Air Accident Investigation Unit Ireland

FORMAL REPORT

ACCIDENT
Sikorsky S-92A, EI-ICR
Black Rock, Co. Mayo, Ireland

14 March 2017

An Roinn Iompair
Department of Transport

Foreword

This safety investigation is exclusively of a technical nature and the Final Report reflects the determination of the Air Accident Investigation Unit (AAIU) regarding the circumstances of this occurrence and its probable and contributory causes.

In accordance with the provisions of Annex 13[1] to the Convention on International Civil Aviation, Regulation (EU) No 996/2010[2] and Statutory Instrument No. 460 of 2009[3], safety investigations and associated safety recommendations are in no case concerned with apportioning blame or liability. They are independent of, separate from and without prejudice to any judicial or administrative proceedings to apportion blame or liability. The sole objective of this safety investigation and Final Report is the prevention of accidents and incidents.

Accordingly, it is inappropriate that AAIU Reports should be used to assign fault or blame or determine liability, since neither the safety investigation nor the reporting process has been undertaken for that purpose.

Extracts from this Report may be published providing that the source is acknowledged, the material is accurately reproduced and that it is not used in a derogatory or misleading context.

[1] **Annex 13**: International Civil Aviation Organization (ICAO), Annex 13, Aircraft Accident and Incident Investigation.
[2] **Regulation (EU) No 996/2010** of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation.
[3] **Statutory Instrument (SI) No. 460 of 2009**: Air Navigation (Notification and Investigation of Accidents, Serious Incidents and Incidents) Regulations 2009.

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In accordance with Annex 13 to the Convention on International Civil Aviation, Regulation (EU) No 996/2010 and the provisions of SI 460 of 2009, the Chief Inspector of Air Accidents, on 14 March 2017, appointed Mr Paul Farrell as the Investigator-in-Charge to carry out an Investigation into this Accident and prepare a Report.

Operator:	CHC Ireland DAC[4]
Manufacturer:	Sikorsky Aircraft Corporation
Model:	S-92A
State of Registry:	Ireland
Registration:	EI-ICR
Serial Number:	920051
Location:	Black Rock, Co Mayo, Ireland (9 nautical miles west of Blacksod)
Date/Time (UTC)[5]	14 March 2017 @ 00.46 hrs

SYNOPSIS

A Sikorsky S-92A helicopter, registration EI-ICR (call sign Rescue 116), which was being operated by a private operator on behalf of the Irish Coast Guard (IRCG), was en route from Dublin, on Ireland's east coast, to Blacksod, Co. Mayo, on Ireland's west coast. The Flight Crew's intention was to refuel at Blacksod before proceeding, as tasked, to provide Top Cover for another of the Operator's helicopters, which had been tasked to airlift a casualty from a fishing vessel, situated approximately 140 nautical miles off the west coast of Ireland. At 00.46 hrs, on 14 March 2017, while positioning for an approach to Blacksod from the west, the Helicopter, which was flying at 200 feet above the sea, collided with terrain at the western end of Black Rock, departed from controlled flight, and impacted with the sea.

During the immediate search and rescue response, the Commander was found in the sea to the south-east of Black Rock and was later pronounced dead. Subsequently, the main wreckage of the Helicopter was found close to the south-eastern tip of Black Rock, on the seabed at a depth of approximately 40 metres. The deceased Co-pilot was located within the cockpit section of the wreckage and was recovered by naval service divers. Extensive surface and underwater searches were conducted; however, the two Rear Crew[6] members were not located and remain lost at sea.

Forty two Safety Recommendations are made as a result of this Investigation.

[4] **DAC**: Designated Activity Company.
[5] **UTC**: Coordinated Universal Time. All timings in this Report are quoted in UTC. At the time of the accident UTC and local time were coincident.
[6] **Rear Crew**: This term is used throughout the Report because it was the term predominantly used by personnel who were interviewed by the Investigation. The Investigation notes that the Operator's manuals use the term '*Technical Crew*' *(TC)*.

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NOTIFICATION

Shannon Air Traffic Control (ATC) notified the AAIU at approximately 02.30 hrs on 14 March 2017 that an Irish Coast Guard helicopter was missing near Blacksod Bay, Co. Mayo, and shortly afterwards that debris was sighted in the sea. Two Inspectors of Air Accidents deployed to Blacksod and arrived at approximately 08.00 hrs. The Chief Inspector of Air Accidents and another Inspector of Air Accidents arrived later that day, and on the following day, to assist with the Investigation.

INVESTIGATION TEAM

In accordance with the provisions of Annex 13 to the Convention on International Civil Aviation, Regulation (EU) No 996/2010, and Statutory Instrument No. 460 of 2009, the State of Occurrence is obliged to investigate aircraft accidents, and therefore the Investigation was conducted by Ireland's AAIU. An extensive on-site phase was carried out from 14 March 2017 to 10 April 2017. This was followed by a further on-site phase from 22 July 2017 to 25 July 2017.

The AAIU Investigation team comprised:

Paul Farrell (Investigator-in-Charge)
Jurgen Whyte (Chief Inspector)
Kate Fitzgerald (Inspector - Engineering)
Howard Hughes (Inspector - Operations)
Leo Murray (Inspector - Operations)
John Owens (Inspector - Engineering)
Kevin O'Ceallaigh (Inspector - Operations)

In accordance with the provisions of Annex 13, several states, agencies and advisers provided assistance to the Investigation:

Ireland

The Irish Aviation Authority (IAA) appointed a point of contact for the Investigation.

United Kingdom (UK)

The Air Accidents Investigation Branch (AAIB - Accredited Representative and Advisers); the Marine Accident Investigation Branch (MAIB); the Maritime and Coastguard Agency (MCA); and, Curtiss Wright (Penny & Giles) Data Recorders Limited.

United States of America (USA)

The National Transportation Safety Board (NTSB - Accredited Representative and Advisers); the Federal Aviation Administration (FAA - Adviser); Sikorsky Aircraft Corporation (Advisers).

Europe

The European Union Aviation Safety Agency (EASA) appointed an Adviser.

Norway

An S-92A-qualified pilot, who is an inspector with the Accident Investigation Board of Norway, and had a background in SAR, Air Ambulance, offshore operations and simulator instruction, was appointed as an Accredited Representative to provide a range of expertise to the Investigation.

On-Scene Support

The Investigation acknowledges the work carried out at Black Rock/Blacksod which involved several Agencies, including: An Garda Síochána; the Irish Coast Guard (IRCG); the Operator; the Irish Defence Forces: the Air Corps, the Army, the Naval Service; the Commissioners of Irish Lights; the Royal National Lifeboat Institution (RNLI); Geological Survey Ireland; and the Marine Institute.

The Investigation also acknowledges the assistance and support provided by the Local Authority (Mayo County Council) and the Civil Defence.

The communities of Blacksod and the surrounding areas, and many persons and organisations from further afield, including mariners who worked in difficult sea conditions, rallied to support the large number of personnel who attended Blacksod to assist in the search operations; this support was invaluable, and proved to be of enormous assistance to all involved.

THE INVESTIGATION

The AAIU Investigation commenced early on the 14 March 2017, on receipt of notification that an IRCG Sikorsky S-92A helicopter, registration EI-ICR, with a call sign of '*Rescue 116*' (R116), was reported missing, followed shortly afterwards by reports of debris being sighted in the sea.

The initial on-site phase of the Investigation lasted approximately one month. Emergency response priority was given to the search for the missing crewmembers. In addition to discharging its investigative responsibilities, the AAIU provided technical assistance in the coordination of the Remotely Operated (underwater) Vehicle (ROV) search operations.

At the Investigation's request, the Operator emailed all of its personnel advising them that they were free to engage with the Investigation and provided contact details for the AAIU. As a result, the AAIU spoke to a significant number of the Operator's personnel during the course of the Investigation. At the Investigation's request, the Operator nominated a point of contact for the Investigation.

In addition, in order to have access to an individual with specific SAR piloting expertise on the S-92A helicopter type, the SAR role in Ireland and the Operator's procedures, the Investigation appointed a senior pilot from the Operator's staff as an Adviser. As per Section 5 (12) of S.I. No. 460 of 2009, the senior pilot was subject to strict protocols, in particular with regard to confidentiality within the Investigation. However, it was agreed that if any issue was identified by the Investigation, which the senior pilot felt should be notified to the Operator as an urgent safety concern, the senior pilot would advise the Investigator-in-Charge (IIC) and the IIC would communicate that concern to the Operator. The Investigation is satisfied that this protocol was adhered to throughout the Investigation.

Air operators are required to have qualified persons, acceptable to the Regulatory Authority, occupying a number of critical management positions which require specific expertise and experience; such persons are referred to in this Report as Post-Holders; such persons are also commonly referred to as '*nominated persons*'.

Prior to the R116 accident, the AAIU had held an open competition (commencing October 2016), through the Public Appointments Service (PAS), for the recruitment of an Inspector of Air Accidents (Engineering). A Panel was formed for the successful candidates, with one person being appointed as an Inspector of Air Accidents to the AAIU in March 2017. On receipt of sanction for an additional appointment, a second successful candidate, who was one of the Operator's Post-Holders, was appointed as an AAIU Inspector of Air Accidents in September 2018. A strict protocol was imposed to ensure that this person had no role in the ongoing Investigation into R116 and was excluded from all matters associated with this Investigation.

This Safety Investigation is exclusively of a technical nature, is in no case concerned with apportioning blame or liability and is independent of, separate from and without prejudice to, any judicial or administrative proceedings to apportion blame or liability. The sole objective of this Safety Investigation and Final Report is the prevention of accidents and incidents. The accomplishment of this objective relies on the aviation community's professional acceptance of, and confidence in, these tenets. Any attempt to use this Report for purposes other than flight safety undermines its fundamental purpose and risks damaging flight safety in the long term.

The Investigation is obliged to report the evidence it finds and to provide its analysis; however, it should be understood that the Investigation is solely concerned with improving flight safety, and to that end nothing written in this Report should be interpreted as a criticism of any individual or organisation. The Investigation requests that media activity in relation to this Report should take due cognisance of these issues so that flight safety is enhanced rather than damaged.

The Final Report in relation to an aircraft accident investigation is the foundation for initiating safety actions which are necessary to prevent further accidents from similar causes, and introducing improvements in areas which the Investigation identifies as actual or potential systemic safety issues. Therefore, the Final Report into an accident must establish in detail what happened, how it happened and why it happened.

The findings, probable cause and/or contributory causes contained in the Final Report may lead to safety recommendations so that appropriate preventive measures can be taken. In that regard, this Report is, in accordance with Annex 13 requirements, structured to include: a record of relevant facts (Section 1 - Factual Information, presented under the 19, ICAO-prescribed headings); an analysis of the relevant facts (Section 2 - Analysis); conclusions in the form of findings, probable cause and/or contributory causes (Section 3 - Conclusions); and Safety Recommendations (Section 4 - Safety Recommendations). Throughout the Report, the first use of an acronym is preceded by its full title. All acronyms are included in a table at the end of the main Report; Appendices are also listed at the end of the Report, and are contained in a separate volume.

Furthermore, the Report is intended to be read as a complete document as the relevance of matters raised in one section (e.g. Section 1 - Factual Information) might only be understood when integrated with other information in later sections; accordingly, it could be inappropriate or misleading to focus on any one particular statement, aspect or comment within the whole report.

In addition to the proximate circumstances and events related to the occurrence, the Report deals with systemic safety issues which were identified during the Investigation. This is in keeping with the ICAO Manual of Aircraft Accident and Incident Investigation, which requires reports to *'discuss and analyse any issue that came to light during the investigation which was identified as a safety deficiency, although such issue may not have contributed to the accident.'* It is neither practicable nor necessary to include all factual information gathered and considered by the Investigation. Accordingly, while this Report cites particular examples of matters which the Investigation considers necessary to support its analysis, findings and recommendations, it should be understood that the Investigation considered a larger body of evidence of which the examples cited are representative.

As prescribed in Annex 13, Section 7.4, a Preliminary Report, AAIU Report No. 2017-006, was published on the 13 April 2017 (hereafter referred to as the Investigation's Preliminary Report) which included two Safety Recommendations, one to the Operator regarding Route Guides and one to the lifejacket manufacturer regarding the installation of Personal Locator Beacons (PLBs).

In addition, Annex 13, Section 6.6, requires that if a Final Report cannot be made publicly available within twelve months, the State conducting the investigation shall make an interim statement publicly available on each anniversary of the occurrence. A First Interim Statement, AAIU Report No. 2018-004, was published on the 16 March 2018 (hereafter referred to as the Investigation's First Interim Statement), which included a further three Safety Recommendations: one to the Helicopter Manufacturer relating to Flight Data Recorder (FDR) position accuracy; one to the Operator regarding a review of its Safety Management System (SMS); and, one to the Minister of Transport, Tourism, and Sport regarding the oversight of Search and Rescue (SAR) aviation operations in the State. A Second Interim Statement was published on 1 March 2019; a Draft Final Report was issued in confidence to interested parties on 13 September 2019; a Third Interim Statement was published on 12 March 2020, and a Fourth Interim Statement was published on 12 March 2021.

During the Draft Final Report comments process, one party invoked Regulation 15 of SI 460 of 2009 and sent a Notice of Re-examination regarding certain Findings, Contributory Causes and a Conclusion in the Draft Final Report to the Minister for Transport, Tourism and Sport. On 23 December 2019, the Minister informed the Chief Inspector of Air Accidents that, in accordance with Regulation 16 of SI 460 of 2009, he was appointing a Review Board to carry out the re-examination requested. On 9 March 2020, the AAIU was advised by the Department of Transport, Tourism and Sport, that a Review Board has been established under SI 460 of 2009 for the re-examination of specific findings of the Draft Final Report into the accident to R116.

The Investigation advised all interested parties, on 9 March 2020, of the Departmental contact details for information relating to the re-examination.

Hearings were held over 44 days in the period from 23 November 2020 to 20 July 2021.

On 1 October 2021, the Chairman of the Review Board provided his Report to the Minister in accordance with Regulation 16(10). On 15 October 2021, the Minister sent a copy of the Chairman's Report to the Chief Inspector, also in accordance with Regulation 16(10), and referred all matters related to the Investigation back to the Chief Inspector to finalise the Investigation report. Regarding the specific Findings, Contributory Causes and Conclusion which were considered by the Review Board, the Investigation has adopted the revised text from the Chairman's Report.

The Investigation acknowledges that addressees of Safety Recommendations may have made progress in addressing those recommendations since the Draft Final Report was issued in September 2019. However, for certainty regarding these matters, this Final Report includes substantially the same Safety Recommendations; addressees can identify any actions taken since September 2019 in their responses to the Safety Recommendations in this Final Report, and these will be included in the updated Safety Recommendations on the AAIU website.

PREAMBLE

The Helicopter, EI-ICR, was owned and operated by a company contracted by the Department of Transport, Tourism and Sport (DTTAS)[7], to provide Search and Rescue (SAR) helicopter services in Ireland. The Operator of EI-ICR was the holder of an Air Operator Certificate (AOC) issued by the IAA, and is henceforth referred to in the Report as '*the Operator*'.

The Operator was also the holder of a Helicopter Emergency Medical Service (HEMS) approval, and the sole holder of an Irish National SAR Approval. Both approvals were issued by the IAA.

Within DTTAS, SAR was managed by the IRCG, under the Maritime Safety Directorate. In addition to operating SAR missions, the Operator commenced HEMS operations in 2013, on an opportunity basis, at the behest of the Irish Coast Guard.

The Operator had four bases in Ireland, situated at Dublin Airport on the east coast, at Shannon and Sligo Airports on the west coast, and at Waterford Airport on the south-east coast. Each base was allocated a rescue call sign as follows: Dublin – '*Rescue 116*', Shannon – '*Rescue 115*', Sligo – '*Rescue 118*', and Waterford – '*Rescue 117*'. EI-ICR was based at Dublin, operating under the call sign '*Rescue 116*' (R116). Flights operated by EI-ICR and its sister helicopters at the other bases are referred to as '*the Operation*'.

Flight crew at each base consisted of both commanders and co-pilots. Two commanders could be rostered together, with one nominated to act as co-pilot for a mission, as was the case on the accident flight. The Operator used the terms (and roles) Pilot Monitoring (PM) and Pilot Flying (PF); these roles could change within a particular mission but the designated commander remained the commander for the entire mission. The term flight crew is used to refer to pilots generally. The Flight Crew for the accident flight are referred to in this Report as the Commander and the Co-pilot; the Rear Crew for the accident flight are referred to as the Winchman and the Winch Operator, using '*proper case*', i.e. the first letter of each word is capitalised; references using non-capitalised words are generic.

The Operator used an Operations Manual (OM), which was a multi-volume document (designated OMA, OMB, OMC, OMD, OMF and OMG), setting out the processes and procedures for conducting operations. The Investigation requested the Operator to provide copies of all volumes of its OM which were extant at the time of the accident. The individual volumes provided were OMA (Rev 01, dated 01 July 2016), OMB (Rev 01, dated 01 July 2016), OMC (Rev 01, dated 01 July 2016), OMD (volumes 1, 2 & 3, Rev 02, dated 01 Jan 2017), OMF (Rev 02, dated 01 July 2016) which was SAR specific, and OMG (Rev 02, dated 01 July 2016) which was HEMS-specific.

[7] During the Investigation the title of the Department was changed to '*The Department of Transport*'. Accordingly, where appropriate, such as when making Safety Recommendations, reference is made to '*Transport*' rather than '*Transport, Tourism and Sport*', and the terms '*the Department*', '*Department of Transport*', and '*DTTAS*' are used interchangeably in this Report.

The Operator set up a '*Dataroom*' in order to manage the requests from the Investigation and the Investigation was requested to copy all correspondence to this '*Dataroom*'. The Investigation was informed that the '*Dataroom*' forwarded queries from the Investigation to the relevant person(s) within the Operator's organisation for reply, and the '*Dataroom*' was to provide a formal response on behalf of the Operator. Many of these formal responses were in the form of emails. Therefore, where relevant, the Investigation has used quotes from these emails in this Final Report.

1. FACTUAL INFORMATION

1.1 History of the Flight

1.1.1 The Call-out

At approximately 21.39 hrs on the night of 13 March 2017, the captain of a Fishing Vessel (FV) contacted Malin Head Marine Rescue Sub Centre (MRSC) to seek medical advice because a crewman on board had suffered an injury. At the time of this call the FV was operating in the North Atlantic Ocean, approximately 140 Nautical Miles (NM) west of Eagle Island, Co. Mayo. At 21.42 hrs, MRSC Malin contacted the Sligo SAR duty pilot, and tasked the Sligo-based helicopter, R118 with airlifting the injured crewman to hospital.

At 22.10 hrs, following consultation with the Dublin-based Commander, who was at home, the Marine Rescue Coordination Centre (MRCC) Dublin alerted the R116 crew via TETRA[8] radio and tasked R116 to provide Top Cover[9] for R118. The details regarding the exact nature of the tasking of R116 and R118, and communications between the relevant agencies, are set out in **Section 1.17.13** of this Report.

One of the Dublin Base duty engineers was alerted by a TETRA call at approximately 22.10 hrs, as he was about to leave the Dublin SAR Base for his home. He returned to the operations building and went to the Co-pilot's rest room, to check that the Co-pilot, who was staying on the base, had received the TETRA call. The Co-pilot confirmed that he had, and that he had spoken by phone with MRCC Dublin. When another Dublin Base engineer arrived from home, the Helicopter was towed out of the hangar to prepare it for refuelling.

The Commander telephoned the Sligo SAR Base from her car, while en route to the Dublin SAR Base and spoke to the winch operator of R118; the winch operator recalled that he informed the Commander that the two pilots were at the helicopter preparing for start-up, and that he was about to head out to join them. The Commander advised him that she had received the call for '*Top Cover*', that she was making her way to the Dublin Base, and that she wanted to know what the intentions of the crew of R118 were. The Sligo winch operator said that he advised the Commander that they were heading offshore to the west and that he assumed R116 would route to Blacksod.

[8] **TETRA**: Terrestrial Trunked Radio – A European standard for a trunked radio system and two-way transceiver specification.
[9] **Top Cover**: An aircraft dispatched in support of another (SAR) aircraft which is conducting an offshore mission. The term is also used to denote an air asset used as a SAR Support aircraft.

An engineer at the Dublin SAR Base, who was waiting in the operations room to receive a final fuel load requirement from the Flight Crew of R116, recalled the Commander coming onto the base, followed shortly afterwards by the two Rear Crew. The four Crew Members gathered in the operations room. One of the Dublin-based engineers recalled the Commander commenting that the Blacksod weather was probably not going to be good enough, and that the Helicopter would route to Sligo. At 22.35 hrs, the Winch Operator telephoned MRCC Dublin seeking an updated position for the FV, because they were unable to see the FV on the Automatic Identification System[10] (AIS). The Winch Operator also telephoned MRCC Dublin to enquire if R118 was having trouble getting into Blacksod; he explained that if R118 couldn't get into Blacksod, then R116 would have to head to Sligo for fuel. MRCC Dublin undertook to check with MRSC Malin. MRCC Dublin subsequently rang the Dublin Base to provide the requested position update for the FV.

An engineer at the Sligo Base recalled that after R118 had departed, the Commander of R116 called the Sligo Base phone; he believed that this call was made from a land line. The Commander and the engineer knew each other and briefly exchanged pleasantries before the Commander told the engineer that R116 would be coming into Sligo for a rotors-running refuelling because the weather at Blacksod was unsuitable.

The Co-pilot arrived at the Helicopter at approximately 22.47 hrs, and told the engineer that the Commander had requested a total fuel on board of 5,000 lbs. Technical Log records indicate that a volume of 900 litres (L) of fuel, was uplifted to the Helicopter. The Commander was first heard on the Helicopter's Cockpit Voice Recorder (CVR) recording at 22.53 hrs.

1.1.2 The Accident Flight

The Helicopter engines were started at 22.55 hrs, and it commenced take-off from RWY 16, at Dublin Airport, at 23.02 hrs. Shortly after take-off, the Helicopter established on a north-westerly track of approximately 300 degrees in accordance with its clearance. On transfer to Dublin Departures, the Helicopter was instructed to establish on a heading of 270 degrees. The Helicopter continued to climb on the westerly heading, until reaching 3,000 feet (ft), when it was transferred to Dublin Area Control Centre (ACC - Lower North Sector).

At 23.11 hrs, the Rear Crew made contact with R118 on TETRA. R118 informed R116 that it was about to land in Blacksod and that it would contact R116 when it was on the ground in Blacksod[11]. In addition, R118 informed R116 that '*conditions at the pad are fine eh eh kind of some low cloud eh approximately five hundred feet eh up to the north while we were inbound through Broadhaven bay over*.'

The Helicopter continued to maintain 3,000 ft, and at 23.13 hrs it commenced tracking towards Sligo. Once established on course to Sligo, the Flight Crew conducted fuel calculations to determine if there was a time/fuel advantage in uplifting fuel at Blacksod instead of Sligo. At 23.20 hrs, having cross-checked their calculations, the Flight Crew elected to route to Blacksod.

[10] **AIS:** A system used to indicate the positions of maritime assets. For further details see **Section 1.6.6**.

[11] The Investigation was informed that R118 approached Blacksod using the SGLOWBS route (Sligo low level route to Blacksod), which is different to the route R116 intended to use.

The Rear Crew informed MRSC Malin of this decision. Shortly after this, the Flight Crew informed Dublin ACC of a change of routing, that they had turned approximately 20 degrees left, and would be routing to Blacksod. Dublin ACC instructed R116 to contact Shannon ACC (Shannon North).

The Helicopter called Shannon Information (ATC) and reported that it was 7 NM south of Kells (located approximately 29 NM north-west of Dublin) at 3,000 ft and that it was en route to Blacksod. Shannon Information asked the Helicopter to confirm that it was operating under IFR (Instrument Flight Rules) and if they were ready for 4,000 ft. R116 responded, confirming that it was operating under IFR and that it would be climbing to 4,000 ft in approximately 20 NM. Shannon Information passed the latest Shannon QNH (atmospheric pressure at sea-level) and asked the Helicopter to confirm if it was routing to Sligo or Blacksod. The Commander read back the QNH and reported that they were routing to Blacksod. Shannon Information informed R116 that R118 was *'just headed off the west coast now, he has no contact with me, if you contact him, can you ask him to give me a call please'.*

At 23.33 hrs, R116 commenced a climb from 3,000 ft, levelling at 4,000 ft three minutes later. Once the Helicopter was level at 4,000 ft, the Commander stated that she was going to select APBSS[12] on the Flight Management System (FMS).

At 00.04 hrs, as R116 was passing overhead Knock Airport[13], the Rear Crew made initial contact with Blacksod helipad to request information on the wind, cloud base and visibility. At 00.09 hrs, Blacksod helipad replied to R116 with an estimated cloud base, which was reported as between 300 and 500 ft. The Commander asked the Rear Crew to request wind direction, speed and visibility. This request was relayed to Blacksod helipad; the reply received was that the wind was west-south-west at 25-33 knots, and the visibility was 2 NM.

As the Helicopter approached the Mayo coast, the Flight Crew commenced the '*DVE*[14] *Approach*' checklist. The Helicopter was at 4,000 ft, tracking towards waypoint '*BLKMO*', the initial waypoint of the APBSS route; BLKMO was almost coincident with Black Rock. At 00.28 hrs, the Helicopter crossed the Mayo coast and flew out over Blacksod Bay, and shortly after this, when the Helicopter was approximately 1.5 NM north of Dugort, Achill Island, Co. Mayo, at 4,000 ft, inter-Crew communications confirmed that the Helicopter was over the water.

The Co-pilot announced that the DVE checks were complete, and at 00.34 hrs, as the Helicopter passed abeam the navigational waypoint '*BKSDA*', '*Alt Pre*'[15] was selected and the Helicopter commenced descent. At this time, the Commander commented on the high terrain at Achill, in the Helicopter's '*nine o'clock position*', and the Winchman announced '*all clear ahead*'. The Co-pilot then informed Shannon ACC that the Helicopter was in the descent and that they were making their way into Blacksod for refuelling. Shannon acknowledged this and asked R116 to report again when airborne.

[12] **APBSS**: A pre-programmed route in the Helicopter FMS (**Section 1.6.6.2**).
[13] **Knock Airport**: Ireland West Airport (EIKN).
[14] **DVE**: Degraded Visual Environment, which OMB defines as visibility less than 4,000 metres or no distinct natural horizon.
[15] **Alt Pre**: Altitude Preselect, a vertical mode selected on the auto-flight system.

