AIRCRAFT ACCIDENT REPORT 2/2006

Air Accidents Investigation Branch

Department for Transport

Report on the accident to Pilatus Britten-Norman BN2B-26 Islander, G-BOMG West-north-west of Campbeltown Airport, Scotland on 15 March 2005

This investigation was carried out in accordance with
The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996

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Department for Transport
Air Accidents Investigation Branch
Farnborough House
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October 2006

The Right Honourable Douglas Alexander
Secretary of State for Transport

Dear Secretary of State

I have the honour to submit the report by Mr R Tydeman, an Inspector of Air Accidents, on the circumstances of the accident to Pilatus Britten-Norman BN2B-26 Islander, registration G-BOMG, 7.7 nm west-north-west of Campbeltown Airport, Scotland on 15 March 2005.

Yours sincerly

David King
Chief Inspector of Air Accidents

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GLOSSARY OF ABBREVIATIONS USED IN THIS REPORT

AAIB	Air Accidents Investigation Branch
aal	above airfield level
ACAS	Airborne Collision Avoidance System
AFIS(O)	Aerodrome Flight Information Service (Officer)
AI	Altitude Indicator
amsl	above mean sea level
ANO	Air Navigation Order
ARCC	Aeronautical Rescue Co-ordination Centre
ASI	airspeed indicator
ATC(C)(O)	Air Traffic Control (Centre)(Officer)
BCAR	British Civil Airworthiness Requirement
CAA	Civil Aviation Authority
CAP	Civil Air Publication
CG	centre of gravity
°C,F,M,T	Celsius, Fahrenheit, magnetic, true
CRM	Crew Rescue Management
CS	Certification Specifications
CWP	Central Warning Panel
DME	distance measuring equipment
DNA	Deoxyribonucleic acid
EASA	European Aviation Safety Agency
ETA	estimated time of arrival
FDP	Flight Duty Periods
FL	flight level
ft	feet
ft/min	feet per minute
HIAL	Highlands and Islands Airports Limited
hPa	hectopascal (equivalent unit to mb)
hrs	hours (clock time as in 12:00 hrs)
HSI	Horizontal Situation Indicator
IFR	Instrument Flight Rules
JAR	Joint Aviation Requirement
kg	kilogram(s)
KCAS	knots calibrated airspeed
km	kilometre(s)
kt	knot(s)
m	metre(s)
MDA	Minimum Descent Altitude
METAR	a timed aerodrome meteorological report
MHz	Megahertz
MRCC	Maritime Rescue Co-ordination Centre
NDB	non-directional radio beacon
nm	nautical mile(s)
NTSB	National Transportation Safety Board
OBI	Omni Bearing Indicator
OPC	Operator proficiency check
QNH	pressure setting to indicate elevation above mean sea level
RAF	Royal Airforce
RIS	Radar Information Centre
ROV	Remotely Operated Vehicle
R/T	Radio Telephony
RVR	runway visual range
SAR	Search and rescue
SAS	Scottish Ambulance Service
ScOACC	Scottish and Oceanic Area Control Centre
SRA	Surveillance Radar Approach
SSA	Sector Safe Altitude
SSR	secondary surveillance radar
TAF	Terminal Aerodrome Forecast
UTC	Co-ordinated Universal Time (GMT)
VASI	Visual Approach Slope Indicator
VFR	Visual Flight Rules
VOR	VHF omni-range

Air Accidents Investigation Branch

Aircraft Accident Report No: 2/2006 (EW/C2005/03/03)

Registered Owner and Operator:	Loganair Limited
Aircraft Type:	Pilatus Britten-Norman BN2B-26 Islander
Nationality:	British
Registration:	G-BOMG
Place of Accident:	7.7 nm west-north-west of Campbeltown Airport, Argyll, Scotland Latitude: 55º 29.2' N Longitude: 005º 53.7' W
Date and Time:	15 March 2005 at 0018 hrs
	All times in this report are UTC

Synopsis

The watch supervisor at the Scottish and Oceanic Area Control Centre notified the accident to the Air Accidents Investigation Branch (AAIB) at 0115 hrs on 15 March 2005. The following Inspectors participated in the investigation:

Mr R J Tydeman	Investigator in Charge
Mr K W Fairbank	(Operations)
Mr S J Hawkins	(Engineering)
Mr A P Burrows	(Flight Data Recorders)

The Glasgow based Islander aircraft was engaged on an air ambulance task for the Scottish Ambulance Service when the accident occurred. The pilot allocated to the flight had not flown for 32 days; he was therefore required to complete a short flight at Glasgow to regain currency before landing to collect a paramedic for the flight to Campbeltown Airport on the Kintyre Peninsula.

Poor weather at Campbeltown Airport necessitated an instrument approach. There was neither radar nor Air Traffic Control Service at the airport, so the pilot was receiving a Flight Information Service from a Flight Information Service Officer in accordance with authorised procedures. After arriving overhead Campbeltown Airport, the aircraft flew outbound on the approach procedure for Runway 11 and began a descent. The pilot next transmitted that he had completed the 'base turn', indicating that he was inbound to the airport and commencing an approach.

Nothing more was seen or heard of the aircraft and further attempts at radio contact were unsuccessful. The emergency services were alerted and an extensive search operation was mounted in an area based on the pilot's last transmission. The aircraft wreckage was subsequently located on the sea bed 7.7 nm west-north-west of the airport; there were no survivors.

The investigation identified the following causal factors:

1. The pilot allowed the aircraft to descend below the minimum altitude for the aircraft's position on the approach procedure, and this descent probably continued unchecked until the aircraft flew into the sea.

2. A combination of fatigue, workload and lack of recent flying practise probably contributed to the pilot's reduced performance.

3. The pilot may have been subject to an undetermined influence such as disorientation, distraction or a subtle incapacitation, which affected his ability to safely control the aircraft's flightpath.

Three safety recommendations have been made.

1. Factual Information

1.1 History of the flight

The history of the flight was derived from witness statements, transcripts of Radio Telephony (R/T) transmissions and recorded radar data.

1.1.1 Background

The aircraft was being operated on behalf of the Scottish Ambulance Service (SAS). G-BOMG was a Glasgow based BN2B Islander aircraft, available for air ambulance tasks on a 24 hour basis. The SAS provided a qualified ambulance technician or paramedic for such flights and, if necessary, specialist medical staff.

1.1.2 Pre-flight activities

The operations officer at the operator's Glasgow base received a request from the SAS, at 2133 hrs on 14 March 2005, for a return flight to Campbeltown Airport. The task was to collect a 10 year-old patient, who was suffering from suspected appendicitis, and fly him to Glasgow for hospital treatment, accompanied by his father. A Glasgow based paramedic had been allocated to the flight by the SAS. Although they did not classify it as an emergency task, the requested maximum transfer time was three hours.

The operations officer first advised the company engineers of the intended flight, then called the allocated pilot at 2136 hrs and informed him of a planned departure time of 2330 hrs. The operations officer also contacted the AFISO at Campbeltown at 2141 hrs to inform him of the 'out of hours' flight.

The pilot assigned to the flight had not flown for 32 days. The operator required the pilot to carry out a short currency flight on his own before being permitted to carry the paramedic on the allotted task. He was notified of this requirement when first contacted by the operations officer, and it was agreed that he would first fly a visual circuit at Glasgow before landing to collect the paramedic for the flight to Campbeltown.

The pilot arrived in the operations room at about 2220 hrs and commenced his pre-flight duties. At this stage, no weather information was available for Campbeltown, though the Glasgow and Prestwick weather reports were available. The pilot appeared to be relaxed and behaving normally.

1.1.3 The currency flight

It was an inclement evening, so the pilot carried out his pre-flight inspection in the company's hangar before boarding the aircraft. It was then towed from the hangar with the pilot on board. He started the engines and at 2306 hrs requested taxi instructions for the short flight. The aircraft took off from Runway 05 at 2315 hrs and flew one visual circuit before landing. The aircraft then taxied back to the company apron and the engines were shut down. It was raining heavily during the turnround so the pilot remained in the aircraft whilst the paramedic, who had reported for the flight at about 2300 hrs, was escorted to it. No one spoke to the pilot during this period. The paramedic entered the aircraft via the left rear access door and seated himself in the forward facing cabin seat on the left side of the aircraft immediately behind the pilot.

1.1.4 Abnormal engine start

Witnesses reported an abnormal engine start sequence for one of the flights. An engine was started and ran for a short while before stopping (the normal engine start sequence was right then left, normally with only a brief pause between the two starts). On this occasion the started engine was heard to run for about a minute before stopping. The engineers suspected that a fault had developed and began to approach the aircraft, expecting to speak to the pilot. However, as they did so the engine was again started and this time the start sequence was normal. The pilot made no contact with the engineers or with operations during this time.

Witnesses were divided as to whether the abnormal start was associated with the currency flight or the subsequent flight to Campbeltown. The transcript of the R/T exchanges between the aircraft and ATC shows that there was an interval of 2 minutes 15 seconds between the pilot receiving start clearance and requesting taxi clearance on the first flight; whereas, on the second flight the interval was 30 seconds.

1.1.5 The flight to Campbeltown

At 2329 hrs the pilot requested engine start, and taxied soon after, using callsign 'LOGAN AMBULANCE ONE'. Whilst taxiing, the pilot received his ATC clearance, which was for a direct route from Glasgow to Campbeltown. However, shortly afterwards the pilot requested a routing via ROBBO (a reporting point to the west of Glasgow Airport) and then to continue west before setting course for Campbeltown. ATC issued a revised clearance which reflected the pilot's request and the aircraft took off at 2333 hrs. After takeoff the aircraft was transferred to the Scottish and Oceanic Area Control Centre (ScOACC) for the climb and cruise portion of the flight.

The aircraft turned left after takeoff and climbed to its assigned cruising level of FL060 (approximately 6,000 ft altitude). The route flown by G-BOMG, derived from recorded radar data, is shown at Paragraph 1.9.3. After passing 1 nm north of ROBBO, the aircraft continued on a westerly track before making a course adjustment onto about west-south-west in the direction of Tarbert. As the aircraft left controlled airspace the ScOACC controller placed it under a Radar Information Service (RIS)[1].

At 2359 hrs the controller noticed that the aircraft had still not turned towards Campbeltown so he asked the pilot of G-BOMG to confirm his routing. The pilot replied that he was intending to pick up the *'210 radial down to Campbeltown'*. The course indicated by the pilot was approximately that of the advisory airway N553D which routed from TABIT reporting point, near the town of Tarbert, to the Macrihanish VOR/DME, inbound on the 032º(M) radial. (The Macrihanish VOR/DME, with the identification coding 'MAC' was the main navigational aid at Campbeltown Airport.) However, the aircraft had already passed the radial which the pilot intended to intercept. A short while later, the pilot transmitted that he was turning towards Campbeltown and soon afterwards the aircraft turned onto a track of about 160º(M). The new track appeared to be taking the aircraft towards the radial nominated by the pilot but, soon after, the aircraft turned once again, taking up a track directly for the 'MAC' VOR/DME.

At 0003 hrs the pilot requested and received descent clearance. Soon after there was a change of controller at ScOACC and the off-going controller briefed the oncoming controller of the non-standard navigation of G-BOMG. At 0005 hrs the controller, observing G-BOMG's descent, announced that radar service was terminated. The aircraft continued its descent to 3,900 ft, which was the minimum Sector Safe Altitude (SSA) when approaching from the north-east. At 0006 hrs the pilot announced that he would contact Campbeltown.

1.1.6 The approach into Campbeltown

On initial contact with the AFISO at Campbeltown, the pilot asked for the latest weather report and was passed the weather that had been observed at 2350 hrs. This recorded a surface wind from 240º(M) at 15 kt, visibility 4,500 m in rain, broken cloud cover at 400 ft and at 900 ft, and a QNH of 1,000 hPa. The pilot was informed that Runway 29 was in use, and that the surface was wet in all sectors.

[1] A RIS is an air traffic radar service under which details of conflicting air traffic are passed by the controller to the pilot, but the pilot is wholly responsible for maintaining separation from such traffic and other aircraft.

He replied "THAT'S UNDERSTOOD QNH ONE THOUSAND I'LL COME TO THE OVERHEAD OUTBOUND FOR THE APPROACH FOR ONE ONE TO HOPEFULLY BREAK VISUAL FOR TWO FIVE".[2]

Details of the approach procedure are shown at Section 1.8, Figures 3 and 4. G-BOMG started a descent from 3,900 ft to reach 3,000 ft when it was some 4 nm inbound to the VOR/DME (3,000 ft was the minimum altitude to cross over the 'MAC' VOR/DME and from which to commence the approach). As the aircraft approached the overhead of the VOR/DME, it commenced a turn towards the outbound track of 307º(M). At 0014 hrs, at a range of 4.1 DME[3] on the outbound leg of the procedure, the pilot announced that he was "BEACON OUTBOUND". The AFISO passed an updated weather report, stating that the cloud base had lowered to 'few' clouds at 300 ft and broken cloud at 400 ft. He also advised the pilot that the Runway 11 lights would be illuminated and asked him to call *'base turn complete'*. This was acknowledged by the pilot, and at 4.5 DME outbound the aircraft commenced a descent from 3,000 ft.

At 0018 hrs the pilot transmitted "LOGAN AMBULANCE ONE BASE TURN COMPLETE". The AFISO replied with updated weather information, stating that the visibility had reduced to between 1,500 m to the north and 2,500 m to the south, and asking the pilot to call *'field in sight'*. This transmission was not acknowledged, but the AFISO assumed that the pilot would be busy in the cockpit at this stage.

1.1.7 Overdue action

When, after 5 minutes, the aircraft had not landed and no engine noise was heard, the AFISO attempted to contact G-BOMG on both the main and standby radio systems; he also confirmed with a colleague in the watch room that the station was transmitting normally. At 0026 hrs the AFISO contacted the ScOACC West Coast Sector supervisor who advised him to continue to attempt to make contact. Meanwhile, ScOACC attempted to use commercial air traffic in the vicinity to relay a message to G-BOMG, and also notified the Distress and Diversion Cell based at the London Terminal Control Centre. ScOACC also notified the operator with a request that the pilot's and paramedic's mobile telephones be contacted in case the aircraft had suffered a total radio or electrics failure; this was attempted but was unsuccessful.

[2] A 'circling approach' is one in which the pilot flies an instrument approach to one runway, with the intention of landing on another runway. It is normally only necessary when there is an instrument approach procedure to one runway only, or when terrain considerations prohibit an instrument approach to the desired runway. The weather minima for circling approaches are normally higher due to the element of visual manoeuvring required before landing.

[3] Slant range in nautical miles from the VOR/DME.

At 0031 hrs, one minute after the latest time that G-BOMG should have landed, ScOACC went immediately to their 'Distress Phase' and notified the appropriate authorities.

1.1.8 Location of the wreckage

The main wreckage of G-BOMG was found on the sea bed, at a position on the 298º radial from the VOR/DME at a range of 8.95 nm, which is 7.7 nm west-north-west of the airport.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	1	1	-
Serious	-	-	-
Minor/none	-	-	-

1.3 Damage to the aircraft

The aircraft had suffered severe structural break-up. The fuselage had separated into three sections: the front fuselage, the centre fuselage with the wings attached, and the rear fuselage. The centre fuselage floor had broken into multiple sections. Both engines had separated from the wings and the left main landing gear leg had separated from its attachment point beneath the left engine.

1.4 Other damage

The damage was confined to the aircraft.

1.5 Personnel information

1.5.1 Commander: Male, aged 40 years

Location:	Left cockpit seat	
Licence:	Airline Transport Pilot's Licence	
Instrument Rating:	Valid to 31 August 2005	
Operators Proficiency Check:	Valid to 31 August 2005	
Line Check:	Valid to 31 October 2005	
Medical Certificate:	Class 1, valid to 14 May 2005	
Limitations:	None	
Flying experience:	Total all types	3,553 hours
	Total on type	205 hours
	Last 90 days	38 hours
	Last 28 days	5 minutes
	Last 24 hours	5 minutes

1.5.1.1 Pilot's background

The pilot had previously been employed as an Assistant Flying Instructor and charter pilot, flying mostly single, piston-engined light aircraft. He joined the operator on 5 October 1998 as a First Officer on the Shorts SD360 at Glasgow. In August 1999 he was transferred to the Saab SF340B and gained his command in August 2001. Although the pilot lived close to Edinburgh, in August 2004, and at his own request, he transferred to the Islander fleet, based at Kirkwall in the Orkney Islands. However, soon after he requested a return to the SF340B at Edinburgh or Glasgow, citing family reasons. Instead he remained on the Islander but was transferred to Glasgow in October 2004.

1.5.1.2 Pilot's currency

The pilot's duty roster included large blocks of standby duty to cover the air ambulance operation. He had been on leave for two weeks immediately prior to the accident flight. He had flown 38 hours in the 90 days prior to the accident, but none in the previous 28 days, except for the five minute 'currency' flight on the night of the accident. His previous flight had been on the evening of the 10 February 2005, 32 days before the accident. The pilot had last flown into Campbeltown on the night of 5/6 February 2005. The recorded arrival time on that occasion was 0040 hrs, after a flight from Glasgow lasting 30 minutes. The pilot's flying logbook contained a relatively large number of flights which were annotated as VFR flights. In the opinion of a senior Islander pilot from the same operator, the number of VFR flights was unusual given the time of year when most of the flights had been made, and the increased likelihood of encountering IFR conditions.

