00.56		PNF	Yes, it is a new one.
18.00.59		PF/RT	One one.
18.01.23		PF	Ooops! (********) not in! Oops!
18.01.27		PNF	*Laughs*
18.01.27		PF	I thought I'd put it in. *Laughs*. Oh dear.
18.01.36		PF	Gear up please.
18.01.37			**Sound of a low pitched beep (gear)**
18.01.41		PNF	How are you doing in the back?
18.01.43		Passenger	*(Jovial comment.)*
18.01.47		PNF	It wasn't me, honest chief.
		PF	*Laughs*
	/		
	/		
	/		
18.02.05		PNF	Okay. I'll just plumb it in for you.

18.02.09		PNF	Okay. They're on the whats-its-name if you want to do it.
18.02.12		PF	Yep.
18.02.19		ATC	Golf Uniform Golf. Contact radar, correction approach one two zero decimal nine bye bye.
18.02.23		PF/RT	Zero nine, Uniform Golf, thanks bye bye.
18.02.27		PNF	Okay, about um, what we say, 201. 201 would be a good.... good heading....
18.02.38		PF	Okay. Can we get rid of this landing light?
18.02.40		PNF	Yep, there it goes.
18.02.46		PNF	.... and whatever you think for height but we need to get 1500 if we can.
18.02.51		PF	Okay.
18.02.59		PF	You with us *(passenger's first name)*?
18.03.00		Passenger	Yeah, loud and clear.
	/		**General chat between PNF and Passenger**
	/		
	/		
18.03.28		PF	Wipers on please.
18.03.31		PNF	Yep, if you want to do it on auto you can, it is there in the box to be had.
18.03.42		PF/RT	Approach, good evening Golf Uniform Golf.
18.03.46		ATC	Golf Uniform Golf, good evening, report leaving the zone.
18.03.49		PF/RT	Okay
18.04.01		PF	I'm not actually terribly happy with this *(PNF's first name)*.
18.04.04		PNF	Are you not? Okay.
18.04.06		PF	I don't know this area will enough so I'm relying on you to tell me what turn-off.
18.04.11		PNF	I've plumbed it into auto now, that'll take us straight to Moira and then straight to Warrenpoint, which takes us along all the low.... the low ground. Which is fine. At this height we'll be okay anyway.
18.04.24		PF	What do you want to go up to? Two and a half?
18.04.26		PNF	Two and half. Well no, if you stop here 'cos otherwise we're going.... getting pretty cold. It's already below zero so stop where you are. That'll be....
18.04.34		PF	We're actually on top of it at the moment.
18.04.37		PNF	Yeah. Okay, two five then, we can let down at the other end.
18.04.41		PF	Can I have the flight director on my side and then I'll....

18.04.43		PNF	That'd make life easier for you wouldn't it. And FMS yeah. Oh, you haven't got FMS selected on that one. That should do the trick.
18.05.15		PF	That'll keep us away from the high ground on the left here will it?
		PNF	There's like a fairly broad valley that Banbridge and the other towns are in.
		PF	Yeah, yeah. Oh good.
18.05.30		PF	I'm not.........
		PNF	Don't worry. We're alright.
		PF	.... sufficiently aware of.... I know there are high grounds over there but it's not.....
18.05.38		PNF	Yep. Alright. This is the zone boundary. The motorway.... you see the motorway going along the zone boundary there.
18.05.46		PF	Okay doke. We stay with her do we for a listening watch?
		PNF	We stay with her for a listening watch, yep.
18.05.55		PF/RT	Uniform Golf clearing the zone.
18.05.58		ATC	Uniform Golf. Roger, report uh.... when you're uh.... approaching the Mournes.
18.06.04		PF/RT	Okay.
	/		
	/		
	/		
18.07.15		PF	Can you read the temperature there *(PNF's first name)*?
		PNF	Well.... zero, just about.
18.07.31		PF	How's that looking?
		PNF	No ice there, fine.
18.07.42		PNF	You can go down to 2,000 if you want quite safely here.
		PF	Okay.
18.08.25		ATC	Uniform Golf. Report your maximum altitude.
		PF/RT	Not above twenty five hundred. Uniform Golf.
		ATC	Thanks.
18.09.04		PNF	That's Banbridge.
		PF	That's where, sorry?
		PNF	Banbridge.
		PF	Oh.
18.09.17		PNF	No sign of ice there.