As the Helicopter was passing 2,400 ft, Approach One (APP1) mode (an automatic mode available on S-92A SAR helicopters to descend from 2,400 ft to 200 ft, unless interrupted at a higher intermediate altitude) was selected on the Automatic Flight Control System (AFCS).

As the Helicopter approached BLKMO, in the descent, while westbound, the Commander noted that they were clear to the right on radar and commenced a slight right turn to allow the descent to complete down to 200 ft, prior to a left turn back to BLKMO.

As the Helicopter tracked north-west from BLKMO, and passed approximately 800 ft in the descent, the Commander asked the Co-pilot to '*confirm we're clear ahead on radar and on E GYP WIZZ* [EGPWS – Enhanced Ground Proximity Warning System]'. The Co-pilot responded '*you are…you are clear ahead on … ten mile range'.*

The Helicopter maintained a north-westerly track until it reached 200 ft, at which point the Commander announced that Approach One was complete and that she was '[…] *just going to help it round the corner … coming to the left'*. As the Helicopter commenced the left turn back towards BLKMO, the Winchman announced that the Helicopter was '*clear around to the left'*. This was followed approximately 30 seconds later by a further announcement from the Co-pilot that they were '*ah clear ahead on E GYP WIZZ and radar*'.

At 00.43 hrs, as the Helicopter was turning back towards BLKMO at 200 ft, the '*Before Landing*' checklist was commenced. During this time, the Co-pilot stated: '*starting to get ground coming in there at just over eight miles in the ten o'clock position*'. Just as the Commander was completing the final item of the '*Before Landing*' checklist, she commented that she was visual with the surface of the sea.

At 00.45 hrs, the Co-pilot announced '*okay so small targets at six miles at 11 o'clock … large out to the right there*'. This was followed approximately 20 seconds later by an Auto Callout '*Altitude, Altitude*', which the Commander said was '*just a small little island that's B L M O itself*'.

Just prior to 00.46 hrs the Winchman announced '*Looking at an island just eh directly ahead of us now guys…you wanna come right* [Commander's name]'. The Commander asked for confirmation of the required turn, and the Winchman replied '*twenty degrees right yeh*'. The Commander instructed the Co-pilot to select heading (HDG) mode, which the Co-pilot acknowledged and actioned. Within one second of this acknowledgement, the Winchman announced '*come right now, come right, COME RIGHT*'.

Shortly after this, the Helicopter pitched up rapidly and rolled to the right. At 00.46:08 hrs, the Helicopter collided with terrain at the western end of Black Rock, departed from controlled flight, and impacted with the sea. The main wreckage of the Helicopter came to rest on the seabed to the east of Black Rock, at a depth of 40 metres (m).

1.2 Injuries to Persons

Injuries to persons are listed in **Table No. 1**.

Injuries	Crew	Passengers	Others
Fatal	4	0	0
Serious	0	0	0
Minor/None	0	0	

Table No. 1: Injuries to persons

Additional Information relating to the Crew Members is provided at **Section 1.5**, Personnel Information and, **Section 1.13**, Medical and Pathological Information.

1.3 Damage to Aircraft

The Helicopter was destroyed. Further details are contained in **Section 1.12**.

1.4 Other Damage

There was minor damage to buildings on Black Rock.

1.5 Personnel Information

1.5.1 General

The Helicopter Crew comprised a standard SAR complement of four persons: the Helicopter Commander, located in the right-hand cockpit seat, the Co-pilot located in the left-hand cockpit seat, a Winch Operator, located on the right-hand side of the forward cabin at the main entrance door (Winch Operator Station), and a Winchman located on the left-hand side of the forward cabin (at the SAR Operator Station).

1.5.2 Helicopter Commander

The Helicopter Commander held a European Union Flight Crew Airline Transport Pilot's Licence (ATPL) Helicopter (H) issued in Ireland by the IAA. The Commander's Sikorsky S-92A type rating was valid to 28 February 2018 (date of test: 9 February 2017). The Commander held a Class I Medical Certificate valid to 15 January 2018.

The Commander began flying training in 1990, gaining a Private Pilot's Licence (PPL) Helicopter (H) in December 1990 and a Commercial Pilot's Licence (CPL) (H) in March 1992. In late 1993, the Commander commenced employment with an Irish helicopter company and completed a Multi-Engine (ME) Rating and an Instrument Rating (IR). During 1994, the Commander was seconded to a SAR operator in the UK, to gain flying experience on the S-61N helicopter. Following this secondment, the Commander was attached to a base at Shannon as an All Weather Search and Rescue (AWSAR) co-pilot.

In early 2000, the Commander completed her command upgrade and was assigned as a captain at Shannon. In 2002, she was assigned to the Waterford SAR Base and was subsequently appointed as Chief Pilot there. In 2013, the Commander completed a type rating and an AWSAR Operator Conversion Course on the S-92A. In July 2013, she completed her Command Check on the S-92A and completed some operational shifts at the Waterford SAR Base before being assigned as a Captain attached to the Dublin SAR Base. The Commander was responsible, amongst other ground duties, for the compilation and management of the Operator's SAR pilot roster. The Commander's licence and medical certification details are contained in **Table No. 2.**

Personal Details:	Aged 45 years
Licence:	Airline Transport Pilot's Licence (ATPL) Helicopter (H), issued by the IAA; Type Rating was valid until 28/02/2018
Medical Certificate:	Class I, valid until 15/01/2018

Table No. 2: Commander's licence and medical certification details

The checks completed by the Commander are listed in **Table No. 3**.

Check Type	Check	Valid to
Licence Proficiency Check (LPC)	09/02/2017	28/02/2018
Operator Proficiency Check (OPC)	09/02/2017	31/08/2017
Pilot Competence Check (HEMS)	06/03/2017	31/03/2018
Pilot Competence Check (AWSAR)	06/03/2017	31/03/2018

Table No. 3: Checks completed by the Commander

Other training completed by the Commander is listed in **Table No. 4**.

Other Training	Completed	Valid to
Emergency and Safety Equipment (Annual Check)	06/03/2017	31/03/2018
Exits Triennial Training	11/03/2016	31/03/2019
Helicopter Underwater Egress Training (HUET) with Short Term Air Supply System (STASS) and Basic Fire Fighting	08/03/2017	30/04/2020
Fatigue Risk Management Refresher Training	02/07/2015	31/07/2017
CRM Recurrent Training	13/10/2016	31/12/2017
Dangerous Goods (Carriage)	19/03/2016	31/03/2018
Controlled Flight Into Terrain	21/09/2016	21/09/2018

Table No. 4: Other training completed by the Commander

Flying Experience:

The Commander's flying experience is detailed in **Table No. 5**.

Total all types:	5,292 hours
Total on type:	825 hours
Total on type P1:	Approximately 725 hours
Last 90 days:	33.6 hours
Last 28 days:	13.2 hours
Last 24 hours:	1.1 hours

Table No. 5: Commander's flying experience

Duty Time:

The Commander's duty time is shown in **Table No. 6**.

Duty Time up to accident:	11 hours 45 min
Rest period prior to duty:	23 hours

Table No. 6: Commander's duty time

1.5.3 Helicopter Co-pilot

The Helicopter Co-pilot held a European Union Flight Crew ATPL (H) issued in Ireland by the IAA. His Sikorsky S-92A type rating was valid to 31 May 2017 (date of test: 12 May 2016). He held a Class I Medical Certificate valid to 31 October 2017 with the provision to wear corrective lenses.

The Co-pilot commenced helicopter flying in 1996. He was issued with his PPL (H) on 15 October 1996 and his CPL (H) on 25 November 1998. He took up employment with a west-of-Ireland helicopter operator in December 1999, flying a Bell 206 Jetranger.

In August 2001, the Co-pilot completed a Multi-Engine (ME) Rating and an Instrument Rating (IR) with a UK company flying a Eurocopter AS355F2 Écureuil helicopter. The Co-pilot completed his type rating on a Sikorsky S-61N in Norway in October 2001 and his AWSAR Operator Conversion Course in December 2001. He was assigned as a co-pilot attached to the Dublin SAR Base and in December 2007, he completed his command upgrade and was assigned as a captain. In May 2013, the Co-pilot completed his type rating on the Sikorsky S-92A in the UK and completed his AWSAR Operational Conversion Course in August 2013.

In December 2013, he completed his Command Check and was assigned as a captain attached to the Dublin SAR Base. The Co-pilot's licence and medical certification details are contained in **Table No. 7**.

Personal Details:	Aged 51 years
Licence:	Airline Transport Pilot's Licence (ATPL) Helicopter (H), issued by the IAA; Type Rating was valid until 31/05/2017
Medical Certificate:	Class I, valid until 31/10/2017

Table No. 7: Co-pilot's licence and medical certification details

The checks completed by the Co-pilot are listed in **Table No. 8**.

Check Type	Check	Valid to
Licence Proficiency Check (LPC)	12/05/2016	31/05/2017
Operator Proficiency Check (OPC)	10/11/2016	31/05/2017
Pilot Competence Check (HEMS)	09/12/2016	31/12/2017
Pilot Competence Check (AWSAR)	09/12/2016	31/12/2017

Table No. 8: Checks completed by the Co-pilot

Other training completed by the Co-pilot is listed in **Table No. 9**.

Additional Training	Completed	Valid to
Emergency and Safety Equipment (Annual Check)	28/07/2016	31/08/2017
Exits Triennial Training	28/07/2016	31/07/2019
Helicopter Underwater Egress Training (HUET) with Short Term Air Supply System (STASS) and Basic Fire Fighting	04/10/2016	30/11/2019
Fatigue Risk Management Refresher Training	01/07/2015	31/07/2017
CRM Recurrent Training	13/10/2016	31/12/2017
Dangerous Goods (Carriage)	06/06/2015	30/06/2017
Controlled Flight Into Terrain	21/09/2016	21/09/2018

Table No. 9: Other training completed by the Co-pilot

Flying Experience:

The Co-pilot's flying experience is detailed in **Table No. 10**.

Total all types:	3,435 hours
Total on type:	795 hours
Total on type P1:	Approximately 695 hours
Last 90 days:	37 hours
Last 28 days:	13.5 hours
Last 24 hours:	1.1 hours

Table No. 10: Co-pilot's flying experience

Duty Time:

The Co-pilot's duty time is shown in **Table No. 11**.

Duty Time up to accident:	10 hours 15 min
Rest period prior to duty:	24 hours 30 min

Table No. 11: Co-pilot's duty time

1.5.4 Helicopter Winch Operator

The Winch Operator served initially as a military SAR Crew Winchman and then as a Winch Operator on Alouette III and AS365F Dauphin helicopters. In 1998, he joined a civilian SAR operator as a senior SAR Crewman. He completed an AWSAR Operator Conversion Course on S-61N in 1998 and was assigned as a dual-rated Winch Operator/Winchman attached to the Dublin SAR Base. In 2013, he completed an AWSAR Operator Conversion Course on the S-92A and was assigned as a dual-rated Winch Operator/Winchman attached to the Dublin SAR Base.

In addition to his SAR Crewman ratings, he was a Pre-Hospital Emergency Care Council (PHECC) registered paramedic. The Winch Operator's medical certification details are contained in **Table No. 12**.

Personal Details:	Aged 53 years
Medical Certificate:	Class II, valid until 08/01/2018

Table No. 12: Winch Operator's medical certification details

The Winch Operator underwent the checks listed in **Table No. 13**.

Check Type	Check	Valid to
Crewman Competency Check (AWSAR)	17/12/2016	17/12/2017
PHECC Paramedic	31/05/2017	31/05/2017

Table No. 13: Checks completed by the Winch Operator

Other training completed by the Winch Operator is listed in **Table No. 14**.

Additional Certificate Training	Check	Valid to
Emergency and Safety Equipment (Annual Check)	17/12/2016	31/12/2017
Exits Triennial Training	16/05/2016	31/05/2019
Helicopter Underwater Egress Training (HUET) with Short Term Air Supply System (STASS) and Basic Fire Fighting	01/05/2015	30/04/2018
Fatigue Risk Management Refresher Training	10/07/2015	10/07/2017
CRM Recurrent Training	21/12/2016	31/12/2017
Dangerous Goods (Carriage)	18/03/2016	31/03/2018

Table No. 14: Other training completed by the Winch Operator

1.5.5 Helicopter Winchman

The Winchman served as a military SAR Crew Winchman on Alouette III and AS365F Dauphin helicopters from 1999. In 2004, he joined a civilian operator as a SAR Crewman.

He completed an AWSAR Operator Conversion Course on the S-61N in 2004 and following an initial assignment at the Sligo Base he was assigned as a Winchman attached to the Dublin SAR Base. In 2013, he completed an AWSAR Operator Conversion Course on the S-92A and was assigned as a dual rated Winch Operator/Winchman attached to the Dublin SAR Base. In addition to his SAR Crewman ratings, he was a PHECC-registered paramedic. The Winchman's medical certification details are contained in **Table No. 15**.

Personal Details:	Aged 38 years
Medical Certificate:	Class II, valid until 09/04/2020

Table No. 15: Winchman's medical certification details

The Winchman underwent the checks listed in **Table No. 16**.

Check Type	Check	Valid to
Crewman Competency Check (AWSAR)	28/03/2016	31/03/2017
PHECC Paramedic	31/05/2016	31/05/2017

Table No. 16: Checks completed by the Winchman

Other training completed by the Winch Operator is listed in **Table No. 17**.

Additional Certificate Training	Check	Valid to
Emergency and Safety Equipment (Annual Check)	26/01/2016	31/03/2017
Exits Triennial Training	28/03/2016	31/03/2019
Helicopter Underwater Egress Training (HUET) with Short Term Air Supply System (STASS) and Basic Fire Fighting	27/07/2016	31/10/2019
Fatigue Risk Management Refresher Training	14/07/2015	31/07/2017
CRM Recurrent Training	13/10/2016	31/12/2017
Dangerous Goods (Carriage)	19/01/2016	31/01/2018

Table No. 17: Other training completed by the Winchman

1.5.6 72-Hour Activity Review

1.5.6.1 General

In accident investigation it is necessary to examine the activity of each of the Crew Members to establish if the nature of such activities had a bearing on the rest and wellbeing of the individual. The Investigation contacted each of the Crew Members' families to seek assistance in understanding their activity profiles in the days immediately preceding the accident. The Investigation also spoke with colleagues of the Crew Members.

One issue which was mentioned by families, and also by colleagues of the Crew Members, was that there had been a bereavement within the Operator's staff community in the week preceding the accident. Funeral ceremonies for this person, a Post-Holder of long service with the Operator, were held on Saturday, 11 March 2017, in Co. Clare, and on Monday, 13 March 2017, in Dublin. Not all of the members of the accident Helicopter's crew were able to attend the ceremonies.

1.5.6.2 Commander

On Friday, 10 March 2017, the Commander largely spent the day with family members and friends, and attending to domestic matters. During the day she met with a colleague to make roster adjustments in order to facilitate staff attendance at their colleague's funeral. She spent the evening at home and retired to bed sometime before 23.45 hrs. On Saturday 11 March 2017, the Commander spent the morning at home before leaving for her shift at the Dublin Base. She returned home around 21.30 hrs.

On Sunday, 12th March 2017, the Commander left for the Dublin Base around 07.00 hrs. She returned home at approximately 14.15 hrs and spent the rest of the day with family and friends, before retiring to bed at approximately 21.30 hrs. On Monday, 13 March 2017, the Commander rose between 06.00 hrs and 06.15 hrs. The Commander dropped her son to his crèche and later departed for the Dublin Base for her shift at 13.00 hrs.

The Commander returned home around 21.25 hrs, and retired to bed about 30 minutes later. At around 22.15 hrs, she went back downstairs to her sister to say that she had been called out and she departed for the Dublin Base.

1.5.6.3 Co-pilot

The Co-pilot had been off-shift from 5 March until 11 March 2017, and reportedly had a relaxing week. He spent Friday 10 March 2017, attending to family and domestic matters, and retired to bed before 23.30 hrs. On Saturday 11 March 2017, he awoke before 08.30 hrs, and departed for the Dublin Base, where he was on shift from 13.00 hrs until 12 March 2017 at 14.00 hrs approximately. This was a delayed finish due to a SAR tasking; during the Co-pilot's shift, he carried out two taskings: one commencing at 19.59 hrs, and one commencing at 12.03 hrs – each flight lasted approximately one hour. It was the Co-pilot's practice, due to the distance from his home to the Dublin Base, to sleep on base during his rostered duties. He spent Sunday afternoon and evening with his family before retiring to bed between 23.00 hrs and 23.30 hrs. On 13 March 2017, he was awoken by an alarm at 07.15 hrs and rose after 08.10 hrs. During the morning he checked work emails, had coffee with a friend and did some household chores. He left home at 12.40 hrs to attend a service for his deceased colleague, and proceeded from the service to the Dublin SAR Base in order to start his shift at approximately 14.30 hrs. He spoke with his wife, by phone, at around 21.15 hrs.

1.5.6.4 Winch Operator

The Winch Operator completed a rostered shift at 13.00 hrs on Friday, 10 March 2017. He was not on duty on Saturday, 11 March 2017 or Sunday, 12 March 2017. It is understood that he spent Saturday attending to domestic matters. On Sunday he visited family members before returning home in the early evening. On Monday, 13 March 2017, he reported for his shift at the Dublin Base at 13.00 hrs. Staff at the Dublin Base informed the Investigation that his mood was quite subdued which they attributed to the fact that he had been unable to attend his colleague's funeral ceremonies on either Saturday or Monday. He departed the base for home at around 21.00 hrs. The Investigation was informed that it seemed that he had retired to bed and was reading, as was his practice, when he was alerted to the tasking via his TETRA radio.

1.5.6.5 Winchman

The Winchman finished a run of two duties on Thursday, 9 March 2017. On Friday, he spent the day with family and was reported to be in good spirits. On Saturday, he attended his colleague's funeral service. He was reported to be in good form, spoke with several colleagues throughout the day and was reportedly reconciled to the bereavement. Sunday was spent with family and friends. On Monday, 13 March 2017, he started his shift at 13.00 hrs.

His wife had occasional text communications with him throughout the day and his wife and children collected him from the Dublin Base at 21.00 hrs. He indicated to his wife that the shift had been difficult due to the emotions around his colleague's death. He was relaxing at home when his TETRA radio activated with the tasking and he departed for the Dublin SAR Base.

He sent a text message to his wife later to say that they were headed to Sligo for fuel, then following R118 out towards the FV and indicated that he intended to sleep on base following completion of the mission.

1.6 Aircraft Information

1.6.1 General

The Sikorsky S-92A helicopter type is fitted with two General Electric CT7-8A turboshaft engines, with Full Authority Digital Engine Control (FADEC). The engines power a fully articulated four-bladed main rotor, with a disc diameter of 17.17 m and a four-bladed tail rotor system, with a disc diameter of 3.35 m. The main and tail rotor blades are manufactured from composite materials. The tail rotor is mounted on a tail rotor gear box installed in the upper section of the tail, and is driven by a shaft from an intermediate gear box (IGB) fitted near the base of the tail pylon. The IGB is driven by a horizontal shaft from the main rotor gear box (**Figure No. 1**).

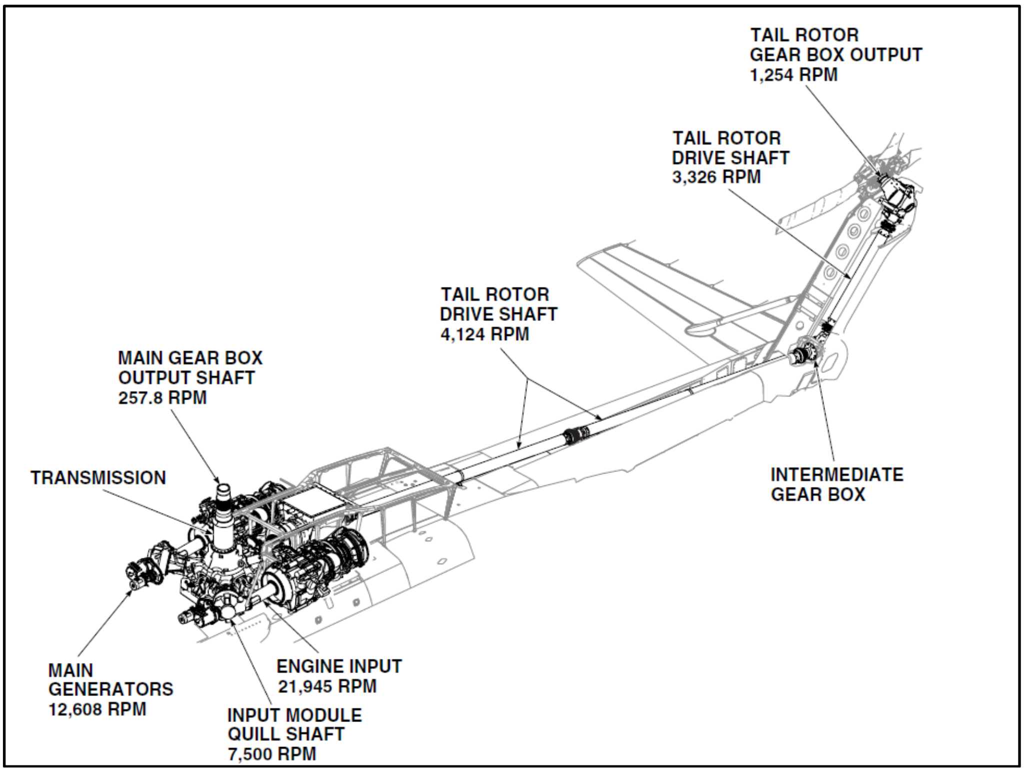

Figure No. 1: S-92A Rotor Drivetrain

The helicopter is 17.09 m long from nose to tail. A composite horizontal stabiliser, 2.98 m long, is mounted on the right-hand side of the tail section (the other principal dimensions of the helicopter are contained at **Appendix A**).

A retractable tricycle undercarriage is fitted, with the main landing gears mounted in the aft section of each sponson[16]. An emergency life raft is fitted in the front section of each sponson (**Section 1.6.4**). The centre (main) portion of each sponson contains a main fuel tank. The helicopter's maximum take-off weight[17] is 12,020 kg. The cockpit is configured for two-pilot operation in a side-by-side layout; each pilot seat is fitted with a five-point restraint harness.

EI-ICR was manufactured in 2007 and was one of a fleet of five S-92A SAR helicopters in use by the Operator (**Photo No. 1**). It was first registered in Ireland in 2013. Its Certificate of Airworthiness was issued by the IAA on 14 June 2013. The associated Airworthiness Review Certificate (ARC) was issued on 8 November 2016 and was valid until 7 November 2017. The Helicopter had operated for a total time of approximately 4,851 hours from the date of manufacture until the occurrence date. Notwithstanding the Daily Check carried out on 13 March 2017, the most recent maintenance inspection was a '*Zone 4 - 50 Hour Inspection*', which was performed on 9 March 2017 at 4,848 hours.

[16] **Sponson**: A structure projecting from either side of the helicopter.
[17] **Weight**: Quantities denominated in Kgs are technically a measurement of mass, although they are frequently referred to as '*weight*'.

Photo No. 1: EI-ICR, Sikorsky S-92A (*Tom Moloney*)

In the SAR configuration as used by the Operator, the Helicopter was fitted with an auxiliary, cabin-mounted fuel tank to permit increased operating range and endurance. A three-person '*litter*' evacuation station was fitted, for the treatment of recovered casualties. A wide-range of medical equipment was carried on board. The Helicopter's forward cabin was fitted with a front-facing crew seat on the left-hand side, normally used by a winchman, and a front-facing crew seat on the right-hand side of the forward cabin, aft of the main sliding door, normally occupied by a winch operator. The seats for the winch operator and winch man were fitted with four-point restraint harnesses. The Helicopter's EO/IR[18] camera system can be operated from the SAR Operator's station forward of the winchman's seat (**Section 1.6.6.12**).

1.6.2 Emergency Exits

On the helicopter type as used by the Operator, in addition to the main sliding door on the right-hand side of the cabin, and the rear ramp door, four cabin emergency exits are fitted, one of which is integral to the main cabin entrance door. Each of the four cabin emergency exits can be jettisoned by rotating the interior or exterior release handle. Push-out cabin windows are also provided. These windows can be jettisoned by pushing on the window from inside the cabin. To facilitate emergency egress from the cockpit, the pilots' windows can be jettisoned by rotating the internal emergency release handle aft, or externally, by pressing a red button and rotating the external release handle counter-clockwise (**Photo No. 2** and **Photo No. 3**).

[18] **EO/IR:** Electro-optic and infrared


Photo No. 2 and **Photo No. 3:** Right-hand side pilot's jettisonable window (emergency exit)

1.6.3 Emergency Flotation System

The Helicopter was fitted with an Emergency Flotation System (EFS), which incorporates five inflatable flotation bags to keep it afloat and facilitate evacuation following a controlled ditching in water, in conditions up to sea-state 6 (wave height 14-20 ft with wind speed of 27-33 knots (kts)). Two of the bags are mounted below the cockpit jettisonable windows; one bag is installed in the aft section of each sponson (left-hand and right-hand) and one bag is installed on the underside of the tail section. When armed, the flotation system can be activated automatically by left and right immersion switches, or manually by either pilot. When activated, compressed gas from high-pressure cylinders inflates each of the urethane-coated, nylon, pop-out flotation bags.

The Operator's normal flight checklist instructs flight crews to arm the EFS when the helicopter is operating over water and travelling at a speed of less than 80 kts. The EFS is designed to be used in a '*controlled ditching*' scenario and it is not designed to absorb the force of a significant water impact. Deployment of the EFS is intended to be carried out once the helicopter has entered the water, and intentional deployment of the EFS in-flight is prohibited.

1.6.4 Life Rafts

A 14-person life raft (with an overload capacity of 21) is stowed in the forward section of each sponson. Each life raft contains a survival kit and an Emergency Locator Transmitter (ELT). Raft inflation can be triggered either electrically from the cockpit, or by manual-pull '*D-rings*' on the sponsons. Each raft is inflated by its own integrated nitrogen bottle. Inflation of the raft causes it to deploy from its container.

1.6.5 SAR Operator Station/Equipment

The helicopter type used by the Operator was equipped with a Wescam MX-15i EO/IR Camera System (commonly referred to by the Operator's personnel as the '*FLIR*' system[19]).

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[19] The Investigation acknowledges that the Helicopter was equipped with an EO/IR camera system. However, the Operator refers to the system with the general term '*FLIR*' throughout its manuals. Accordingly, in this Report, references to '*FLIR*' should be taken to refer to the EO/IR system.