The pilot recorded in his flying logbook occasions when he had carried out instrument approaches, and this showed that he had flown three in the preceding 90 days. His most recent instrument approach was a Surveillance Radar Approach (SRA) to a circling manoeuvre, flown on 31 January 2005. Prior to that he had recorded two instrument approaches on the 28 January 2005, on the occasion of his last proficiency check with a training captain. In total, since he had qualified on the Islander on 2 September 2004, he had recorded a total of six instrument approaches, at least two of which were flown as 'cloud break' procedures[4]. The pilot had recorded only one night IFR instrument approach procedure since completing training on the Islander, and this was one of those flown as a 'cloud break' procedure. The pilot had not recorded any VOR approaches on the Islander in his flying logbook.

[4] Although an instrument approach would normally be associated with an approach to land, it may also be used as a 'cloud break' procedure, to descend through cloud with the intention of continuing the flight once VFR conditions are achieved.

1.5.1.3 Pilot's rest

The pilot was rostered for a night standby duty on 14 March 2005, to be conducted from home and commencing at 2300 hrs. He had finished a two week leave period on 12 March, and had been rostered for a day off on the 13 March. During his leave he had gone on holiday to Italy with his family, returning to the UK on 9 March and travelling home on 12 March. He spent the remainder of the weekend at home with his family. On the evening of 13 March he had retired at about 2245 hrs and had an uninterrupted night's sleep.

On the day of the 14 March the pilot awoke at about 0645 hrs and spent the day attending to domestic tasks. He was called at 2136 hrs by the operations officer and notified of the intended flight. He dressed and drove to work, arriving at about 2220 hrs. There was no indication that the pilot attempted or achieved any sleep during the day or early evening.

1.5.1.4 Pilot's flying assessments

The pilot's flying training records since joining the operator showed a satisfactory level of performance and that he made normal progress when converting to the Islander. He passed his Licence Proficiency Check in August 2004 with a good overall standard, though failed the initial non-precision NDB instrument approach due to exceeding the allowed deviation. The item was retaken and passed. The pilot passed an Operator's Proficiency Check (OPC) on 28 January 2005 with all items reported as flown to a good standard. The OPC included a NDB approach flown at Campbeltown.

1.5.2 Paramedic: Male, aged 34 years

Location: Left cabin seat immediately behind the pilot, facing forward

The paramedic was employed by the Scottish Ambulance Service, South West Division, and was based at Paisley. He had worked for the service for nine years and ten months, and had been engaged on air ambulance duties as a paramedic for the previous two years. He had been notified of a call-out at 2230 hrs on the evening of the 14 March 2005 and had been requested to report for a 2330 hrs departure.

1.6 Aircraft information

1.6.1 General information

Manufacturer:	Pilatus Britten-Norman Ltd
Type:	BN2B-26 Islander
Aircraft Serial Number:	2205
Year of manufacture:	1989
Number and type of engines:	2 Lycoming O-540-E4C5 piston engines
Total airframe hours:	6,221 hours
Total airframe cycles:	40,018 cycles
Certificate of Registration:	UK Registered on 14 August 2002
Certificate of Airworthiness:	Transport (Passenger) Category issued by the UK Civil Aviation Authority on 13 September 2002 and expiring on 12 September 2005

1.6.2 Aircraft description

The BN2B-26 Islander is a high wing, fixed landing gear, all-metal aircraft with a maximum takeoff weight of 2,994 kg (see Figure 1). It is powered by two Lycoming O-540 piston engines which each drive a two-bladed variable-pitch Hartzell propeller. The aircraft has conventional mechanical flying control surfaces operated by cables and push-pull rods. Both the elevator and rudder have mechanically operated trim tabs. The electrically actuated flaps have three positions, UP, TAKEOFF and LAND. G-BOMG was fitted with a two-axis autopilot. The aircraft can be configured to seat up to nine passengers but G-BOMG was configured in the air ambulance role with two seats at the front (for pilot and passenger), a stretcher assembly occupying the centre section of the cabin on the right, a paramedic's seat on the left behind the pilot's seat, and two seats at the rear (see Figure 2). The aircraft has three doors: a pilot's door on the front left side and a cabin door on each side. The cabin door on the right side of G-BOMG was not easily accessible due to the stretcher assembly.

1.6.3 Aircraft weight and balance

The aircraft's weight at the time of the accident was approximately 2,580 kg and its centre of gravity (CG) was at approximately 22.8 inches aft of datum. These values were within the aircraft's weight and centre of gravity envelope, and represent a mid weight aircraft at a slightly aft CG position.

Figure 1

Photograph of a BN2B-26 Islander aircraft

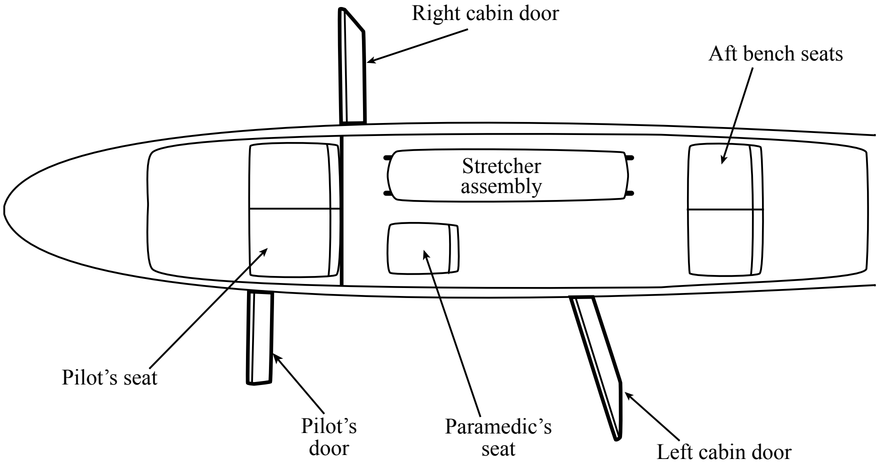

Figure 2

Seat and door configuration of G-BOMG

1.6.4 Aircraft maintenance history

The aircraft's maintenance schedule included a daily check, a weekly inspection, a 150 hour/60 day inspection, a 300 hour inspection and a 600 hour inspection. A 300 hour inspection was completed on G-BOMG on 7 January 2005 and a 150 hr/60 day inspection was carried out on 4 March 2005. The last weekly check was carried out on 11 March 2005 and the last daily check was carried out during the early morning of 14 March 2005. Before the pilot's first flight on the evening of 14 March 2005 the aircraft had been fully refuelled and an engineer had added two quarts of oil to each engine. The only unresolved recorded defect at the time was related to a problem with the stretcher's back rest, though this did not affect the aircraft's airworthiness.

1.7 Meteorological information

1.7.1 General

The Met Office provided an aftercast of the weather situation on the night of 14/15 March 2005, using archived charts and data from a radiosonde launched from Castor Bay, Northern Ireland, shortly before the accident.

The synoptic situation at 0001 hrs on 15 March 2005 showed an occluded front moving across the Campbeltown area with an initially light to moderate, moist, west-south-westerly airflow establishing over the area. The associated weather was cloudy with outbreaks of rain or drizzle. Surface visibility was between 1,800 m and 4,000 m in rain or drizzle, but locally 6 km where precipitation was lighter or had ceased. There was broken or overcast stratus cloud with a cloudbase between 200 and 400 ft, with multiple cloud layers to more than 6,000 ft. The surface temperature at Campbeltown was +9ºC, the dew point was also +9ºC and the 0ºC isotherm was at 6,500 ft. The surface wind was from 250º(T) at 10 to 15 kt and the wind at 1,500 ft was from 250º(T) at 15 kt.

The commander of a Royal Navy helicopter, which was on scene about one hour after the accident, reported a cloudbase of about 500 ft. The visibility was reported as about 5 nm with occasional showers. He also reported that there was no turbulence in the area and that the sea state was slight.

1.7.2 Pre-flight meteorological information

The operations room at Glasgow acted as the focal point for crew pre-flight activities. When the pilot arrived, the operations officer issued him with relevant flight paperwork, though this included only limited weather information in the form of Meteorological Aerodrome Reports (METARs) and Terminal Area Forecasts (TAFs). The computer system used to extract meteorological reports did not recognise automatically generated reports and, since these were the only recent reports from Campbeltown, they did not appear on the briefing information given to the pilot. Additionally, because Campbeltown was not a 24 hour airport, there were no current TAFs available.

In order to obtain further graphical weather information it would have been necessary for the pilot to extract it himself from the computer, or to ask the operations officer to do so. On the night of the accident, he did not request any additional weather information, and the operations officer could not recall seeing the pilot at a computer terminal prior to walking out to the aircraft. No printed weather information was recovered from the aircraft wreckage.

1.7.3 Campbeltown Weather Reporting

The weather observations at Campbeltown were made by an automated system. If the AFISO was on duty at the time, he would inspect the recorded weather data and, if necessary, make appropriate adjustments. The AFISO's shift would normally end at 1800 hrs local. For 'out of hours' flights, such as that made by G-BOMG, the AFISO would be contacted by telephone or pager and would normally report to the ATC tower at least 45 minutes before the aircraft's ETA. He would commence his duties by taking a weather observation and passing this by telephone or facsimile to the appropriate aircraft operator – in this case the operator at Glasgow. On the evening of 14 March 2005, this observation was timed at 2320 hrs and passed by facsimile to the operations officer.

The 2320 hrs report (see Paragraph 1.7.4) from Campbeltown arrived in the operations room after the pilot had left to carry out his short currency flight. The operations officer therefore gave the report to the paramedic, who had arrived after the pilot, and who then took it to the aircraft. The weather report, which was placed inside an envelope before being given to the paramedic, was also not recovered from the aircraft wreckage.

1.7.4 Campbeltown METARs

The relevant METARs for Campbeltown were as follows:

2250 hrs	(Automatic observation)
Surface wind	From 250º(M) at 13 kt
Visibility	6 km
Cloud	Few cloud at 500 ft Overcast at 900 ft
Weather	Not reported
Temperature/Dew point	+9ºC / +8ºC
QNH	999 hPa

2320 hrs	(Automatic observation, manually adjusted)
Surface wind	From 260º(M) at 8 kt
Visibility	5,000 m
Cloud	Broken cloud at 400 ft and at 900 ft
Weather	Moderate rain
Temperature/Dew point	+9ºC / +8ºC
QNH	999 hPa

2350 hrs	(Automatic observation, manually adjusted)
Surface wind	From 240º(M) at 15 kt
Visibility	4,500 m
Cloud	Broken cloud at 400 ft and 900 ft
Weather	Rain
Temperature/Dew point	+9ºC / +9ºC
QNH	999 hPa[5]

The AFISO at Campbeltown made the following observation at 0018 hrs, at the time that the aircraft was believed to be inbound to the airport:

0018 hrs	(Automatic observation, manually adjusted)
Surface wind	From 280º(M) at 12 kt
Visibility	1,500 m (north), 2,500 m (south)
Cloud	Few cloud at 300 ft Broken cloud at 400 ft
Weather	Moderate rain
Temperature/Dew point	+9ºC / +9ºC
QNH	1,000 hPa

At 0026, some 8 minutes after the accident, the AFISO at Campbeltown observed that the cloudbase had dropped to 200 ft above the airport. The following automatic METAR was recorded about 30 minutes after the accident:

0050 hrs	(Automatic observation)
Surface wind	From 240º(M) at 6 kt
Visibility	1,900 m
Cloud	Broken cloud at 200 ft
Weather	Not reported
Temperature/Dew point	+9ºC / +9ºC
QNH	1,000 hPa

1.7.5 Glasgow Meteorological Reports

TAF timed at 2051 hrs, valid from 2200 hrs to 0700 hrs:

Surface wind	From 070º(M) at 10 kt
Visibility	8 km
Cloud	Scattered cloud at 1,000 ft, Broken cloud at 1,800 ft
Weather	Light rain

[5] A QNH of 999 hPa had been recorded automatically but the pilot was passed an observed actual QNH of 1,000 hPa.

There was a 40% probability of the cloud base dropping temporarily to 800 ft and visibility to 3,000 m in rain. There was a 30% probability of the visibility improving temporarily to in excess of 10 km with no significant weather.

2150 hrs METAR

Surface wind	From 060º(M) at 13 kt
Visibility	8 km
Cloud	Few cloud at 700 ft
	Scattered cloud at 1,800 ft
	Broken cloud at 2,400 ft
Weather	Rain
Temperature/Dew point	+3ºC / +2ºC
QNH	1,001 hPa

2220 hrs METAR

Surface wind	From 060º(M) at 12 kt
Visibility	9 km
Cloud	Scattered cloud at 1,400 ft
	Broken cloud at 2,000 ft
Weather	Light rain
Temperature/Dew point	+3ºC / +2ºC
QNH	1,001 hPa

The meteorological conditions at Prestwick Airport, which was 22.8 nm from Glasgow, were broadly similar.

1.7.6 Airborne information

The pilot of G-BOMG first contacted the AFISO at Campbeltown at 0008 hrs, and was passed the 2350 hrs weather report. At 0014 hrs, when the aircraft was outbound in the approach procedure, the AFISO advised the pilot that the cloud base had lowered to 'few' cloud at 300 ft and 'broken' cloud at 400 ft. He also reported the visibility as being either 3,500 m or 4,500 m.[6] At 0018 hrs, when the pilot had transmitted that he was inbound to the airport, the AFISO advised a further reduction in visibility to 1,500 m to the north and 2,500 m to the south of the airport.

[6] This is based on the AFISO's recollection as his transmissions were not recorded.

1.7.7 Operational weather requirements

The requirements relating to the selection and usability of aerodromes with regard to forecast and actual weather conditions were contained within the operator's operations manual, and were based upon those of the Joint Aviation Requirements – Operations 1 (JAR-OPS 1).[7]

For selection as a destination, the meteorological reports and/or forecasts were required to show that, for the period one hour before to one hour after the aircraft's ETA, the weather would be above the applicable planning minima. For the type of instrument approach available at Campbeltown, this would have required a cloud ceiling of at least 380 ft amsl for an approach and landing on Runway 11, increasing to 1,045 ft if the approach to Runway 11 was to be followed by a circling manoeuvre to land on Runway 29. The required visibilities would have been 1,300 m and 1,500 m respectively. These values corresponded to the actual approach minima.

If the meteorological reports for the destination indicated that the applicable minima above could not be met, or if no meteorological information was available, then the requirements stipulated that two alternate aerodromes should be selected. For each of the alternates, the applicable planning minima were based on an additional margin above the applicable approach minima.

1.8 Aids to navigation

1.8.1 Campbeltown instrument approach procedures

The main approach navigation aid at Campbeltown was the Macrihanish VOR/DME facility, with the identification code 'MAC'. The airport was also equipped with an NDB facility, coded 'CBL'. After the accident, a check of the 'MAC' VOR/DME's serviceability was made with other air traffic in the area and at the NATS facility at Swanwick, both of which showed that the VOR/DME was operating normally. As a precaution, the facility was removed from service at 0330 hrs and full standard operating checks were carried out which confirmed that it was operating to specification. The facility was returned to service at 1711 hrs that day.

There was no instrument approach procedure for Runway 29; the pilot of G-BOMG was flying a VOR/DME approach to Runway 11 when the accident occurred. This procedure had originally been developed when the airfield was a Royal Air Force base but was not retained when Highlands and Islands Airports

[7] JAR-OPS 1 covers the Commercial Air Transportation of Aeroplanes.

Limited (HIAL) assumed control of the airport in 1996. However, the operator adopted the procedure as a company discrete procedure which was approved by the CAA, including for use outside normal aerodrome operating hours. The relevant approach chart was found attached to the chart holder on the control yoke of G-BOMG. Details from it are shown in Figures 3 and 4.

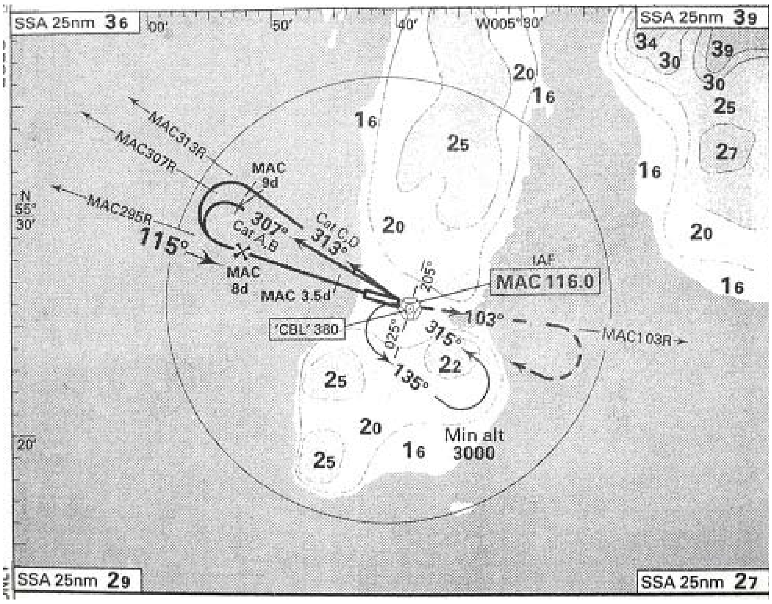

Figure 3

Extract of approach chart recovered from G-BOMG showing lateral profile

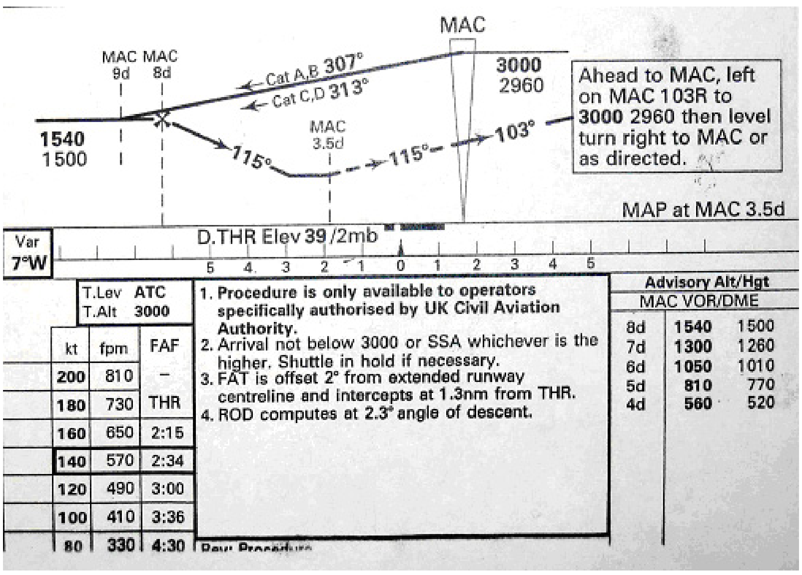

Figure 4

Extract of approach chart recovered from G-BOMG showing vertical profile and notes

The approach procedure commenced from the 'MAC' VOR/DME at a minimum of 3,000 ft amsl. The outbound course for the Islander (a category A aircraft) was 307º(M), to a range of 9 DME, descending to 1,540 ft. The left 'base turn' was flown level at 1,540 ft, to intercept the 295º(M) radial, giving an inbound course of 115º(M). Final descent started at 8 DME, and the Missed Approach Procedure, if required, commenced at 3.5 DME. Advisory information on the chart, in the form of rates of descent at various airspeeds, assisted a pilot to fly a nominal approach angle of 2.3º. Additionally, advisory altitudes were provided for each mile of the inbound leg.