18.09.27		PNF	Are you bored with this in the back? Do you want me to turn you off?
		Passenger	No, I'm okay.
18.09.43		PNF	Do you want the light on?
		Passenger	No, I'm okay thanks.
18.10.05		PNF	Just over 12 miles to run to WARRN.
		PF	So Warrenpoint takes us out over the Lough does it?
		PNF	Yes it does, so when you've got about 5 miles to run to WARRN you can start to let down to about 1,500.
		PF	Right.
		PNF	And then we'll do the rest of the let down once we've passed it.
		PF	Okay.
18.10.41		PF	Temperature's good
		PNF	No. No icing out there.
18.12.06		PF	Right start of the gentle descent.
		PNF	Yep. I'll sign off with Aldergrove 'cos we'll lose them otherwise.
		PF	Okay.
18.12.19.9		PNF/RT	Aldergrove, Golf Uniform Golf is QSY as we begin our descent.
		ATC	Uniform Golf. Thanks, Good night.
		PNF/RT	Good night.
18.12.54.5		PNF	Quite claggy out there, *(passenger's first name)*.
18.12.59.1		Passenger	Yes, just a bit. Was it tonight?
18.13.01.9		PNF	Eh.... I don't know, but we were in snow at one point, *(PF's first name)* told me.
		PF	Yeah.
18.13.30.0		PNF	Not below 1,500 'till we get there.
18.13.33.1		PF	Okay.
18.13.39.8		PNF	There's a little ridge just before Warrenpoint that we're going over at the moment.
18.13.44.1		PF	Right.
18.13.46.0		PNF	And slow down I think now.
18.14.03.1		PF	Height hold's in, heading hold's in. NAV capture.
18.14.09.3		PNF	Excellent, there we go.
18.14.16.7		PNF	Yes, you're over the ridge now, see how the Rad Alt's picking up again.
		PF	Yeah.
18.14.29.4		PNF	Okay, don't let it turn you early. In fact I'd go on Heading for a bit. Um....

18.14.39.0		PF	Well, about south? That about right?
18.14.40.3		PNF	Just maintain south for a little while, yes please.... 'cos it's turning you inside the....
		PF	Okay.
18.14.50.5		PNF	Okay. Now there's WARRN so you can begin your turn and descend all the way down to 500 feet.
18.15.04.5		PNF	And you've got 5 miles to run.
18.15.13.9		PF	Two miles a minute, that should be about right.
		(mumbling)	
18.15.22.7		PNF	Should break out shortly anyway I think. If it's like it was when we left of course.
18.15.27.7		PF	Can you dangle the Dunlops for me.
18.15.29.5		PNF	I will. There we go. EAPS are on **(chime of pax sign)** passenger sign is on.
18.15.35.5		PF	Can you run through the checks for me please, *(PNF's first name)*.
		PNF	I will do.
18.15.43.8		PF	If you shout them out, I'll....
18.15.45.8		PNF	Okay. Gear?
18.15.47.4		PF	Down, three greens.
18.15.48.5		PNF	EAPS?
18.15.50.7		PF	On and we have both indicated.
18.15.53.7		PNF	Yeah. Radar?
18.15.55.5		PF	....is off.
18.15.57.2		PNF	T's and P's?
18.16.00.9		PF	All in the green.
18.16.02.7		PNF	Fuel okay. Now turn on to one three zero if you would please. Okay.
18.16.11.2		PNF	I'll just go off that for a moment, yeah.
18.16.20.3			**AVAD chimes 'one....'**
18.16.21.8			**END OF RECORDING**

ANNEX B

Toxicology Tests

The following information resulted from the post mortem conducted by the State Pathologist, and toxicology reports completed by Beaumont Hospital, Dublin and the RAF Institute of Pathology and Tropical Medicine.

PNF

Toxicology (Beaumont)	Alcohol Level
Cavity Blood	12 mg per 100 ml
Vitreous	13 mg per 100 ml
Blood carboxyhaemoglobin level	0.8%

No other traces of drugs or stimulants were found.

Toxicology (RAF Institute)	Alcohol Level
Spleen blood	27.8 mg per 100 ml
Chest cavity blood	less than 8 mg per 100 ml
Loose eye fluid	less than 8 mg per 100 ml
Kidney fluid	11.3 mg per 100 ml

PF

Liver microscopy :- some fat infiltration, consistent with mild alcohol abuse, was found.

Toxicology (Beaumont)	Alcohol Level
Blood from abdominal cavity	196 mg per 100 ml
Blood from aorta	220 mg per 100 ml
Blood from pericardium	195 mg per 100 ml
Blood carboxyhaemoglobin level	3.5%

No other traces of drugs or stimulants were found.