The camera system incorporates a daylight camera with continuous zoom lens, an infrared thermal camera with stepped zoom lens and a fixed focal length daylight/low-light spotter scope. It also incorporates an interface for the Spectrolab NIGHTSUN XP searchlight system, which can also be used as a standalone illumination source. The imagery can be viewed from the SAR Operator Station located on the left-hand side of the forward cabin and can also be selected for viewing on a cockpit Multi-Function Display (MFD), if a pilot selects it. The FAA-Approved, Helicopter Manufacturer's, Rotorcraft Flight Manual (RFM), Supplement for use of the EO/IR system states '*Do not navigate or manoeuvre based on Wescam imagery*'.

An Avalex AVR-8240-XM digital video recorder (**Section 1.11.15**), which is also installed in the SAR Operator station, provides the capability of recording video from the EO/IR camera. The Operator's OMF prescribes that '*FLIR should not be used in isolation for judgement of distances*.' OMF also states that '*a secondary navigation source may not necessarily be authorised in the OMB for aircraft navigation but may augment aircraft situational awareness* […] *Secondary navigation equipment:* […] *iv. FLIR identified ground feature*'.

A '*Toughbook*' computer is also fitted to the SAR Operator's station (**Section 1.6.8**).

1.6.6 Avionics

1.6.6.1 General

The avionics suite on EI-ICR included, amongst other components, the following systems:

- A Universal Navigation UNS1 Flight Management System (FMS) with GPS and Multi-Mission Management Systems (MMMS)
- Two Honeywell AA-300 Radio Altimeters (Rad Alt)
- Dual digital Automatic Flight Control Systems (AFCS) with modified software for SAR profiles
- Honeywell MKXXII Enhanced Ground Proximity Warning System (EGPWS) with modified software for SAR profiles
- Honeywell Primus 701A Airborne, Ground and Sea Mapping Weather Radar System
- Euroavionics Euronav 5 Moving map display system
- Skytrac Systems ISAT-100 Flight Following System with CDU and Voice Capability
- Wescam MX-15i EO/IR camera system
- Global Wulfsberg Flexcomm II VHF/UHF/AM/FM tactical communication transceiver
- Saab Airborne R4A Automatic Identification System transponder
- Memory map – Toughbook
- Dual Attitude Heading Reference Systems (AHRS)
- Emergency Locator Transmitter (ELT) with GPS position broadcast

- Automatic Deployable ELT (ADELT) System
- Helicopter Emergency Egress Lighting System (HEELS)
- Honeywell Primus HF-1050 High Frequency Radio System
- ASKNES Aviation Polycon Wireless SAR intercom System

The Rockwell Collins Avionics Management System (AMS) consists of five MFDs, two Mode Select Panels (MSPs) and two Data Concentrator Units (DCUs). DCUs collect and process signals from the Air Data Computer (ADC), the AHRS, the drive train sensors, and the Full Authority Digital Engine Control (FADEC) system. Each MFD provides the capability to select various page formats using fixed function bezel keys located at the top of the display. The available page formats are: Primary Flight Display (PFD), Engine Instrument and Caution Advisory System (EICAS), Navigation (NAV), Health (HLTH), and Utility (UTIL). Display Control Panels (DCPs) for the pilot and co-pilot are located on the centre console; the DCP sets various parameters, on its associated side of the cockpit, on the PFD and NAV displays. **Photo No. 4** shows the layout of the Operator's cockpit screens.

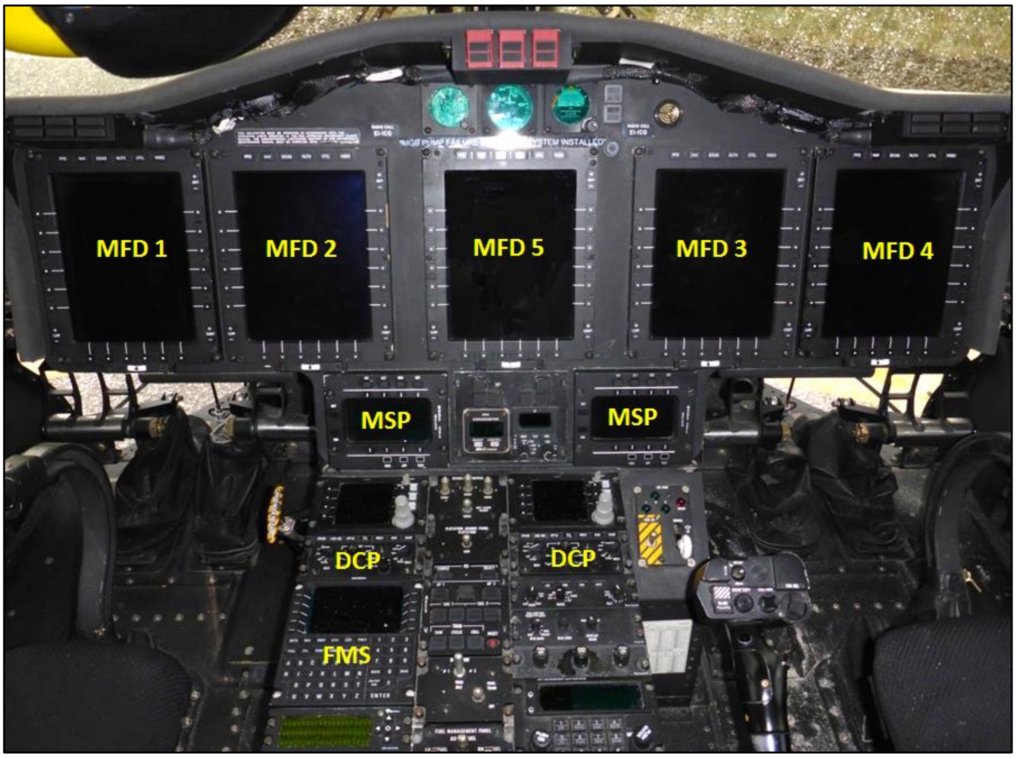

Photo No. 4: Cockpit Displays and Control Panels

1.6.6.2 Flight Management System with Multi-Mission Management System

The Flight Management System (FMS) receives primary position information from short and long range navigation sensors such as Distance Measuring Equipment (DME), Very High Frequency Omni-directional Range (VOR) and Global Positioning System (GPS). Primary position data received from each sensor is combined in the FMS, to derive a best computed position. The latitude and longitude of the helicopter's position is presented on the cockpit navigation display page.

The FMS utilises the derived best-computed position to provide the capability to navigate the helicopter along a selected flight path. Flight planning is accomplished by accessing the internal navigation database provided by third parties and/or an operator, and/or pilot-defined data. The data available to the pilot for selection includes waypoints, routes, airways, arrivals, departures, approaches and runways to create the desired flight plan. The FMS data can be displayed on the MFDs. The flight plan can be displayed as a line diagram on the cockpit navigation display page. The flight plan overlays weather radar data if selected for display. Navigation data including next waypoint ID, distance, time-to-go, desired track, wind speed and direction, and present position is also displayed.

The MMMS includes the ability to steer the aircraft through six distinct search modes (flight patterns) – rising ladder, race track, expanding square, search sector, orbit, and border patrol. Characteristics of all patterns can be manually altered or customised by the flight crew depending on the mission.

1.6.6.3 Radar Altimeter

A Dual '*Honeywell AA-300*' Radar Altimeter (Rad Alt[20]) system was fitted. The Rad Alt system provides the height of the helicopter above the surface whenever it is within 2,500 ft of the surface. This system provides radar altitude for the cockpit PFDs. A '*Radar altitude Alert*' refers to a pilot-selected setting, which displays on the PFD and as a '*bug*' selection on the analogue radar altimeter on the NAV page. When descending through the radar altitude alert setting, the '*ALTITUDE*' aural alert will be generated once.

An analogue radar altimeter is displayed in the upper right corner of the NAV page on the PFD. The analogue gauge disappears when Radar Altitude is greater than 1,050 ft and reappears when Radar Altitude is less than 1,000 ft. A digital readout of Radar Altitude is shown inside the analogue gauge. The digital readout disappears when Radar Altitude is greater than 2,500 ft and reappears when radio altitude is less than 2,450 ft.

The Radar Altitude Hold Mode (RALT) maintains the helicopter at a Radar Altitude. The Radar Altitude at the time of capture will be the reference radar altitude.

1.6.6.4 Automatic Flight Control System Modes, including SAR modes

The RFM Supplement and the Operator's OMF refer to eight SAR modes, which are controlled from either MSP. Four SAR approach modes (Approach 1 – APP1; Approach 2 – APP2; Approach to Point – ATPT; Mark On TOP – MOT) are included: three hover modes (Velocity Hover Hold – VHLD; Position to Hover Hold – PHLD; Crew Hover – CHOV); and one departure mode (Depart – DPT). In each approach mode, the helicopter transitions from a high speed, high altitude condition to a low speed, low altitude condition. The approaches attempt to follow programmed deceleration and descent schedules, with decreasing airspeeds corresponding to decreasing radio altitudes. The Investigation notes that a search mode, '*SRCH*' is also provided, but this is not described in the RFM Supplement or in the Operator's OMF.

[20] **Rad Alt**: A term which is commonly used to refer to the Radar Altimeter, which itself is often referred to as a Radio Altimeter.

Descent from cruise flight is made with '*ALTP*' (Altitude Preselect) mode, using barometric altitude (an altitude reference is set for the aircraft's flight director). Below 2,400 ft, with the Rad Alt active, the SAR approach modes are available. One of the SAR modes, APP1, automatically transitions the helicopter from flight below 2,400 ft to low level operations. Once initiated, the helicopter will intercept and maintain an altitude/airspeed profile (called '*the line*') and continue down to 200 ft Above Water Level (AWL) and 80 KIAS (kts Indicated Airspeed) (**Figure No. 2**), unless interrupted by the pilot to level at a higher altitude. The commanded descent rate is 500 Feet per Minute (FPM) when '*above the line'* and 200 FPM when '*on the line'* [21]. The commanded deceleration rate is 1.2 kts per second.

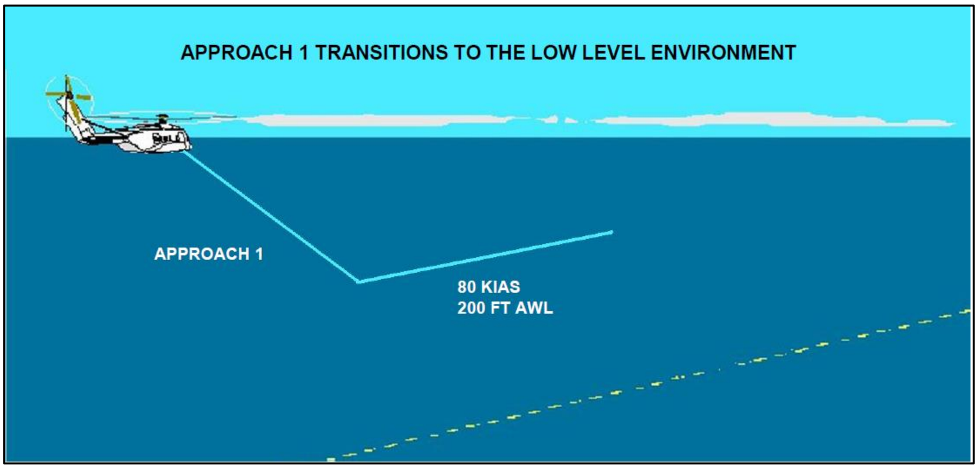

Figure No. 2: SAR Mode APP1

On reaching 200 ft, the helicopter will transition to RALT mode and will transition to Indicated Airspeed Hold (IAS) mode when it reaches 80 KIAS. APP1 is a vertical navigation mode only, which means that it controls the descent of the helicopter. During APP1, the pilot may also select a heading or FMS roll mode. If no roll or heading mode is selected, the helicopter will generally maintain its current heading. The FDR from the accident flight indicates that the Flight Crew selected APP1 during the descent (**Section 1.11.9**).

The Operator's OMA provides general instruction in relation to the use of modes:

'*Autopilot – Coupler / flight director modes*

It is standard procedure to operate the aircraft coupled, encouraging better overall management of aircraft systems, navigation and passenger comfort. It is important to involve both pilots in the process at all times to maintain a closed loop. All mode selections and de-selections shall be announced, and confirmed by the other pilot. The PF may make coupled mode selections himself or may request the PM to make selections, in particular at times of high workload. All mode selections below 500 feet at night or in IMC [Instrument Meteorological Conditions] *shall be made by the PM, on the PF's request, with the exception of selection of GA (and any other mode that may be engaged directly by buttons on the flight controls) and full disengagement of the coupler / FD. The PF may adjust modes once captured but shall call the adjustments he is making (for example, to IAS, HDG or ALT), so that the PM is aware and can monitor.*

[21] An *'on the line'* approach is initiated when the current speed and altitude match the programmed rates.

[...]
Coupler / FD management
[...]
The four steps are:

a. Select / arm (system)
b. (System) selected / armed
c. (System) captured (correct indication displayed on the FMA)
d. Checked'

PF asks PM to couple a mode	
PF	**PM**
"Select altitude"	
	"Altitude selected"
"Altitude captured"	
	"Checked"

1.6.6.5 Enhanced Ground Proximity Warning System

The Helicopter was equipped with a '*Honeywell MK XXII*' Enhanced Ground Proximity Warning System (EGPWS). The EGPWS uses system inputs, including geographic position, attitude, heading, air-speed, ground speed, glideslope, landing gear position, and engine parameters. These are used in conjunction with the internal terrain, obstacle, and airport databases, to predict potential conflicts between the helicopter's flight path and terrain or an obstacle, and provide visual and aural alerts. In addition, a graphic display, generated from the EGPWS databases of the surrounding terrain, can be displayed on an MFD.

GPS signals received by the helicopter are processed by the EGPWS computer to provide both horizontal (lateral) and vertical (altitude) position information. This position in space is then compared to a terrain database and an obstacle database contained in the EGPWS computer to produce a virtual picture which can then be displayed to aid a pilot's situational awareness. The EGPWS also uses barometric pressure, Radar Altitude and GPS altitude to derive '*geometric altitude*', using the same Mean Sea Level (MSL) reference as the terrain, obstacle and runway/helipad databases in the system.

The Helicopter Manufacturer's RFM states:

'ENHANCED GROUND PROXIMITY WARNING SYSTEM (EGPWS) The EGPWS will not provide power line warnings. Power lines are not included in the EGPWS data base. Navigation must not be predicated upon the use of EGPWS information. NOTE The Terrain and Obstacle display is intended to serve as a terrain and obstacle awareness tool only. The display and/or database may not provide the accuracy and/or fidelity on which to base routine navigation decisions and plan routes to avoid terrain or obstacles.'

The RFM also says the EGPWS is designed to decrease instances of Controlled Flight Into Terrain (CFIT) by increasing pilot situational awareness. The RFM says:

> '*The look ahead modes prevent the aircraft from running into sharply rising terrain or man made obstacles* […] *An obstacle database tells the system the location and height of known man made obstacles which are more than 100 feet high. Not all obstacles are in the database and some areas of the world have no obstacle coverage. Power lines are generally not included in the obstacle database*.'

Note: Neither the terrain at Black Rock, nor the lighthouse was contained in the EGPWS data bases at the time of the accident; **Section 1.17.11** contains further details.

EGPWS was a development from GPWS which was introduced to improve the safety of large fixed-wing aircraft. Airports have significant numbers of large fixed-wing aircraft, from different operators, routinely and frequently flying into and out of those locations. Consequently, any issue with EGPWS terrain or obstacle databases for airport approaches, which by definition have been carefully surveyed and designed, would likely be detected and reported by multiple aircraft operators, and also the airport operator, and consequently would be liable to be resolved expeditiously. The Operator was the only operator using its Route Guide, and the frequency of operations along each route is not known nor recorded.

The EGPWS can provide flight crews with a display of the surrounding terrain and obstacles contained in its databases, relative to the helicopter's position. If the EGPWS detects that the helicopter is in conflict with, or will come into conflict with, database terrain or obstacle(s), it provides a combination of annunciator lights, colour display(s) and aural alerts. This is subject to system selections as described below.

The Investigation notes that the EGPWS manufacturer's manual states '*The MK XXII is a Situational Awareness tool, and an alerting and warning device. It is not to be used for navigation of the aircraft.*'

If an alert occurs when terrain is not selected on any MFD, terrain will automatically appear on an available NAV or PFD ARC page. If no NAV or PFD ARC[22] page is selected, then the system will change one MFD to a NAV ARC page with terrain displayed.

The EGPWS uses two sets of modes to protect against CFIT: (1) Six Basic modes (1-6), that do not utilise a terrain database and, (2) look-ahead modes that require GPS position information and a terrain database. Both sets provide visual and aural alerts when terrain/obstacle clearance is not assured.

The basic modes include:

[22] **PFD ARC**: The PFD ARC display adds additional information to the PFD while still observing a portion of the compass card.

- Mode 1 - Excessive Rate of Descent. The RFM states that this mode is not used.

- Mode 2A/B - Excessive Terrain Closure Rate. This mode provides alerts when the helicopter is closing with the terrain at an excessive rate. It is not necessary for the helicopter to be descending in order to produce a Mode 2 alert, level flight (or even a climb) towards obstructing terrain can result in hazardous terrain closure rate. The Terrain Closure Rate variable is computed within the EGPWS computer by combining Radio Altitude and Vertical Speed. If the helicopter penetrates the Mode 2A alerting envelope, the aural message 'TERRAIN TERRAIN' is generated initially, and amber caution lights are illuminated. If the helicopter continues to penetrate the envelope, then the aural message 'PULL UP' is repeated continuously and the red warning lights are illuminated until the warning envelope is exited. When the Mode 2B warning envelope is penetrated, the aural message 'TERRAIN....' is repeated and the amber caution lights are illuminated until the envelope is exited.

- Mode 3 - Inadvertent Descent After Take-off. This mode provides alerts when the helicopter loses a significant amount of altitude immediately after take-off or during a missed approach. Mode 3 is enabled after take-off or go-around when the landing gear is not in the landing configuration, or when the airspeed is greater than 50 knots. If the helicopter penetrates the Mode 3 boundary, the aural message 'DON'T SINK' is generated and amber caution lights are illuminated. The visual annunciators remain active until a positive rate of climb is re-established.

- Mode 4 - Insufficient Terrain Clearance. This mode provides alerts when the helicopter descends below a pre-determined terrain clearance or floor. Mode 4 contains three sub-modes that depend upon helicopter airspeed and landing gear configuration:

    - Mode 4A - Unsafe Terrain Clearance - Gear Up. This mode is specific to flight with landing gear retracted. Above 60 KIAS, the system annunciates 'TERRAIN'; below 60 KIAS, the system annunciates 'TOO LOW GEAR'. This mode is generally active during cruise and approach when the gear is up.

    - Mode 4B - Unsafe Terrain Clearance – Gear Down. This mode is specific to flight with the landing gear extended. A 'TOO LOW TERRAIN' alert is given when radar altitude is below 100 ft for airspeeds above 120 KIAS. As airspeed reduces, the alert boundary decreases to 10 ft and 80 KIAS.

    - Mode 4C - Unsafe Terrain Clearance - At Take-off - is active during the take-off phase when airspeed is greater than 50 KIAS and the gear is up.

- Mode 5 - Glideslope Alert. This mode is enabled when all of the following are present: (1) ILS is the active navigation source; (2) the helicopter is receiving a valid glideslope signal; (3) Rad Alt is less than 1,000 ft; and (4) Landing gear is down.

- Mode 6 - Additional Alerts, including Altitude Advisories, Low Altitude, Bank Angle and Tail Strike modes. This mode provides aural callouts for descent below pre-defined altitudes and minimums and also for excessive bank angle and tail strike warnings.

1.6.6.6 Low Altitude Switch

To allow for helicopter operations that require low altitude flight, an EGPWS *'Low Altitude'* function can be enabled with a switch. The RFM states '*LOW ALT - Low altitude mode desensitizes the system to allow for low altitude VFR flight*'. This means that, for obstacles which are contained in the EGPWS databases, warning thresholds will be reduced; however, if an obstacle is not in the EGPWS databases, selecting '*LOW ALT*' will have no effect as warnings will not be generated. The EGPWS manufacturer's manual states:

> '*The pilot must maintain visual contact with all terrain and obstacles at all times when using the Low Altitude mode. The Low Altitude mode must not be engaged during IFR conditions. The 'look down' angle is reduced with 'Low Altitude' engaged. Warning time is greatly reduced. Noted exception is Offshore Platform IFR approaches.'*

The EGPWS manufacturer's manual states that the LOW ALTITUDE reduces the look ahead from 1.1 NM to 0.75 NM at 120 kts and that *'Forward airspeed will also modify the look-ahead envelope. Below 100 knots, the envelope is reduced until it is completely inhibited at 70 knots or less.'* The Operator's OMA states:

> '*The low altitude mode significantly reduces terrain warnings. The low altitude mode may only be used when intentionally operating at low level, including during an approach offshore. The low altitude mode may be used at any time in VMC* [Visual Meteorological Conditions] *but it is not to be used in IMC except when carrying out an ARA* [Airborne Radar Approach] *let-down offshore.'*

The Operator's OMB States:

> '*EGPWS low altitude mode shall not be selected when operating IMC or at night except as required when performing offshore platform IMC approach procedures or SAR operations. In these cases it shall be deselected when climbing back above MSA … LOW ALT shall not be selected when operating IMC except as required when performing offshore approach procedures or low level SAR procedures*'.

When this function is engaged:

- Mode 1 is inhibited (note: this mode is not used on the S-92A helicopter)
- Mode 2 warning boundaries are significantly reduced
- Mode 3 warnings are inhibited above 100 ft AGL
- Mode 4 warning boundaries are significantly reduced
- Mode 6 '*ALTITUDE, ALTITUDE*' callout is enabled
- Terrain Advisory look ahead distances are reduced

Note: Selection of LOW ALT for the EGPWS is the third item on the Operator's DVE Approach checklist. CVR data indicates that at 00.28 hrs the Co-pilot said '*low alt selected'* in response to a request from the Commander during the DVE checks. The Helicopter's Indicated Airspeed (KIAS) at the time of the accident was 77 kts.

1.6.6.7 Weather Radar

A '*Honeywell Primus 701A*' weather radar system was fitted. This system is a high resolution, fully stabilised, high power, digital radar, designed for high resolution weather detection and terrain mapping. The radar manufacturers' manual includes the following warning:

> *'THE SYSTEMS PERFORM ONLY THE FUNCTIONS OF WEATHER DETECTION OR MAPPING. IT SHOULD NOT BE USED OR RELIED UPON FOR PROXIMITY WARNING OR ANTI-COLLISION PROTECTION'.*

OMF stated '*Navigation must not be predicated on the use of weather radar modes.'* In OMF Section 3.18 SAR over-water DVE IMC/night let-downs one of the minimum equipment requirements was '*Radar, serviceable in approved navigation modes'*. However, when the Investigation asked the Operator to provide details of the approved radar navigation modes it was informed that there were no approved navigation modes. The Operator informed the Investigation that '*OMF has now removed reference to "approved navigation modes" and now specifies "radar set to appropriate range and mode (GMAP1 or GMAP2)"'*.

The radar can be operated in numerous configurations to display weather or terrain mapping information on the radar indicator, the MFDs, or on a combination of these displays. Stabilisation is provided for +/- 30 degrees combined pitch, roll, and tilt.

Weather is presented on the PFD ARC and NAV display format pages. The radar has a horizontal forward looking scan angle of 120 degrees or 60 degrees, which is pilot-selectable. The 120 degree sector has a normal scan rate of 12 '*looks* [sweeps] *per minute*', while the 60 degree sector scan has a faster update of 24 '*looks per minute'*.

Rotary control knobs, labelled '*RANGE*', located on both pilot DCPs, are used to select the operating range of the radar. The selection system permits range selections of 0.5, 1.0, 2.5, 5.0, 10, 25, 50, 100, 200 and 300 NM (full scale).

A rotary control is used to select the tilt angle of the antenna beam with relation to the horizon. Clockwise rotation tilts the beam upward to +15°; counter-clockwise rotation tilts the beam downward to -15°. A digital readout of the antenna tilt angle is displayed on the weather radar display.

A rotary control and push/pull switch is used to control the receiver gain. Pushing in on the GAIN[23] switch causes the system to enter the pre-set, calibrated gain mode. Calibrated gain is the normal mode used for weather avoidance. In calibrated gain, the rotary portion of the GAIN control does nothing. Pulling out on the GAIN switch causes the system to enter the variable gain mode with VAR displayed. Variable gain can be used for additional weather analysis and for ground terrain mapping. In Weather (WX) mode, variable gain can increase receiver sensitivity over the calibrated level to show very weak targets or it can be reduced below the calibrated level to eliminate weak returns.

[23] **Radar GAIN**: A measure of the sensitivity of the radar system.

In weather detection mode, storm intensity levels are displayed in four bright colours contrasted against a black background (**Figure No. 3**). Areas of very heavy rainfall will appear in magenta, heavy rainfall in red, less severe rainfall in yellow, moderate rainfall in green, and little or no rainfall in black (background). Areas of detected turbulence appear in white; the system can be configured so that the white colour blinks. Range marks and identifying numerics are provided to facilitate evaluation of storm cells.

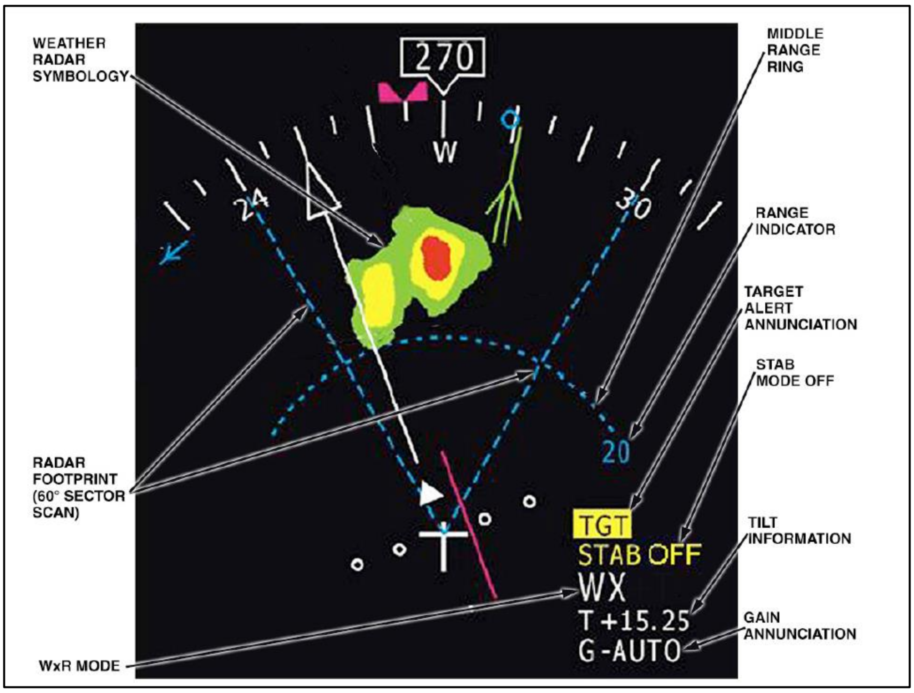

Figure No. 3: Generic Weather Radar Display (Source: *RFM*)

The terrain mapping function is selected by setting the controls to GMAP1 or GMAP2. Selection of the GMAP1 function causes system parameters to be optimised to improve resolution of small targets at short ranges or under sea clutter[24] conditions. GMAP1 provides maximum target resolution. When using the GMAP1 mode for over water terrain mapping/search, the clutter reduction (*CR) button allows use of the CR1 or CR2 modes for sea clutter reduction. For high sea-states CR1 is recommended to reduce the sea clutter returns. CR2 is recommended for use in medium sea-states. Sea clutter reduction will remain operational as long as the GMAP1 mode is being used.