Sector Safe Altitudes (SSA) were published on the company's approach charts; to the north-east the minimum safe altitude was 3,900 ft amsl, and to the north west it was 3,600 ft amsl. The approach chart also included the note:

> *"Arrival not below 3000 or SSA whichever is the higher. Shuttle in hold if necessary."*

1.8.2 Instrument approach minima

The operating minima for the approach were as follows:

VOR/DME RWY 11:

Minimum Descent Altitude	380 ft
RVR[8] / Visibility	1,300 m

CIRCLING MINIMA :

Minimum Descent Altitude	1,045 ft
RVR / Visibility:	1,500 m

1.8.3 Navigation facility coverage

The UK Aeronautical Information Publication (UK AIP) contains notes concerning the coverage of the 'MAC' VOR/DME. A general note states:

> *'Due to terrain, coverage at low level is reduced in Sectors … RDL (radial) 351º - 086º.'*

[8] Runway Visual Range is a measure of the horizontal visibility along the runway.

In relation to the Advisory Route N553D which runs from TABIT to MAC, a warning states:

> *'Due to terrain the MAC VOR/DME are not reliable below FL 90 at ranges exceeding 20 nm.'*

1.8.4 Maritime aids

A lighthouse was situated on the Mull of Kintyre, 11 nm from the accident location. The lighthouse's characteristics were a group of two flashes at 20 second intervals, nominally visible at 24 nm range (at sea level).

1.9 Communications

1.9.1 General

During the course of the accident flight the pilot of G-BOMG was in communication with Glasgow Aerodrome Control (118.800 MHz), ScOACC West Sector (127.275 MHz, 'bandboxed' with 126.300 MHz), and Campbeltown Information (125.900 MHz). Speech transcripts were obtained for all frequencies. There was no requirement for the recording of the Campbeltown frequency, although suitable equipment was installed and transmissions from G-BOMG were recorded. However, an undetected fault with the equipment prevented the Campbeltown AFISO's transmissions from being recorded.

1.9.2 Radio communications

Prior to takeoff, the initial clearance issued to G-BOMG by Glasgow Aerodrome Control was as follows:

> "LOGAN AMBULANCE ONE AFTER DEPARTURE WHEN READY CLEAR DIRECT TO CAMPBELTOWN WITH A LEFT TURN OR RIGHT TURN AS YOU WISH SQUAWK FIVE FOUR ONE SEVEN CLIMB TO MAINTAIN ALTITUDE SIX THOUSAND FEET."

The pilot read back the clearance correctly, and then, about 30 seconds later, transmitted:

> "I'D JUST LIKE ROUTE THROUGH OUT TOWARD ROBBO INITIALLY TO AVOID ARRAN AND THEN CONTINUE WEST BEFORE C- ON DOWN TO CAMPBELTOWN THIS EVENING AMBULANCE ONE."

The controller then issued a revised clearance, being a left turn after departure and direct routing to ROBBO, a reporting point bearing 279º(M) from the Glasgow VOR/DME at range 16 nm. After takeoff the aircraft was transferred to ScOACC and instructed to climb to FL060. The controller asked the pilot whether he would be routing direct to Campbeltown or via ROBBO, to which the pilot replied:

> "VIA ROBBO AND OUT TO THE WEST BEFORE ROUTING SOUTH ER SOUTH EAST ER SOUTH WEST TOWARD CAMPBELTOWN LOGAN AMBULANCE ONE."

Some 19 minutes later, when it became clear that the aircraft had continued to fly further west than the controller had anticipated, he asked the pilot to confirm his intended route. The pilot replied:

> "JUST LOOKING TO PICK UP THE ER TWO ER TWO ONE ZERO RADIAL DOWN TO CAMPBELTOWN LOGAN AMBULANCE ONE."

The controller did not hear this transmission because of another transmission on a second frequency he was operating. About a minute later he asked the pilot of G-BOMG to repeat his intentions. The pilot replied:

> "WE'RE JUST TURNING DIRECT DOWN TOWARD CAMPBELTOWN NOW LOGAN AMBULANCE ONE."

The aircraft subsequently established on a track for Campbeltown and, at 0003 hrs, the pilot requested descent clearance. The Scottish controller replied that there was no known traffic to affect the descent and the pilot transmitted:

> "UNDERSTOOD DESCENDING THREE THOUSAND NINE HUNDRED FEET THEN CAMPBELTOWN QNH ALL THE NINES LOGAN AMBULANCE ONE."

At 0006 hrs, when G-BOMG was about 10 nm north of Campbeltown, the pilot announced that he would contact Campbeltown Information. On initial contact with Campbeltown, the pilot was passed the latest weather, including a QNH of 1,000 hPa and informed that Runway 29 was in use. The pilot replied:

> "THAT'S UNDERSTOOD QNH ONE THOUSAND I'LL COME TO THE OVERHEAD OUTBOUND FOR THE APPROACH FOR ONE ONE TO HOPEFULLY BREAK VISUAL FOR TWO FIVE."

At 0014 hrs, with the aircraft 4.1 DME outbound in the instrument procedure, the pilot announced that he was "BEACON OUTBOUND." The AFISO passed an updated weather report, advised that the runway and approach lights would be switched to Runway 11 for the instrument approach, and requested that the pilot call *'base turn complete'*. The pilot acknowledged, saying:

> "THAT'S UNDERSTOOD THANKS".

The next call from the aircraft was at 0018 hrs, when the pilot transmitted:

> "LOGAN AMBULANCE ONE BASE TURN COMPLETE."

The AFISO replied with updated weather information and asked the pilot to call "FIELD IN SIGHT". This transmission was not acknowledged, and no further transmissions were received from G-BOMG.

1.9.3 Radar recordings

The progress of the flight, detected by the Lowther Hill primary radar and secondary surveillance radar (SSR), was recorded by the ScOACC. The radar system, used for both the primary radar and SSR, utilised a rotating radar transmitter/receiver, known as the radar head, which could only produce a radar return if the radar head was pointing at the aircraft. At the time of this accident, the rotational speed (or sweep rate) of the radar head at Lowther Hill was approximately 5.8 seconds (ie 5.8 seconds between illuminated radar returns).

The positional accuracy of the SSR was within the recorded resolution of 0.09° for bearing and 1/16 nautical mile for range, together with the 50 ft resolution of the mode C altitude readout. Positional information from the primary radar was also available for the majority of radar sweeps; however, primary radar provided only slant range and bearing, resulting in positional information that was not accurate relative to the ground.

The track of G-BOMG, based on the SSR radar returns, is presented in Figure 5. The radar returns cover a period from 2334:21 hrs to 0016:22 hrs. With a transponder setting of 5417 and mode C selected, the first return of G-BOMG was from above the end of Runway 05 of Glasgow Airport, at about 740 ft aal, with a calculated ground speed of approximately 72 kt.

The cruise altitude (FL060) was reached at 2342:30 hrs, just over 6 nm west of Glasgow Airport. This altitude was maintained until 0003:10 hrs, with the aircraft 19 nm from, and tracking towards, the Machrihanish VOR/DME.

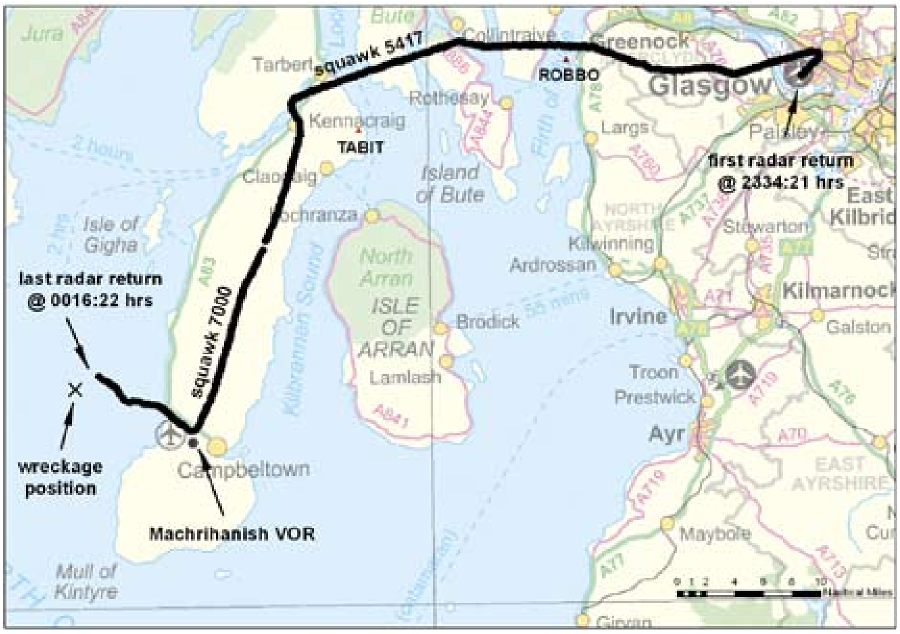

Figure 5

Radar track of G-BOMG

G-BOMG descended to 3,900 ft amsl, 13.5 nm before the VOR/DME, and maintained this altitude until 6.5 nm from the VOR/DME (slant range) before commencing a further descent, reaching 3,000 ft amsl at 4 DME. At 0011 hrs, 3 DME, the aircraft began to deviate slightly to the right of the track to the VOR/DME. One minute later, the aircraft commenced a turn to the right, away from the VOR, taking up a track of about 310º(M).

At 0013:45 hrs, G-BOMG turned to the left onto an intercept course with the 307° radial from the VOR/DME, and then began to descend. This latter portion of G-BOMG's track, in the vicinity of the Machrihanish VOR/DME, is presented in Figure 6.

The average groundspeed over the last 30 seconds of radar returns was 125 kt (approximately 131 KCAS taking into account the wind at 1,500 ft), having steadily increased from an average of about 120 kt earlier in the descent. The last radar return (0016:22 hrs) positioned G-BOMG at 8.1 DME on the 307° outbound radial, descending at 1,050 ft/min. The SSR mode C for the last return indicated FL017. Correcting for the Campbeltown QNH of 1,000 hPa, the aircraft's Mode C derived altitude at this point would have been 1,340 ft. Allowing for a maximum resolution error of plus or minus 50 ft in the Mode C returns, the aircraft's altitude would have been between 1,290 ft and 1,390 ft. The procedure minimum altitude at the position of the last radar return was 1,540 ft.

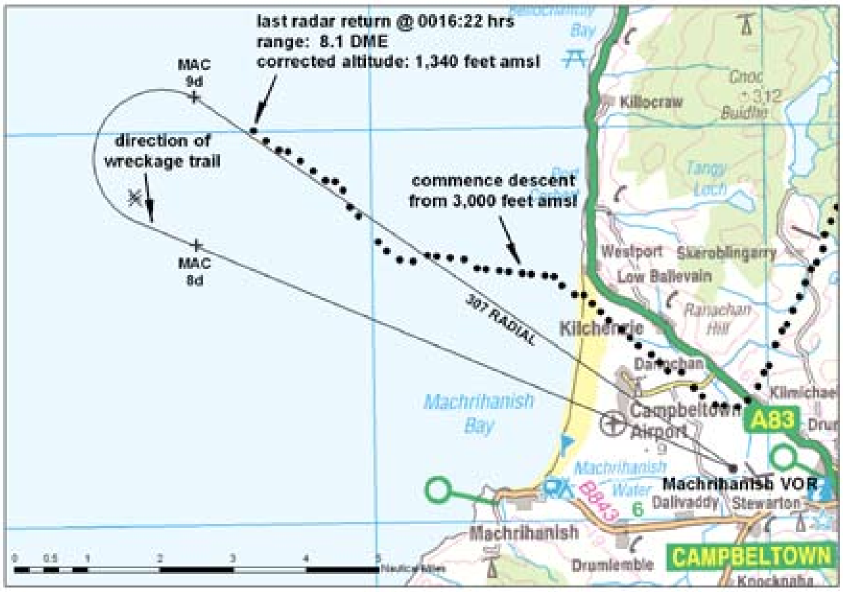

Figure 6

Radar track of G-BOMG in the vicinity of the Machrihanish VOR

1.10 Aerodrome information

Campbeltown Airport is one of ten airports managed and maintained by HIAL. The airport, formerly a Royal Air Force station, is situated about 3 nm west-north-west of Campbeltown, towards the southern end of the Kintyre Peninsula on Scotland's west coast. The aerodrome reference point is at 55º 26.23' N, 005º 41.18' W and the elevation is 42 ft.

The airport has a single runway, designated 11/29, of 3,049 m (10,003 ft) length. The runway was equipped with high intensity runway lighting, green threshold lights and Visual Approach Slope Indicator systems (VASIs) at either end, set to a 3º approach angle. The approach lights for Runway 11 consisted of centre line lights and two sets of lighted lateral bars. The aerodrome chart in use on the accident flight included notes to the effect that circling manoeuvres were not permitted to the south of the aerodrome, and that the runway braking action was only moderate to poor when classified as 'wet'.

Special permission had been granted to the operator by the CAA and HIAL to operate non-scheduled Public Transport flights outside the published aerodrome operating hours.

1.11 Flight Recorders

The aircraft was not fitted with either a Flight Data Recorder or a Cockpit Voice Recorder; neither was required to be fitted under the applicable regulations.

1.12 Wreckage and impact information

1.12.1 Accident site

The accident site was located in the sea off the coast of Kintyre, 7.7 nm west-north-west of Campbeltown Airport. The wreckage was at a depth of 78 m and the wreckage trail was approximately 209 m long and 50 m wide. The two engines, located 7 m apart, at a position 55°29.21'N 005°53.68'W, were the northern-most pieces of wreckage. The remaining wreckage was distributed south of the engines on an approximate track of 171°(M). The main wreckage, consisting of the wings and fuselage, was located 117 m from the engines along this track. A plot showing some of the recorded wreckage debris is shown in Figure 7. The approximate tidal stream at the time of the accident was flowing in the direction of 142°(M) at 1.4 kt.

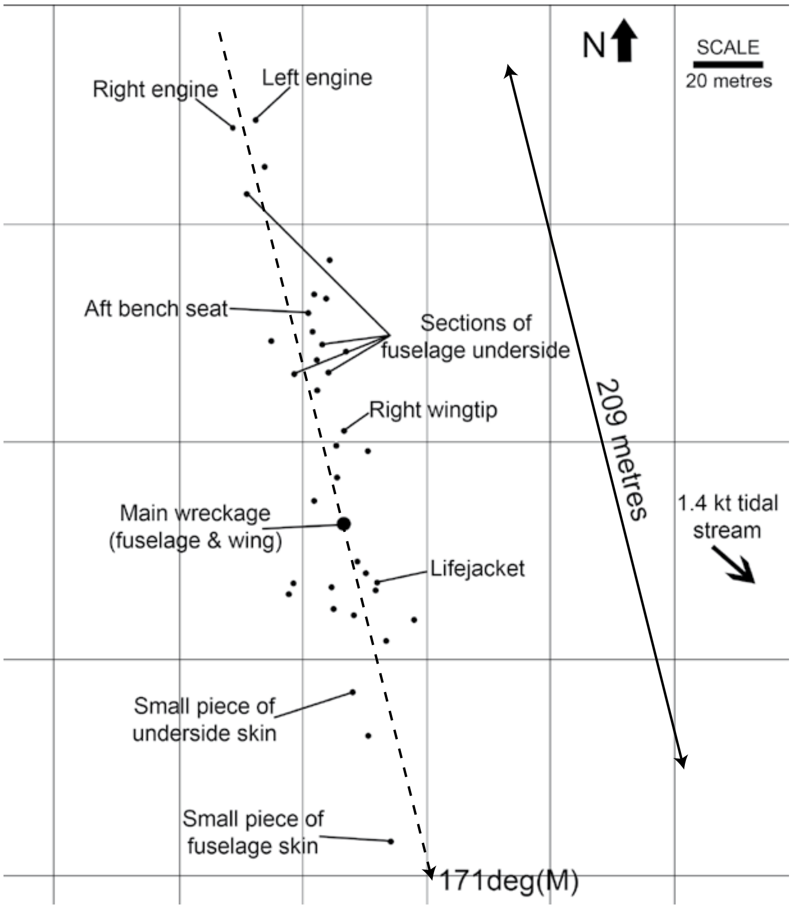

Figure 7

Plot of some of the wreckage debris at a depth of 78 m

1.12.2 Wreckage recovery

The first wreckage recovered was found floating on the surface by the search and rescue vessels. The floating wreckage recovered included the three doors, the left main gear leg, some un-inflated life-jackets, a paramedic's bag and other light material from the aircraft's cabin.