Toxicology (RAF Institute)	Alcohol Level
Aorta blood	230.3 mg per 100 ml
Pericardial blood	245.4 mg per 100 ml
Bile	435.5 mg per 100 ml
Kidney fluid	282.6 mg per 100 ml

Abdominal blood was also subjected to Volatile Screen by Headspace Gas Chromatography with Ionisation Detection in the RAF Institute. The results were:

Acetaldehyde	24.6 mg per 100 ml
Ethanol	567.1 mg per 100 ml
Acetone	2.3 mg per 100 ml
Propane - 2 - ol	1.9 mg per 100 ml
Propane - 1 - ol	0.8 mg per 100 ml
Butane - 1 - ol	1.0 mg per 100 ml

The blood and bile of the PF were also subjected to micro-biological investigation. They were found to contain the following:

Blood:-	Hafnia Alvei Enterococcus durans Enterobacter species
Bile:-	Hafnia Alvei Enterococcus durans

Chief Pilot (Passenger)

NOTE: The toxicology for the Chief Pilot, who was a passenger on the aircraft, is included here solely for comparison purposes. It was possible to obtain from his remains samples which permitted a better comparison with those of the PF. The samples obtained from the PNF were fewer and therefore of less use for comparison purposes.

Toxicology (Beaumont)	**Alcohol Level**
Vitreous humour	16 mg per 100 ml
Cavity blood	34 mg per 100 ml
Blood carboxyhaemoglobin	5.5%

No other traces of drugs or stimulants were found.

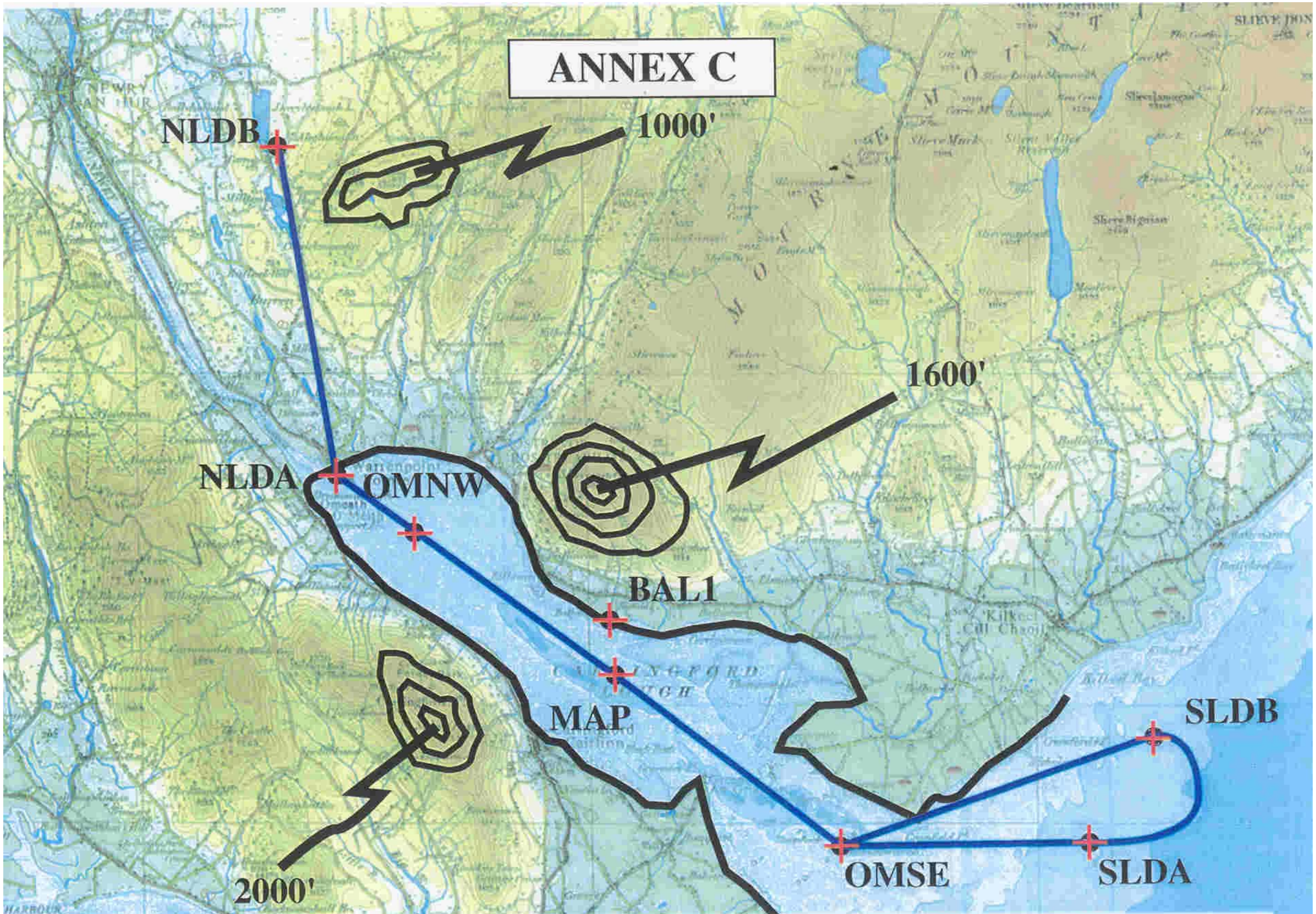
Toxicology (RAF Institute)	**Alcohol Level**
Bile	53.2 mg per 100 ml
Vitreous fluid	less than 8 mg per 100 ml
Kidney fluid	22.5 mg per 100 ml
Liver fluid	105.3 mg per 100 ml