Selection of GMAP2 gives a high-sensitivity terrain mapping mode; the reflected signal from various surfaces is displayed as magenta, yellow, or cyan (most to least reflective). Switching to the GMAP2 mode will turn off the clutter reduction feature.

Note: A review of both the CVR and FDR (**Section 1.11**) determined that during the approach to Black Rock, the radar sector scan was set for 120° (60° either side of the helicopter's longitudinal axis); the radar range was selected to 10 NM, and GMAP2 was also selected.

[24] **Sea clutter**: Refers to the radar signals returned from a wavy and turbulent rough sea surface. The radar returns from small targets can be obscured by the sea clutter.

1.6.6.8 Skytrac Systems ISAT-100 Flight Following System

The Helicopter was equipped with a *Skytrac Systems ISAT-100 Flight Following System* with a *Cockpit Display Unit.* The system includes the capability to transmit data via short burst data (SBD) and voice telephony via the Iridium LEO (Low Earth Orbit) satellite network. The system consists of a 12 channel parallel GPS receiver with a stated accuracy of less than 25 m. The satellite transceiver uses an operating frequency of 1616-1626.5 MHz, with a maximum power output of 5 Watts. According to the Skytrac Systems Manual, the ISAT-100 is not classified as '*equipment known to have a high potential for interference*' in accordance with FAA Policy No. ASW-2001-01[25] dated 25 April 2002.

The Skytrac Systems Manual states that the power-up time to GPS position acquisition is 48 seconds from cold, and 0.1 seconds for re-acquisition. The GPS position is transmitted to Skytrac, and can be accessed in real time through a secure, web-based portal. The use of Skytrac on EI-ICR is described in **Section 1.11.11**.

1.6.6.9 Automatically Deployable Emergency Locator Transmitter

The Helicopter was equipped with a Model 503 Automatically Deployable Emergency Locator Transmitter (ADELT), which is located on the left side of the Helicopter, between the intermediate gearbox and the ramp door (**Photo No. 5**). Further details are contained in **Appendix B**.

1.6.6.10 VHF/UHF/AM/FM Tactical Communication Transceiver

The Helicopter was fitted with a Global Wulfsberg Flexcomm II VHF/UHF/AM/FM tactical communication transceiver.

This unit allows the crew to communicate with non-aviation units and agencies. The transceiver on the accident helicopter type is located in the tail section (**Photo No. 5**).

Photo No. 5: Location of ADELT (green) and Wulfsberg transceiver (yellow)

[25]**ASW-2001-01:** '*66 FR 50246 - Policy for Certification Guidelines for Compliance to the Requirements for Electro-Magnetic Compatibility (EMC) Testing for ''Equipment Known to Have a High Potential for Interference'' When Installed on Rotorcraft With Electronic Controls That Provide Critical Functions*'.

1.6.6.11 Moving Map Display

The Helicopter was equipped with a Euroavionics Euronav 5 moving map display which had a number of maps/charts available for selection. The Euroavionics digital moving map provides the following functions:

- **Maps**: The full colour Euronav System features selectable map illustrations. Either vector[26] or scanned raster[27] maps can be displayed. All map material can be displayed in North-Up or Track-Up modes with the helicopter position placed on the bottom or centre of the screen. The map range can be adjusted by means of the on-side range control. Map labels move with the map but remain upright to enable easy reading in Track-Up mode.

- **Terrain Maps**: Raster maps based on Digital Terrain Elevation Data (DTED) or other digital terrain data.

- **Air Databases**: The system also uses proprietary databases showing airspace structures, topographical airport information like runways, available frequencies, NDBs, VORs and restricted airspace.

- **Flight Analysis by Flight Recording**: Flight recording of flight track and altitude profile can be reviewed or analysed after landing. Events during flight are displayed as a flag in the map. A previous flight track can be used for guidance.

- **User Database**: Four user databases can be used to store other user-defined map data.

The RFM states '*Do not use the EuroNav Digital Map system for primary navigation*.'

OMB states:

> '[…] *Where applicable EuroNav may be selected on one of the inboard MFDs. Select a suitable range scale to enhance threat and error management* […] *The EuroNav V is a moving map display system which displays on the cockpit MFDs. It provides task management capabilities which allow the pilot and co-pilot to operate independently enabling each to view maps and perform tasks as required*.'

Euronav was not available in the Flight Simulation Training Device (FSTD) which the Operator's crews used. The Operator informed the Investigation that the normal cockpit configuration was:

- PF to have PFD display mode selected, with lower half of screen in ARC with EGPWS displayed, TCAS active and with Flight Plan overlaid or with lower half of screen displaying the compass rose or with lower half of screen displaying radar in ARC Mode.

[26] **Vector Graphics**: Images comprising of lines and curves.
[27] **Raster Graphics**: Images comprising of a dot matrix structure.

- PF to set his inboard MFD to either Euronav or EGPWS in full mode.

- PM to have PFD display mode selected, with lower half of screen in ARC with EGPWS displayed, TCAS active and with Flight Plan overlaid or with lower half of screen displaying the compass rose.

- PM to set his inboard MFD to Radar in ARC Mode.

The Operator informed the Investigation that in the Simulator, which didn't have Euronav available, the cockpit screen configuration would be:

- PF to have PFD display mode selected, with lower half of screen in ARC with EGPWS displayed, TCAS active and with Flight Plan overlaid or with lower half of screen displaying the compass rose or with lower half of screen displaying radar in ARC Mode.

- PF to set his inboard MFD to EGPWS in full mode.

The Operator informed the Investigation it believed that crews are aware of all the possible configurations for both the helicopter and the simulator, and would select the most appropriate combination to give optimum configuration for the flight regime in which they were operating.

Some pilots reported to the Investigation that in the simulator, because Euronav was unavailable, they operated with EGPWS on both the lower half of their PFD and their inboard MFD.

OMF states, for Night over land operations:

> '[…] *The Euronav alone should not be used for primary navigation as it provides insufficient detail and is not kept up-to-date* […] *Using only the FMS / Euronav will get the aircraft in the general vicinity of the landing site, however use of the appropriate charts with careful route selection and study is required to positively identify the landing site* […] *Secondary navigation equipment: Independent GPS position (*[…] *cockpit moving map* […]*)*'.

During a Review Flight (**Section 1.16.1**), which the Investigation undertook on one of the Operator's helicopters, it was noted that the moving map imagery did not extend as far as Black Rock and instead, the BLKMO waypoint was shown against a white, featureless, chart margin (**Photo No. 6**).

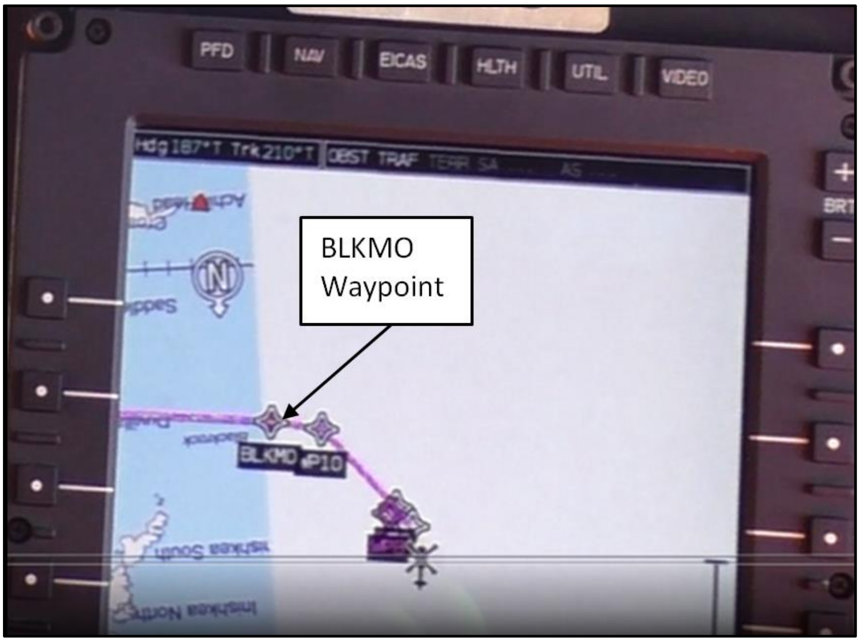

Photo No. 6: Euronav imagery from Investigation's Review Flight

In relation to the Euronav imagery, the Investigation asked certain questions of the Operator and received answers as follows:

- What was its approval process for the map data loaded onto the Euronav? The Operator responded saying that there was no approval process. The Operator explained that in mid-2015 new charts were uploaded after the Waterford SAR Base raised an issue with the paper charts and the Euronav Charts being out of sync; this was the first time the Ireland operation was involved in updating charts after the initial S-92A rollout. The Operator said that after the update it had an '*in date*' poor quality 1:500,000 and an '*out of date*' good quality 1:250,000 chart in the system. The imagery the Investigation observed on its Review Flight appears to have been from the 1:250,000 Aeronautical Chart, and did not extend as far west as Black Rock.
- How were the charts that were loaded on the Euronav at the time of the accident specified? The Operator said that its supplier could not get the Irish Charts digitally, and so had to scan them in. The Operator presumed that the entire chart area would have been scanned, as had been the case with the earlier chart versions.
- Why was it deemed appropriate to have aeronautical charts loaded in the system which stopped short of Black Rock? The Operator said that it wasn't deemed appropriate, that it had engaged with its supplier and that the Operator's efforts were focussed on trying to improve the scan quality as the map was unusable.
- Was any guidance provided to crews about the use of Euronav when operating outside of the areas provided in the map imagery? The Operator said that no guidance had been provided, but noted that Euronav was not to be used for primary navigation.

1.6.6.12 Wescam MX-15i Surveillance System

The subject Helicopter was fitted with a MX-15i (EO/IR) Surveillance System. The IR system is commonly referred to by the Operator's personnel as the Forward Looking Infrared (FLIR) system.

The MX-15i System consists of the following main components:

- Turret
- Hand Controller
- GPS

The turret provides hardware and software functions that allow crew members to operate the MX-15i System using the Hand Controller. External communication interfaces can be utilised to control operation remotely through the helicopter's computer systems.

The turret contains a video-switching matrix that manages output to external display monitors, digital video recorders (DVR) and other associated video equipment. Graphical overlays on top of the displayed video provide the primary method for viewing system status information. Infrequently used status information and other control parameters are viewed through user menus.

OMF states:

> *'FLIR works by highlighting the temperature differential between a target and its surrounding environment. It is particularly effective on cold clear nights where there is a clear temperature differential between land and sea, and targets such as vessels and people, and the surrounding environment. The FLIR picture is dependent on the thermal output of the target, target size, aircraft height and speed. FLIR effectiveness is adversely affected by rough sea conditions, fog, mist and rain but can prove beneficial in hazy conditions. In particular the following factors are relevant:*
>
> ***Diurnal effect:***
>
> *Objects warm up during the day as they absorb solar radiation and at night they release this radiation back into space. All objects have a different rate of absorption and release. Therefore, twice a day targets can merge into the background or become poorly defined as target and background temperatures merge.*
>
> ***Mist/light precipitation:***
>
> *In light rain and mist conditions, targets without their own source of thermal output begin to wash out and become less well defined on the screen, thus reducing detection range and clarity. Providing the search FLIR camera angles are adhered to, no adjustment in sweep widths is necessary.*

Heavy snow and rain:

In these conditions, the FLIR performance degrades significantly as the weather conditions worsen to a point where a 'visual only' search should be considered. Outside of heavy rain and snow showers however, the FLIR usually works well.

Industrial haze:

In conditions where the visibility is reduced by industrial haze, suspended dust particles and such, the FLIR detection range will be far in excess of the visual detection range.

Generally FLIR performance at night is better than by day. At night there is a greater difference between the target and the background temperature. This produces a more clearly defined image on the monitor screen.

FLIR should not be used in isolation for judgement of distances.

FLIR may be used to search for vessels, life-rafts, persons in the water, or missing persons overland. It can also be used to assist in navigation and confirm terrain or targets with the radar. It is a valuable tool that depends on effective communication and CRM between the operator and the rest of the crew.'

1.6.7 Automatic Identification System

The Helicopter was equipped with a '*Saab Airborne R4A*' AIS. The AIS System included a signal converter located above the rear fuselage, an antenna below the fuselage on the left-hand side, and a GPS antenna fitted approximately half way up the tail-boom. AIS is a transponder surveillance system that is operated in Ireland by the IRCG on foot of *'Directive 2002/59/EC of the European Parliament and of the Council of 27 June 2002 establishing a Community vessel traffic monitoring and information system'*.

In general terms, AIS messages are transmitted on two channels in the VHF[28] marine band (AIS 1 [Channel 87B, 161.975 MHz] and AIS 2 [Channel 88B, 162.025 MHz]). In order to allow many types of AIS equipment to communicate together, each unit can only transmit its message at a predetermined time, so that it is not transmitting at the same moment on the same channel as another unit.

Each channel is divided into 2,250 equal time slots that repeat every minute. The AIS messages are designed to fit into between one and three slots depending on the type of information being sent.

In Ireland, the system comprises AIS base stations located at sixteen radio sites around the coast on elevated ground. The data from these base stations feeds into a number of servers, which then deliver data to the IRCG control centres. Various agencies such as the Health Service Executive (HSE) are also provided with this data.

[28] **VHF:** Very High Frequency.

The Operator's helicopters transmit an AIS SAR message every 10 seconds. This message contains details of the helicopter's unique identifier, speed and course over ground, latitude, longitude and altitude.

Relevant AIS data for R118 and R116 were provided to the Investigation by the IRCG (**Section 1.11.12**). The final AIS positions of R116 were used to direct the initial emergency response and to inform the Investigation.

Further technical information relating to AIS is presented as **Appendix C** to this Report.

1.6.8 Toughbook Computer

In addition to the Helicopter's avionics suite, a stand-alone ruggedized Toughbook computer, loaded with specific application software and map data, was located at the SAR operator's console. A detailed description of the Toughbook functionality can be found at **Appendix D**.

The Toughbook was pre-loaded with the following maps:

- 1:50,000 ordnance survey maps (Island of Ireland) (elevations in metres)
- All marine charts (Ireland and UK) (elevations in metres)
- IAA 1:250,000 and 1:500,000 aeronautical charts (elevations in feet)
- CAA 1:250,000 and 1:500,000 aeronautical charts (UK) (elevations in feet)
- Road atlas and regional maps (Ireland and UK)

The 1:50,000 imagery loaded on the Toughbook did not show any terrain or lighthouse at the location of Black Rock; instead, it showed plain blue, indicating open water. The Operator stated that the 1:50,000 ordnance survey chart data was supplied to the Operator, via the IRCG, by Ordnance Survey Ireland (OSI) in September 2012 and was subsequently configured for use on the Toughbook by one of the Operator's suppliers. The Operator provided a copy of the original imagery it had received and the Investigation noted that it did not show anything at the location of Black Rock. Furthermore, the eastern section, which was approximately half of the image, contained National Grid lines, whereas the western portion did not.

The Investigation asked OSI to explain what imagery had been requested and what it had supplied. The OSI informed the Investigation that:

> *'In January 2012, OSI received an email that clearly described a request for use of the OSI 1:50,000 Discovery series mapping in inland or in mountainous areas. The email mentions the words 'inland' twice, 'mountainous' areas three times.*
>
> *The email says that the location of an emergency is often passed on by the original informant using a grid reference or local place names. The request specifically said that the intention was to be able to view the Discovery series maps.*

The need to use 1:50,000 Discovery series mapping in this way, for finding inland locations makes sense to OSI, as anyone in trouble would most probably have a 1:50,000 Discovery series paper map.

The OSI 1:50,000 Discovery series mapping is not meant to be used for aeronautical navigation and any such use would be incorrect. A very obvious example of this is that the OSI 1:50,000 Discovery series mapping references height information in meters above mean sea level (not feet above mean sea level).

Additionally, it is critical to note, that in the area of interest the requested OSI 1:50,000 Discovery series map does not extend westwards beyond the Irish Grid Easting co-ordinate 52,000. The western edge of the OSI 1:50,000 Discovery topographic map detail in the area in question is approximately 4 kilometres east of Black Rock Island.

OSI is aware that Black Rock Island was a waypoint on the Operator's Route Guide. OSI does not know the origin of this information for Black Rock Island, including the origin of its height value.

OSI can confirm that after the incident it was tasked by the Irish Aviation Authority to confirm the co-ordinates of the lighthouse position on Black Rock Island, the altitude of the base of the lighthouse, the altitude of the top of the lighthouse, the height of the lighthouse structure and the ground elevation of the highest nearby point. OSI can confirm that the latest IAA Aeronautical Charts (published May 2019), at scales of 1:500,000 and 1:250,000, now reference a height of 262 feet for Black Rock Island. The previous versions of these Charts referenced a height of 282 feet for Black Rock Island (this previous height was not supplied by OSI).

OSI has no knowledge of how its data was treated for representation in the computer application mentioned. Nor do OSI know what other data might also have been represented in the system and how that integration process was completed or how that data was interpreted.

OSI understood that the 1:50,000 Discovery map was supplied to fulfil a specific request for use in inland areas. The edge of the topographic map detail was clearly recognisable as there was no gird index further west of Irish Grid Easting co-ordinate 52,000, which are the same as the bounds of the topographic map detail in the digital map. Therefore, the edge of the paper map and the digital tile were the same, approximately 4 kilometres east of Black Rock Island.

Despite the supply of paper maps in 2007, 2017 and digital maps in 2012, no clarifications were sought from OSI about the fitness for purpose of the intended use of the maps, the operational scale of the maps or any other matter.

OSI can assist with producing customised mapping for customer needs if requested to do so, and has previously done so for another aviation application.'

The Investigation asked the Operator what was the approval process for the map data loaded onto the Toughbook, and the Operator said that there had been no formalised Flight Operations Department approval process for map data loaded onto the Toughbook, but that procedures were being developed. The Investigation asked the Operator what processes were in place to ensure that the data obtained from OSI, via IRCG, was adequate for the intended purpose. The Operator said that as the data originated from the State Agency responsible for the official, definitive surveying and topographic mapping of the Republic of Ireland, it was not considered necessary to systematically check the supplied map image files for accuracy. The Operator said that visually, the mapped terrain on the digitised maps appeared to be identical to the paper maps carried, and that prior to the accident there had been no reports of inaccuracies in the digitised maps.

The Operator went on to explain that it did carry out (in December 2012) a three-part check of the accuracy of the configuration and calibration process – which had been completed (between October 2012 and December 2012) by a 3rd party vendor. This involved checking individual test waypoints corresponding to grid-line intersections, for various locations throughout Ireland; cross-checking location and feature outlines with other aeronautical and marine mapping data on the Toughbook; and, flight testing to ensure that the helicopter's real-time GPS location as displayed on the map was accurate. The Operator stated that these checks were not to review the underlying information provided by the OSI, but rather to ensure that the Operator's waypoints over-laid accurately with the maps supplied. Furthermore, the Operator informed the Investigation that it had made no attempt to mislead OSI or withhold information about what the data was to be used for.

In relation to OSI maps, the Operator subsequently informed the Investigation that:

> '*while the maps were not intended for aeronautical navigation they could be used for situational awareness. For example, a tasking might involve a grid reference provided by a Mountain Rescue team or a member of the public, as opposed to a Lat/Long. The TC could convert the grid reference to an approximate Lat/Long such that the pilots could enter into the FMS. Alternatively the IRCG may task an aircraft to a townland or headland with a "local" name that might not be detailed on the 1:250000 or 1:500000 maps and so again the TC could get out the appropriate 1:50000 map & try to identify the actual area. Copies of the maps are held in each Ops room and on-board the aircraft*.'

Furthermore, the Operator also informed the Investigation that:

> '*procedures to formally record the uploading of subsequent versions of maps have been developed and are now contained in the Operator's OMC* […] *The processes developed do not extend to checking the underlying content of the maps as they are uploaded, which are provided by a State agency with expertise in this area. That said, crews have always been, and continue to be, in a position to report errors identified in the maps provided.*'

1.7 Meteorological Information

1.7.1 Introduction

In order to establish a general picture of the meteorological conditions prevailing at the time of the occurrence, the Investigation obtained meteorological data from several sources, including Met Éireann – the Irish National Meteorological Aviation Services Division (ASD), and local eye-witnesses.

1.7.2 Met Éireann

ASD is tasked with providing a wide range of meteorological facilities to civil, military and general aviation to meet the State's obligation as an ICAO contracting State. ASD comprises the Central Aviation Office at Shannon Airport, together with the meteorological offices at Dublin Airport, Cork Airport and Casement Aerodrome. It issues Terminal Area Forecasts (TAFs) and Local Area Forecasts (LAF) for the various airports and smaller airfields in the country, as well as local weather warnings (SIGMETS) for the Irish Flight Information Region (FIR), and en route documentation and briefings. The following weather information was provided to the Investigation.

1.7.2.1 General Situation

> *'The general weather situation was warm sector conditions across Ireland with a very weak cold front orientated northeast - southwest and situated just to the northwest of the country moving south-eastwards through relatively high pressure. The surface wind was southwest 20 kt, gusting 30-35 kt, with visibility between 2-3 km in mist and drizzle, overcast with a cloud base of 300 - 400 ft. Surface temperature was 10 deg. C.'*

Reports indicated that the frontal surface passed through the Belmullet area at circa 01.00 - 01.30 hrs.

The Significant Weather Chart issued by Met Éireann at 18.13 hrs UTC on 13 March 2017 and valid for 00.00 hrs UTC 14 March 2017 is reproduced in **Appendix E.**

1.7.2.2 Belmullet Automatic

The Belmullet automatic synoptic weather station, which is operated and utilised by Met Éireann, is located approximately 13 km to the north of Blacksod and approximately 27 km to the northeast of Black Rock; it is 9 m (30 ft) above mean sea level (AMSL). A graphical representation of the weather conditions at Belmullet between 00.00 hrs and 01.00 hrs on 14 March 2017 is presented at **Appendix F, Figure No. F1**. A general interpretation of the recorded parameters identified the following: overcast skies, with a cloud base of between 300 and 400 ft, a visibility of between 2,000 and 4,000 m (2 km-4 km) and continuous light precipitation.

1.7.2.3 Hourly Weather Conditions

A summary of the hourly weather conditions experienced in the occurrence area (18 km west of Blacksod) for the period 23.00 hrs on 13 March 2017 until 04.00 hrs on the 14 March 2017 is presented at **Appendix F**, **Table No. F1**.

1.7.2.4 Aftercast

An aftercast, which was prepared by Met Éireann, for the occurrence site area centred at Black Rock for 00.45 hrs on the 14 March 2017, is presented in **Table No. 18**.

Meteorological Situation:	Warm sector conditions across Ireland. A cold front orientated northeast-southwest and situated just to the northwest of the country was moving south-eastwards
Wind (surface):	Southwest 20 kt, gusting 30-35 kt
Wind (2000 ft):	West-southwest 35 kt
Wind (surface-300 ft):	The existing stable warm sector conditions and data received from the Castor Bay sounding suggest that there was a relatively uniform flow, in terms of direction and wind speed, in the vertical between the surface and 300 ft
Visibility:	2-3 km
Weather:	Mist and drizzle
Cloud:	Overcast with a cloud base of 300 - 400 ft
Surface Temp/Dew Pt:	10/9 deg. C
MSL Pressure:	1025 hectopascals (hPa)
Freezing Level:	8,000 ft

Table No. 18: Aftercast for occurrence site area 00.45 hrs on the 14 March 2017

1.7.2.5 Sea Area Forecast

A Sea Area Forecast for Irish Coastal Waters was issued by Met Éireann at 18.00 hrs on 13 March 2017, and is presented at **Appendix F**, **Table No. F2**.

1.7.2.6 Forecast for Search/Rescue Area

On the evening of the 13 March 2017, a forecast was issued by Met Éireann at 22.34 hrs, for a position west of the intended SAR location for R118 and is presented at **Appendix F**, **Table No. F3 - Forecast No. 1**.

A second forecast was issued by Met Éireann 02.28 hrs on 14 March 2017 for the Blacksod Bay area and is presented at **Appendix F**, **Table No. F3 - Forecast No. 2**.

1.7.3 Local Witnesses – Weather Observations

On the evening of the 13/14 March 2017, two attendants were at Blacksod Lighthouse to provide fuel, local communications and local weather updates for both helicopters (R118 and R116). As was normal practice, when the weather was inclement, an attendant would drive to a local viewing point known as '*Deirbhiles Twist*' to make a weather observation for the pending arrival of a helicopter. This viewing point is located approximately one mile west of Blacksod Lighthouse and is at a height of approximately 200 ft AMSL. A second hill, known as '*Termon Hill*', is located slightly north of the viewing point at a height of approximately 300 ft AMSL and is used as a visual reference to estimate cloud base.

Prior to the arrival of R116, one of the attendants drove to the viewing point at 00.05 hrs to check the prevailing weather conditions (**Table No. 19** - Observation No. 1).

When R116 did not arrive as expected, an attendant went to the viewing point to see if he could see the approaching R116 and also checked the prevailing weather conditions (**Table No. 19** - Observation No. 2).

Information	Weather Observation No. 1	Weather Observation No. 2
Location	Viewing point	Viewing point
Date/Time	14 March 2017 at 00.05 hrs	14 March 2017 at 01.15 hrs
Wind	WSW 25 - 30 kt	WSW 25 - 30 kt
Visibility	Horizontal 3 - 5 miles (5-8 km)	20 metres
Weather	Intermittent light rain	Intermittent light rain
Cloud base	400 - 500 ft ASL	200 ft ASL

Table No. 19: Visual weather observations, before and after the accident

The RNLI Achill Lifeboat launched at 01.30 hrs in response to a MAYDAY alert from MRSC Malin. The lifeboat crew informed the Investigation that at time of launch, visibility was particularly poor and forced the lifeboat to proceed with caution, at a low speed. Poor visibility persisted until the lifeboat cleared the western tip of Achill Island, at Achill Head.