The remaining wreckage was recovered from the seabed using saturation divers operating from the Diving Support Vessel *Seaway Osprey* (see Figure 8). After an initial survey of the wreckage by a Remotely Operated Vehicle (ROV)[9] the divers were deployed at 0100 hrs on 21 March 2005. Over the ensuing 12 hours the paramedic's body was recovered and then all significant wreckage was recovered. The pilot's body was not found near the wreckage; therefore, following the wreckage recovery, the ROV was employed for an additional three and a half hours to search for the body but it was not found during this time.

All major parts of the aircraft were accounted for following the wreckage recovery except for the aircraft's left wingtip. The left wingtip was discovered in the fishing net of a trawler on 2 May 2005 when it was approximately 2.5 nm north-west of the wreckage field.

Figure 8

Seaway Osprey – Diving Support Vessel used to recover the wreckage

[9] The ROV was a small submersible vehicle fitted with a camera and sonar that was remotely operated by a crew on the vessel.

1.12.3 Wreckage examination

1.12.3.1 General

The aircraft had suffered severe structural break-up consistent with impact with the sea. The wreckage as laid out in the AAIB's hangar is shown in Figure 9. The aircraft's fuselage had broken into three sections: the front fuselage, the centre fuselage with the wings attached, and the rear fuselage. The three sections were held together on the seabed primarily by wiring and control cables. A large section of the centre fuselage floor had broken into multiple pieces. The forward and centre sections of the fuselage lower skin exhibited evidence of 'hydraulicing'[10], indicative of a moderate to high speed impact with the sea. Both engines, with propellers attached, had separated from the wing structural mounts. The right main-gear leg was still attached to the wing and was bent aft while the left main gear leg had separated. The left horizontal tailplane underside had an impact print consistent with the shape and size of the left main gear leg. Both the left and right wing tips, and outboard wing leading edges had suffered impact damage. The nose gear leg was bent aft and to the right. The cockpit area, including the windscreen and instrument console had suffered little damage, but the cockpit roof had collapsed due to the loss of structure on the sides. The flaps were in the UP position. An emergency checklist was found in its normal, stowed position on the right hand instrument panel.

Figure 9

Recovered aircraft wreckage

10 Hydraulicing is a bulging type distortion that occurs when a fluid exerts a high pressure on a thin skin against a solid structural frame.

1.12.3.2 Flight Controls

All flying control surfaces were intact and accounted for. An examination of the flying control cables and push-pull rods did not reveal any evidence of a pre-impact failure. All disconnections found were as a result of overload and consistent with the impact forces. There was also no evidence that the controls had been jammed. The rudder trim actuator was in the position for neutral rudder trim. The elevator trim actuator was in a position that with neutral elevator would result in slight elevator trim tab up (0.8 inches up at the trailing edge). This would have resulted in a cockpit indication of one graduation nose down trim. According to the aircraft manufacturer this elevator trim position combined with the aircraft's weight and centre of gravity at impact would have resulted in a hands-off trim speed of between 110 and 120 KCAS using an approach power or cruise power setting. At idle power or full power the aircraft would not have been in trimmed flight.

1.12.3.3 Powerplant

The left engine power lever was found in the full forward position and the right engine power lever was 2 inches aft of the full forward position. Both propeller levers were found in the fully forward position. The left mixture control lever was slightly forward of IDLE CUTOFF and the right mixture control lever was almost full forward. Both carburettor heat levers were set to OFF. However, when the engines were torn from their wing mounts significant force would have been applied to the engine control cables, potentially disturbing the pre-impact positions of all of the engine control levers.

Both propeller blades from the left engine were bent aft and had chordwise scratches near the tips. Both blades also had one or more large leading edge indentations near the tips (see Figure 10). The propeller blades from the right engine had suffered similar damage to the left engine blades; the blades were both bent aft with chordwise scratches and they both had one or more large leading edge indentations (see Figure 10). Both sides of the aircraft fuselage, in line with the propeller's path, exhibited evidence of slash marks consistent with propeller blade strikes. On this type of aircraft the minimum clearance between the propeller and the side of fuselage is 10 inches. A strip examination of the propeller hubs was carried out. All four blades were latched in the fine pitch position (ie had not been feathered) and no evidence of a pre-impact failure within the variable-pitch mechanisms was found.

A strip examination of both engines was carried out and both were found to be in a similar condition. All the cylinders contained varying amounts of sea water and the piston heads were severely corroded. The spark plugs had varying degrees of corrosion but were otherwise normal. Both engines could be rotated manually once the plugs had been removed. The valves and valve pushrods operated normally. There was no evidence of either engine having suffered from overheating distress or from a mechanical failure.

Figure 10

Left (L) and right (R) engine propeller blades – note leading edge indentations and chordwise scratches

All engine control cables had failed due to overload when the engines separated from the aircraft. There was no evidence of a pre-impact control cable disconnection.

All four magnetos (two from each engine) could be rotated manually but severe corrosion had partially destroyed the casings, preventing them from being functionally tested on a rig.

The right-engine fuel pump operated normally and still contained some fuel. The left-engine fuel pump casing had broken up which prevented the pump from being functionally tested. Both engine-driven vacuum pumps had damaged casings and could not be tested, but both contained rotational scoring marks consistent with impeller rotation at impact.

An examination of the air intake boxes revealed that the carburetor heat mechanism was in the carburetor heat OFF position on both engines.

1.12.3.4 Fuel System

The aircraft had two fuel tanks – one in each wing. The aircraft had been fully fuelled prior to the pilot's first circuit flight before the subsequent flight to Campbeltown. Assuming normal fuel burn rates, the two fuel tanks would have contained a total of approximately 100 US gallons of useable fuel at the time of impact. During the recovery operation both fuel tanks were opened by the divers while the wings were still on the seabed to reduce the weight of the wings and reduce the hazards associated with bringing a large amount of fuel onto the ship. A significant amount of fuel was observed streaming upwards out of both tanks due to the fuel's lower density in comparison to that of seawater.

The engine fuel selector valves were set to feed fuel from their respective fuel tanks; these were the normal positions for flight. The switches for the electrically powered auxiliary fuel pumps (two for each wing tank) were set to ON; this was the normal position during an approach to land.

1.12.3.5 Instruments

The aircraft was equipped with two altimeters and both contained water and had suffered internal damage from exposure to the high water pressure at depth[11]. The main altimeter had its subscale set to 1,000.5 hPa and the secondary altimeter had its subscale set to 1,001 hPa. The last reported altimeter setting from Campbeltown Airport before the accident was 1,000 hPa. The airspeed indicator (ASI) and vertical speed indicator also contained water. There were no witness marks on the faces of any of the pitot-static instruments[12] that might indicate a pre-impact reading. The pitot-static plumbing system is formed by a series of pipes that run from the combined pitot-static tube under the left wing to connections on the aft faces of the pitot-static instruments. There were multiple bends, kinks and breaks in the pipework but the end connections were secure. Both the primary (vacuum driven) and standby (electric) Attitude Indicators (AIs) had suffered water and corrosion damage which prevented functional testing, but a strip examination of the primary AI revealed rotational scoring marks within the gyroscopic rotor housing consistent with rotation at impact. There were no witness marks on the face of either AI that might indicate the aircraft's attitude at impact.

The Horizontal Situation Indicator (HSI), depicted in Figure 11, had its 'Heading Select' bug set to 157° and its 'Course Select' arrow set to 103°. The required

[11] The water pressure at a depth of 78 m is nine times greater than the atmospheric pressure at sea level.

[12] The pitot-static instruments are the altimeters, airspeed indicator and vertical speed indicator.

'Course Select' setting for the VOR approach into Campbeltown was 115°. These HSI settings could have changed during the impact sequence, although the 'Course Select' arrow is reasonably secure as it rotates in concert with a sizeable mass within the instrument. The Omni Bearing Indicator (OBI), which was also capable of displaying VOR deviation information, had a course setting of 309° which was within 2° of the 307° outbound radial for the Campbeltown VOR approach.

Figure 11

Horizontal Situation Indicator (HSI) from G-BOMG – note yellow course selector arrow set to 103° and orange heading bug set to 157°

An examination of the tungsten filament bulbs within the Central Warning Panel (CWP) did not reveal any stretched filaments[13]. However, none of the filaments from the instrument lights (which were selected ON as it was a flight at night) had stretched either.

1.12.3.6 Electrical System

The immersion of the aircraft in sea water for more than six days rendered any testing of electrical components unviable. Six unrelated circuit breakers were found tripped; however, no evidence of pre-impact arcing or burning in any wiring looms was found. One wiring loom running along the overhead cockpit area had suffered some damage but this was consistent with the break-up of the surrounding structure. There were small brown soot deposits surrounding some of the breaks in these wires which indicated that the wires were powered during the impact sequence.

[13] During a high energy impact a hot tungsten bulb filament sometimes stretches, which provides an indication that the bulb was ON at impact.

1.12.3.7 Structure

All structural damage and failures were consistent with having occurred during the impact sequence, and all of the primary structural components were accounted for. The damage to the three doors matched the damage to their surrounding door frames, indicating that the doors were closed at impact.

1.12.3.8 Autopilot

The autopilot master switch was in the OFF position.[14] The autopilot computer could not be tested for serviceability due to water ingress.

1.12.3.9 Aircraft lighting

The aircraft's anti-collision beacon and navigation lights were selected ON, as were the cabin and cockpit lights. The landing lights were selected OFF.

1.12.3.10 Ice and rain protection

The switches for pitot and stall warning probe heating, and for propeller de-icing were selected ON. The switches for airframe de-icing, heated windshield and for the ice inspection lamp were selected OFF.

1.13 Medical and pathological information

1.13.1 The pilot

The body of the pilot was not found during the Search and Rescue (SAR) operations nor during the subsequent salvage operation. It was eventually found some nine months after the accident, on 18 December 2005, by the crew of a fishing vessel trawling four miles off the coast in Macrihanish Bay.

A post mortem examination was carried out. Confirmation that the body was that of the pilot of G-BOMG was only possible through DNA analysis. The examination, although made difficult by *post mortem* changes in the body, revealed no obvious external injuries and no internal injuries or fractures. It was not possible to state the cause of death or whether the pilot had been wearing a life-jacket.

The pilot held a valid Class One medical certificate which had been appropriately issued. Enquiries into the pilot's medical background established that he had

[14] The operator's procedures for the Islander included setting the autopilot master switch ON as part of the after start checks.

recently experienced some anxiety in his domestic and work life, which may have been connected with his change of base to the Orkneys. The pilot had undergone counselling for this, the most recent session being on 17 February 2005. The counsellor found that, although the pilot appeared to have some anxiety related to his work relocation, he did not have an abnormal mood state or appear to be at risk of suicidal behaviour. In the opinions of the counsellor and an aviation pathologist at the RAF Centre of Aviation Pathology, no psychological factors related to the counseling were likely to have played a part in the accident.

1.13.2 The paramedic

The body of the paramedic was recovered from the aircraft wreckage and a post mortem examination was carried out. The paramedic had suffered a major injury to the front of his head, which would almost certainly have rendered him unconscious and was potentially fatal in its own right. The injury itself was indicative of a very forcible impact to the head. The examination also showed changes in the lungs which were very suggestive of drowning. Given the circumstances of the accident, the post mortem findings suggested that the paramedic had initially been rendered unconscious from a major head injury and had subsequently drowned, all this probably occurring within a matter of minutes. There was no sign of carbon monoxide in the paramedic's system, or of any underlying disease which could have played a part in his death.

1.14 Fire

There was no fire.

1.15 Survival aspects

1.15.1 Search and Rescue operations

The Clyde Maritime Rescue Co-ordination Centre (MRCC) and the Aeronautical Rescue Co-ordination centre (ARCC) at RAF Kinloss controlled the SAR operations, having been alerted at 0040 hrs. The subsequent search area, based on the estimated position and time of the last radio call from G-BOMG, was centered on a point 8 nm from Campbeltown, bearing 295º(M), being approximately the 'final approach fix' for the approach to Runway 11.

Lifeboats were deployed from stations at Islay, Campbeltown and Port Rush in Northern Ireland. These were joined by Sea King SAR helicopters from HMS Gannet at Prestwick Airport and RAF Valley in Anglesey. A Royal Navy Sandown class minesweeper was on a training exercise some 35 nm away and diverted to the area to assist in the search operations. Coastguard rescue teams from Campbeltown and Tarbert conducted shoreline searches throughout the night and following day.

At 0228 hrs the lifeboat crews began to recover floating wreckage from the sea and commenced a slow sweep of the area for casualties, though none were found. At 0456 hrs the Royal Navy vessel reported a strong sonar contact, believed to be the aircraft fuselage, at a reported depth of 78 m, and prepared to deploy its ROV to investigate further. The ROV confirmed that the wreckage was that from an aircraft, but tidal conditions prevented it from being able to make a positive identification or detailed inspection of the fuselage.

The floating parts of aircraft wreckage were recovered to Campbeltown dock and then taken under police supervision to secure storage at Campbeltown Airport to await AAIB inspection. Whilst shoreline searches continued, SAR operations ceased at 1030 hrs.

1.15.2 Accident survivability

The cockpit area of the aircraft had not suffered significant damage and a survivable space for the pilot had been preserved. There was no evidence of a significant impact with the controls or the instrument panel. The pilot's seat had a three-point harness consisting of an adjustable lap strap with airliner style buckle, and an inertial reel shoulder harness integrated with the lap strap. The lap strap buckle was found undone and there was no evidence of it having been forced open – the buckle still operated normally. The harness was secure at all three points and the harness stitching was intact.

The body of the paramedic was still in his seat when the wreckage was discovered. His seat was attached to a reinforced floor panel which had separated from the fuselage floor structure; the stretcher assembly was also attached to this panel. The floor panel, seat and stretcher were found upright on the seabed adjacent to the right side of the open fuselage structure. The paramedic's body was still restrained in the seat by a two-point adjustable lap strap. The lap strap was secure at both points and the stitching was intact.

The paramedic's head injury was characteristic of having struck a solid object. In order to determine the likely point of head impact the aircraft operator carried out a test (at the request of the AAIB) in a similar Islander with a person of the same height as the paramedic. The person was seated in the same position as the paramedic with a fastened lap strap. They then flexed forwards trying to reproduce the effects of a rapid deceleration. Under static conditions the person's head just missed the back of the pilot's seat; however, under a rapid deceleration or with a slightly looser lap strap the person's head would have hit the top of the pilot's seatback.

The aircraft was fitted with eight passenger shoulder harnesses on inertial reels but the lap straps in use were not compatible with the shoulder harness attachment points. Therefore, there was no shoulder harness available to the paramedic where he was seated.

A total of five adult life-jackets, two infant life-jackets and a lifecot were recovered. Some of these would have been stowed under the seats and some in seat back pockets. Two of the adult life-jackets were found floating free from their nylon pouches while the remaining three were still packed away. The infant life-jackets and lifecot were also still in their pouches. None of the life-jackets had been inflated and the seals on the pressurized canisters were intact. The two adult life-jackets that were found floating free were both tested by pulling their inflation chords. One life-jacket inflated and the other life-jacket had a tear which prevented inflation but its canister fired. According to the aircraft's equipment manifest the aircraft should have been carrying six adult life-jackets, one infant life-jacket and one lifecot. It was therefore not possible to establish whether one adult life-jacket was missing or whether the aircraft had been carrying an extra infant life-jacket instead of an adult life-jacket.

It was not standard practise for the pilot or paramedic to wear life-jackets or immersion protection suits. The sea temperature at the time of the accident was approximately 9°C. At this temperature, based on standard predictive sea survival curves, the survival time for an average person, who was able to remain afloat but not wearing immersion protection, was one hour. However, there is considerable variation in survival rates between individuals.

1.16 Tests and research

1.16.1 Flight trial

1.16.1.1 General

In the final stages of the accident, G-BOMG descended below the coverage of the ScOACC radar. A flight trial was flown from Glasgow on 17 May 2005 in an Islander aircraft that was similar to G-BOMG. The aim of the flight was to determine whether any useful information could be deduced about the aircraft's final track and descent profile, using the observed characteristics and coverage of the radar. As with the flight in G-BOMG, the progress of the flight trial was followed by the Lowther Hill primary radar and SSR, and recorded at the ScOACC. As well as flying the same route into Campbeltown as taken by G-BOMG, five separate elements of all, or part, of the instrument approach profile were flown.

Campbeltown Airport reported a surface wind from 310º(M) at 10 kt, 35 km visibility and scattered cloud. The wind at 1,500 ft was from 320º at 10 to 15 kt. The Campbeltown QNH was 1,022 hPa. For the trial to provide a meaningful track comparison with the accident flight, it was necessary to compare the wind data with that of the night of the accident. A comparison of the winds at 1,500 ft on the night of the accident and for the trial flight showed that they were of similar strengths but from directions about 70º apart. As it was not practical to allow for the wind difference during the flight trial, an assessment was made of the likely effects of the different wind. The maximum position error between the 9 DME turn point on the outbound leg and the wreckage location, flying the most likely ground track at pattern airspeed of 120 kt, would be expected to be approximately 0.2 nm as a result of the different winds, and a track error of 3º, based on the approximate aircraft track at impact.