The blood of the Chief Pilot was also subjected to micro-biological investigation. It was found to contain the following:

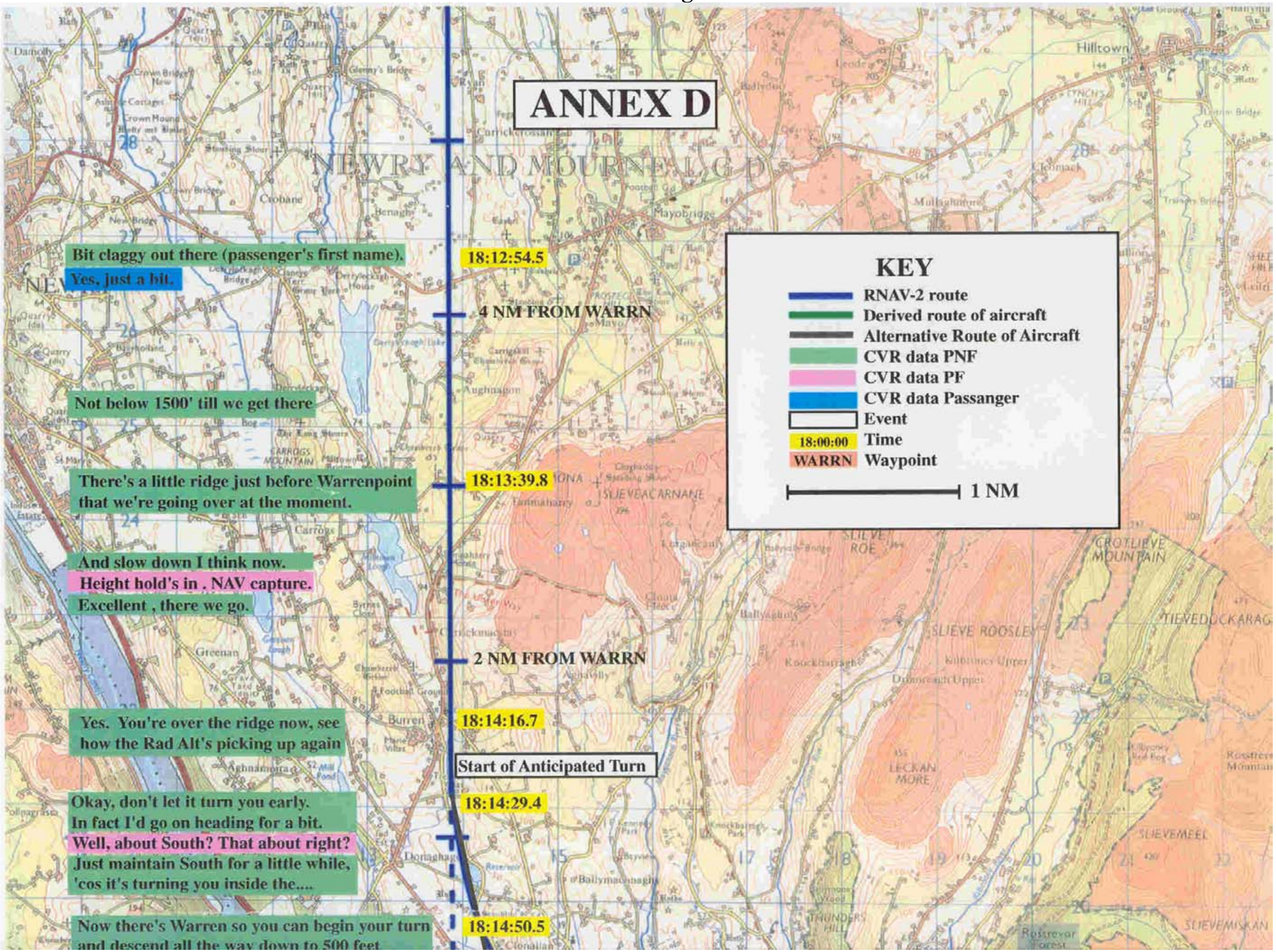
Enterococcus faecium
Escherichia Coli
Enterobacter species