1.7.4 Airborne Weather Transmissions

A number of weather report transmissions were received by R116 during its transit to the west coast, which were recorded on the CVR. Extracts of relevant transmissions are presented at **Table No. 20**.

Time	Source	Transmission	Remarks
23.11 hrs	R118 to R116	[…] *conditions at the pad are fine eh eh kind of some low cloud eh approximately five hundred feet eh up to the north while we were inbound through Broadhaven Bay over*	R118 had just landed at Blacksod and was taking on fuel.

Time	Source	Transmission	Remarks
00.08 hrs	lighthouse Attendant to R116	[…] *indications of between three four five hundred (feet here) it's good enough to come in* […]	lighthouse Attendant had driven up the hill to the reference point
00.10 hrs	lighthouse Attendant to R116	[…] *the wind is west-south-west, west-south-west, twenty five to thirty three knots, visibility at sea level here with me is two miles at the minute* […]	Following a request from R116
00.16 hrs	Shannon ATC to R116	[…] *midnight to zero nine hundred in the …morning the wind is two twenty at thirteen knots the visibility will be ten plus the cloud is broken eighteen hundred feet becoming between midnight and zero two hundred in the morning broken twelve hundred and temporarily between after zero two hundred three thousand metres in mist and light rain and drizzle broken seven hundred becoming between zero two hundred and zero five hundred two fifty at thirteen knots broken at two thousand* […]	Sligo TAF
00.17 hrs	Shannon ATC to R116	[…] *the wind is surface wind two two zero degrees one six knots visibility is ten plus cloud overcast one thousand eight hundred feet QNH is one zero two five hectopascal* […]	Shannon ATC relayed the latest actual weather report for Sligo
00.18 hrs	Shannon ATC to R116	[…] *Dublin met report is on the hour midnight eh two forty at sixteen knots ten plus few seventeen hundred feet broken twenty five hundred feet temperature twelve dew point eight QNH setting is one zero two eight hectopascals no sig* […]	Following request from R116 to Shannon ATC

Table No. 20: Extract of weather report transmissions

1.8 Aids to Navigation

1.8.1.1 General

There were no ground aids applicable to the navigation of the helicopter. All navigation was conducted using the AFCS, AHRS, FMS, and on-board documentation.

Information provided by the Operator regarding routes to landing sites and transit routes were contained in the on-board FMS database, and a hard-copy in a display book, consisting of transparent, A4-sized plastic pockets. The document is titled '*FMS Route Guide*', but was commonly referred to by flight crew as the '*Low Level Route Guide'* or simply the '*Route Guide'*. Pilots can also input ad-hoc routes based on selected waypoints and the needs of a specific flight. The Aeronautical Charts required to be carried are described in **Section 1.18.1**.

1.8.2 FMS Route Guide

The (FMS) Route Guide is one of what was referred to by flight crew as '*the three books*'. The Investigation was informed that '*the three books*' referred to the (FMS) Route Guide, the Landing Site Directory (LSD) and the RNAV (Area Navigation) Waypoint Listing.

Upon request, the Operator provided the Investigation with a copy of the '*Route Guide'* and '*Landing Site Directory'* which were extant on the night of the accident. The Investigation requested that these be provided in the same format as they would have been presented to helicopter crews at the time of the accident. They were provided in a ring binder, and in the case of the Route Guide, each route spanned two consecutive, non-facing, A4-sized pages, the first page being the chart and the second being a page of associated text. The Investigation understands that in EI-ICR, each route was most likely presented on two facing pages, in a transparent pocket binder. The Route Guide used both landscape and portrait layouts; all information tables were provided in portrait format, whereas the majority of route images were in landscape. The Investigation notes that the Route Guide text was in Times New Roman font, whereas the Landing Site Directory text was in Calibri font.

Correspondence indicates that on 10 May 2013, during a major revision of the Route Guide layout at the time of the S-92A introduction, one of the Operator's pilots who was invited to offer an opinion on a proposed Route Guide format, suggested/asked '*Would it be possible to arrange the paste such that each route spans a 'double page spread' Inside the file? This would involve all maps being on even-numbered pages with the text appearing on the following odd-numbered page*'. It is not known in which specific order the pages of the APBSS route were presented to the accident Flight Crew.

On the copy of the Route Guide provided to the Investigation, each route comprised a one-page image showing an overlay of the route on a segment of an IAA Aeronautical Chart. Another portrait-oriented page contained additional information about the route. The scaling of the route images was not standardised; each scanned image appeared to have been enlarged as much as possible. It was not apparent from any of the routes reviewed by the Investigation which particular version of IAA chart was used as the basis for each route.

The information page for the route was laid out as a series of tables titled: Navigational Plan; Hazards/Obstacles; Coastal NDBs/lighthouses; Comms; Latitude and Longitude.

All versions of the aeronautical charts issued by the IAA contained information panels which indicated that the charts in question were for use in VFR conditions only. Examples of this wording included '*Chart users are requested to refer any comments on the portrayal or content of aeronautical and topographical information to the VFR Charts* [...] *Email: vfrcharts* [...] *Users should at all times adhere to Visual Flight Rules and the relevant Rules of the Air*'. Route guides did not include this cautionary text, or the legend from the IAA charts on which they were based. On the IAA's aeronautical charts, lighthouses were identified by placing a red dot of fixed diameter at the location, and placing the elevation in black, italic numerals adjacent to the red dot. The Investigation is aware that earlier versions of these IAA charts (and the latest versions) included a text entry adjacent to each lighthouse which provided the lighthouse's flashing pattern; no such text entry adjacent to each lighthouse was present on the pictorial representation of the route. The tabulated text section of the Route Guide did contain a reference to lighthouse flashing patterns.

Three of the 29 routes (APBSS, APBSN and LOWCAST) started close to a high obstacle. Two of the routes to Blacksod, APBSS (**Figure No. 4** and **Figure No. 5**) and APBSN ('*Blacksod North*'), started at a red dot, adjacent to which were the numerals '*282*'. The word '*Blackrock*' appeared to the right of the red dot. '*LOWCAST*' ('*Bull lighthouse to Castletownbere Refuel*') started at Bull Rock a 272 ft lighthouse which the Hazards/Obstacles table described as '*Bull Island 336*'. Blacksod and Castletownbere are both refuelling sites used by the Operator's helicopters. The Investigation notes that the title '*Route LOWCAST* (*Bull lighthouse to Castletownbere Refuel)*' identified that it started at a lighthouse, whereas APBSS's title, '*Route APBSS* (*Blacksod South) Route*' did not identify that it started at a lighthouse. These three routes (APBSS, APBSN and LOWCAST) were the only three routes which included on the route chart the text '*LEG*' followed by the leg number (e.g. Leg 1/7, Leg 2/6, Leg 4, etc.).

The Investigation notes that routes could, and did, cross terrain and obstacles e.g. '*Route SGLOWBS (Sligo to Blacksod)'* crossed the Glash Island Lighthouse (chart height 89 ft, tabulated obstacle height 100').

The Operator informed the Investigation that its routes '*are VFR routes, not IFR*.' The Investigation asked the Operator what this statement was based on and how this information was conveyed to crews. The Operator responded saying that it has always been the case and that it had always trained its crews to understand this.

On the issue of training of crews to use routes from the Low Level Route Guide, the Investigation understands that prior to the accident the routes were not available in the simulator used by the Operator. The Investigation was informed that Flight Simulation Training involved a Line Oriented Flight Training ('*LOFT*') style mission whereby crew were required to construct a temporary route and navigate to a simulated casualty. A route from the Low Level Route Guide was typically flown during a combined HEMS and SAR competence check flight. The Investigation was informed by individual pilots that because the routes were at pilots' home bases, they were not briefed in detail however, the Operator stated that '*Routes were briefed and line checks completed as part of all competence check flights*'.

The Operator informed the Investigation that:

> '*Since the introduction of the S92 in 2012, every 6 months all pilots have received 8 hours simulator training. 2 of these 8 hours are dedicated to a real time LOFT SAR mission at night in DVE conditions. Since the Accident, the LOFT mission profile was changed; one LOFT mission profile is specifically "route" related, the other is open water related but with emphasis on low level malfunction handling. Every simulator session is preceded by four hours of briefings including TKI & operational briefings.*'

The Investigation found that there was: no formal procedure or training laid down by the Operator to tell its crews how to use the Route Guide; no design standard for routes; no formal, standardised training/checking of route briefing; and, that the Operator did not have a SAR standards pilot who would visit bases to interact with operational crews, promoting best practice and providing feedback to management on matters of concern which were identified. The Operator informed the Investigation that there was '*no regulatory or contractual requirement for the Operator to have a SAR standards pilot function and that there is no regulatory or contractual basis against which such a role could be assessed*.'

In this regard, the Investigation notes that the Operator's parent company is a participant in an international helicopter industry safety initiative called HeliOffshore which is '*the global, safety-focused association for the offshore helicopter industry*.**'** One of the initiatives which this organisation has promoted is the Line Operations Safety Audits (LOSA). Regarding LOSA, ICAO Doc 9803 states '*LOSA uses expert and highly trained observers to collect data about flight crew behaviour and situational factors on "normal" flights.*' One of the Operator's parent company personnel, during an interview in a HeliOffshore LOSA promotional video, noted '*If they fly with a trainer, whether in the aircraft or in the simulator, they know they're being watched, they know they're being examined and so they are putting more effort into making sure they do things right*.'

Another operator, contributing to the same video, noted '[LOSA is] *done totally independently outside of the training function or management function, so the benefit of that is we don't see angel like behavior that you'd get maybe in the simulator or when you have a training or management function present. It's very much just a case of pilots monitoring other pilots to see what's working and what's not working.*'

The Investigation notes that in June 2019, an industry periodical website quoted a senior safety manager with the Operator's parent company as saying that '*LOSA provides a chance to observe crews in a natural and relaxed state to better understand threats and errors in a real environment, so is much more than a checklist or audit*', and that LOSA will move to Ireland in 2020.

The particular route in use on the night, '*APBSS*', incorporated a section called '*General Comments*'. Only four of the 29 routes had a '*General Comments*' section. Two of the routes, which had a '*General Comments*' section, were designated '*Route LOWDUB1 (Dublin Low Level Route 1)*' and '*Route LOWDUB2 (Dublin Low Level Route 2)*'. For each of these Dublin routes, the '*General Comments*' stated '*Over water legs are to be flown at 500'*. The Operator informed the Investigation that, although not explained in the Route Guide, the purpose of 500 ft restriction on these overwater legs was for ATC considerations and not related to obstacle clearance. LOWDUB1's '*Navigational Plan*' table listed terrain of 100 ft for Leg 1 and 50 ft for Leg 2. The '*Hazards/Obstacles*' table contained a 1,000 ft entry for Legs 1 and 2; the 1,000 ft hazard/obstacle was approximately 0.5 NM south of the waypoint where Leg 2, an overland leg, joined Leg 3, an overwater leg, which crews were instructed to fly at 500 ft. The Operator informed the Investigation that '*This entry identifies a hazard (in this case a populated area) which is proximate but not on the route over which crews should not fly below 1000 ft*.' The Investigation notes the Operator's comment; however, what the Operator described was not clear to the Investigation from the Route Guide as presented.

The first page of the Route Guide was a Route Index under the Heading '*FMS Route Guide*'. It listed the number, designator and name for each of the routes. For example, Route 1, designated '*APBSS*', had the title '*Blacksod South*'. Of the 29 routes, 25 of the designators incorporate the letters '*LOW*' e.g. '*Route SGLOWBS (Sligo to Blacksod)*', '*Route LOWCARL (Carlingford Lough)*', '*Route LOWDUB1 (Dublin Low Level Route 1)*'. **Note:** LOWDUB1 is described as '*Dublin LL Route 1*' in the FMS Route Guide index page.

The second page of the Route Guide stated:

> '*The following contains route information copied from S61 RNAV information/file. It has been updated for FMS compatibility. It is a work in progress and should be used with the necessary caution until all routes/waypoints are proven.*
>
> *Caution all waypoints are set up as *overfly**
>
> *All routes have new 5 to 8 character designators but should make sense to you. Again it is a work in progress so if you have any comments/suggestions, please revert.'*

In the FMS Index, three routes were available to approach/depart the Blacksod Refuel site: '*Route 1 APBSS (Blacksod South)*', '*Route 2 APBSN (Blacksod North)*' and '*Route 4 SGLOWBS (Sligo to Blacksod)*'.

The Flight Crew's plan was to use Route 1 (APBSS) and, with reference to the Helicopter's FMS Route Guide Index, entered the Route '*APBSS*' into the Helicopter's FMS for the arrival route into Blacksod.

None of the routes in the Route Guide included information about the vertical profile to be flown when following a route. Some routes did include suggested minimum altitudes; for example, the three Inishbofin routes each included, in the '*Comms*' table, the text '*Suggest 500' minimum altitude for approach*'.

The Investigation noted that in conversation with many of the Operator's personnel the term '*Low Level Route Guide'* was used to refer to the FMS Route Guide. Furthermore, the term '*Low Level Route'*, and the abbreviations '*LLR'* and '*LL*', appear often in the headings and bodies of email correspondence about the Route Guide, and also in Base Flight Safety Meeting (BFSM) minutes (**Section 1.17.4**).

When questioned as to why they called it '*Low Level*', the consensus view was that that was what it was always called. The Investigation asked what did the term '*Low Level'* mean to them as SAR operators; several indicated that 200 ft would be low level and a few indicated that 50 ft would be low level. The Investigation did not find any guidance to inform crews about the definition of the term '*Low Level'* in respect of the Route Guide.

Email threads amongst Operator's personnel, from the time of the S-92A introduction into service, said that the S-92A FMS flew routes very differently to the S-61N, particularly when tight turns were involved. The S-92A FMS incorporated a feature to designate a waypoint as '*overfly*', also termed '*flyover*'. The UNS1 FMS manufacturer's manual states '*A flyover waypoint is a waypoint which will cause the navigation computer to delay making an automatic leg change until the aircraft is directly over the waypoint.'. 'Smart Turn*', was the Operator's term for an automatic leg change which would occur if '**overfly**' was de-selected for a particular route waypoint. The UNS1 FMS manufacturer's manual states that '*Automatic leg changes occur before the TO* [to] *waypoint at a distance based upon groundspeed, leg change magnitude, and roll steering bank limit for the present altitude. The maximum distance before the waypoint at which the leg change will occur is 12 NM'.*

The email threads said that all waypoints were designated overfly and would remain so to avoid confusion, with the onus on crews to change them to smart turn if and as required. Emails noted that FMS routes were used in conjunction with EGPWS, Radar and Euronav to assist navigation and advised caution in the use of overfly/smart turn, as such selections in conjunction with wind direction and strength would alter the helicopter's track over the ground.

An email thread in 2014 regarding a wind turbine, which was a new hazard for one of the low level Dublin routes, revealed a reticence to add a waypoint for the wind turbine to the FMS waypoint database, because it might be flown towards using the '*Direct To*' (DTO) FMS function. However, the email thread said that it was important that local [Dublin] pilots were aware of the wind turbine and it was suggested that it should become part of the base brief for visiting crews. These emails also said that three waypoints had earlier been added to the FMS waypoint database for the locations of three wind turbines on the low level route for Cork Airport; however, it was noted that these were the only three waypoints in the company database that crews actively sought to avoid as opposed to aiming towards them.

1.8.3 Safety Recommendation IRLD2017005 – Route Guides

In the Investigation’s Preliminary Report, although the Investigation was still at a preliminary stage, the Investigation was of the opinion that all routes contained in its Route Guide should be reviewed or re-evaluated to enhance the information provided to crews. Accordingly, the Investigation issued the Safety Recommendation **IRLD2017005** to the Operator relating to the Operator’s Route Guide.

> CHC Ireland should review/re-evaluate all Route Guides in use by its SAR helicopters in Ireland, with a view to enhancing the information provided on obstacle heights and positions, terrain clearance, vertical profile, the positions of waypoints in relation to obstacles and EGPWS database terrain and obstacle limitations (**IRLD2017005**).

The response received to date is presented in **Appendix G** to this Report.

1.8.4 Blacksod South Route ‘*APBSS*’

The Investigation asked the Operator what the acronym ‘*APBSS*’ stood for; the Operator said that it stood for ‘*Approach Blacksod South*’. The Navigation Plan for this route comprised a total of 7 legs, with legs 1 to 4 used for the arrival, and legs 5 to 7 for the departure as shown in the Navigation Plan. The legs are defined by means of named waypoints identified by 5-letter identifiers. By inputting the route ‘*APBSS*’ into the FMS the associated waypoints in the Navigation Plan are loaded. A copy of the APBSS route information, as provided to the Investigation, is reproduced in **Figure No. 4**.

	1 Route Guide	 SM 03/02/15

Route APBSS (Blacksod South) Route

Navigational Plan: South Route

Leg	From	To	Distance	Track	Terrain
Leg 1	BLKMO	BKSDA	6	104	310' Black Rock
Leg 2	BKSDA	BKSDB	4	088	Over Sea
Leg 3	BKSDB	BKSDC	4	035	Over Sea
Leg 4	BKSDC	BLKSD	3	246	345' Blacksod
Leg 5	BLKSD	BKSDB	2	150	Over Sea
Leg 6	BKSDB	BKSDA	4	268	Over Sea
Leg 7	BKSDA	BLKMO	3	284	310' Black Rock

Hazards/Obstacles:
1. Black Rock Lighthouse 310'
2. Iniskee Islands 230'
3. Inisglora 200'
4. Duvillaun More & Beg on departure from BSF 250'
5. Aerial west of Blacksod 250'
6. The LZ is surrounded by an 8' granite wall. Both the house and lighthouse have aerials and lights.
7. Achill Island Cliffs 2200'

Coastal NDB's/ Lighthouses:
1. Black Rock Lighthouse: Fl. W. R. 12secs
2. Blacksod Light: Gp. Fl. (2) WR 7.5secs

Comms:
1. Blacksod Radio CH16 Marine FM

General Comments:
Severe turbulence may be experienced during this approach due to the proximity of Achill Island. In strong winds from a south/ south westerly direction use of **APBSN (Blacksod North)** is advised.

	Latitude			Longitude		
	Deg	Min	Sec (dec)	Deg	Min	Sec (dec)
BLKMO	54	04	00	010	19	00
BKSDA	54	03	50	010	09	30
BKSDB	54	04	40	010	02	40
BKSDC	54	07	40	010	00	40
BLKSD	54	05	90	010	03	80

Figure No. 4: Route Guide information page for '*APBSS*' Blacksod South.

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The Route Guide also shows the '*APBSS*' route overlaid on a section of an IAA-issued VFR chart (**Figure No. 5**). The start of the inbound route (and end of the outbound route) is the BLKMO waypoint. Based on the GPS coordinates provided in the APBSS table, the waypoint '*BLKMO*' was located in the water just off the eastern end of Black Rock. The inbound route ends at the Blacksod helipad which is situated adjacent to Blacksod Lighthouse.

There is no legend provided in the Route Guide. From examination, the symbology used in the Route Guide was as follows:

- The route identifier ‘*APBSS*’ was shown in black lettering on a yellow background at the top of the chart.
- The route was identified by a black line (legs are numbered sequentially in black, inbound to the helipad and outbound to Black Rock) with black crosses marking each waypoint.
- The 5-letter waypoint identifiers were in black lettering on a yellow background.
- Hazards and Obstacles listed on the title page were identified by white numerals within red circles, outlined in black.
- Lighthouses were marked with a small red dot with an elevation (in italic numerals) adjacent to the red dot. The elevation was a numerical value; no units were indicated. Two lighthouses are marked: Black Rock Lighthouse ‘*282’* at the first waypoint inbound and Blacksod ‘*43’* adjacent to the helipad refuelling facility.

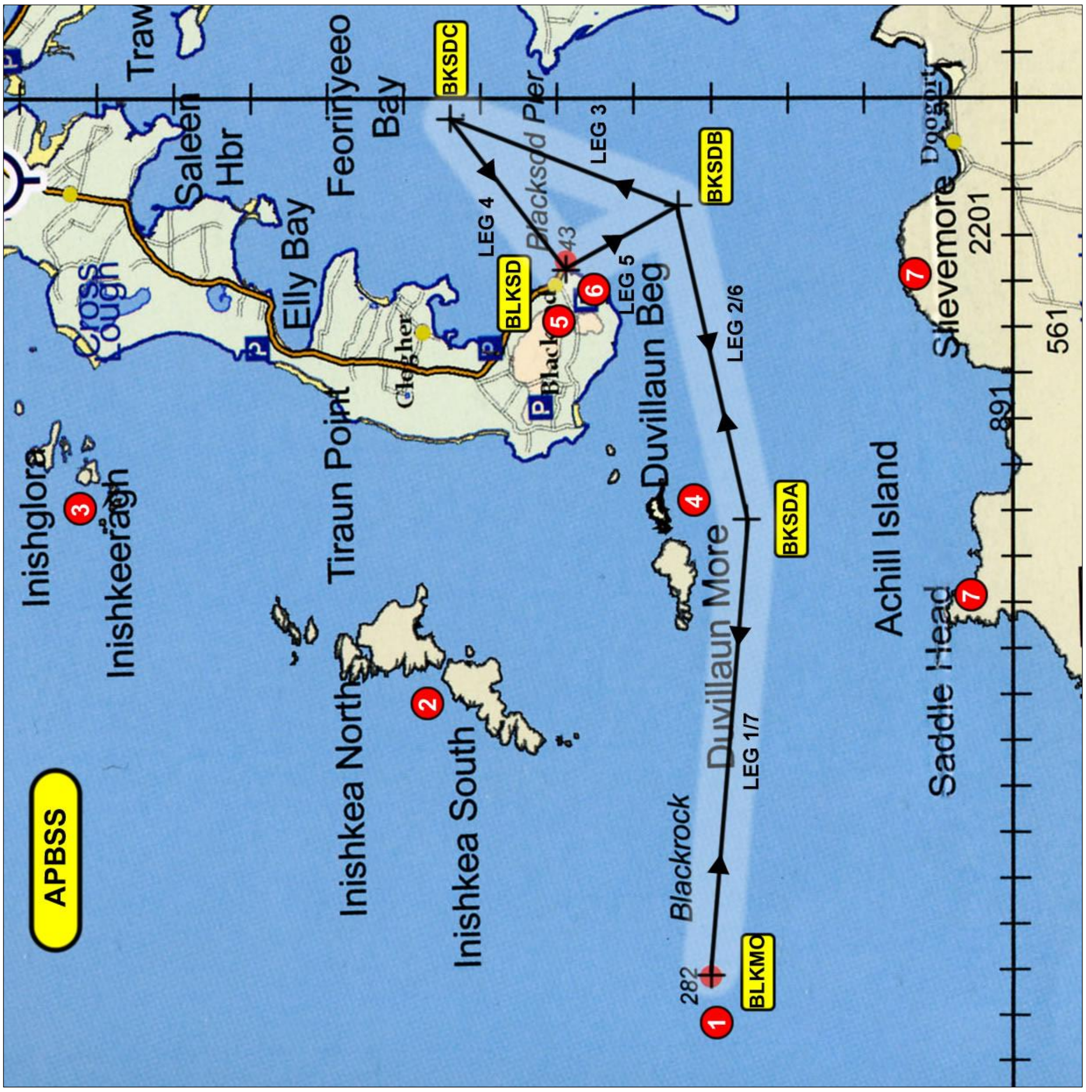


Figure No. 5: ‘APBSS’ Route Guide chart information (orientation as per Route Guide)

Regarding this version of APBSS, the Investigation notes the following:

- This route was designated as '*Route APBSS (Blacksod South) Route*' in the Route Guide, and was the first route in the guide.
- The '*Hazard/Obstacle*' table quoted the height of the Black Rock Lighthouse as *310*' but the chart showed it as *282*. The Operator advised the Investigation that it was company policy to add 10% to obstacle heights in Route Guides, but no documented procedure[29] to support this was provided to the Investigation.
- The APBSS route has two references to '*310' Black Rock'* in the Terrain column of the Navigational Plan. There is also a reference to '*1. Black Rock Lighthouse 310*" in the Hazards/Obstacles section. The Coastal NDB's/Lighthouses section also contains reference to '*Black Rock Lighthouse*'.
- The Route image and the Navigational Plan and Hazards/Obstacles tables, referred to seven obstacles, designated with numbers 1 through 7 and seven legs, also designated with numbers 1 through 7. Legs 1-4 are for getting into Blacksod; legs 5-7 are for getting out of Blacksod. Leg 1 starts at Black Rock, and leg 7 ends at Black Rock.
- Following the route, either inbound or outbound, resulted in Black Rock being overflown. The Operator was unable to say definitively why APBSS started and ended at a high obstacle, but two possibilities were suggested by several personnel to whom the Investigation spoke: it may have been that the route's originator considered that placing the waypoint on the obstacle would ensure that crews were always aware of its location; alternatively, it may have been a throwback to earlier-generation navigation systems which required re-calibration by overflying a known terrain features to re-set the system datum.
- APBSS, APBSN and LOWCAST were the only three routes in the Route Guide which included Leg designations on the chart.
- Obstacle designators appeared in the vicinity of the obstacle to which they referred but did not follow a positioning convention in relation to the obstacle e.g. the obstacle 1 designator was approximately 0.6 NM (centre-to-centre) west of Black Rock Lighthouse (to which it referred), the obstacle 4 designator was to the east of the Duvillaun islands (to which it referred), the obstacle 7 designator appeared twice to the north of the Achill Island cliffs (to which they referred). These designators were approximately 6 mm in diameter.
- Black Rock Lighthouse was indicated on the Route Guide by a red disc (approximately 4 mm in diameter) with a waypoint designator (perpendicularly crossed lines) which obscured some of the lighthouse marker; the BLKMO waypoint label was positioned approximately 0.6 NM (centre-to-centre) south of the waypoint at Black Rock. The word '*Blackrock*' appeared on the Route Guide image, approximately 0.8 NM to the east of Black Rock.

[29] The Operator's OMG, for Helicopter Emergency Medical Service (HEMS) and Special Operation, does say in relation to estimated site (non-surveyed) landing sites that dimensions should be factored by a minimum of 10% to account for any inaccuracies. However, an estimated site is defined as one where no reliable information has been obtained and thus would not apply to Route Guides. Furthermore, the use of estimated sites is limited to day only.