1.16.1.2 En Route phase

The route flown to Campeltown followed that taken by G-BOMG. Flying at FL060 initially, stable VOR indications were received at ROBBO from the 'MAC' VOR/DME and 'CBL' NDB, and throughout the remainder of the flight. Signals from the DME were not received until the aircraft was within 22 nm of the station, when flying a southerly course towards it.

1.16.1.3 Run One

The aim of the first run was to establish if, and to what extent, the aircraft would remain 'visible' to radar whilst flying the lateral instrument procedure profile at a steady 1,540 ft, this being the correct minimum altitude for the procedure until making the final approach. Useable VOR radial information became available outbound in the procedure between two to three miles from the 'MAC' VOR/DME. The aircraft was descended to 1,540 ft on the Campbeltown QNH and established on the 307º(M) radial. A standard rate one turn was commenced at 9 DME, with the aim of flying the lateral profile as accurately as possible. A steady radar return was achieved until the aircraft was almost at its furthest point in the procedure, at 10.1 DME. Radar contact was regained at a range of 9.4 DME, as the aircraft intercepted the inbound approach course.

1.16.1.4 Run Two

The second run was flown at a steady altitude of 1,300 ft, with a 25º banked turn at 9 DME onto a 'closing heading' of 157º, corresponding to the heading selected on the pilot's HSI. Radar returns were lost at 7.3 DME outbound, and not regained until the aircraft was established on the closing heading at 7.9 DME. The track flown took the aircraft to within 0.2 nm of the accident site.

1.16.1.5 Run Three

This third run followed a similar lateral profile as the second, but with a turn using 25º to 30º angle of bank and flown at 1,400 ft. The last radar contact was at 7.9 DME, and was regained when the aircraft was inbound at 8.2 DME. The aircraft track passed 0.27 nm to the left of the accident site.

1.16.1.6 Runs Four and Five

The final runs were intended to replicate as accurately as possible the descent profile of the accident flight, and to establish a likely lateral track, had the aircraft turned, using 25º angle of bank, at 9 DME directly onto a closing heading of approximately 157º(M) to intercept the inbound course. The aircraft flew a descent outbound matching as closely as practical the observed speed and descent rate of G-BOMG, and this was maintained beyond that point at which radar returns of the accident flight ceased.

In both cases the aircraft flew to within 0.2 nm of the wreckage location. On Run Five, which most closely followed G-BOMG's descent profile, the aircraft reached 200 ft above the sea within 0.2 nm of the wreckage location.

1.17 Organisational and management information

1.17.1 Operational Control

A number of fixed and rotary wing air assets were available to the SAS, which would process requests for ambulance transfers and allocate tasks to the most appropriate resources. Among the available resources were three Islander aircraft, of which G-BOMG was one. The operator was responsible for operational control of these aircraft through a 24 hour flight watch from the company's Glasgow base.

Support for the flying operation, such as filing of flight plans and activation of airfields was carried out by the company's operations controller, whilst activation and control of medical resources was the responsibility of the SAS.

1.17.2 Air ambulance tasking

Requests for air ambulance transfers were processed by the SAS 'Air Desk' controller at its regional headquarters at Dundee, who would allocate the task to the most appropriate resource. On the evening of the accident two of the operator's Islanders were available for tasking in the air ambulance role; G-BOMG at Glasgow and a sister aircraft at Kirkwall.

Air ambulance tasks were classified as 'planned' or 'emergency'. Emergency tasks required that an aircraft be dispatched as soon as possible, whilst planned tasks would include a target maximum time for transfer of the patient to hospital. The task on which G-BOMG was dispatched was classified as 'planned', with a requested maximum patient transfer time of three hours. The request was made to the Air Desk at 2127 hrs and the operator was contacted at 2133 hrs.

1.17.3 Flight crew rostering

The operator's Flight Times Limitation scheme was defined in its operations manual. The stated purpose of the scheme was to interpret the requirement of the Air Navigation Order and the Civil Aviation Publication (CAP) 371; *'The avoidance of fatigue in aircrews'*.

For the Glasgow based air ambulance operation, three pilots would normally cover each 24 hour period. Two pilots would cover consecutive shifts between 0700 hrs and 2100 hrs, normally at 30 minutes readiness in the crew rest room at the airport. The night period from 2100 hrs to 0700 hrs would be covered by one pilot, who would maintain 60 minutes readiness from home.

The operator's Operations Manual stated that:

> *'Some flexibility in actual Flight Duty Periods (FDPs) will be necessary when the period of an ambulance flight is expected to encroach on a watch change. On such occasions a late finish for one pilot or an early start for another will be necessary'.*

1.17.4 The operator's recency requirements

The operator's operations manual contained recency requirements for pilots, which were in line with those contained in JAR-OPS 1. In order to maintain currency, a pilot was required to conduct a minimum of three takeoffs and landings on the type or class of aircraft in question, within the preceding 90 days. Additionally, to maintain currency for single pilot operations at night or under IFR, a pilot was required to have completed a minimum of five IFR flights and three instrument approaches within the preceding 90 days. This requirement could be replaced with an instrument approach check on the aircraft. There were no company records kept of an individual pilot's IFR flights and instrument approaches. Instead, pilots were required to record such flights in their flying logbooks, which would be scrutinized at the time of their recurrent proficiency checks. The operator had a requirement in additional to that of JAR-OPS 1, in that pilots, who had not flown for 28 days or more, were required to complete a currency flight before being permitted to carry passengers.

1.17.5 Paramedic aircraft training and status

Medical staff allocated by the SAS for flying duties underwent a two day training course in various aspects of aircraft operation. The first day would consist of training in the theory of flight and general aircraft operations, whilst the second day would be conducted at an aircraft and would concentrate on the aircraft's safety equipment and practical issues. If one of the operator's pilots was available he would also take part in the training process on the second day, though this was not a requirement. The paramedic on G-BOMG had undergone such training on 14 and 15 June 2002.

Although medical staff allocated to ambulance flights were trained by the SAS in safety equipment and procedures, they had no role in the actual operation of the aircraft and were thus carried as passengers. The aircraft commander therefore retained responsibility for ensuring that the paramedic was adequately briefed on the aircraft safety equipment and procedures before flight.

1.17.6 Crew Resource Management (CRM) Training

In common with most air carriers, the operator's CRM training syllabus followed a three year cycle with all major subjects being covered in that time. The pilot of G-BOMG last underwent annual recurrent CRM training in April 2004. The subjects covered at that stage included stress and fatigue issues. The operator's CRM instructor was aware of the need to cover those aspects pertinent to single pilot operations when Islander pilots were undergoing training.

1.17.7 Commencement and continuation of an instrument approach

The minimum meteorological requirements for commencement and continuation of an approach were contained in the operator's operations manual, and conformed to the requirements of JAR OPS-1, The manual stated:

"An approach may be started irrespective of the RVR, but it may not be continued past the outer marker or equivalent position unless the reported controlling RVR/visibility ... is equal or better than the specified minimum."

As no outer marker existed for the approach (being over the sea), the *'equivalent position'* was a point 1,000 ft above the airport elevation. Reported cloud base was not a factor in determining whether an approach ban existed.

1.18 Additional information

1.18.1 Certification requirements regarding seat restraint systems

The BN2B-26 variant of the Islander was certified in 1979 and its certification basis was British Civil Airworthiness Requirements (BCAR) Section D at Issue 6, which did not include a requirement to fit shoulder harnesses to passenger seats.

The current European Aviation Safety Agency (EASA) Certification Specifications (CS) for Normal, Utility and Aerobatic category aircraft[15] include a requirement in CS 23.785 that:

'b) Each forward-facing or aft-facing seat/restraint system in normal, utility, or aerobatic category aeroplanes must consist of a seat, safety belt and shoulder harness with a metal-to metal latching device that are designed to provide the occupant protection provisions required in CS 23.562.'

This requirement is fundamentally unchanged from JAR 23.785 which was first introduced on 11 March 1994. Therefore, all new-build aircraft (in the Normal, Utility and Aerobatic category) as of 11 March 1994 needed to be equipped with shoulder harnesses for all seats.

However, in the UK, the CAA decided that from 1 February 1989 onwards all new-build aircraft (in the aforementioned categories) should be required to have shoulder harnesses fitted to passenger seats. This requirement was added to the Air Navigation Order (ANO 1989) Schedule 4, Scale B stating[16]:

15 Normal, Utility and Aerobatic category aircraft are those aircraft with a seating configuration, excluding the pilot seats(s), of nine or fewer and a maximum certificated takeoff weight of 5,670 kg or less. G-BOMG was in this category.

16 The quoted text is from Air Navigation Order (1995) which is a reworded version of the 1989 text but the requirement is the same.

'On all flights in aeroplanes in respect of which a certificate of airworthiness was first issued (whether in the United Kingdom or elsewhere) on or after 1st February 1989 the maximum total weight authorised of which does not exceed 5700 kg which in accordance with the certificate of airworthiness in force thereof is not capable of seating more than 9 passengers (otherwise than in seats referred to under sub-paragraphs (a) and (b)), a safety belt with one diagonal shoulder strap or a safety harness for each seat intended for use by a passenger.'

G-BOMG was first issued its Certificate of Airworthiness on 24 May 1989, and therefore the passenger shoulder harness requirement in the ANO was applicable to the aircraft. However, the operator of G-BOMG was operating under JAR-OPS[17] and had an exemption from the CAA which meant that it did not need to comply with Schedule 4 of the ANO.

Under JAR-OPS the operator was required to satisfy JAR-OPS 1.730 (Amendment 9) which required that pilot seats, seats alongside pilot seats, cabin crew seats and observer seats be fitted with a safety belt and shoulder harness. However, there was no requirement to fit a shoulder harness to passenger seats. The paramedic on the G-BOMG flight was classified as a passenger and therefore there was also no operational requirement to provide him with a shoulder harness.

1.18.2 Shoulder harness modification on G-BOMG

The aircraft, G-BOMG (serial number 2205), was delivered new in 1989 with modification NB-M-1298 *Introduction of Passenger Upper Torso Restraints* embodied. This modification installed eight inertia reel shoulder harnesses in the passenger compartment. However, these shoulder harnesses were only compatible with certain lap straps. The seats and lap straps used by the operator of G-BOMG did not have buckles that were compatible with the passenger shoulder harnesses in modification NB-M-1298. The operator used seats that were interchangeable among their fleet of five Islander aircraft and G-BOMG was the only aircraft out of the five to be fitted with modification NB-M-1298. Therefore, neither the paramedic's seat nor the aft bench seats in G-BOMG had the appropriate lap straps which were compatible with the fitted passenger shoulder harnesses.

17 JAR-OPS 1 covers the Commercial Air Transportation of Aeroplanes.

1.18.3 Previous AAIB safety recommendation relating to shoulder harnesses

In July 2001 the AAIB published a report on a public transport accident involving a Cessna 404, registered G-ILGW, which occurred on 3 September 1999 and which resulted in eight fatalities and three serious injuries (AAIB Report No 2/2001). The report made the following statement and safety recommendation:

> *'The increased statistical risk in operating FAR/JAR Part 23 aircraft, in comparison with the larger FAR/JAR Part 25 'Transport Airplanes', is a strong incentive to incorporate at least some of [the] upgraded seat requirements into the existing light aircraft fleet, particularly for those types in continuing production. For example, dynamic testing has shown the advantages of the fitting of upper torso restraints. Similarly, it is possible for seat attachment fittings to be strengthened without imposing a requirement that the FAR/JAR 23.562 injury criteria be demonstrated.*
>
> ***Safety Recommendation 2001-40***
>
> *It is therefore recommended [that] the CAA should undertake a study to identify those elements of the current JAR 23 seat standards which may be used for retrofit into existing aeroplanes whose maximum certificated take-off mass is less than 5,700 kg. And, separately, for those designs in continuing production which are not covered by the current JAR 23 standards. These elements should then be applied at least to those that are operated in the Transport Category (Passenger)'.*

The CAA accepted this recommendation and initiated a study to identify any relevant parts of the JAR 23 seat standards that could be applied retrospectively to aircraft. The study focused separately on 'in-service' aircraft and those 'in continuing production' at weights under 5,700 kg operated in the Public Transport category. The study identified that, of the JAR 23 seat standards, only the feasibility of retrospective application of upper torso restraint (ie shoulder harnesses) was worth pursuing. An investigation was then undertaken to examine this issue.

The investigation, which was completed in July 2003, reviewed the fatal accident statistics for UK registered aircraft with maximum takeoff weights between 2,300 kg and 5,700 kg for the period between 1993 and 2003. There were 39 fatalities during this period although 26 of the fatalities were attributed to high speed impact and therefore classified as non-survivable. Among the potentially survivable accidents there were 13 fatalities, of which eight were in seats without shoulder harnesses (six potential survivors from Public Transport and two potential survivors from Private flights). A similar analysis was conducted of aircraft with maximum takeoff weights of less than 2,300 kg, which identified 10 potential survivors (six from Public Transport and four from Private flights) that could have benefited from an upper torso restraint.

The CAA investigation references a National Transportation Safety Board (NTSB) analysis of light aircraft accidents which concluded that 76% of fatalities in survivable accidents could have been non-fatal if those occupants had been wearing shoulder harnesses.

The CAA concluded from its investigation (full details of which are included in Appendix A, CAA reference 9/61/10DE/JAR7-10(26))

> *'that there is sufficient justification to include in JAR-26*[18] *a requirement to mandate the provision of Upper Torso Restraint systems to all aeroplanes engaged in Commercial Air Transportation operations'.*

The CAA proposed the following amendment to JAR 26 Subpart B: Commercial Air Transportation (Aeroplanes) to read as follows:

> *'26.2xx: Aeroplanes in the normal, utility & aerobatic category with 9 passenger seats or less, a maximum certified take-off weight of 5670 kg (12500 lb) or less and manufactured after (**date to be determined**), are required to have a safety belt and shoulder harness fitted to each passenger seat. The seat belt and shoulder harness must be designed to protect the occupant from serious head injuries when subject to the inertia loads resulting from the ultimate static load factors prescribed in CS 23.561(b)(2).'*

This proposed amendment was sent under an NPA (Notice for Proposed Amendment) together with a Regulatory Impact Assessment (RIA) to the JAA in October 2004. At the time of writing the JAA had not yet responded to the NPA.

[18] JAR 26 prescribes specific additional airworthiness requirements with which operators must ensure that compliance has been established if operating in accordance with JAR-OPS. At the time of writing EASA had not taken over responsibility for JAR 26.

1.18.4 Single pilot public transport flights

1.18.4.1 General

The Air Navigation Order stipulated the minimum number of flight crew members required for public transport IFR flights. In the case of twin piston engine aircraft with a maximum total weight authorized of 5,700 kg or less, the requirement was for one pilot, provided that the aircraft was fitted with an approved and serviceable autopilot. G-BOMG was in this category.

1.18.4.2 Previous accident

On 14 June 2000 a Piper PA-31 aircraft, registration G-BMBC, crashed in the Mersey estuary whilst attempting to land at Liverpool Airport after a flight from Ronaldsway Airport on the Isle of Man (AAIB Bulletin No 1/2001). The aircraft was engaged on an air ambulance flight and, in addition to the single pilot, carried the stretcher patient and his wife, a nurse and a medical student. All five on board died in the accident.

The investigation found no fault with the aircraft that may have caused or contributed to the accident. The report considered that an existing undiagnosed medical condition may have incapacitated the pilot, or that he may have been distracted or disorientated at a critical stage of flight.

1.18.4.3 Previous recommendation

The report made a safety recommendation concerning the minimum flight crew requirements for public transport flights. It observed that, while the majority of public transport flights were required under the ANO to carry a crew of two pilots, the type of aircraft involved in the accident was legally only required to carry one. In the light of the accident, in which the pilot was either disorientated, distracted or incapacitated (or a combination of all three), the investigation concluded that the presence of a co-pilot on the flight could have averted the accident. The report therefore recommended that:

> *'… the CAA, in conjunction with the JAA, review the circumstances in which the carriage of a second pilot is required for public transport flights'.* ***(Safety Recommendation No 2000-50)***

The CAA accepted the recommendation and in September 2002 published the following response:

> *"The JAA Study Group that deals with flight crew matters reviewed the minimum crew requirements for Commercial Air Transport flight at their meeting in March 2002. The Study Group considered the existing JAR-OPS regulations in light of the number of recorded incidents of pilot incapacitation reported in the UK since 1976. After deliberation the Group decided that the number of serious incapacitations did not warrant an amendment to the existing JAR-OPS requirements and consequently did not recommend any changes."*

2 Analysis

2.1 Impact analysis

The predominant initial impact damage to the aircraft was to its nose, lower fuselage and left and right wing tips. The damage to the nose and underside was consistent with a slight nose low impact (less than five degrees nose down) at a low vertical speed (consistent with an approach descent) and a moderate forward speed of between 90 and 130 kt, which is consistent with the elevator trim speed of 110 to 120 kt. The damage suffered to the wing tips did not indicate on its own which had struck the surface of the sea first. However, the separation of the left main gear leg while the right main gear leg remained attached indicates that the left main gear leg was exposed to a higher deceleration force on impact with the sea than the right leg. This evidence combined with the fact that the nose gear leg was bent aft and to the right, is consistent with a slight left wing low (5 to 15 degrees left bank) impact. Once the left wing tip hit the sea a large left yawing moment would have been produced causing the aircraft to cartwheel and hit the sea with its right wing tip.