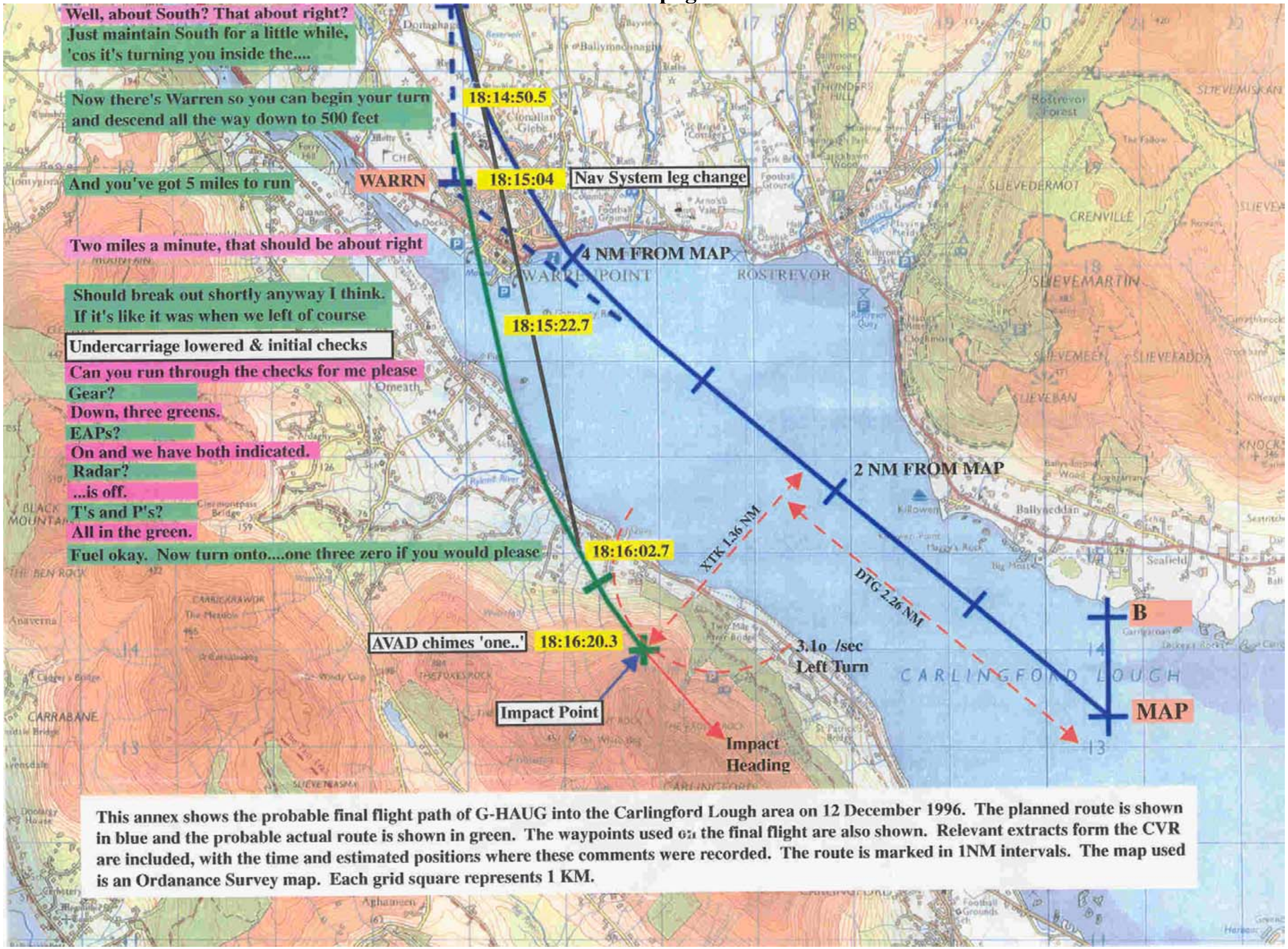
(Intentionally blank)

ANNEX C



This annex shows an enhanced copy of the approach procedure to Ballyedmond found in the wreckage of G-HAUG. The original measured 10 cm by 8 cm and was drawn in a plain lined paper note book. The note book also contained several pages of waypoints used in the operation. In this copy, the contents of the original sketch are shown in a heavy outline, and the sketch has been superimposed on an Ordance Survey map, with a scale of 1/2" : 1 mile, to assist the reader.


ANNEX D
KEY
RNAV-2 route
Derived route of aircraft
Alternative Route of Aircraft
CVR data PNF
CVR data PF
CVR data Passanger
Event
18:00:00 Time
WARRN Waypoint
1 NM
Bit claggy out there (passenger's first name).
Yes, just a bit.
18:12:54.5
4 NM FROM WARRN
Not below 1500' till we get there
There's a little ridge just before Warrenpoint
that we're going over at the moment.
18:13:39.8
And slow down I think now.
Height hold's in . NAV capture.
Excellent , there we go.
2 NM FROM WARRN
Yes. You're over the ridge now, see
how the Rad Alt's picking up again
18:14:16.7
Start of Anticipated Turn
Okay, don't let it turn you early.
In fact I'd go on heading for a bit.
Well, about South? That about right?
Just maintain South for a little while,
'cos it's turning you inside the....
18:14:29.4
Now there's Warren so you can begin your turn
and descend all the way down to 500 feet
18:14:50.5
NEWRY AND MOURNE L G D
Hilltown
Mayobridge
SLIEVEACARNANE
SLIEVE ROE
CROTLIEVE MOUNTAIN
SLIEVE ROOSLEY
LECKAN MORE
SLIEVEMEEL
SLIEVEMISKAN
THUNDERS HILL
Burren
Greenan
Carrogs
Crobane
Donaghaguy