- The ratio of the squares of the diameters of the obstacle 1 designator and Black Rock Lighthouse marker discs indicates that the area of the lighthouse marker was less than half the area of the obstacle marker.
- Obstacle 5 was designated *'Aerial west of Blacksod 250'*. However, under the heading '*Terrain*' in the Navigational Plan table for leg 4 (the arrival into Blacksod), the entry read *'345' Blacksod*'.
- The islands named '*Inishkea North*' and '*Inishkea South*' on the chart were referred to in the obstacle table as '*Iniskee Islands*'
- The GPS coordinates for waypoint '*BLKMO*' show it was located in the water just off the eastern end of Black Rock. This meant that when approaching '*BLKMO*' from the west to initiate the APBSS route, the helicopter must overfly the Black Rock terrain and obstacle (lighthouse) just prior to the start of the route.
- Hazards/Obstacles entry 4 read '*Duvillaun More & Beg on departure from BSF 250'* The designator '*BSF*' was the three-letter designator for Blacksod Lighthouse which was used with the old S-61N RNAV database. The designator should have been updated to '*BLKSD*'; it had been updated to '*BLKSD*' on the Route '*APBSN*'.
- No vertical profile guidance or minimum heights/altitudes were provided for route legs.
- Legs 1 and 7 are reciprocal legs, i.e. they have same endpoints but were flown in opposite directions. However, the distance quoted for Leg 1 was six miles, but the distance quoted for leg 7 was three miles.

The Investigation was provided with a number of photographs taken in the Dublin Base at approximately 03.30 hrs on the morning of the accident. One of these photographs (**Photo No. 7**) shows the two pages of APBSS, in a ring binder, which was the Dublin Base's copy of the Route Guide. It is not known if the Crew consulted this copy of the Route Guide prior to departure.

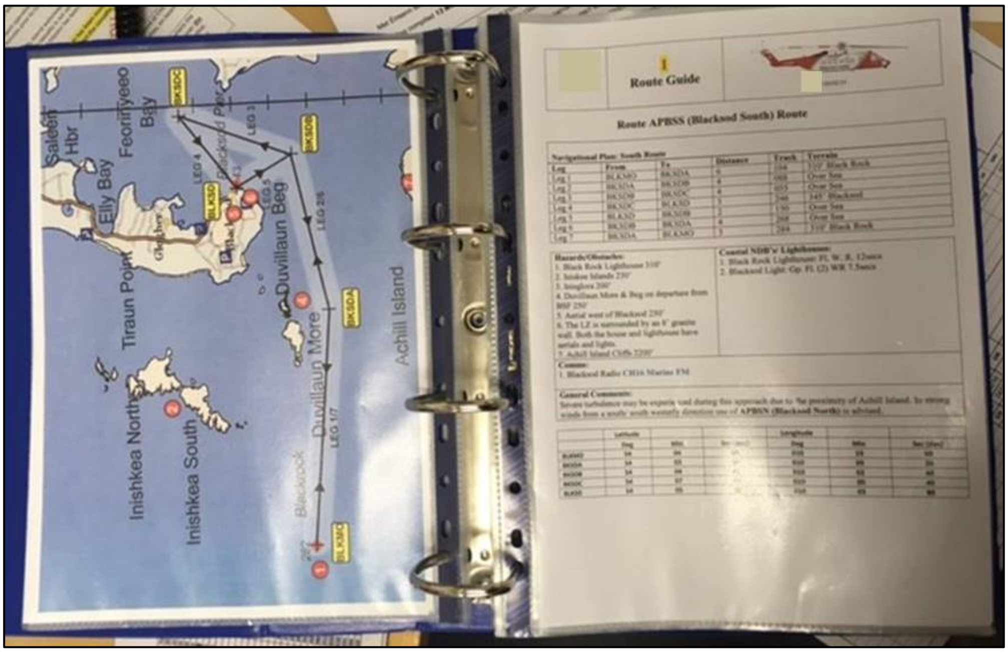


Photo No. 7: Route Guide (APBSS Pages) taken at Dublin Base at 03.30 hrs on 14 March 2017

The Investigation notes that the route imagery in this photograph is not the same as that contained in the Route Guide provided by the Operator (**Figure No. 5**). In particular, it is noted the terrain at Achill Island, Obstacle 3 and one of the Obstacle 7 designators are not shown. In addition, the Investigation is of the opinion that this image could invoke a greater sense of '*open-water*' than the version provided by the Operator. This led the Investigation to question which version of APBSS was available to the Crew of R116.

Route guide updating was a '*secondary duty*' at base level and the Investigation was not provided with evidence of a defined procedure for the distribution of updates to the Route Guide or how it was monitored that such updates had been incorporated into the relevant Route Guides in aircraft. This lack of a procedure to track what exactly was incorporated into an individual copy of the Route Guide, and the fact that the relevant sections of Route Guide from R116 were not recovered after the accident, meant that it was not possible for the Investigation to determine what image for APBSS was available to the Flight Crew.

1.8.5 Route Familiarisation

Regarding Routes generally, the Investigation notes that OMA states:

> '*In order to be nominated as a commander the pilot must have:* […]
>
> *b. Adequate knowledge of the route or area to be flown and of the aerodromes, including alternate aerodromes, facilities and procedures to be used*
>
> *c. Had initial familiarisation training of the route or area to be flown and of the aerodromes, facilities and procedures to be used. This route / area and aerodrome knowledge shall be maintained by operating at least once on the route or area or to the aerodrome within a 12-month period.*'

OMA states that route training and check records were to be maintained on the Operator's Qualifications Management System (QMS) for a period of five years. The Investigation was not provided with any specific records for either Pilot regarding route training and check records. However, the Investigation was provided with copies of the last AWSAR and HEMS Pilot Competence Check for each Pilot; both checks were carried out concurrently on a single flight. The Investigation notes that:

- The HEMS check assesses, *inter alia*, '*Familiarity with established HEMS operating sites in the landing site directory*', low level flight in poor weather and selections from the air of HEMS operating sites.
- Route/Fuel planning is assessed during the AWSAR check but there is no reference in either competence check to Route Guide familiarity.
- As part of the competence checks, a low level route from the Route Guide was used. However, the Investigation notes that each of these checks was carried out at the Pilots' home base, and accordingly from their day-to-day experience, they would have been familiar with the routes used, and would therefore be aware of obstacles and safe operating altitudes. The particular (Dublin) routes used for the Pilots' competence check flights prescribed an over water altitude of 500 ft, due to ATC considerations, in the '*General Comments*' section.
- Each of the competence checks was carried out under '*day*' conditions.

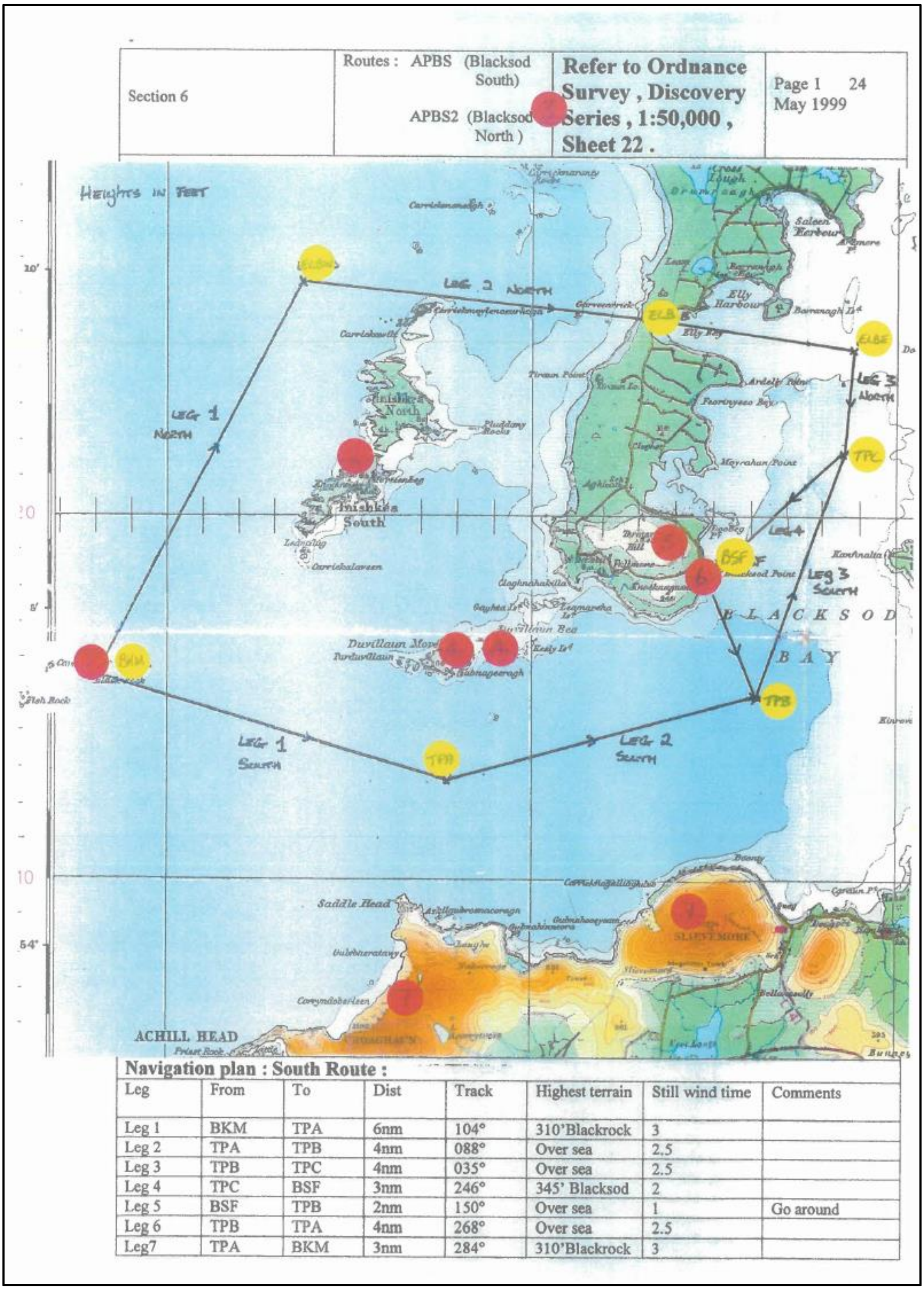
The Investigation understands that, in general, because routes flown during competence checks were at pilots' home bases, candidates were not required to conduct a thorough briefing of the route based on the contents of the Route Guide.

The Operator's OMA provided extensive guidance regarding minimum flight altitudes; this guidance would apply to non-SAR flights but could inform decisions on SAR flights also. OMD contains significant details of the Operator's Route and aerodrome competence qualifications. In particular, OMD stated that: aerodrome and area of operation training was required for pilots to qualify them for areas of operation to which they are assigned; training should provide adequate knowledge of the route to be flown; and, sub-bases within a geographic area did not require an additional route and aerodrome check. However, a local base area examination or detailed briefing was required to cover any differences to mitigate risk. Furthermore, OMD stated that an orientation was to be provided upon arrival at a sub-base, with documentation to record that the pilot has been thoroughly prepared. The Operator stated that the text in OMD related to Commercial Air Transport (CAT) operations. OMG states that HEMS operations are conducted under the auspices of EASA OPS and comply with CAT regulations. Accordingly, HEMS is a CAT activity, and therefore OMD required these records for base orientation to be completed prior to a visiting pilot being able to undertake any HEMS missions that might be tasked during their duty period. The Investigation was not provided with documentation to record that either of the Flight Crew members had completed a sub-base orientation at Sligo or Shannon. Furthermore, the Sligo SAR Base brief did not make reference to Blacksod or its associated routes. The relevant extracts from OMA and OMD can be found at **Appendix H**.

1.8.6 Route Guide Origins, Updating and Usage

The Investigation asked the Operator what were the origins of its Route Guide. The Operator was unable to be definitive, but said that the routes were '*possibly*' inherited by the company when it took on the original SAR contract using S-61N helicopters. The Operator said that the routes were designed to be used in a variety of circumstances and that the prescriptive use of vertical profiles '*had the potential to introduce risk as well as to mitigate it*'. It said that SAR crews were trained in a large number of scenarios and the routes were merely there as a framework on which to build a plan for entry/exit to a number of known sites. The Operator said that it was a guide as opposed to a prescriptive approach plate.

The Operator undertook a major revision of the Route Guide with the introduction of the S-92A into service. This project was an amalgam of work: to revise all waypoint designators from the three character format used with the S-61N to the five character format used with the S-92A; to move from a manual preparation method involving stickers and photocopied chart sections, to a system involving scanned imagery and graphic overlays; and to standardise the Route Guide (and related documents, namely the Landing Site Directory and RNAV Waypoint list) across the Operator's base network. The Operator was unable to provide a copy of the earlier Route Guide used on the S-61N, as none had been retained. However, a copy of an old version of the Blacksod South Route, dated May 1999 and called '*APBS*', was located in Blacksod Lighthouse. It was part of a presentation made in 2001 to the Lighthouse Operators by the commercial organisation that preceded the Operator in providing helicopter SAR services to the State (**Figure No. 6**).



Navigation plan : South Route :

Leg	From	To	Dist	Track	Highest terrain	Still wind time	Comments
Leg 1	BKM	TPA	6nm	104°	310'Blackrock	3	
Leg 2	TPA	TPB	4nm	088°	Over sea	2.5	
Leg 3	TPB	TPC	4nm	035°	Over sea	2.5	
Leg 4	TPC	BSF	3nm	246°	345' Blacksod	2	
Leg 5	BSF	TPB	2nm	150°	Over sea	1	Go around
Leg 6	TPB	TPA	4nm	268°	Over sea	2.5	
Leg7	TPA	BKM	3nm	284°	310'Blackrock	3	

Figure No. 6: Copy of Blacksod South route from May 1999

The Investigation compared this version with the route images in use at the time of the accident. The following points were noted:

- The 1999 version was overlaid on an Ordnance Survey map.

- The obstruction markers appear to be placed on the obstructions rather than in the vicinity of the obstructions. For example, there is a red sticker over Black Rock, even though this meant that the waypoint designator was displaced from the obstacle.
- The obstruction marker at Black Rock overlaid the Route Legs, whereas in the Route Guide in use on the night of the accident, the legs and waypoint marker overlaid the lighthouse symbol, while the obstruction marker was situated approximately 0.6 NM to the west of the lighthouse.
- Legs 1 and 7 were reciprocal legs but had different lengths (6 NM vs 3 NM); this anomaly was perpetuated in the APBSS version extant at the time of the accident.
- The tracks from 1999 are the same as those that were in the Route Guide in 2017. However, as 18 years had elapsed these tracks would have changed by approximately 3 degrees in the intervening period, due to changes in the magnetic variation.
- The 1999 version specified a '*Go around*' Leg.
- The diameter of the obstacle and waypoint markers used in the 1999 version was 8 mm.
- The ratio of the squares of the diameters of the 1999 obstacle markers (8 mm) to the 2017 obstacle markers (6 mm) indicates that areas of the 1999 obstacle markers were 75% larger than the areas of the 2017 obstacle markers.

The Investigation was informed that the objective of the Route Guide revision project was to transpose the S-61N Route Guide to make it compatible with the S-92A and did not consider the enhanced capabilities of the S-92A.

The Operator did not have defined processes for designing routes or selecting waypoints. This meant that decisions regarding these matters could be based on the best judgment of a small group of committed, knowledgeable and well-intentioned personnel, without independent/external review or oversight. During the Route Guide revision project, it was identified in an email that a list or database was required to manage the routes and to track revisions and proving of routes. However, the Investigation was not provided with evidence that such a list or database was produced. Workaround solutions for keeping track of route proving were suggested (in company emails) which included the idea of a list at each base, where different crews could check off routes which had been proven.

The Investigation was informed that the Operator's Parent Company's Standards Department, with which the Operator had a service arrangement, had no involvement in the preparation, updating or approval of the Route Guide.

The email correspondence indicated that routes were viewed as being base-centric, i.e. each base was seen as the owner of a number of routes and as being responsible for providing the route information for production and amendment of those routes.

Suggestions were made (by email) regarding the need for routes to be test flown, several times, in different conditions (and different combinations of overflies and smart turns), and adjusted if necessary before being passed to be used '*in anger'*. The Investigation was informed that there was no laid down process for route proving/approval and no evidence was provided that such check flights were undertaken and documented.

In July 2013, there was a proposal to record all routes that had been test flown; to update the index page on the Route Guide to state whether or not a route had been test flown; and to add a notice to the index page stating that '*No crews are allowed to use routes at night or in poor visibility unless indicated here that they have test flown'.* Emails also suggested that a list of all routes in each area [Base] was to be developed and displayed on the Ops Room wall, along the lines of; *'Route', 'Date Test Flown', 'By Whom'* and any *'Comments'.* The Operator's Safety and Quality Integrated Database (SQID) system (**Section 1.17.4.2**) had the potential to provide a means to record and track the actions associated with the Route proving task. The Investigation notes that the associated email chain involved several pilots, including a Post-Holder; however, SQID was neither used nor suggested for this purpose.

Whilst the emails reviewed seem to indicate committed efforts by a number of persons at all bases, there was no one individual/Post-Holder responsible for driving the project and none of those involved had been trained for this type of work. Four years after the Route Guide transposition, the document still contained the warnings '*It is a work in progress and should be used with the necessary caution until all routes/waypoints are proven … Again it is a work in progress so if you have any comments/suggestions, please revert*'. The investigation was not provided with any evidence that the project to finalise the Route Guide had been assigned to an accountable Post-Holder. In particular, the Investigation was not provided with evidence of a plan to bring the Route Guide from the status of '*work in progress*' to that of '*approved*'.

Those involved in producing the Route Guide had no training in the design or preparation of Route Guides. It was explained to the Investigation that bases submitted information to update the Route Guide. This was then incorporated, and the update was circulated to all bases. The Operator had no formal processes for checking of the content for safety, consistency or errors, nor was there any formal process for flight evaluation of routes. All involved in the project undertook this work in addition to their rostered duties, which of necessity took priority.

There was no documented procedure for how flight crew were to use the Route Guide. Prior to the accident, the FMS routes were not available for use in the FSTD which the Operator used for training its flight crew.

1.8.7 Top Cover Mission Six Days prior to the Accident

On 8 March 2017, the IRCG tasked R116 to provide Top Cover for R118, which had been tasked with a medical evacuation mission from a vessel approximately 200 NM west of Blacksod. R116 routed to Blacksod, and refuelled, before following R118 in the direction of the vessel. R118 completed the transfer of the casualty from the vessel and released R116 to return to base. The Winch Operator on the accident flight was also the winch operator on the 8 March 2017 flight.

The 8 March 2017 crew was initially alerted at 00.40 hrs, was airborne at 01.40 hrs, and refuelled at Blacksod. The commander, co-pilot and winchman spoke with the Investigation. They said that weather conditions on the night at Blacksod were good. During their cross-country transit they conducted an initial briefing for using APBSS to get into Blacksod for fuel. The initial brief called for a route height of at least 500 feet AGL (Above Ground Level). One of the crew had previously been based at Sligo and interjected that there was a large rock [Black Rock] on the route. On consulting the obstacle table and route image, this was confirmed and it was then planned to fly the route at a higher altitude (900 ft). However, on approaching Blacksod, visibility was so good that it was possible to route directly into Blacksod without following the APBSS route.

Following refuelling, during their departure from Blacksod, the 8 March crew inspected Black Rock using both FLIR and the naked eye as they passed it at a safe altitude of approximately 1,000 ft. The winchman, who was operating the FLIR (EO/IR), signalled to the Winch Operator (who was strapped into his crew seat on the opposite side of the aircraft) that the image on the FLIR screen was the rock formation which the pilots were discussing at that time. The Winch Operator signalled an acknowledgement to the winchman. However, the winchman informed the Investigation that he did not think the FLIR image, or the flight crew's conversation, would have made such an impression on the Winch Operator that he would have been sensitised to the presence of Black Rock when he returned there on the accident flight. The Investigation also notes that from the seat which the Winch Operator occupied, the view out of the helicopter was restricted by the surface of the sponson.

The routing followed by the mission of 8 March 2017 is shown below in **Figure No. 7**.

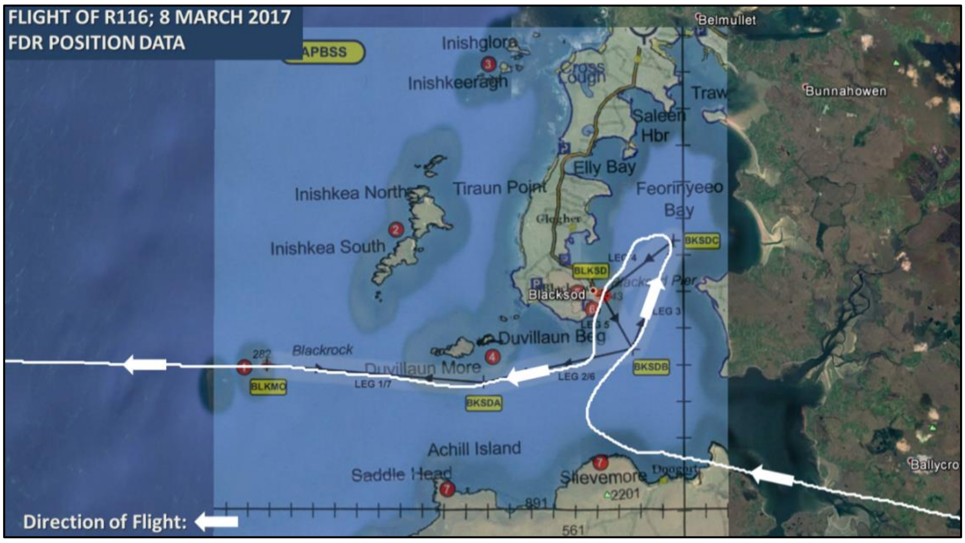


Figure No. 7: Routing followed by the mission of 8 March 2017

1.9 Communications

1.9.1 Introduction

The Helicopter was equipped with a wide array of communications equipment providing voice and data capabilities, for use during SAR missions. A technical description of this equipment can be found at **Appendix I**.

1.9.2 Communications Procedures

The use of the InterCom System (ICS) and the responsibility for the operation of the radio communications systems on board is described in Section 8.3.17 of OMA as follows:

- *'PM's primary task is to monitor the aircraft's flight path* […] *perform ATC radio calls* […]
- *The secondary task of PM is accomplishing non-flight path actions (non-ATC radio communications* […]*). The secondary task should not compromise the primary task of monitoring the flight path.'*
- *'PF's primary task is to control and monitor the aircraft's flight path* […] *ATC radio calls as required.*
- *The secondary task of PF is monitoring non-flight path actions (non-ATC radio communications* […]*). The secondary task should not compromise the primary task of controlling and monitoring the aircraft flight path.'*

It would be normal for pilots to conduct ATC communications, as a radio telephony licence, which is issued coincident with a pilots' flying licence, is mandatory for operating VHF AM radios on ATC frequencies.

Section 6.3 of OMF states:

> *'The winch crew will normally operate marine FM, while PM operates VHF AM and SATCOM / HF. PM will inform the crew which communications box he is using so that they may select volume up or down as required. When PM is operating on one of the communications boxes, he will ask PF to monitor the other communications box if required. All crew members should announce on the intercom when a call is about to be made so that intercom chat or other transmissions may cease.'*

Notwithstanding this, responsibility for the operation of the various non-ATC radios is generally dependent on the phase of flight and workload of individual crew members.

1.9.3 In-Flight Communications

1.9.3.1 General

The Investigation received recorded data related to the in-flight communications from a number of sources, including the CVR, the FDR, ATC and IRCG recordings of radio transmissions.

The FDR recorded a number of parameters related to the on-board communication systems:

- Pilot_Radio_Keying
- Copilot_Radio_Keying
- ICS_STATION_3_RADIO_KEYING
- ICS_STATION_4_RADIO_KEYING

A graphic representation of these parameters is shown in **Figure No. 8**. It became apparent early in the Investigation that the four FDR parameters did not record the same format of data, and did not record all the transmissions made from the Helicopter. The *Pilot_Radio_Keying* and *Copilot_Radio_Keying* parameters are associated with transmissions on the respective VHF-aero radio; Radio 1 for the Pilot and Radio 2 for the Co-pilot. For example, the Commander made a number of transmissions to ATC at the beginning of the flight. These transmissions do not appear on the *Pilot_Radio_Keying* parameter because the transmissions were via the Co-pilots VHF radio, and were recorded on the *Copilot_Radio_Keying* parameter. The remaining parameters are associated with all radio transmissions conducted via the particular audio panel in use; ICS_STATION_3_ RADIO_KEYING for the Winch Operator, and ICS_STATION_4_RADIO_KEYING for the Winchman. It became apparent to the Investigation that these parameters were not recording all transmissions from the Helicopter. For example, at 23.11 hrs the Winch Operator made contact with R118 via TETRA (**Section 1.1.2**). As can be seen in **Figure No. 8**, this transmission was not recorded on the ICS_STATION_3_RADIO_KEYING. The FDR does not record transmissions from customer-specific radios, such as TETRA, that were added post-manufacture.