During the impact sequence, as the nose struck the water, both engines would have been torn from their structural mounts and the tail of the aircraft would have pivoted up and forwards due to its momentum and the compromised floor structure. The impact forces would have resulted in significant distortion and disruption of the fuselage which released the three doors from their hinge mountings and caused the paramedic's seat and stretcher to separate from the floor structure. Overall, the impact damage and subsequent breakup is consistent with a controlled flight into the sea at or close to a normal descent rate and speed.

2.2 Wreckage analysis

All the primary structure of the aircraft was accounted for and there was no evidence to indicate that any part of the aircraft had separated prior to impact with the sea. Continuity of the flying controls was verified and all disconnections could be accounted for by the impact loads. There was also no evidence that the controls had been jammed. Both the elevator trim and rudder trim positions were set close to neutral, indicating that the pilot was not trying to compensate for an abnormal flying condition such as an engine failure. The leading edge damage to the propeller blades was consistent with the blades having struck the side of the fuselage. This would be expected from either a bulging of the fuselage sidewalls at impact or from an inboard movement of the engines due to wing twist at impact or during the engine separation;

the normal clearance between the propeller disk and the side of fuselage is only 10 inches. There were large leading-edge indentations on both propeller blades from both engines which indicate that some power was being delivered to the propellers (a windmilling propeller would have left one blade with significantly less damage than the first blade that struck the fuselage). The similar nature of the damage between the left and right propellers indicates that they had similar rotational energy, meaning that both engines were delivering approximately equal power. This finding is consistent with the fact that no mechanical failure or evidence of overheating distress was found during the engine strip examinations. However, the possibility that both engines were operating at a low power setting due to carburettor icing could not be ruled out. The atmospheric conditions at the time were conducive to the formation of carburettor ice[19] and neither carburettor heat selector was set to HOT. The possibility of fuel contamination leading to a partial loss of power could also not be discounted but it would be very unlikely for fuel contamination to affect both engines equally more than 45 minutes into a flight.

Both altimeters had the correct subscale setting for the reported atmospheric conditions (to within 1 hPa, which corresponds to 28 ft). Unfortunately it was not possible to test the accuracy of the altimeters due to internal damage from the high water pressure they were exposed to at depth. The pitot/static plumbing system was examined and although there were no disconnections, the disruption of the pipework rendered any leak testing or checks for obstructions unviable. However, the pilot would have had an opportunity to detect a gross error in the altimeter readings during his first circuit flight and the subsequent flight to Campbeltown.

A failure of the primary AI could not be ruled out because the instrument could not be tested, but rotational scoring marks within the gyroscopic rotor housing indicate that the gyro was rotating at impact (although its rotational speed could not be determined). The two vacuum pumps which supply suction to drive the primary AI could also not be tested due to impact damage but both had evidence of rotational scoring consistent with both pumps operating at impact. The fact that the aircraft hit the sea in a controlled flight attitude also indicates that a failure of the AI leading to disorientation was unlikely.

The immersion of the aircraft in sea water for more than six days rendered testing of electrical components including powered instruments and the autopilot computer unviable. One wiring loom, which was damaged as a result

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[19] The temperature of 9°C and dewpoint of 9°C, reported by Campbeltown Airport at the time of the accident, placed the risk of carburettor icing in the '*Serious icing - any power*' category of the CAA's carburettor icing chart (reference CAA Safety Sense Leaflet 14 on Piston Engine Icing).

of the fuselage break-up, exhibited evidence of short-circuits which indicates that the aircraft was being supplied with electrical power at the time of impact. No evidence of pre-impact arcing or burning within any of the wiring looms was found.

An examination of the tungsten filament bulbs within the CWP and within the instrument lights was inconclusive. Although the instrument lights were switched on (because it was a night flight) the light bulbs did not contain any stretched filaments, which indicated that the deceleration forces at impact were probably not sufficient to stretch a hot filament.

In summary, the aircraft appears to have hit the sea in a controlled flight attitude with symmetric power and no evidence of a technical fault could be found that might explain the flight into the sea.

2.3 Route analysis

2.3.1 En Route

The clearance the pilot initially received was for a direct route from Glasgow to Campbeltown which, at FL060 would have taken the aircraft safely over the high ground on the Isle of Arran and provided the most expeditious route. When the pilot last flew to Campbeltown, 37 days before the accident and at a very similar time of night, he recorded a flight time of only 30 minutes which is consistent with having flown a direct route. On the evening of the accident, the pilot made a conscious decision before takeoff to initially route further to the west, stating it was "TO AVOID ARRAN". A possible explanation for this is that the pilot considered there may be turbulence over the Isle of Arran, which the revised route would avoid. However, the forecast and actual winds on the evening were not strong enough to warrant a significant deviation from the direct route, especially given the nature of the task, and the delay already incurred because of the need for the currency flight.

It is not clear what the pilot's precise routing intentions were. When the ScOACC controller queried his routing, the pilot's response suggests that, at that moment, he was unaware of his position in relation to 'MAC' VOR/DME. The pilot then stated that he would intercept the 210º radial inbound to 'MAC'. This is technically incorrect, as it would in fact be the 030º radial from 'MAC' which the pilot was referring to, though this is not an uncommon error and is not in itself suggestive of a navigational problem. In any event, the pilot had already passed the quoted radial, and instead appears to have initiated a turn towards it as a result of the query from ATC.

Although the coverage of the 'MAC' VOR signals are reported in the UK AIP as being unreliable below FL090 in the area, the aircraft was seen to turn onto a track of about 160º (M), suggesting that the pilot was, for a short while at least, making a conscious effort to intercept the quoted radial. He might therefore have been receiving VOR signals, otherwise, the heading the aircraft turned onto would be inconsistent with a heading for 'MAC' from a dead-reckoning position. Additionally, data from the flight trial suggests that steady, useable VOR and NDB signals would probably have been received throughout the aircraft's initial westerly track from ROBBO.

A further possible explanation of the pilot's chosen route may be that, in routing his aircraft around the high ground of Arran, he would have felt more comfortable descending below the SSA of 3,900 ft before reaching the 'MAC'. However, the aircraft descended below SSA with only about 6.5 nm to go to the 'MAC'; at this point the aircraft would have only been some 3 to 4 nm further east had it taken a direct route over Arran, and over the same general terrain. It is therefore unlikely that this was the reason for the longer than expected route to Campbeltown.

The prescribed approach procedure started at a minimum altitude of 3,000 ft from overhead the 'MAC', and a note on the chart stated that pilots should, if necessary, enter the holding pattern in order to lose excess altitude. However, for an aircraft of the Islander's performance, starting the procedure at 3,900 ft, the relevant SSA, would present no difficulty in reaching the intermediate altitude of 1,540 ft prior to the final descent point without having to enter the holding pattern. Given the weather conditions, it is unlikely that the pilot would think he may gain visual contact with the airport at 3,000 ft rather than 3,900 ft, so there was no obvious benefit from descending below the SSA. Despite the pilot's undoubted knowledge of the terrain under his aircraft at the time, to do so was contrary to safe practise as well as the operator's procedures.

2.3.2 Initial approach into Campbeltown

Radar data shows that the aircraft, having reached 3,000 ft, started to drift to the right of the 'MAC' VOR/DME as it approached, which could be as a result of the aircraft entering the VOR/DME's 'cone of silence'[20]. This would also account for the apparently late track adjustment to the 307º radial outbound in the procedure. However, DME signals would not be so affected, and the radar data shows that the aircraft commenced a turn onto an outbound track at between 1 and 1.5 nm before the 'MAC'. This relatively early turn had the

[20] An area directly above a radio beacon such as a VOR in which, because of the physical characteristics of the transmitter, reliable signals cannot normally be received.

effect of reducing the time available on the outbound track to establish on the correct radial and increasing the likelihood of having to make a significant track correction once the VOR signals became reliable, as appears to have been the case. Nevertheless, the aircraft established on, or very close to, the 307º radial outbound, showing that the pilot was navigating correctly with respect to the procedure's lateral profile.

The aircraft started a descent from 3,000 ft at 4.5 DME, as it was correcting to the 307º radial, although further descent from 3,000 ft was permitted as soon as the aircraft was established outbound. It is probable that the pilot chose to delay the descent until the aircraft was established on, or close to, the 307º radial. In any case, the descent was started in sufficient time to have comfortably taken the aircraft down to the minimum outbound altitude of 1,540 ft before the 9 DME turn point was reached. Radar data shows that the majority of the outbound descent was flown within the 500 to 1,000 ft/min band recommended in the company procedures.

2.4 Descent below minimum altitude

The final 34 seconds of radar returns show an average descent rate of 1,050 ft/min, which was maintained as the aircraft passed below the outbound minimum altitude of 1,540 ft, until the point that radar contact was lost. At this point the aircraft was at a speed consistent with its position on the procedure, and was correctly tracking the outbound radial.

It is very unlikely that the descent below the outbound minimum altitude was deliberate. The procedure permitted further descent, down to the procedure Minimum Descent Altitude (MDA), only once the aircraft had established inbound to the 'MAC' and had passed the 8 DME position. From this point the pilot would be expected to fly an approach path based on the advisory altitude and range table shown on the approach chart (Figure 4). Although there may have been some merit in descending at a slightly faster rate to MDA once stabilized on the inbound track, in order to establish visual contact with the runway or approach lights, there would have been none in descending before the 8 DME point had been reached.

The aircraft's altitude at the point of the last radar return was approximately 1,340 ft, which is consistent with the observed radar performance during the flight trial. At this stage the aircraft was therefore about 200 ft below the minimum altitude. Had the pilot realised the error at this point and climbed back to the minimum altitude, it is probable that further radar returns would have been received from the aircraft, which was not the case.

The position and orientation of the wreckage trail were not consistent with the aircraft having been flying a standard ‘rate one’ turn from the 9 DME point. However, they are consistent with a turn onto a ‘closing’ heading which would intercept the 295º radial (ie 115º track inbound to the ‘MAC’). Data from the flight trial further suggested that the aircraft had turned onto a closing heading at the 9 DME point, and this is supported by the selected heading indicator in the cockpit (see Paragraph 2.4). The flight trial also suggested that the final observed rate of descent had remained largely unchanged to the point of impact with the sea.

2.5 Final radio transmission

The pilot made a final transmission at 0018 hrs, stating:

> “LOGAN AMBULANCE ONE BASE TURN COMPLETE.”

It is evident from the position and orientation of the wreckage trail that the pilot had not actually established the aircraft inbound to the ‘MAC’ VOR/DME at the time he made the radio transmission. Instead, it is likely that he made this transmission when the aircraft was still on a closing heading.

The time between the last radar return and the last transmission (about 100 seconds) is approximately equal to the time that the aircraft would have taken to proceed to the 9 DME position, turn onto a closing heading and reach the eventual accident location. It is also about the time that the aircraft would have taken to descend from its last recorded altitude to sea level at a more or less steady rate of descent. It follows therefore that the pilot’s last transmission was made when the aircraft was very close to the accident location and, as the aircraft appears to have flown into the sea at a shallow angle, at very low altitude. The apparent normality of the pilot’s last radio transmission indicates that he was unaware of the extreme situation his aircraft was most probably in at that stage of the flight.

Although the possibility does exist that some unexplained event occurred after the pilot’s last transmission, this is unlikely. This is because of the relatively short distance between the likely point of the pilot’s last transmission and the position of the wreckage. If such an event had occurred, it must have resulted in a steep descent to the sea surface, which is not supported by the technical evidence. This shows that the aircraft did not suffer a catastrophic in-flight event, nor was it at an extreme attitude when it hit the sea.

2.6 Cockpit selections and indications

There were anomalies with the settings of certain flight instruments in the cockpit. The OBI should have been used as a back-up instrument to the HSI to indicate deviation from the selected VOR radial. Normal practice for the approach would have been to set both instruments to show deviation from the outbound 307º radial and then, during the turn back towards the MAC, to reset them to the inbound course of 115º. In this way the OBI, which was situated immediately below the HSI, would have provided a back-up display and confidence check of the HSI. However, the OBI was found set to 309º which, though not accurately set, indicates that it had not been reset from the outbound course, and was therefore not capable of providing useful information to the pilot regarding the desired inbound course.

The HSI selector was also found to be miss-set to an inbound course of 103º. Although it is possible that the setting became changed in the accident itself, the construction of the instrument would suggest that this was not the case. The HSI was probably therefore either set incorrectly, or in the process of being set, when the accident occurred. In either situation, with a course of 103º set, the pilot would have received an indication of maximum deviation (more than 5º from the selected course) at a point when he would have been expecting the HSI to register that the aircraft was approaching the inbound course. With the OBI still set to the outbound course, there was no instrument cross check available to the pilot.

The reason for the miss-set instruments will never be known. The pilot was familiar with Campbeltown Airport and had the approach chart in front of him, attached to the control yoke, so it is very unlikely that the course was deliberately set to 103º. There are two probable scenarios to account for the instrument settings.

Firstly, the pilot may have been in the process of changing the settings when the accident occurred. He may have set the HSI to an approximate course, intending to set it accurately once another task had been completed, or was actually in the process of changing it when the aircraft hit the sea. Normal practice would be to re-set the instruments as soon as the aircraft started it's turn inbound, in order to monitor the deviation from the inbound course at the earliest opportunity.

Secondly, the pilot may have thought that he had accurately set the HSI, in which case there may have been some other, unknown factor, such as a distraction or human performance issue which contributed to an error of selection. In this case the unknown factor must have been such as to cause the pilot to forget to set the OBI, or to prevent him from doing so. Had there been a distraction or reduction in pilot performance, the lack of deviation information on the HSI, when it would have been expected, may have compounded the situation.

The HSI heading select ‘bug’, used as a heading reference in manual flight or as an autopilot command in automatic flight, was set to 157°. At 42° difference from the inbound course, this would represent a typical closing heading for the inbound course, reinforcing the hypothesis that this was how the pilot was flying the procedure.

The autopilot master switch was found selected to OFF. Standard procedure was to select the switch ON after start and for it to remain so, though there were no company requirements regarding the conditions of use of the autopilot. Although the switch could conceivably have been knocked to OFF in the accident sequence, this is thought unlikely due to the position of the switch. The normal method of disconnecting the autopilot was to use a disconnect button on the pilot’s control yoke, whilst the master switch would remain ON to allow re-selection if desired. The pilot was known to have favoured manual flight, and it is therefore probable that the pilot was flying the aircraft manually during the accident flight.

The landing lights were found selected OFF and the electric fuel pumps selected ON; selection of both items to ON was part of the approach checklist. If switched on in cloud, the bright landing lights could be disorientating, and the pilot may have chosen to leave them off until the aircraft was clear of cloud. There is also the possibility that the pilot selected them ON, as called for in the checklist, but then turned them off because of their disorientating effect.

2.7 Meteorological factors

When the pilot left the operations room at Glasgow he did not have the latest weather information for Campbeltown. Although this would be an unusual situation for the majority of public transport flights, it was largely a result of the ‘out of hours’ nature of many air ambulance flights. There is no reason to doubt that the paramedic handed the Campbeltown weather information to the pilot before departure for Campbeltown. However, as the weather information was not a forecast, the requirements in terms of arrival weather could not be met. In this case departure was permitted as the requirements to have two alternate airfields available were met.

Had the pilot not seen the Campbeltown weather report until after takeoff, he would have been basing his weather assessment purely on the observed and forecast weather at Glasgow and Prestwick, which were noticeably better than Campbeltown. However, he probably saw the 2320 hrs Campbeltown weather report that the paramedic took to the aircraft since, when he informed the ScOACC controller that he was descending, he correctly quoted the Campbeltown QNH of 999 hPa. This had not been passed to him by ATC and there was no other source from which he would have gained the information.

The pilot's approach plan was completely dependent upon the weather conditions. It would have been clear to him from the 2320 hrs weather report that an instrument approach would be required, and that the surface wind favoured Runway 29 for which there was no instrument approach available. The pilot's options were therefore to carry out a VOR/DME approach to Runway 11 and either to land with a tailwind component on the long runway, or to fly a circling approach to land into wind on Runway 29.

The 2350 hrs weather, passed when the pilot first contacted Campbeltown, was very similar to the 2320 hrs weather which the pilot had probably seen, though the surface wind had increased in strength, making a downwind landing less desirable. The pilot declared that he would aim to fly the circling approach to land on Runway 29, though his use of the word 'hopefully' indicates that he was aware that the conditions may preclude it. When the pilot was passed a weather update as he was flying outbound, it would also have become clear that conditions were deteriorating to the extent that it may not have been possible to land even from the 'straight in' approach to Runway 11, with its less restrictive weather minima.

The pilot was legally entitled to plan for either approach as the reported visibility was above the minimum of 1,500 m which applied to the circling manoeuvre. In response to the pilot's last transmission, the AFISO passed a visibility of 1,500 m to the north of the airport (where any circling manoeuvre would have taken place) which, although at the minimum required value, would still not have prevented the pilot from making the approach.

The airframe de-icing system and ice inspection lamps were selected OFF. It is unlikely that the aircraft was subject to airframe icing to the extent that the performance of the aircraft was affected. Although the cruise portion of the flight had been conducted close to (though probably just below) the freezing level, the aircraft had descended into warmer air some time before the approach commenced.