This annex shows the probable final flight path of G-HAUG into the Carlingford Lough area on 12 December 1996. The planned route is shown in blue and the probable actual route is shown in green. The waypoints used on the final flight are also shown. Relevant extracts form the CVR are included, with the time and estimated positions where these comments were recorded. The route is marked in 1NM intervals. The map used is an Ordanance Survey map. Each grid square represents 1 KM.

ANNEX E

HSI Display

As noted in the main report, the HSI was probably used in Arc or Map Display. However it is possible that it was used in Compass Display. The sequence shown in Fig 1 and Fig 2 of this Annex indicate the probable display on the HSI screen, in all three modes. The sequence shows the probable displays at selected points i.e.:

- Just before the anticipated turn point when heading mode was selected.
- Just after the anticipated turn point.
- Overhead waypoint WARRN.
- When a heading of 130º was called.

In these representations, only information pertinent to the investigation is shown. The HSI display normally displays other information, in digital format, around the periphery of the display. Such information includes ground speed, selected heading etc.

It is noteworthy that the course indication in the top LH corner of the display would have remained constant, at 130º, once the aircraft passed the anticipated turn point.

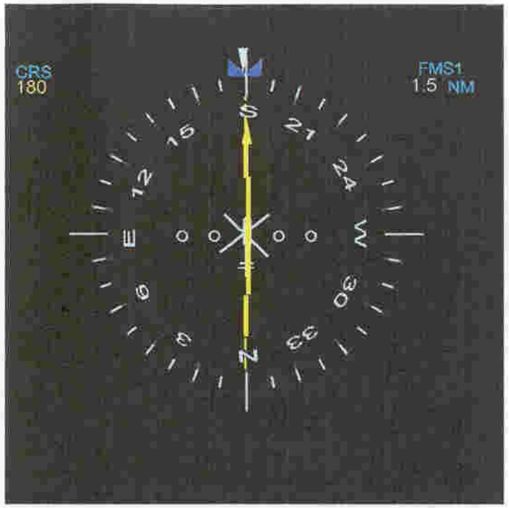
Other points to note are the probable small movement of the deviation bar in Compass and Arc modes, the relatively small deviation display in Map Mode and the small change in this indication, and the disappearance of data outside the display sector in Arc and Map Display.

It was not possible to determine what range was selected if the HSI had been in Map Display. For demonstration purposes, a range ring of 10 nm has been selected in this representation. The significant point with regard to Map Display is that once the aircraft had overflown waypoint WARRN, the route was no longer visible on the HSI, because the 50º course change exceed the 45º visible sector. This would have occurred irrespective of what range setting was selected.

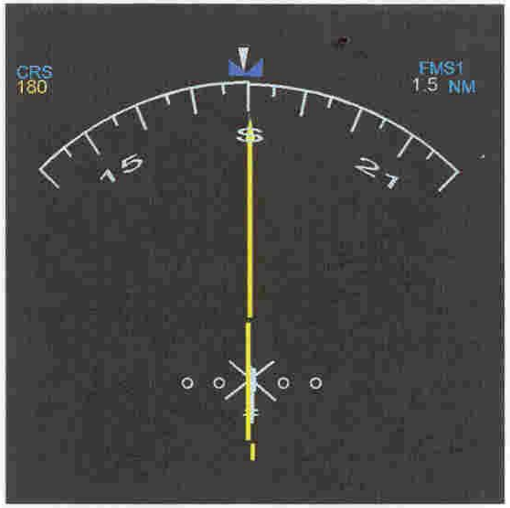
These probable displays are based on the aircraft commencing a very gradual turn after the anticipated turn point, i.e. as shown in the green flight path in Annex D. If the aircraft had initially turned Left approximately 10º at the anticipated turn point, and then flown straight until the PF was instructed to turn on to 130º, as shown by the black flight path in Annex D, the effect on the HSI displays would have been minimal. The significant changes would have been a slightly different heading indication, and a slightly later loss of information on the left edge of the display in Arc or Map Display.

The small degree of change in the display after the anticipated turn point, especially after passing WARRN, would not give a strong visual clue to a pilot, especially one unfamiliar with the area, that significant and potentially dangerous deviation off track was in train.