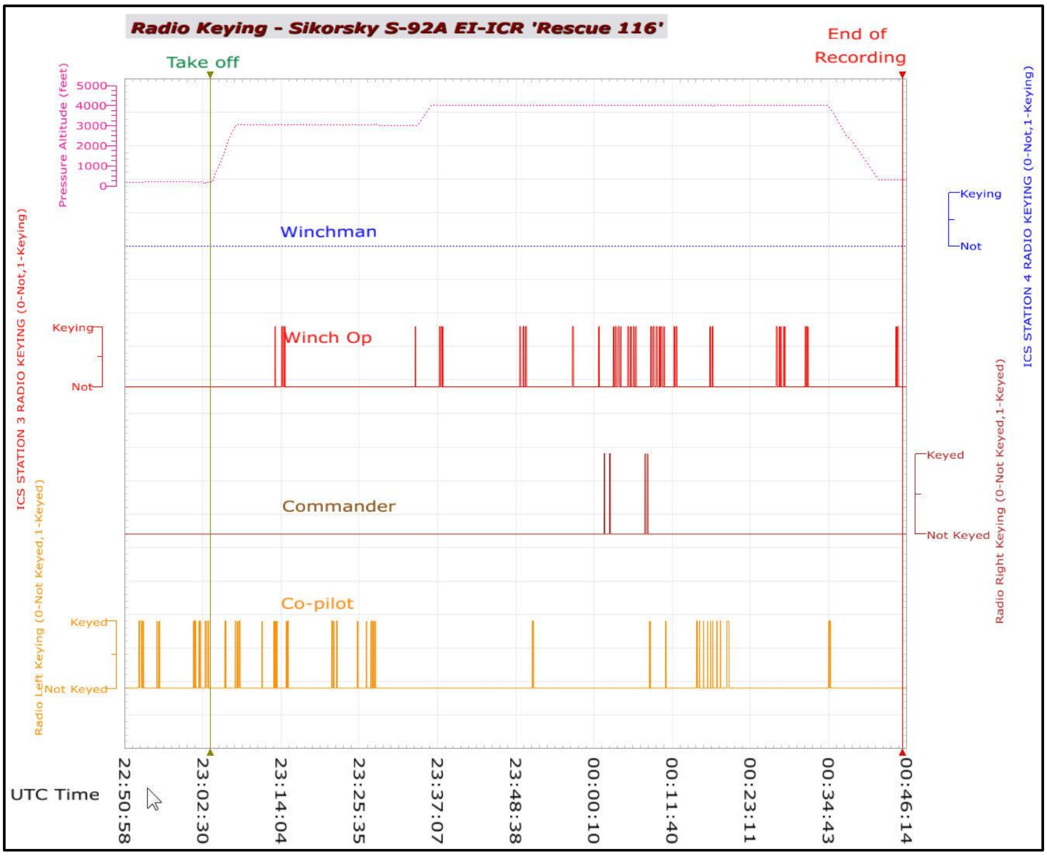


Figure No. 8: FDR Recorded Transmission Data

The Investigation then reviewed all other recording sources to complete a summary of transmissions from the Helicopter during the flight. The transmission sources were VHF-aero band radios, TETRA radio, Marine VHF radios, and HF radio.

A summary of the in-flight communications is listed in **Table No. 21**. The total number of transmissions (*Total Tx*) refers to the number of times the respective Crewmember pressed the transmit button on any of the on-board radios. These transmissions are further broken down into the purpose of the transmissions; *ATC-related Tx, Mission-related Tx, or R118-related Tx*.

Role	Total Tx	ATC-related Tx	Mission-related Tx	R118-related Tx	Overall Tx Duration (mm:ss)	Overall Comms Duration (mm:ss)
Commander	24	16	0	8	1:14	4:24
Co-pilot	39	29	10	0	2:31	6:23
Winch Op	114	0	79	35	10:11	28:49

Table No. 21: Summary of Radio Transmissions from R116

The ATC-related communications refer to any transmission made to Dublin or Shannon ATC services relating to the operation of the aircraft. For example, ATC-related Tx included requests for taxi or take-off clearance, or navigation instructions. The R118-related transmissions are transmissions made directly to R118 from R116 during the flight. For example, the Commander is listed as making eight transmissions related to R118. These transmissions were the Commander's attempts to call R118 on various VHF-aero frequencies as it could not be contacted through any other radio communications. The mission-related transmissions were made in connection with the overall mission being conducted by R116. For example, the Co-pilot made 10 transmissions directly relating to the mission, consisting of requests to Shannon ATC for updated weather reports for Sligo and Dublin, which were obtained prior to the Commander deciding to route to Blacksod instead of Sligo. The transmission duration (Overall Tx Duration) refers to the amount of time that the transmit button was pressed during the flight by the respective Crew member. The communications duration (Overall Comms Duration) refers to the amount of Crew time dedicated to communications activities. For example, the Co-pilot contacted Dublin ATC at 22.53 hrs to file a verbal flight plan. The Co-pilot made four transmissions, totalling 24 seconds duration. However, the entire interaction including the response from Dublin ATC, gave an overall communications duration of 48 seconds.

1.9.3.2 R116 Radio Communications

A summary of R116's communications with ATC and other agencies, its attempts to contact R118, and inter-crew observations regarding communication difficulties is provided at **Appendix J**.

1.10 Aerodrome Information

1.10.1 General

The intended landing site was a helipad (elevation 10 feet AMSL) situated in a compound adjacent to Blacksod Lighthouse, at Blacksod Point, on the southern tip of the Erris peninsula, Co. Mayo. The compound at Blacksod had refuelling facilities and was used by civil and military helicopters. The compound (approximate dimensions 60 m by 45 m) comprised of two helipads surrounded by a stone wall nine feet in height.

The main pad was constructed of concrete and measured 20.2 m by 20.2 m; the second pad was too small to accommodate the Sikorsky S-92A. A number of obstacles were present at the site; the two most prominent being the main lighthouse building on one side of the compound and a private house situated on the opposite side.

1.10.2 Landing Site Directory

Information for each landing site used by the Operator, including Blacksod, was contained in an Operator-compiled LSD.

The LSD provided information on the 40 landing sites listed in the guide index. The Directory was prefaced with the following:

> **S92 Landing Site Directory**
> **Revision #21: 09/09/2015**
> **To check you have the latest update see**
> **[URL]/ FMS DATABASE/ APPROVED LANDING SITES/S92**
> **CURRENT**

A map of Ireland with all surveyed landing sites marked on it was also provided, which contained the statement '*Rev 23: 27-04-2016*'. The LSD contained two landing sites, whose amendment date was 01/02/2016, which fell between the dates of Revision #21 and Revision #23. OMC, Section 2.8, stated that the validity of the LSD was to be verified by contacting the Operator's LSD coordinator.

Each landing site had an amendment number and amendment date. The Blacksod landing site was at amendment 2 and was dated 01/02/2013. OMG states '*If operating to a site where more than 12 months have passed since the last survey / update, then the site shall be restricted to day operations only until a resurvey / update has been conducted*'. The Investigation notes that a number of night HEMS missions involving landing at Blacksod were carried out after 01/02/2014, i.e. more than 12 months after the published date of the last survey.

This revision information in the LSD was followed with '*LSD Notes/ Performance Requirements*':

'*Hospital Sites:*
1. *HEMS missions shall be operated PC1*[30]

2. *SAR missions classified as life or death shall be operated:*

- *PC1 or*
- *PC2 no-exposure at sites not suitable for PC1.*

3. *SAR missions not classified as life or death shall be operated PC1.*
Note: If the hospital site is not suitable for PC1 and the casualty is not classified as life or death then an alternative landing site must be used.

Non-hospital Sites:
1. *HEMS and AA* [Air Ambulance] *missions shall be operated PC2 no-exposure.*

2. *SAR missions may be operated PC2 with exposure.*

Night: For night operations the site shall be adequately illuminated from the ground. Prior to commencing the approach the commander shall ensure that the lighting is sufficient to illuminate the site itself and any obstructions that could create potential hazards during approach, landing and departure procedures. Consideration may also be given to using the Night-sun.'

An additional table provided guidance for crews regarding HEMS Day/Night and SAR suitability for each landing site. The information relating to Blacksod is reproduced in **Table No. 22**.

Landing Site	HEMS: DAY	HEMS: NIGHT	SAR	AMDT. #
Blacksod	Y	Y		2

Table No. 22: Guidance for crews regarding HEMS Day/Night for Blacksod

The entry for each landing site comprised a page of information in tabular format with an additional page containing aerial photographs of each landing site taken in daylight conditions. The photographs of the landing sites were presented with overlays of sectors in red that were not to be used due to the presence of obstacles. The '*BLKSD-Blacksod Refuel'* landing site was listed in the LSD index under Tab '*7*'. It is shown in **Figure No. 9**

[30] S.I. No. 19/1999 - Irish Aviation Authority (Operations) Order, 1999 provides the following definitions:
PC1/'*Performance Class 1*' means, in relation to a helicopter, performance such that, in the case of critical power unit failure, it is able to land on the rejected take-off area or safely continue the flight to an appropriate landing area, depending on when the failure occurs;
PC2/'*Performance Class 2*' means, in relation to a helicopter, performance such that in the case of critical power unit failure, it is able to safely continue the flight, except when the failure occurs prior to a defined point after take-off or after a defined point before landing, in which case a forced landing may be required.
'*Exposure*' is a term applied to a Performance Class when there are criteria which temporarily affect a helicopter's compliance with the terms of that Performance Class.

BLKSD Blacksod Refuel		Day and Night: PC2 Subject to WAT and Obstacle Accountability	
Description: Lighthouse re-fuel facility. Compound surrounded by 9' wall.		Latitude:	54.05.90
		Longitude:	W 010.03.80
Site Dimension:	See Photo	Elevation:	10'
Surface:	Concrete: 20.2m x 20.2m	Lighting:	YES
ATC:	Shannon : 127.5	Fuel:	YES

LANDING HEADING: The following shall be applied to LDP/DPBL

Heading (magnetic):	0°-30°	30°-60°	60°-90°	90°-120°	120°-150°	150°-180°
Add: (feet)	9'	30'	56'	56'	N/A	9'
Heading (magnetic):	180°-210°	210°-240°	240°-270°	270°-300°	300°-330°	330°-360°
Add: (feet)	9'	50'	N/A	N/A	33'	43'

TAKE-OFF HEADING: The following shall be applied to TDP/DPATO

Heading (magnetic):	0°-30°	30°-60°	60°-90°	90°-120°	120°-150°	150°-180°
Add: (feet)	9'	30'	N/A	N/A	9'	9'
Heading (magnetic):	180°-210°	210°-240°	240°-270°	270°-300°	300°-330°	330°-360°
Add: (feet)	9'	50'	50'	9'	N/A	43'

Obstacle	Obstacle	Bearing	Distance(m)	Height(ft)
1	Light Poles	045°-090°	80m	30'
2	Fuel Tank	070°	23m	19'
3	Main Building	090°	46m	56'
4	Trees	250°	36m	50'
5	House	310°	40m	33'
6	Boat Mast behind house	320°	30m	43'
7				
8				
9				
10				
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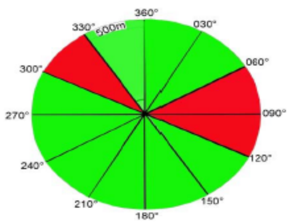
13				
14				



Red Zone is a no fly zone for normal operations but may be used for a balked landing subject to (Obstacle + LDP) as listed above.

Note:
Severe Downdrafting in southerly wind caused by Achill head.

Turbulence on pad caused by surrounding 9' wall in strong winds.

When operating with exposure on SAR missions, no risk to third parties can be accepted unless the mission is classified as life or death.

BLKSD	Amdt : 2	01/02/2013		Page 1

Figure No. 9: Landing Site Directory information for '*BLKSD-Blacksod Refuel*'

1.11 Flight Recorders

1.11.1 Multi-Purpose Flight Recorder (MPFR)

The Helicopter was fitted with a Penny & Giles D51615-102 MPFR, which is also used on other aircraft/helicopter types. The MPFR (**Photo No. 8**) is a dual-purpose unit incorporating a CVR and an FDR, which records the most recent 25 hours of flight data and just over two hours of audio data in a solid state Crash Survivable Memory Module (CSMM). In the event of a crash or water landing a 10 g impact switch or an immersion switch interrupts electrical power to the MPFR which stops it recording. An Underwater Locator Beacon (ULB) was attached to the MPFR. It was designed to activate upon immersion in water and transmit an acoustic signal on a frequency of 37.5 kHz for up to 30 days.

The ULB signal was first detected by a team from the [Irish] Marine Institute (MI), operating from a local fishing vessel, on 15 March 2017. The signal location was subsequently confirmed by an AAIU Inspector of Air Accidents using detection equipment provided by the UK AAIB, and on 22 March 2017, the main wreckage of the Helicopter was visually identified on the sea bed during ROV search operations.

Photo No. 8: The MPFR from EI-ICR (ULB visible on left-hand side)

The MPFR was observed by ROV, attached to its original mounting points in the forward, left-hand avionics rack (**Photo No. 9**), and recovered by Irish Naval Service divers on 24 March 2017, 10 days after its immersion.

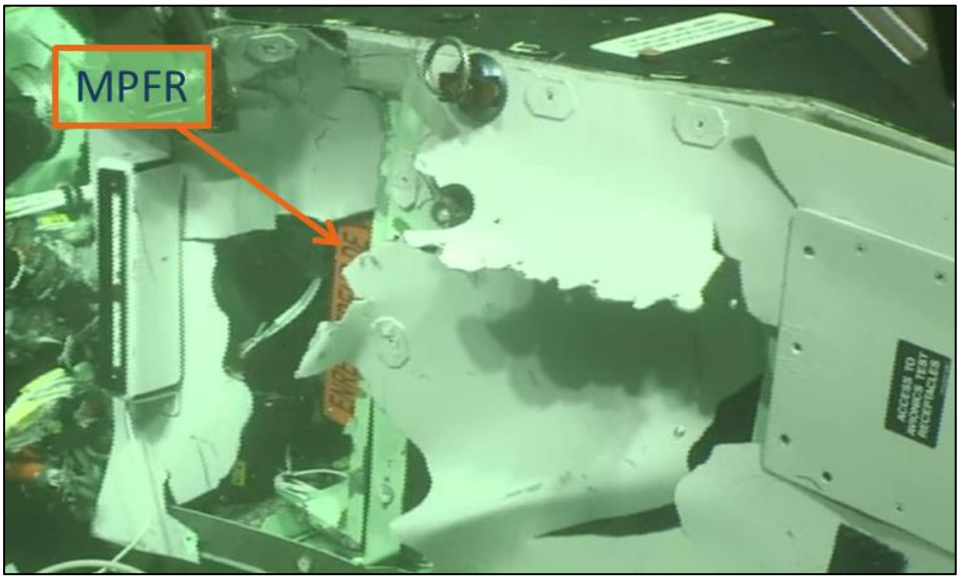


Photo No. 9: The MPFR in the left-hand Avionics Rack on the seabed (*MI*)

The MPFR exterior main chassis protects the internal circuitry that controls the operation of the device. Inside the main chassis and internal circuitry is the CSMM, which consists of two concentric outer and inner tubes packed with protective insulating material. This construction protects the storage media, called the *Accident Protected Memory Board* (APMB), which is located at the centre of the MPFR (**Photo No. 10**).

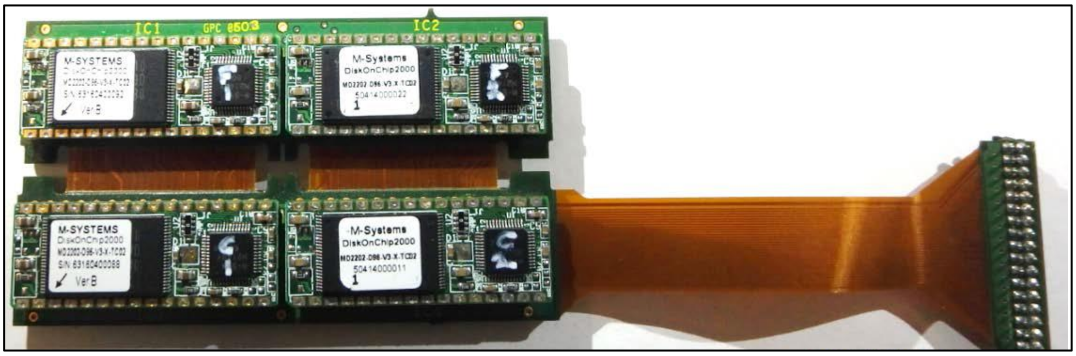


Photo No. 10: Example of an Accident Protected Memory Board (APMB)

The CSMM design uses Disk-on-Chip (DOC)[31] technology. A total of four DOC modules are used in the MPFR, with each DOC module consisting of a controller and three flash memory Integrated Circuits (ICs). The DOC modules are installed on a main circuit board that provides the interconnection to the chassis electronics. The four DOC modules are defined as FDR1, FDR2, CVR1 and CVR2 (**Photo No. 11**). FDR1 and FDR2 are used to store flight data; the two FDR DOC modules provide redundancy. CVR1 is dedicated to the storage of audio recorded from the Cockpit Area Microphone (CAM) and CVR2 is dedicated to the recording of the crew microphone channels.

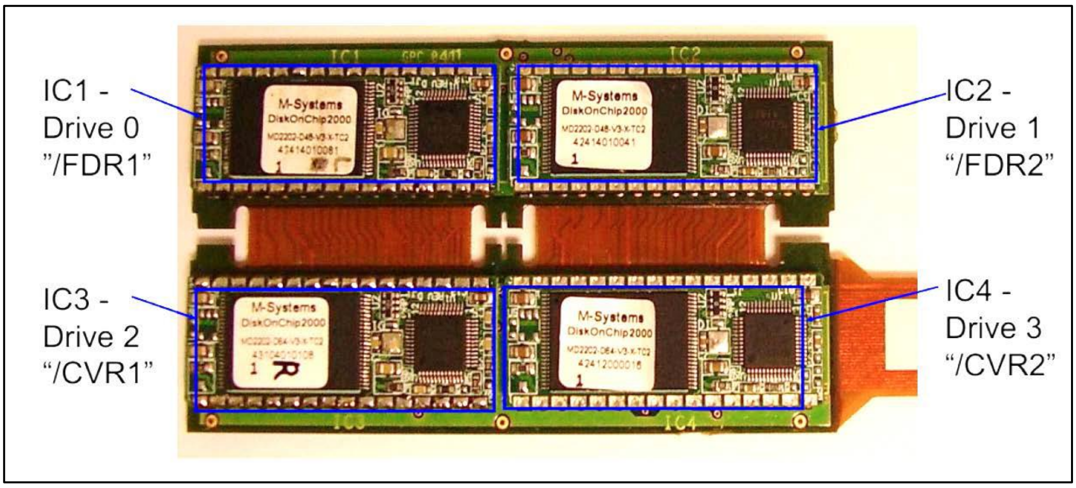


Photo No. 11: Location of FDR1, FDR2, CVR1 and CVR2 DOC modules on APMB

1.11.2 Data Recovery

1.11.2.1 General

The data recovery process required the disassembly of the MPFR due to the duration of immersion in seawater. The MPFR was transported, under AAIU escort, to the UK AAIB Recorders Laboratory. During the disassembly, some minor external damage was noted on the chassis of the recorder. However, the CSMM and APMB containing the CVR and FDR data did not show any signs of physical impact damage.

[31]**DOC:** The '*DiskOnChip*' is a proprietary product line which can be integrated into small embedded applications. The device was supplied as a module in a 32-pin dual in-line package with a pin-out and electrical interface compatible with a particular memory chip socket.

It was noted that water had entered the inside of the crash protected enclosure. **Photo No. 12** shows the MPFR memory board following removal. Examination of the memory board showed evidence of corrosion on the contacts of several of the memory devices. Electrical testing revealed short circuits which necessitated additional measures to recover the CVR and FDR recordings. These measures included de-soldering individual memory devices and re-installing them on a functional memory board provided by the MPFR manufacturer.

Photo No. 12: MPFR Memory Board with discolouration of glass spheres

At the request of the AAIU Investigation, the UK AAIB undertook a comprehensive study of the corrosion on the MPFR (**Appendix K**) to establish whether there were wider safety implications associated with the observed corrosion. The study revealed that the *'first generation (GEN1)'* of this particular type of MPFR was manufactured from 2001. However, in 2006 the manufacturer reviewed the design of the MPFR and identified that a change in the composition of an insulation material from boric acid to a copper-based product would improve the performance of the device if subjected to fire.

This change was classified by the manufacturer as '*minor*'. As such, it was not necessary to apply to EASA for certification and the change was approved under the manufacturer's privileges. MPFRs with this modification were termed '*second generation (GEN2)*' MPFRs by the manufacturer. Based on data provided by the manufacturer, it is estimated that up to 1,950 *GEN2* MPFRs were manufactured between 2001 and 2013.

The AAIB's study identified that, of 15 reported cases of MPFRs that had been submerged in sea water, five had suffered from corrosion of the APMB. All five of these units were fitted with the GEN2 CSMM, incorporating a combination of copper-based insulation and APMBs coated in Polyurethane. On four out of five of these units there was corrosion on the electrical pins, leading to damage or loss of the pins (**Photo No. 13**).

The electrical pins on the memory devices of the MPFR on EI-ICR were made from '*Alloy 42*', which consists of 58% iron and 42% nickel, plated in either tin-lead or tin. It should be noted that the corrosion on the pins of the memory devices was not as a direct result of exposure to salt-water. The combination of salt-water with the copper-based product resulted in a copper/water solution that was able to permeate the polyurethane conformal coating and come into contact with the pins of the memory devices.

Thereafter, a chemical '*single substitution reaction*'[32] took place, whereby the iron in the *Alloy 42* was depleted to the extent that the pins' structural integrity was lost and their electrical connections were broken.

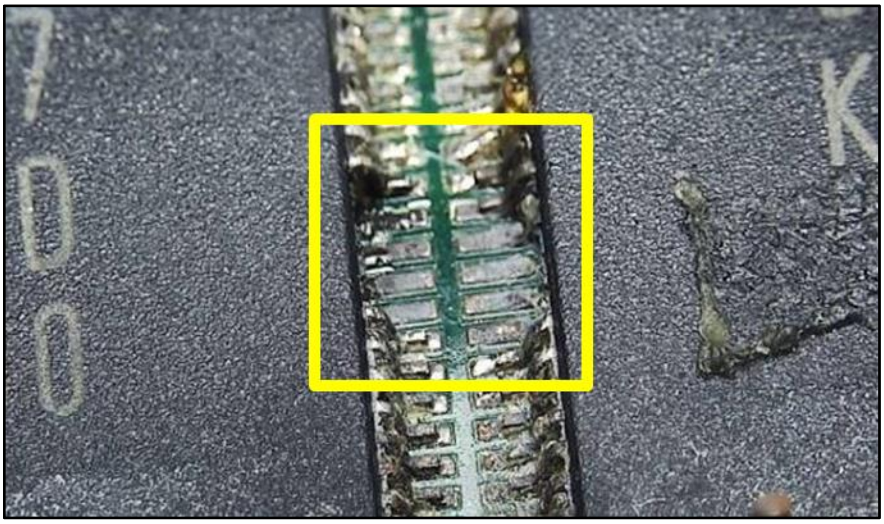


Photo No. 13: Underside of FDR1 DOC; pins are damaged or missing due to corrosion

In 2013, a '*third generation (GEN3)*', alternative design of the APMB, referred to by the manufacturer as the *Replacement Crash Survivable Memory Module* (RCSMM), was introduced. The previous generation CSMM insulation materials remained the same, but the conformal coating applied to the APMB was changed to '*Parylene*'[33].

The manufacturer advised that this type of conformal coating had been demonstrated to provide improved protection compared to the Polyurethane used in the first and second generation CSMM. The CSMM with the alternative design of APMB was retested and passed all crash survivability requirements[34]. To date, the CVR and FDR data has been successfully recovered from all GEN2 MPFRs that have suffered corrosion of the APMB following sea water immersion.

1.11.2.2 Safety Action Taken

During discussions regarding the content of the UK AAIB study, the following safety actions were identified and acted on by the manufacturer of the MPFR:

- As of December 2017, the MPFR manufacturer started to replace second generation CSMMs fitted to commercial aircraft with third generation CSMMs.

[32] **Single Substitution Reaction**: A specific type of oxidation-reduction reaction in which an element or ion is replaced by another in a compound.
[33] Parylene is the trade name for a variety of chemical vapour deposited poly (p-xylylene) polymers used as moisture and dielectric barriers.
[34] European Organization for Civil Aviation Equipment (EUROCAE) ED-55 '*Minimum Operational Performance Specification For Flight Data Recorder Systems*' Category A134, ED-56A '*Minimum Operational Performance Specification For Cockpit Voice Recorder System*' Amendment 1, (J)TSO-C123a and (J)TSO-C124a.

- In February 2018, the manufacturer of the MPFR issued Service Bulletin (SB) No. D51615-31-22 requiring the replacement of second generation memory modules with third generation memory modules in the affected MPFRs.

- On 8 February 2018, EASA issued *Safety Information Bulletin (SIB) No. 2018-05 Multi-Purpose Flight Recorders* (**Appendix L**), which recommends that owners and operators of the second generation MPFR accomplish the actions specified in the manufacturer's SB No. D51615-31-22.

- EASA informed the Investigation that it understood that the MPFR manufacturer planned to complete the modification program by September 2023.

As of December 2018, the MPFR manufacturer estimated that there were approximately 800 GEN2 CSMU-equipped MPFRs affected by the EASA SIB No. 2018-05. The manufacturer has informed the Investigation that, as of September 2019, 164 units have been modified in accordance with the SIB. It will take several years to complete the program.

The Investigation's First Interim Statement indicated that the manufacturer of the MPFR was developing specialist techniques to recover data from memory devices fitted to second generation CSMMs if they suffer from a loss of pins due to water immersion. As of December 2018, the MPFR manufacturer has developed an '*Advanced Recovery*' procedure for memory devices where the CSMU memory pins have corroded. The process uses laser ablation to gain access to the memory IC lead frame, with a special adaptor being used to then connect the IC to a reader. The MPFR manufacturer then reconstructs the file system from the raw data.

As stated in the Investigation's First Interim Statement, in light of the identified safety action being taken by the MPFR manufacturer and EASA, the Investigation did not consider that a Safety Recommendation was necessary. The Investigation notes the MPFR manufacturer's positive engagement with the Investigation process, and acknowledges the pro-active approach taken by the MPFR manufacturer in addressing the issues noted in this Report.

1.11.3 Cockpit Voice Recorder - General

The Helicopter's CVR system was designed to record a total of six audio files from four separate audio channels:

- Three separate audio channels (the Commander, Co-pilot and Rear Crew) from the Helicopter intercommunication system for at least the most recent 30 minutes. The Rear Crew channel records audio from both rear crew members on a single track.
- A combined single audio track of the three intercommunication system channels for at least the most recent 120 minutes.
- Cockpit Area Microphone for at least the most recent 30 minutes with a bandwidth of 150 Hz to 6 kHz.
- Cockpit Area Microphone for at least the most recent 120 minutes with a reduced bandwidth of 150 Hz to 3.5 kHz.

All six channels recorded audio for the flight. In each case, the respective channels exceeded the respective recording minimum durations (30 minutes/120 minutes) required by the EUROCAE specification documents.

Channel	**Audio duration**	**Channel Description**
'CV1'	0.33:54	Rear Crew Channel
'CV2'	0.30:42	Co-pilot Channel
'CV3'	0.31:19	Commander Channel
'CVC'	2.03:10	Three combined CV Channels (CV1, CV2, CV3)
'HQC'	0.33:43	Cockpit Area Microphone (150 Hz to 6 kHz)
'LQC'	2.02:30	Cockpit Area Microphone (150 Hz to 3.5 kHz)

A transcript of the final one minute and 41 seconds of the CVR recording was included as an Appendix to the Investigation's Preliminary Report and an updated version is included at **Appendix M** to this Report. Following the publication of the Investigation's Preliminary Report, the Investigation continued the process of analysing the CVR recordings in order to construct a transcript of the full duration of the recorded audio. All radio transmissions to and from the Helicopter were cross-referenced to the recordings provided to the Investigation by the IRCG, Dublin ATC and Shannon ATC. The full transcript was then validated and synchronised with the HUMS positional data[35] to construct a graphic representation of the geographic location of all voice and audio recordings.