2.8 Environmental factors

There would have been few environmental cues to the pilot that the aircraft had become dangerously low. The weather observations made at Campbeltown just after the accident indicate that the cloud base in the accident area was probably as low as 200 ft, so the aircraft would have been in cloud until shortly before it struck the sea. Had there been cultural lighting in the area, it may have alerted the pilot to the situation at the last moment, but there was none. As the aircraft turned inbound it was initially pointing out to sea, then towards the Mull of Kintyre, which had no appreciable lighting. It is unlikely that the lighthouse on the Mull could have assisted, given the prevailing visibility and relatively long time interval of its signal. The airport, runway and approach lights themselves would not have been visible due to the very low altitude of the aircraft whilst still at about 8 nm from the runway.

Only the relatively low intensity navigation lights and anti-collision beacon were selected on, so there would not have been an appreciable change in the light 'bloom' when the aircraft left cloud, as would be seen if the more powerful, forward facing landing lights had been on. Finally, information from a SAR helicopter pilot suggests that the sea surface itself would have provided the pilot little or no visual cues about the aircraft's low height.

2.9 Possible technical malfunctions

The engineering investigation could not completely rule out the possibility that a technical defect contributed to the accident, though no evidence was found to suggest it. There were no specific indications that the pilot was preoccupied with an emergency late in the flight; there was no mention of such to ATC, his voice sounded normal and the aircraft's emergency checklist was found in its stowed position.

The reported engine start problem at Glasgow was most probably related to the currency flight, since the time period between the pilot requesting start clearance and taxiing were much greater on that flight. If that, or any other defect, had caused the pilot concern on the currency flight about the safe operation of the aircraft, it would be expected that the pilot would have sought engineering assistance either before engine start or on his return, but he did not.

The possibility that G-BOMG may have been subject to a complete pitot/static system fault which denied the pilot reliable altitude information was considered unlikely, although it could not be ruled out. The recorded data shows no evidence of an altimetry problem, and the Mode C derived altitude at the point of the last radar contact is consistent with the observed radar coverage in the area. If a blockage of the static pressure line affected the pressure instruments, this would have had to occur before, or during, the final descent from 3,000 ft, since otherwise the pilot would not have had altimetry information to achieve the observed flight profile up to this point. It is unlikely that, having made a deliberate control input to descend the aircraft, the pilot would then fail to realise that the altimeter or vertical speed indictor were not indicting a descent. A more likely scenario may be a blockage during the final descent, causing the altimeter indications to 'freeze', though unless the indications had frozen precisely at the desired level-off altitude, it would be expected that the pilot would detect the fault. A blockage or partial blockage of the static line would also have caused the ASI to significantly over-read during the descent (the ASI measures the difference between total and static pressure) which may have alerted the pilot to a problem or would have caused him to slow down unnecessarily; however, the aircraft's airspeed, based on groundspeed, was normal.

2.10 Human Factors

2.10.1 Pilot fatigue

The pilot was well rested prior to the day of the accident flight, and had achieved a normal sleep pattern for the 72 hours prior to the accident. He reportedly achieved about seven hours 45 minutes of sleep during the night and was not known to have suffered from any sleep disorders that may have reduced the quality of his sleep. The average human adult physiologically requires about eight hours of sleep for optimal performance and alertness, so the pilot was probably close to maximum 'sleep credit' at the start of the day. Although he had been rostered a night standby duty, the pilot was called only infrequently on such duties and did not normally aim to achieve any sleep during the day. Such seems to be the case on the day of the accident. The difficulty of achieving sleep during the day preceding an initial night duty is well recognised, and for many individuals the best that can be achieved is a period of rest.

How long an individual remains awake is a physiological factor that can affect performance and alertness. Generally, performance and alertness can be maintained up to 12 hours of wakefulness, after which some reduction in performance occurs. Sixteen to 17 hours of continuous wakefulness can be associated with significantly reduced performance and alertness. At the time of the accident the pilot had been awake for 17 hours 15 minutes and is therefore likely to have been suffering from fatigue to some extent.

2.10.2 Pilot workload

Single pilot IFR operations place a considerable workload upon a pilot, and are therefore subject to extra regulatory measures for public transport operations. As the flight neared the destination the pilot's workload increased, as he faced increasing demands of his basic flying and navigational skills, as well as his airmanship and decision making processes.

An individual's performance level will initially increase as the levels of arousal, or stress, increase. However, an optimal point is reached where any additional stress will lead to a reduction in performance. This is due in part to the fact that the individual tends to become focused on that which is perceived to be the most important task.

The pilot made the following transmission after receiving the latest weather information:

> "…I'LL COME TO THE OVERHEAD OUTBOUND FOR THE APPROACH FOR ONE ONE TO HOPEFULLY BREAK VISUAL FOR TWO FIVE".

The pilot's incorrect read-back of the runway in use ('two five' instead of 'two nine') may be significant. The pilot knew that the runway was actually 29, but his read-back was of information which was stored in his short term working memory. Verbal information is usually stored in the short term memory in acoustic form and errors normally take the form of acoustic confusions, of which 'five' and 'nine' is an example. Such an error may indicate that the pilot was working at a stress level which was causing a narrowing of his attention to that which he considered his primary task, whilst the accuracy of the read-back suffered.

A number of additional, but unknown, factors may have contributed to the workload of the pilot, including an undeclared emergency of some sort, a distraction within the aircraft, or disorientation. The pilot's fatigue level would also have exacerbated the situation. The term 'hopefully' used by the pilot may indicate his lack of confidence that the plan to fly a circling approach would be successful. This would have been an additional stressor. However, although there was undoubted pressure to land from the point of view of the ambulance task, the pilot would have been well aware that the aircraft carried sufficient fuel to return to Glasgow if a landing was not possible.

2.10.3 Pilot's currency

Although the pilot met operator's requirements concerning currency, his lack of recent flying practise would have in itself provided a source of stress as well as making minor errors more likely. From the pilot's logbook, it would appear that he had flown very few instrument approaches on the Islander, and only one night approach.

Given the time of year it would seem unlikely that the pilot had not flown more instrument approaches than were recorded in his logbook, even though he was required to log such approaches under the operator's procedures. The number of VFR flights recorded was also considered unusually high for the time of year, so it is possible that the pilot's recent instrument approach currency was actually the minimum required. However, he did demonstrate his ability to fly a non-precision approach to the required standard in his OPC on 28 January 2005, and that approach was flown at Campbeltown.

2.10.4 Pilot performance

The combined effects of fatigue, possible over-load and lack of recent flying practise would have caused the pilot's performance to become more variable, especially in tasks that required sustained attention, such as precision instrument flying. A number of elements of the flight remain unexplained but are indicative of a reduced or variable performance.

The initial routing, whilst being a conscious decision by the pilot to route further west than was usual, cannot be fully explained. Nor can his apparent inattention to the aircraft's navigation, which added time to the flight, which was an urgent ambulance task. The descent below SSA, though deliberate, was unnecessary and contrary to procedures, as well as being uncharacteristic of the experienced and well regarded pilot. The early turn to the outbound leg of the procedure can only be seen as a time saving manoeuvre, but one which would have added to his workload at a busy time of the flight.

Apart from the pilot's one read-back error, his radio transmissions appeared to be normal and relaxed. If, as is probable, the last transmission was made very shortly before the accident, it indicates that the pilot's situational awareness may have been seriously degraded, as he was therefore unaware of the aircraft's very low altitude. The chances of miss-reading an altimeter are highest when a long descent is being made. In this case the required descent was only about 1,500 ft, giving a maximum of about two minutes before a level-off was required. Even if the pilot thought he had started the final descent from

3,900 ft, as he should have done, this is unlikely to account for such a gross miss-reading of the altimeter or an absence of altitude monitoring.

The pilot was clearly attending to lateral navigation on the outbound leg, but once he had started the turn onto a closing heading there would have been no immediate navigation task until establishing on the inbound radial. As such, if he had neglected to monitor the altitude because of his attention being focused on achieving the outbound radial, then he would have been expected to pick up the altitude error once his navigational workload reduced. Additionally, it would be expected that adequate opportunity would exist to re-set the instruments for the final approach.

The main performance issue is the descent below the minimum altitude for the outbound leg, and the apparent continued descent to sea level. Although there are signs of overload and fatigue, it is unlikely that the pilot became so focused on one aspect of flying the aircraft that he neglected to monitor the aircraft's altitude for a protracted period. It is therefore possible that a further factor such as distraction or disorientation may have played a part.

Whatever factors contributed to the pilot's variable performance, the fact that the aircraft descended below minimum altitude whilst still outbound from the 'MAC' shows that they were playing a part at this time, and were not confined to the very last seconds of the flight. Earlier in the flight, the pilot's route was queried by ATC, and at that point he appeared unsure of his position. This may indicate that some factor was acting to reduce the pilot's performance even at this stage. If the pilot was dealing with a technical issue within the aircraft, he made no mention of it to ATC. If any technical issue were such as to hazard the aircraft it may be expected that the pilot would have chosen to return to Glasgow, especially given the likely weather conditions at Campbeltown.

2.11 Survivability issues

According to the RAF pathologist the initial impact would have been survivable by the pilot due to the preserved survivable space in the cockpit area. The fact that the buckle from the pilot's harness was undamaged and undone also indicates that the pilot probably survived the initial impact and was able to free himself from the aircraft. However, if the impact with the sea was unexpected, then it would have been extremely difficult for him to don a life-jacket. All the adult life-jackets listed in the manifest except for one were recovered, although it is possible that the aircraft was equipped with an extra infant life-jacket instead of an adult life-jacket, in which case all life-jackets were accounted for. The pilot's body was not on the seabed near the wreckage and it is therefore possible that he was able to remain afloat for some time. However, the sea temperature of 9°C would have resulted in the eventual onset of hypothermia, and according to predictive sea survival curves, it is unlikely that he would have survived for more than one hour.

The paramedic's head injury may have been fatal but the evidence of water inhalation in the lungs indicates that the head injury was probably not immediately fatal and that the paramedic had continued to breathe while underwater, albeit probably in an unconscious state. The paramedic was restrained in his seat by a lap strap which was still fastened, but there was no shoulder harness to prevent his head from hitting the pilot's seatback – the likely point of head impact. The JAR-OPS requirements did not require that the paramedic's seat be fitted with a shoulder harness because the paramedic was classed as a passenger. The aircraft was also certified before dynamic seat testing and the fitting of shoulder harnesses to passenger seats were required. Furthermore, the ANO requirement to fit shoulder harnesses to passenger seats for post-1989 production aircraft was not applicable because the operator had an exemption.

G-BOMG had been modified and was fitted with eight shoulder harnesses in the passenger compartment, but these were incompatible with the lap strap buckles on the paramedic's seat and the aft bench seat. The lap strap buckles were not changed because none of the operator's other Islander aircraft were fitted with passenger shoulder harnesses.

Following the G-BOMG accident the operator modified one of its other Islander aircraft with shoulder harnesses (modification NB-M-1298) and a compatible lap strap buckle on the paramedic's seat (this was in response to a request from the SAS).

The CAA's study of UK fatal accidents (CAA reference 9/61/10DE/JAR7-10(26)) showed that lives could be saved by requiring shoulder harnesses (also known as Upper Torso Restraints) to be fitted to aircraft in the Normal, Utility and Aerobatic categories. The cost of requiring the retrofit of shoulder harnesses to aircraft needs to be balanced against the benefits. The CAA study considered the financial implications of retrofit and decided that there was sufficient justification to require the retrofit for those aircraft being operated for public transport but not those used for private flights. However, the CAA's proposed amendment to JAR 26, to require shoulder harnesses to be fitted to Normal, Utility and Aerobatic category aircraft used for commercial air transportation, has not yet been acted upon by the JAA or EASA.

It was therefore recommended that:

> The European Aviation Safety Agency and Joint Aviation Authorities should review the UK Civil Aviation Authority's proposal to mandate the fitment of Upper Torso Restraints on all seats of existing Transport Category (Passenger) aeroplanes below 5,700 kg being operated for public transport, and consider creating regulation to implement the intent of the proposal. (Safety Recommendation 2006-101)

2.12 Single pilot public transport flights

The accident and its probable causes have similarities with the accident involving G-BMBC on 14 June 2000, in that distraction or disorientation may have been factors. As a result of the investigation into that accident, a recommendation was made concerning the carriage of a second pilot on public transport flights. The JAA study group which ultimately considered the recommendation concluded that no change to the existing requirements was warranted. However, the study group appears to have based its judgment on a statistical analysis of serious pilot incapacitation events alone, rather than including possible cases of distraction or disorientation.

G-BOMG appeared to have flown into the sea in a controlled manner whilst making an approach to land at night and in adverse weather conditions. The circumstances of the accident strongly suggest that the pilot was subject to factors which degraded his performance to the extent that he was unable to adequately monitor the aircraft's altitude, descending the aircraft until it hit the sea. If this were indeed the case, the presence of a second pilot may have prevented the accident.

Factors which are likely to have contributed to the accident include fatigue, workload and lack of recent flying practise. Other factors that may have played a part are distraction, pilot disorientation and a subtle incapacitation, unrecognised as such by the pilot. No evidence of a technical fault was found that could explain the accident, though a malfunction affecting critical flight instruments could not be entirely ruled out.

Air ambulance flights occupy a unique position within the public transport framework, and the operation of such flights may at times entail a greater level of overall risk. Although air ambulance flights are subject to the same regulations as other public transport flights, they are, by their very nature, more likely to have to operate under adverse circumstances. Fixed-wing air ambulance flights are also more likely to operate over the more remote areas of the United Kingdom, where aerodromes tend to be smaller and less well equipped, and where weather factors may be less favourable. Flights are often made at short notice outside of normal operating hours, and with an additional time pressure on crews which is not present with other types of operation.

It was therefore recommended that:

> Considering the unique circumstances of air ambulance flights, the Civil Aviation Authority, in conjunction with the Joint Aviation Authorities should review the circumstances in which a second pilot is required for public transport flights operating air ambulance services. (Safety Recommendation 2006-102)

The aircraft was not required to be equipped with any electronic device such as a Terrain Awareness and Warning System or a radio altimeter which would have alerted the pilot to his dangerous proximity to the sea. In the absence of a second pilot, the presence of an independent low height warning device such as a radio altimeter would, if it was correctly set, have provided a warning to the pilot that he was dangerously low and thus may have prevented the accident.

It was therefore recommended that:

> The Civil Aviation Authority, in conjunction with the Joint Aviation Authorities, should consider mandating the carriage of a radio altimeter, or other independent low height warning device, for public transport IFR flights operating with a single pilot. (Safety Recommendation 2006-103)

3 Conclusions

3.1 Findings

3.1.1 The aircraft

1. The aircraft was certified, equipped and maintained in accordance with existing regulations and approved procedures. With the exception of a single non-airworthiness item, concerning the stretcher assembly, the aircraft was free of recorded defects.

2. The aircraft's weight and centre of gravity were within limits during the accident flight.

3. The aircraft had been refuelled to full on the evening of 14 March 2005, and the aircraft's wing fuel tanks contained a substantial amount of fuel at the time of the accident.

4. There was no evidence of pre-impact failure in any of the aircraft's systems and the aircraft was intact when it hit the sea.

5. The aircraft's elevator trim setting would have resulted in a hands-off trim speed of 110 to 120 KCAS using an approach or cruise power setting.

6. Fuselage and wing sections showed damage consistent with the aircraft having struck the sea in a controlled flight attitude, at a typical operating speed and with symmetric engine power.

7. No evidence of a technical fault was found that might have contributed to the accident.

9. The HSI and OBI settings were not consistent with the aircraft's position in the approach procedure.

10. The altimeters were set to within 1 hPa of the reported QNH, corresponding to a maximum display error of about 28 ft.

11. The primary attitude indicator was probably capable of displaying reliable attitude information at the time of the accident.

3.1.2 Flight operations

1. The air ambulance task by SAS was legitimate and conformed to standard procedures detailed in the operator's operations manual. The operator was responsible for operational control of the flight.

2. For the purpose of air ambulance work, the operator had permission from the CAA and HIAL to operate non-scheduled public transport flights outside published aerodrome operating hours.

3. It is probable that when the pilot left the operations room for the flight he had seen only limited weather information for Glasgow and Prestwick.

4. The flight met the requirements for the provision of meteorological information.

5. Although the pilot had declared his intention to route to the west after takeoff rather than direct to Campbeltown, the actual route flown was unusually long, given the nature of the task.

6. Reliable VOR and NDB signal from Campbeltown would probably have been received as the aircraft passed ROBBO, and for the remainder of the flight.

7. The pilot appears to have been unaware of his precise position in relation to the 'MAC' when his route was queried by ATC.

8. At some stage prior to arriving at Campbeltown, the pilot had probably seen the 2320 hrs weather report, taken to the aircraft by the paramedic.

9. The pilot's stated intention was to fly the VOR/DME procedure to Runway 11, and then to circle to land on Runway 29.

10. The weather information available to the pilot indicated that the cloud base would very probably prevent a circling manoeuvre to Runway 29, and that even a landing on Runway 11 may not be possible. However, the pilot was permitted to commence an approach in the weather conditions that prevailed.

11. Visibilities were at or above the minimum required for landing on either runway.

12. Glasgow and Prestwick remained suitable as diversion airports, and the aircraft had sufficient fuel to divert to either if it was unable to land at Campbeltown.

13. The pilot descended the aircraft to 3,000 ft before reaching the 'MAC' VOR/DME, which was below SSA and contrary to procedures.

14. The 'MAC' VOR/DME was operating to specification at the time of the accident. The associated procedure was approved by the CAA for use by the operator, including outside of normal airport operating hours.

15. The aircraft established correctly on the 307º outbound radial, and the observed speed and rate of descent on the outbound leg were consistent with normal flight profiles.

16. The aircraft descended below the minimum outbound altitude of 1,540 ft with a steady rate of descent of about 1,000 ft/min. At the last recorded radar position it was 200 ft below the minimum altitude and still descending.