FIG 1

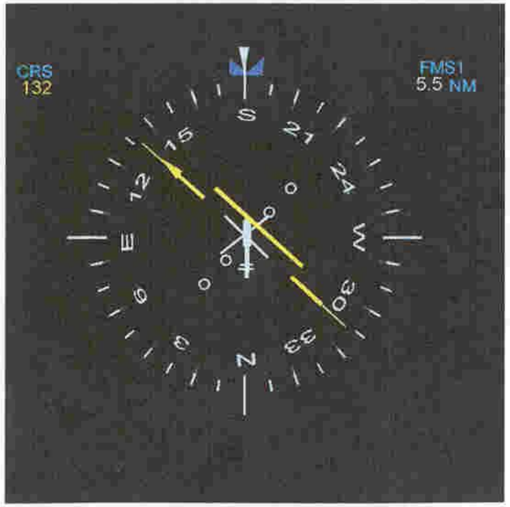


HSI Compass Display just before Anticipated Turn Point

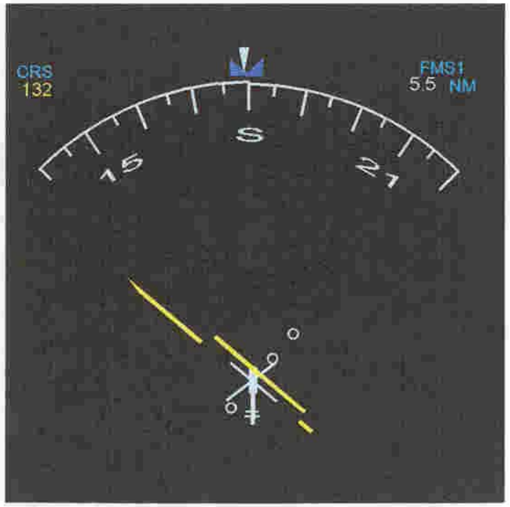


HSI Arc Display just before Anticipated Turn Point

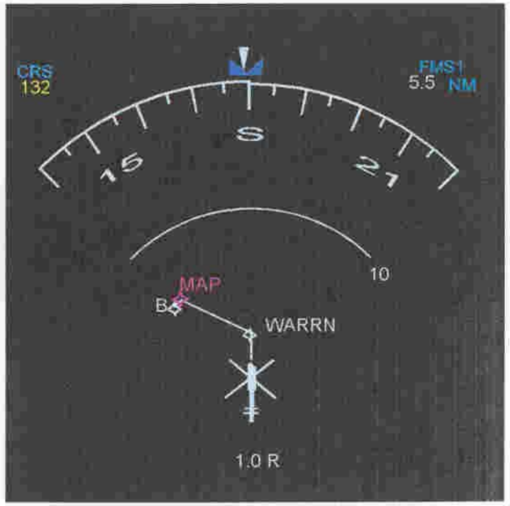
HSI Map Display just before Anticipated Turn Point



HSI Compass Display just after Anticipated Turn Point

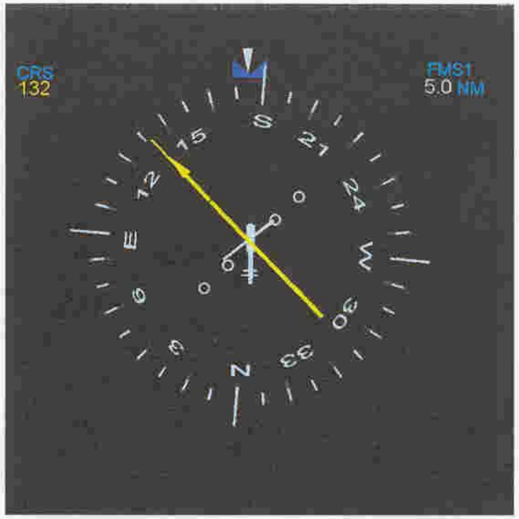


HSI Arc Display just after Anticipated Turn Point

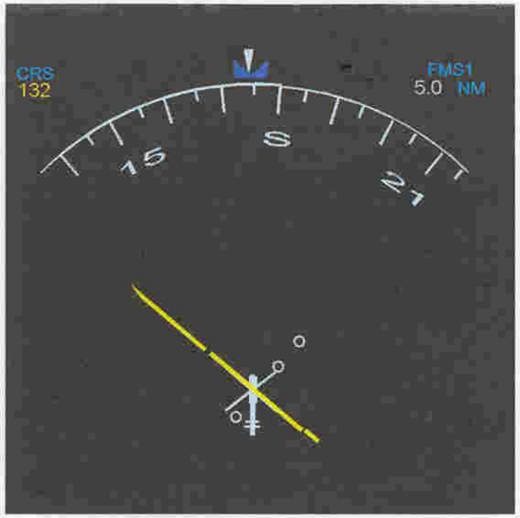


HSI Map Display just after Anticipated Turn Point

FIG 2



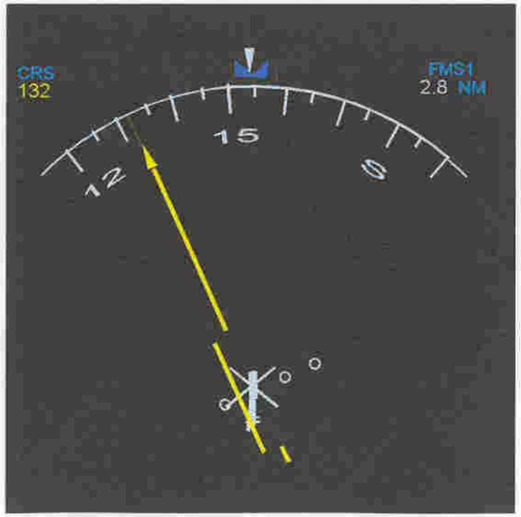
HSI Compass Display overhead WARRN



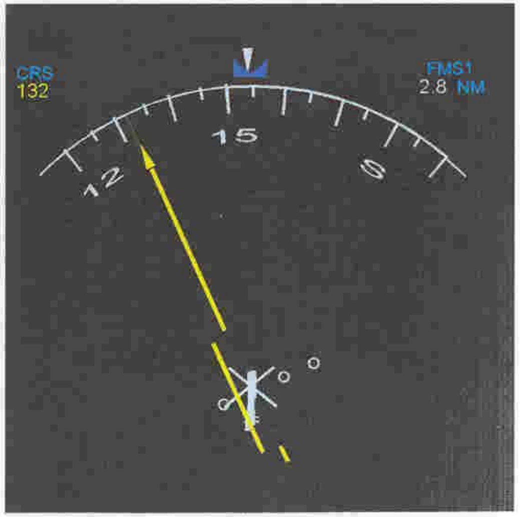
HSI Arc Display overhead WARRN

HSI Map Display overhead WARRN

HSI Compass Display when a Heading of 130 was called



HSI Arc Display when a Heading of 130 was called



HSI Arc Display when a Heading of 130 was called

GLOSSARY OF ABBREVIATIONS

AAIB	Air Accidents Investigation Branch
AAIU	Air Accident Investigation Unit
ADELT	Automatically Deployable Emergency Locator Transmitter
ADF	Automatic Direction Finder
ADI	Attitude Director Indicator
AFTN	Aeronautical Fixed Telecommunications Network
AIC	Aeronautical Information Circular
AIP	Aeronautical Information Publication
ANO	Air Navigation Order
AP	Autopilot
APR	Approach
ARINC	Aeronautical Radio Inc.
ATC	Air Traffic Control
ATPL (A)	Airline Transport Pilot's Licence (Aeroplanes)
ATPL (H)	Airline Transport Pilot's Licence (Helicopters)
AVAD	Automatic Voice Alerting Device
CAA	Civil Aviation Authority (UK)
CDU	Control and Display Unit
C of A	Certificate of Airworthiness
claggy	Colloquial expression meaning cloudy conditions and poor visibility
CVR	Cockpit Voice Recorder
D	Direct
DAFCS	Digital Automatic Flight Control System
DME	Distance Measuring Equipment
DR	Dead Reckoning
EAPS	Engine Air Particle Separator
EFIS	Electronic Flight Instrument System
EGPWS	Enhanced Ground Proximity Warning System
ETA	Estimated Time of Arrival
FAA	Federal Aviation Authority (USA)
FD	Flight Director
FDR	Flight Data Recorder
FIR	Flight Information Region
FMS	Flight Management System
Ghz	Giga hertz
GMT	Greenwich Mean Time
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
HDG	Heading
HSI	Horizontal Situation Indicator
hpa	Hectopascal
IAA	Irish Aviation Authority
IAC	Irish Air Corps

IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
IMES	Irish Marine Emergency Service
IRE	Instrument Rating Examiner
IRT	Instrument Rating Test
JAA	Joint Aviation Authority
JAR	Joint Airworthiness Requirements
km	kilometre
Mhz	Mega hertz
NAV	Navigation
NCU	Navigation Computer Unit
NDB	Non Directional Beacon
nm	nautical miles
PF	Pilot Flying
PNF	Pilot not Flying
QSY	Code for "Change of transmission to another frequency"
RAC	Rules of the Air & Air Traffic Services
RAF	Royal Air Force
Rad-alt	Radar Altimeter
RPM	Revolutions Per Minute
RUC	Royal Ulster Constabulary
SOP	Standard Operating Procedure
SVFR	Special Visual Flight Rules
TAS	True Air Speed
UK AIP	United Kingdom Aeronautical Information Publication
UTC	Universal Time Co-ordinated
VDU	Visual Display Unit
VOR	Very High Frequency Omni Range