17. The autopilot was probably not in use in the final stages of the flight.

18. Had the aircraft simply 'dipped' below 1,540 ft and then climbed back up, it is probable that further radar returns would have been received.

19. The cloud base in the accident area was probably as low as 200 ft and the visibility approximately 2,000 m. There would have been few environmental cues to alert the pilot to the aircraft's very low altitude.

20. The location and orientation of the wreckage trail was consistent with the aircraft having descended at a more or less constant rate after it disappeared from radar, and having turned at the 9 DME point directly on to a heading to intercept the inbound course.

21. The presence of a second pilot may have prevented the accident.

22. Had the aircraft been equipped with a radio altimeter, or other electronic low height warning device, which was correctly set to warn of a low height situation, the accident may not have occurred.

3.1.3 Personnel

1. The pilot was correctly licenced and qualified to operate the flight.

2. The pilot was in compliance with the applicable flight and duty time limitations.

3. The pilot held an appropriate medical certificate. No psychological factors were likely to have played a part in the accident.

4. The pilot had undergone formal training in stress and fatigue issues as part of the company's recurrent training programme.

5. Although the pilot had flown a short currency flight on the night of the accident, he had not previously flown for 32 days and therefore lacked recent flying practise.

6. The pilot met the minimum requirements regarding currency in instrument approaches, but it is probable that he had flown comparatively few of these on the Islander.

7. It is probable that the pilot was suffering, at least to some extent, from the affects of fatigue.

8. The pilot may have been operating under high workload, or even overload, conditions in the latter stages of the flight, which may have degraded his situational awareness.

9. The paramedic was experienced as a passenger in the Islander aircraft, and had received appropriate training in safety procedures and equipment.

3.1.4 Survivability

1. The pilot's body showed no obvious external injuries and no internal injuries or fractures. A survivable space was preserved in the cockpit area and it is probable that the pilot survived the impact.

2. The paramedic was probably rendered unconscious in the impact when his head hit the pilot's seat in front due to the lack of upper torso restraint.

3. There was no operational or certification requirement for the aircraft to be fitted with shoulder harnesses on the passenger seats and, under the

certification standards applicable to G-BOMG, there was no requirement relating to passenger head injury protection.

4. It was not normal practise for the pilot or paramedic to wear immersion protection or a life-jacket during such flights.

5. Average survival time in the sea, at a temperature of 9°C, would have been no more than one hour.

3.2 Causal factors

The investigation identified the following causal factors:

1. The pilot allowed the aircraft to descend below the minimum altitude for the aircraft's position on the approach procedure, and this descent probably continued unchecked until the aircraft flew into the sea.

2. A combination of fatigue, workload and lack of recent flying practise probably contributed to the pilot's reduced performance.

3. The pilot may have been subject to an undetermined influence such as disorientation, distraction, or a subtle incapacitation, which affected the pilot's ability to safely control the aircraft's flightpath.

4 Safety Recommendations

The following safety recommendations were made:

4.1 **Safety Recommendation 2006-101**: The European Aviation Safety Agency and Joint Aviation Authorities should review the UK Civil Aviation Authority's proposal to mandate the fitment of Upper Torso Restraints on all seats of existing Transport Category (Passenger) aeroplanes below 5,700 kg being operated for public transport, and consider creating regulation to implement the intent of the proposal.

4.2 **Safety Recommendation 2006-102**: Considering the unique circumstances of air ambulance flights, the Civil Aviation Authority, in conjunction with the Joint Aviation Authorities should review the circumstances in which a second pilot is required for public transport flights operating air ambulance services.

4.3 **Safety Recommendation 2006-103**: The Civil Aviation Authority, in conjunction with the Joint Aviation Authorities, should consider mandating the carriage of a radio altimeter, or other independent low height warning device, for public transport IFR flights operating with a single pilot.

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October 2006

Appendix A

CAA study and proposed JAR amendment regarding fitment of Upper Torso Restraints (CAA reference 9/61/10DE/JAR7-10(26))

PROPOSED NPA (No 26-XXX)

UPPER TORSO RESTRAINT INSTALLATION ON TRANSPORT CATEGORY (PASSENGER) AEROPLANES WITH MAXIMUM TAKE-OFF WEIGHT < 5700 KG

1. **Paragraph Affected:** **JAR 26.2XX**

2. **Proposal:** Add a new requirement to JAR-26 Subpart B: Commercial Air Transportation (Aeroplanes) to read as follows:

   "*26.2xx: Aeroplanes in the normal, utility & aerobatic category with 9 passenger seats or less, a maximum certified take-off weight of 5670kg (12 500lb) or less and manufactured after (**date to be determined**), are required to have a safety belt and shoulder harness fitted to each passenger seat. The seat belt and shoulder harness must be designed to protect the occupant from serious head injuries when subject to the inertia loads resulting from the ultimate static load factors prescribed in CS 23.561(b)(2).*"

3. **Background**

A fatal accident occurred to a UK registered Cessna Titan (G-ILGW) near Glasgow Airport on 3/9/99. The UK Air Accident Investigation Branch in their report 2/2001 made the recommendation (2001-40) that the UK-CAA undertake a study to identify those elements of the current JAR-23 seat standards which may be used for retro fit into existing aeroplanes whose maximum certified take off mass is less than 5,700 kg and, separately, for those designs in continuing production which are not covered by the current JAR standards. These elements should then be applied at least to those that are operated in the Transport Category (Passenger).

From the study completed in March 2002 the UK-CAA was satisfied that one element of the latest requirement standards for seat/restraint systems was worthy of further investigation.

From a review of the accident statistics it is now clear that a significant number of lives could have been saved and would continue to be saved, with the installation of upper torso restraints on all Part 23 aeroplanes in the passenger transport category below 5700 kg.

The following justifications and statistics are related to the UK fleet and accident database only. Insufficient data were available to review the European fleet, and in addition, no assessment was made of regulatory differences that may exist between the NAAs.

4. **Justification**

The requirement in CS 23.785 "Seats, berths, litters, safety belts & shoulder harnesses", is fundamentally unchanged from JAR 23.785 since it was first issued on 11 March 1994:

> *b) Each forward-facing or aft-facing seat/restraint system in normal, utility, or acrobatic category aeroplanes must consist of a seat, safety belt and shoulder harness with a metal-to-metal latching device that are designed to provide the occupant protection provisions required in CS 23.562.*

While this standard enhances the design of new build aeroplanes, some NAA's have found it appropriate to provide equivalent retroactive standards to at least part of the existing fleet. For example, the retroactive requirement in the UK is as follows:

> Reference ANO Schedule 4, Section 5, Scale B (i)(f) applicable to aeroplanes flying for any purpose (Public Transport or other):

*On all flights in aeroplanes in respect of which a certificate of airworthiness was first issued (whether in UK or elsewhere) on or after **1 Feb 1989** the max weight not greater than 5,700 kg & 9 pax seats or less a safety belt with one diagonal shoulder strap or safety harness for each pax seat is required.*

The retroactive requirement in the USA is:

Reference FAA: Sec 23.2 Special Retrospective Requirements:
*Aeroplanes in normal, utility & aerobatic category with 9 pax seats or less manufactured after **12/12/86** are required to have a safety belt and shoulder harness.*

While these retroactive requirements have gone some way to enhancing standards within the current fleet, potentially survivable accidents continue to occur to aeroplanes which pre-date the need for Upper Torso Restraint. That means there are a number of aeroplanes in the Transport Category (Passengers), below 5700kg, that do not have Upper Torso Restraints on seats other than the front row (pilot stations). For example, the accident aeroplane refered to in Section 3 (G-ILGW) was first registered prior to 1st February 1989 and was therefore not required to comply with ANO Schedule 4, Section 5, Scale B(i)(f) and passenger seats were not fitted with UTR. The continued operation of aeroplanes with seats not equipped with UTR exposes the occupants to increased risk of death and injury over those occupants flying in aeroplanes designed to seat design standards that include UTR restraint systems. Proposed action is for retroactive installation of Upper Torso Restraint on all Part 23 aeroplanes used for Transport Category (Passenger) operations within Europe.

UK accident data and the current UK fleet profile are analysed in order to assess accident rates and potential life savings. While this analysis is aimed at quantifying the number of passengers who may have survived as a result of the fitting of UTR, other benefits could be obtainable by reducing the number of serious injuries or the severity of those injuries.

Based on the results of the March 2002 UK-CAA study, only the sole option of fitting UTR to passenger seats has been evaluated in the following data.

4.1 <u>Accident data analysis</u>

4.1.1 Table 1: Accidents to UK registered aeroplanes with MTOW between 2300 & 5700 kg for last 11 years.

Year	A/C Type	Reason	**TC(P) /Private	# on Board	Fatalities (excl f/r)*	Survivors
1993	EMB 110	CFIT	TC(P)	2	2	-
1993	PA31	Unknown – high speed high AOA impact	TC(P)	1	1	-
1995	EMB 110	Loss of control in IMC conditions a/c began to break up prior to impact	TC(P)	12	12	-
1996	BN2A-26	Loss of control on approach	TC(P)	2	1 (0)	1
1998	Ces 421	Loss of control, spiral dive in	P	4	3	1
1999	PA31	Unknown – wreckage in mountainous area, CFIT probable	TC(P)	2	2	-
1999	C404	Engine Failure (See Section 3.)	TC(P)	11	8 (6)	3
2000	PA31	Pilot lost control, crashed into sea	TC(P)	5	5	-
2001	BE 58	Unknown - crashed in sea	P	1	1	-
2003	Ces 421	Crashed 100m from R/W, severe fire	P	3	1 (1)	2
2003	PA 31	Eng failure, loss of fuel, ditched in sea	P	3	3 (1)	-
SUM	-	-	7TC(P), 4P	46	39 (8)	7

**It has been assumed that all occupants are in the front row for "# on board" = 1 or 2 occupants, and that front row occupant are already provided with UTR.*
***TC(P) = Transport Category (Passenger)*
P = Private Category

4.1.2 Summary/analysis of Table 1

Fatality rate: 39 in 11 years of which it is assessed that 26 of the fatalities can be attributed to CFIT or high speed impact and can be classified as non-survivable, (highlighted above). This leaves 13 occupants that died in potentially survivable events, but removing the front row occupants leaves 8 potential survivors, (6 off TC(P) plus 2 off P), among the fatalities who could benefit from additional UTR fitment.

4.1.3 Table 2:- Accidents to UK registered aeroplanes with MTOW less than 2300 kgs for last 11 years with more than 2 persons on board, (It is assumed when 1 or 2 people are on board that both are in pilot seats with UTR and thus could not contribute to a pax UTR safety improvement statistics).

Year	A/C Type	Reason	TC(P)/ Private	# on Board	Fatalities (excl f/r)	Survivors
1992	SocataTB 20	Flight into terrain	P	4	4	-
1992	Ces 172D	Crashed on TO	TC(P)	3	1 (1)	2
1993	TB20	Struck tree	P	3	3 (1)	-
1993	WAS. 52	Hit hillside	P	3	3	-
1994	PA34	Airframe broke up in flight	P	4	4	-
1994	Ces 182Q	Struck hill	?	3	2	1
1994	Robin 100	Hit power cables on approach	P	4	4	-
1995	MS880B	Crashed on initial climb	P	3	2 (1)	1
1995	BE58	Crashed in field	TC(P)	4	4 (2)	-
1996	R1180	Crash land following power failure	TC(P)	4	4 (2)	-
1998	Rock 114	Overran runway	P	4	2 (2)	2
1999	Ces. 172	Crashed in mountainous area CFIT	TC(P)	3	3	-
1999	Moo.20J	Spun in	P	4	4	-
1999	GR. AA5B	Crashed on landing	TC(P)	3	3 (1)	-
1999	PA28	Stalled spun in	TC(P)	3	3	-
2000	PA28	Crashed on TO	TC(P)	3	1 (0)	2
2000	PA28	Airframe broke up in flight	P	4	4	-
2001	Roc 114	Steep descent, wing detached, then high speed impact	TC(P)	4	4	-
2001	Ces 182	Crashed on landing, caught fire	P	4	1 (0)	3
2002	PA32	Struck mountains in poor weather CFIT	P	4	4	-
SUM			8TC(P), 11P	71	60 (10)	11

4.1.4 Summary/analysis of Table 2

A total of 60 fatalities in ten years, (31 off P, 29 off TC), of which it is assessed that 39 of the fatalities can be attributed to CFIT or high speed impact and can be classified as non-survivable, (highlighted above). This leaves 21 occupants that died in potentially survivable events. Removing the front row occupants, (as previously noted, it has been assumed that all occupants are in the front row for "# on board" = 1 or 2 occupants, and that front row occupant are already provided with UTR), leaves 10 potential survivors (6 off TC(P) and 4 off P), among the fatalities that could benefit from additional UTR fitment.

4.1.5 Combined accident data analysis

Combining all of the accident data in Section 4 above, contained in Tables 1 and 2, (i.e. for UK registered aeroplanes for last 11 years for MTOW between 2300 & 5700 kgs and for MTOW less than 2300 kgs with more than 2 persons on board), produces a total of 18 individuals, (12 off Transport Category and 6 off Private), where improvements to the seat environment may have increased the occupant's chances of survival.

NTSB analysis of light aeroplane accidents, (Ref., data supplied by NTSB to General Aviation Safety Panel (GASP) during development of 14 CFR 23.562), has indicated that 76% of fatalities in survivable accidents could have been non-fatal if those occupants had been wearing shoulder harnesses. (Note that the fatalities caused during the primary impact can be reduced by an improved restraint system, and in addition there will be a tendency for reduced injury severity for the immediate non-fatals. With a higher proportion of less severe injuries there is an improved chance for safe evacuation thereafter, with reduced fatalities associated with exposure to post crash fire or drowning hazards).

Hence 18 x 0.76 = 13.68 lives could potentially have been saved in 11 years or approximately 1¼ people per year by fitting additional UTR to all applicable types.

Focussing on Transport Category Passenger (TC(P)) aeroplanes only, the total of non front row fatals is 12 persons in survivable accidents; 12 x 0.76 = 9.12 lives that may been saved by UTR fit over 11 years, or approximately 0.83 lives per year.

4.1.6 Current/ future utilisation

It can be postulated that the older aeroplanes will tend to reduce on the UK Register and be replaced by newer versions. These newer A/C will be in compliance with the ANO and FAR updates referenced above, and will thus have UTR already fitted. As of 1 March 2003 there were 1165 TC(P) aeroplanes on the UK Register that pre-date the ANO/FAR revisions out of a total of 2430 TC(P) aeroplanes <5700 kg on the UK Register. Thus the potential life saving due to additional UTR of 0.83 / year should be reduced in line with the applicable number of A/C that could have additional UTR fitted. This results in a revised figure of 0.83 X 1165/2430 = 0.40 lives / year that could potentially be saved by fitment of additional UTR.

5. Safety And Economic Considerations

Based on an analysis of data from the UK aircraft register (as at 1 March 2003), for TC(P) aeroplanes which have less than or equal to 9 passenger seats (but excluding the passenger seat adjacent to pilot in the total that follows) and which pre-date the applicability of the ANO and FAR 23.3 amendments referenced above: gives a total of 2978 seat places on 1165 individual aeroplanes which could be modified so as to have additional UTR fitted.

5.1 Restraint System upgrade costs (Based on data obtained in June 2003)

Precise figures have been difficult to obtain and tend to be very A/C type and seat layout/installation dependant, thus significant scatter in costs can occur. In some cases the facility for fitting additional UTR may be simple, and both parts and labour costs may be low. However, in some cases there is no alternative or convenient means of passing the upper strap loads to A/C wall structure so that the UTR is seat back mounted. In these cases the seat may also need replacing and local floor attachment reinforcements may also be necessary in order to carry the additional offset (UTR) loads; in such cases the costs are much more significant.

Based on data supplied by Raytheon, Cessna and an STC holder, an average cost per seat of UTR retro-fitment ~ $ 1800 has been computed, (comprises parts ~$1000, installation/sundries ~$800).

Hence estimated total cost for UK fleet of UTR installation on seat places that could be modified = 1800 x 2978 = $ 5.36 Million.

6. Summary and Recommendations

Upper Torso Restraint systems are widely recognized as a safety enhancing feature which can reduce the number of fatalities following a survivable accident and reduce the number of seriously injured and the severity of those injuries. This recognition is reflected in the airworthiness standards of FAR/JAR/CS 23, which now include UTR as a mandatory requirement within the basic design codes.

While these enhancements have benefited passenger protection on new aeroplanes, the existing fleet is not immediately affected, and accidents continue to occur where passengers may have benefited if UTR systems had been fitted. Some National Aviation Authorities have recognized the need to enhance existing standards and have proposed national requirements to address this issue, at least for part of their existing fleet.

In the UK, retroactive requirements are conditional on the date of first registration. The UK-CAA has analysed UK accident data and estimated the potential life savings that could be achieved by fitting UTR to passenger seats on light aeroplanes on the UK register, i.e. beyond that required in the ANO schedule 4 Section 5 Scale B (i) (f). The UK-CAA has also estimated the associated costs with modifying the fleet with such additional UTR.

Based on the UK experience, together with the similar US experience that led to publication of FAR Part 23 Amendment 23-32, and with the belief that this experience is likely to be applicable throughout Europe, the UK-CAA has concluded that there is sufficient justification to include in JAR-26 a requirement to mandate the provision of Upper Torso Restraint systems to all aeroplanes engaged in Commercial Air Transportation operations.

It is recommended that this proposal be considered by Central JAA for publication as an NPA, with a view to it being adopted within JAR-26.

End