1.11.4 Cockpit Voice Recorder – Content

For the initial portion of the flight, the Investigation relied on the content of the '*CVC*' channel, as it contained the combined recording of all the ICS channels for the flight. The '*CVC*' channel recording began, on the afternoon prior to the accident flight, with the sound of the EGPWS callouts of '*Glideslope, Pull Up, Warning Terrain*'. These callouts are indicative of the conduct of the '*Avionics Checks'* contained on page 4 of the Operators '*S-92A Normal Checklist dated 2016 July 1'*. Immediately following this check, the Commander and Winch Operator can be heard sequentially completing the '*Hoist Pre-Flight Check'* and the '*Hoist Shear Test'* from page 5 of the '*Normal Checklist*'. During this process, the Winch Operator said '*your windows are filthy aren't they?*' to which the Commander replied '*I know, I know I'm just going to get a step ladder there now in a second…'cause, eh, I won't be seeing out of those at night*'. The Investigation was informed by staff at the Dublin SAR Base that the aircraft had been washed on the morning of 13 March 2017. The Commander had approached a staff member at the Dublin SAR Base, saying that the Helicopter windows were streaky and asking for a step ladder and cleaning materials. The staff member escorted the Commander to obtain the necessary items. Later, the Commander advised the staff member that she was finished cleaning the windows and that the cleaning materials and step ladder had been returned to the appropriate locations. The Investigation was also informed that it was not unusual for pilots to clean helicopter windows.

[35] Appendix A to the AAIU Interim Statement No. 2018-004 dated 16 March 2018 stated that "*In light of the errors previously identified in the FDR position data, the Investigation will use the corrected position data recorded on the HUMS for all analysis of the helicopter's flight path or position*".

The Winch Operator and Winchman can then be heard conducting checks on equipment during the afternoon prior to the accident flight, including carabiners, the pilots' Nav Box, cockpit items including pilots' lifejackets, STASS[36] bottles, pilot torches, and cabin items including '*Mark Fifteen*' lifejackets and PLBs[37]. This sequence of checks lasted around six minutes. Transmissions from the Dublin ATC Ground controller to other aircraft were audible on the CVR, allowing the Investigation to determine that the recording occurred at approximately 14.10 hrs on 13 March 2017. The next ATC communication recorded on the CVR was from an aircraft that had just landed at EIDW was recorded. This established the time on the CVR as 22.49 hrs.

The CVR and FDR were synchronised by referencing the radio transmissions of the Co-pilot and Commander of R116 to ATC and comparing them to the *'Co-pilot Radio keying'* and *'Pilot Radio Keying'* parameters recorded on the FDR. This verified the start time of the CVR recording of the accident flight as 22.43:32 hrs UTC. At the start of the recording, the Co-pilot is on board the Helicopter. The APU[38] is heard to start at 22.49 hrs. A member of the ground crew is then heard asking the Co-pilot (by name) about how much fuel is required. The Co-pilot responds that the Commander (by name) said '*five* [thousand pounds]'.

The Co-pilot contacted ATC at 22.53 hrs requesting engine start, and advised that they would be departing west bound to '*either to Sligo or Blacksod, we're not sure at the moment*'. At this point in the recording, the Commander was on board the Helicopter and in the cockpit. At 22.53 hrs, the Commander advised the Co-pilot, '*just giving you direct to Sligo there we'll put everything in en route*'.

The Crew continued with the checklist items, including a departure and emergency brief by the Commander. The Helicopter taxied onto RWY 16/34 and completed a power assurance/hover check at 23.02 hrs. The Co-pilot advised the ATC controller that '*we're quite heavy here with fuel so if you're happy intersection Iona one six departure down one six right turn out'*. Permission was granted by ATC for a departure down RWY 16 with a right turn towards the West. The Helicopter departed EIDW at 23.03 hrs, with the Commander as the handling pilot. At 23.06 hrs, the Crew established contact with '*Rescue 118*' (R118) via TETRA, and R118 advised that they were just landing at Blacksod and would contact them after they had landed. The Commander acknowledged this saying '*oh great thanks you might just find out what the conditions are like there as well*'.

The Helicopter reached an initial cruising altitude of 3,000 ft at 23.07 hrs, and the Commander remarked '*we'll just get out of Dublin* [airspace] *and then we can start to have a look at everything*'. The Winch Operator advised the crew of the location of the FV, which was inserted into the FMS as the next navigation waypoint after Sligo. The FV's position was 277 NM west-north-west of R116, which at the Helicopter's groundspeed of 73 kts would take over three hours to reach. The Commander was then heard requesting the Co-pilot to calculate a fuel quantity and time required for a flight to Sligo and onwards to the FV.

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[36] **STASS:** Short Term Air Supply System.
[37] **PLB:** Personal Locator Beacon.
[38] **APU:** The Auxiliary Power Unit was selected to OFF shortly after engine start-up and remained OFF for the rest of the flight.

At 23.11 hrs, the Winch Operator used the TETRA radio to make contact with R118 which had just notified '*Malin Head Coast Guard*'[39] that they were on the ground at Blacksod. In response to the Winch Operator's request for weather, R118 was recorded by Malin Head CG Radio replying, '*Rescue one one six affirm yeh conditions at the pad are fine eh eh kind of some low cloud eh approximately five hundred feet eh up to the north while we were inbound through Broadhaven Bay, over'.* The Flight Crew had not heard the transmission from R118, and the Winch Operator advised the Commander '*conditions good at Blacksod*'. At 23.13 hrs, R116 was cleared by ATC to route direct to Sligo. The Winch Operator informed MRSC Malin that they were routing to Sligo for refuelling and that if the plan changed they would notify MRSC Malin. At 23.14 hrs, ATC cleared the Helicopter to climb to 4,000 ft when ready, which the Commander said will be required '*at some stage*'. The Commander then handed over control of the Helicopter to the Co-pilot, at 23.15 hrs, requested the '*three books*' (from the Rear Crew), and carried out fuel calculations. The Winchman inquired '*Do you want Blacksod in*' and the Commander asked '*what's the designator for that?*' The Winchman said '*B L K S D*', and the CVR indicated that the Commander entered this designator into the FMS. The Commander calculated the time and fuel required to fly to the FV via Sligo or Blacksod respectively, and concluded that using Blacksod as a refuelling site would save 700 lbs of fuel and 30 minutes flying time. The Commander concluded at 23.20 hrs that *'it kinda makes more sense guys really to go to Blacksod'.* The Rear Crew expressed their agreement and the Commander asked the Co-pilot '*what do you think?*' and he agreed '*yeh*'. The Commander said '*We're going to have a good bit of clag around but we've got time*'; the Co-pilot agreed saying '*we've got time*'. The Commander continued '*We're not under any pressure so … eh … happy enough with that and look if we don't get in we've got plenty of fuel to*'; the Co-pilot interjected '*get us to Sligo*' and the Commander continued '*get back so I'm just going to give you a direct to em Blacksod now. You'll get a left turn*' and the Co-pilot answered '*alright*'.

The Winch Operator observed that, depending on when R118 arrived at the FV, the routing to Blacksod may allow R116 to return to base without a further refuelling. The Commander noted that they were under no time pressure and that they had plenty of fuel to get to Sligo if they were unable to land at Blacksod. The Winch Operator notified MRSC Malin by TETRA of their intentions, which included a revised elapsed time of one hour and 12 minutes to Blacksod. MRSC Malin replied that they would notify personnel at Blacksod of the planned arrival of R116. The Commander advised Dublin ATC, at 23.21 hrs, of the change of plan which the Commander stated would require a left turn of around 20 degrees. At the same time, R118 called on TETRA to advise that they were just airborne from Blacksod and routing to the FV, which was 143 NM west-north-west of Blacksod. This placed R118 approximately 72 minutes flying time ahead of R116, excluding the time required for R116 to conduct an approach, land, re-fuel and depart from Blacksod.

Over the following ten minutes, the Commander reviewed the fuel calculations for the mission, including the fuel required to return to Dublin after the mission was completed. At 23.24 hrs, the Winchman asked the Commander '*Have we an approach into Blacksod?*' to which the Commander replied '*Yeh we do, we'll just pop it in*'.

[39] **Malin Head Coast Guard**: The radio call-sign used to refer to MRSC Malin.

At 23.26 hrs, the Shannon Air Traffic Control Officer (ATCO) contacted the Commander and said '*rescue one six roger, rescue one one eight is just eh headed off the west coast now, he's no contact with me so if you are talking to him yourself can you get him to give me a call please*.' The Commander acknowledged the request. The Commander advised the Rear Crew of Shannon's request, telling them that it was not urgent. The Winch Operator contacted R118 by TETRA and told his counterpart, who he referred to by name, to tell his pilots to contact Shannon ATC. R118 called Shannon ATC within one minute. Shannon requested R118's ETA at the FV location, which was confirmed as 00.47 hrs.

At 23.27 hrs, the Commander advised Shannon ATC that R116 was seven miles south of Kells (located approximately 29 NM north-west of Dublin), at three thousand feet, routing to Blacksod. The Commander confirmed to Shannon ATC that R116 was operating under IFR and would climb to four thousand feet in another twenty miles. At 23.33 hrs, R116 began a climb from 3,000 ft to 4,000 ft in order to maintain terrain separation for the rest of the transit to Blacksod.

At 23.36 hrs, the Helicopter had levelled at 4,000 ft, and the Commander said '*Just going to re-familiarise myself with Blacksod … south … okay* [Co-pilot's name] *I think we just plug that in*'. The Co-pilot noted '*what's the wind doing? From the west, okay.*' The Commander acknowledged saying '*yeh … reduce the speed as much as we can, there's the northern one, but I'd rather not*'. The Co-pilot added '*showing forty knots from the west*' and the Commander acknowledged '*yeh shouldn't be too lumpy as well … APBSS … Just going to pop that* [APBSS] *in now*'. The Commander then complained that '*bloody lights in this thing drive me mad*'; the Co-pilot agreed saying '*yeh eh they're atrocious*' and the Commander responded '*They're so annoying I'm pressing buttons here*'. The Commander advised the Co-pilot '*My eyes are still in*' and he acknowledged '*no problem*'. The Commander then asked the Co-pilot '*k ... just double check this yeh Black Rock eh M O that's the first one*' and the Co-pilot acknowledged '*yeh*'. The Commander continued '*S D A, S D B, S D C … D B and then the rest is out*'; the Co-pilot acknowledged '*Thank you*'. The Commander said '*ah sending you direct to the ... this one*', the Co-pilot acknowledged '*Okay*' and the Commander continued '*this offshore one …going direct to L M O'.*

The Commander continued '*we'll just stay up here and we can and once we're happy and we're clear … no point in rushing unless we … or we're going to be sitting there*'. The Co-pilot acknowledged this saying '*Do our let-down out there*'. At 23.40 hrs, the Commander stated that '*I'm planning to go round the houses*' and gave an arrival estimate of 00.40 hrs, which the Co-pilot noted as being in one hour.

Following agreement in the cockpit on the flight plan, the Commander checked with the Rear Crew members to confirm that they were also happy with the plan. Both the Winchman and Winch Operator confirmed that they were happy. The Winchman asked the Commander by name if she wanted a coffee, to which the commander replied '*No, I'm grand*'. The Winch Operator said that he was looking forward to seeing the staff at Blacksod for the second time in a week. He described a previous mission for R116 involving a similar supporting role. He said that the previous week, the other helicopter (R118) had winched at 200 miles out, and that R116 had got within 20-30 miles (of the casualty vessel) by the time that R118 had completed the SAR winching.

After this discussion, the flight continued with minimal extraneous conversation. The Flight Crew contacted Shannon, at 23.51 hrs, to confirm that EIKN was closed, while the Rear Crew continued to try, unsuccessfully, to establish two-way communications with R118. The Winch Operator bemoaned the lack of communications with R118, saying that '*yeh, no point in us not having comms with one one eight…that's what we're here for*'. At 23.52 hrs, the Commander remarked that '*God I'd say I haven't been in Blacksod in about fifteen years*' to which the Winchman replied '*Yeh, it's been a while for me too alright*'. The Commander then asked the Co-pilot directly '*how about you* [Co-pilot name] *have you been in recently*?' To which the Co-pilot replied '*no not recently* [Commanders name], *been a while*'. At approximately 23.59 hrs, the Winch Operator and the Co-Pilot had a discussion about the Winch Operator's experiences with radio communication the previous week.

At 23.54 hrs, MRSC Malin advised R116 that the visibility at Blacksod was now down to three miles. The Winch Operator informed the Commander, who acknowledged the information and requested a report of the cloud base and the wind also. The Winch Operator relayed the request to MRSC Malin. At 23.55 hrs, the Commander asked '*can you guys take that one there that book out of the way it's kind of annoying me I need to do this*'. Between 23.54 hrs and 00.05 hrs the four Crew Members were involved in combined efforts to contact R118 via the different communications options on board. R116 was unable to establish communications with R118 during this period. MRSC Malin did advise that they were receiving AIS transmissions from R118.

At 00.05 hrs, the Commander said '*just going to double check that route em* [Co-pilot's name] *to see if … we need to do any overflys*[40]' and she followed shortly afterwards with '*yeh it does say here em severe turbulence may be experienced during this approach due to proximity of Achill Island*'. The Co-pilot acknowledged, and the Commander went on '*in strong winds from the south south westerly direction so*' to which the Co-pilot responded '*Okay*'. The Commander continued '*we're kind of there but more westerly*', the Co-pilot acknowledged, and the Commander continued '*eh use of A B P S Blacksod North ... sure we'll give it a go if we don't like it we'll just go north*[41]', which the Co-pilot acknowledged '*Yeh Okay*'.

The Commander continued '*overfly that's good...overfly... eh I think we'll just keep them all overflys … might be away far enough from the land aren't we … yeh … that one we'll probably make a smart turn though*'. The Co-pilot concurred saying '*it's quite tight for an overfly*'. The Commander then said '*BKSDC … we'll cancel overfly that one*'. Cancelling '*overfly*' made the waypoint a '*Smart-turn*[42]' waypoint.

[40] **Overfly:** Also termed '*flyover*'. The UNS1 FMS Manual states that '*A flyover waypoint is a waypoint which will cause the navigation computer to delay making an automatic leg change until the aircraft is directly over the waypoint.*'

[41] The '*General Comments*' section of the Operator's Route Guide: '*Route APBSS (Blacksod South) Route*' states that '*Severe turbulence may be experienced during this approach due to the proximity of Achill Island. In strong winds from a south/ south westerly direction use of APBSN (Blacksod North) is advised.*'

[42] **Smart Turn:** The Operator's term for an automatic leg change. The UNS1 FMS Manual states that '*Automatic leg changes occur before the TO* [to] *waypoint at a distance based upon groundspeed, leg change magnitude, and roll steering bank limit for the present altitude. The maximum distance before the waypoint at which the leg change will occur is 12 NM*'.

At 00.08 hrs, Blacksod helipad contacted R116 on Marine Channel 16. The Winch Operator said that they would arrive in 20 minutes, and requested information on the wind, cloud base, and visibility at the helipad. One of the helipad personnel advised the Winch Operator that the cloud base was '*three, four, five hundred feet*' and '*is good enough to come in*'. He also advised that the wind was west-south-west at 25-33 kts, and that the visibility was two miles. The Winch Operator asked the Commander if she had heard the transmission from Blacksod, but was told to standby, as the Commander was replying to an ATC transmission about communications with R118. The Commander then told the Winch Operator that she had copied the transmission as '*three hundred feet and whatever*'.

At 00.10 hrs, the Commander briefed the Co-pilot on the approach into Blacksod:

> '*I think we just go straight over and when we're happy enough to step it down em down below two four we'll do the approach one all the way down, let it just fly the route, get the speed back until we're comfortable and literally just let it fly all the way round em if we're happy with the visuals on the first run-in it'll be on my side so it'll be my landing. We'll go in, if not we'll just do a circuit all the way around and eh we'll make sure it's on a two four zero heading*'

The Winchman asked if Blacksod was approved for '*hot re-fuelling*'[43]. The Commander replied that she didn't know as she had not been there, but presumed that it was. The Commander asked the Winch Operator what he had done during the mission the previous week, and, though initially unsure, he recalled that they had kept '*spinning'* (rotor blades turning) the week before. The Commander then confirmed that the Helicopter would be at 22,400 lbs on arrival, which would allow them to do a PC1 arrival.

At 00.13 hrs, immediately following the Commander's briefing, the Co-pilot said that he wouldn't mind getting a look at '*the map*'. The Commander then took control of flying the Helicopter. The Commander advised the Co-pilot that it was on the first page. The Commander told the Co-pilot that everything was an overfly waypoint, with the exception that one waypoint which was a '*smart turn*'. The Co-pilot did not verbalise any obstacle information.

The Co-pilot asked what the '*escape route*' was if they did not become visual. The Commander replied '*direct to back down here or even just head south* […] *there's a mast up there somewhere they're saying on the west*'.

The Co-pilot agreed with this plan, and the Commander said that if they were unsuccessful at getting into Blacksod using the APBSS Route they could try to the '*North*' and if not, then they could route to Sligo. The Co-pilot was requested to get weather for Sligo. At 00.14 hrs, the Co-pilot offered '*to come back on the sticks*', but the Commander declined saying '*I'm happy enough there if you are actually … I'll stay on it*'. She also requested him to confirm her calculations of the minimum fuel required to return from Blacksod, via Sligo, to Dublin.

[43] **Hot Refuelling:** A term used to refer to refuelling the helicopter with rotor blades and/or engines running. This procedure reduces the on-ground time for refuelling, and is permitted in accordance with the Operator's OMA Section 8.2.1.7 '*Refuelling with engines / rotors running'*.

The Commander observed that they were passing over the high ground at the Nephin Mountains. '*There is a two six four five which is past Nephin isn't it*'. The Winchman replied that they had '*all the Nephins there*' and quoted a figure of '*630*', the approximate height in metres of the Nephin Beg Mountain when viewed on the OSI 1:50,000 map. The Co-pilot then contacted Shannon ATC and requested the latest weather report for Sligo and Dublin. Shannon provided the current Terminal Area Forecast for Sligo and the Commander noted, at 00.16 hrs, that they would '*get in on that on that low route*'.

When the weather for Dublin was provided, the Co-pilot noted that at that time both Sligo and Dublin were '*wide open'*. The Commander then asked the Co-pilot to check the fuel figures, and the Co-pilot replied, at 00.19 hrs, '*they look pretty good* [Commander's name] *to be honest with you, you seem to have covered all the bases*'. Shannon ATC then enquired how far west R116 intended to travel, and whether they intended to go all the way to the FV. The Commander advised the Co-pilot '*eh no idea*' and the Co-pilot advised Shannon that, while it was not their intention to go as far as the ship, it was a possibility because '*we're having problems getting two way with eh rescue one one eight at the moment*'. He said that they would land in Blacksod, refuel, and figure it out from there. At 00.21 hrs, the Commander commented that Achill was to the South of their track with a height of 2,267[44] ft, and that they were to be sure that they were clear of it before they descended. The Co-pilot asked how much fuel would be uplifted at Blacksod. The Commander and Co-pilot reviewed the fuel required for the various legs and for potential winching. Then the Commander asked the Co-pilot to check the fuel calculations to ensure that it was added up correctly, and offered the use of a calculator if necessary. The Co-pilot checked the calculations and confirmed that the figure of 5,800 lbs calculated by the Commander was good.

The Investigation was informed by several personnel that custom and practice was that the winchman or the winch operator would be called forward to the cockpit area to receive a briefing prior to an approach, which the Operator informed the Investigation would be carried out from the MFDs. On the Accident flight, at 00.24 hrs, the Winchman asked the Flight Crew '*could you show me our approach into Blacksod guys just so I have an idea with the eh FLIR when we get into it*'. The Co-pilot replied '*so it's to here, in, overfly, overfly, overfly, smart turn, here, not visual, back to here*'. The Winchman noted that the high ground was '*obviously in here somewhere*', and the Commander replied '*Down here…this is our first point here; we go S.D.A.* [an apparent reference to waypoint BKSDA]*, that's kinda when we're abeam Achill*'. The Winchman observed that there was going to be a strong tailwind on the approach. The Commander advised '*yeh we're just going to bring the speed back em we'll just we'll keep it coupled the whole way keep the speed back and it's much more manageable as we go around the corner there*'. The Commander said that if they were not happy on the first pass, '*we'll go back around, we'll couple it up go back around, and we go back in again though it's been donkey's years since I've been in here but we'll stay nice and controlled*'.

[44] The Commander stated '*two two six seven*' at 00.21 hrs, and stated '*two two five seven*' at 00.34 hrs. The latter is consistent with the spot height of 2,257 ft located near Achill Head as shown on the VFR Aeronautical Charts (1:500,000 and 1:250,000 scale) issued by the IAA, and on the 1:250,000 EURONAV imagery of the IAA aeronautical chart.

The Commander's stated descent plan was to cross the coast abeam the Achill area, start the DVE checks, and start descending once they passed waypoint '*BKSDA*'. The Commander noted that they had '*the high ground just coming in to our eh nine o'clock two two five seven*' and could start getting down. At 00.26 hrs, the Co-pilot checked with the Rear Crew if there had been any contact with R118. The Winch Operator advised that R118 and the Coast Guard had been in contact via satellite phone. He asked if the FV was 140 NM offshore. The Commander replied '*off Eagle Island, wherever that is…Where's Eagle Island*?'

The Winch Operator and Winchman discussed this question in a manner which suggested that they were looking at a map on the monitor at the SAR Operator's Station, and the Winch Operator then informed the Commander that *'oh yeh eagle island is at eh off the coast to the north there…yeh off Mayo'*. However, the specific map that was being displayed was not verbalised on the CVR.

OMF prescribed '*DVE approach checks*' which it said '*should be completed prior to the initial SAR approach / descent in a degraded visual environment.*' At 00.27 hrs, the Commander noted that they were abeam Achill and requested the DVE checks. The Crew commenced the DVE Approach checks (**Figure No. 10**, in blue).

	APPROACH	
1	Approach Briefing	Complete
	a. Approach type/use of FD/speeds	
	b. STAR/procedural sector	
	c. FAT/Crossing altitudes/timing	
	d. Minima (DA/MDA/MAP), weather	
	e. Runway elevation	
	f. Go-around procedure/after G/A	
2	Navaids	Set
3	MFD's	Set
4	Altimeters/Bugs/MSA	Set

	DVE APPROACH	
1	Landing Gear	Down, 3 greens
2	Radar	Mode/scale A/R
3	EGPWS	LOW ALT
4	Analogue Rad Alt	Set
5	Bugs	Set
	a. V_{TOSS}	Set
	b. ALTP	A/R
	c. MINS	MSA
	d. RADALT	A/R
	e. HVR RA	Set
6	Surface W/V	Noted
7	External lights	Set A/R
8	Let down procedure	Brief
9	Fuel	Review
10	Position	Confirm (2 separate sources)

Figure No. 10: Extract from Operator's S-92A Normal Checklist

The undercarriage was selected down and confirmed as having three greens. The Co-pilot called '*Radar*' and the Commander confirmed that the radar was ON and displayed on the Co-pilot's side, and requested the Co-pilot to select GMAP2 mode. The Co-pilot confirmed the selection of GMAP2, checked the TILT of the antenna and was satisfied with the GAIN setting on the radar, stating that he would '*bring that up to about four*', to which the Commander replied *'yea, you should get a good picture'*. The required scale was not specifically mentioned.

During the checks, the Commander requested and the Co-pilot confirmed that the EGPWS was selected to LOW ALT[45]; the Analogue Rad Alts were selected; the V_{TOSS}[46] bug was set to 38 kts; and ALT PRE was set to 2,400 ft, for the APP1 approach, which was to be flown fully coupled. MINS (minimums on pressure altimeters) were set to 2,200 ft. Rad Alt was set to 180 ft. The Commander stated '*if we get visual below we said three hundred feet at the moment so we'll aim just to go down to the two hundred*'. The Co-pilot said that he understood, and confirmed that 180 ft was set on the Rad Alts. The Commander stated that the Hover Rad Alt would be brought up to 150 ft '*just in case*'. The wind velocity was announced by the Co-pilot as being 240 degrees at 40 kts. The Commander requested that all the external lights were to be switched on, with the exception of the NIGHTSUN, which was to be armed. The Co-pilot called out each lighting system as he switched it on: Position lights, logo lights, rotor lights, scene lights, and he confirmed with the Winchman that the NIGHTSUN was armed. There was no indication from the CVR that the Approach checks (**Figure No. 10**, in yellow) were conducted.

OMA 8.3.19.3 '*Using the checklist system*' states '*Steps that require dual pilot action and / or verbal confirmation are signified in bold with a solid line connecting the challenge and response*'. The Investigation notes that '*Let down procedure*' is not marked with such a bold line.

OMF prescribes more details for the item 8, '*Let down procedure*', and item 9, '*Fuel*', as follows:

*'**8.** Let-down procedure .... Brief*

- ***a.** Crew brief to include the following:*
  - ***i.** Tracks and waypoints*
  - ***ii.** Use of FD: APP modes and altitudes; roll channel use*
  - ***iii.** Capture speed*
  - ***iv.** Decision point*[47]
  - ***v.** Go-around heading and altitudes*
  - ***vi.** Use of APU*[48]

***9.** Fuel .... Review*

- ***a.** Quantity remaining*
- ***b.** Fuel burn on scene*
- ***c.** Minimum off-scene fuel (bingo)'*

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[45] **LOW ALT Switch:** See Section 1.6.6.6 of this Report.

[46] **V_{TOSS}:** Take-off Safety Speed, the minimum speed at which the best angle of climb may be achieved with one engine inoperative.

[47] **Decision Point**: The point at which the PM must either have acquired sufficient visual references to continue with the approach or hover manoeuvre, or else conduct a go-around.

[48] **Use of APU**: OMF says '*Use of APU: The implications of an AC generation malfunction in the low-level DVE environment could potentially have serious consequences. With the APU selected on, the implications may be reduced significantly. Consideration should be given to turning on the APU prior to descent in to a DVE. The 'offload' fuel burn of the APU is approximately 60 lb/hour*.' However, the Helicopter Manufacturer informed the Investigation that '*the S-92A electrical system is fully redundant, such that if an AC Generator malfunctions there is no loss of functionality and thus no immediate consequence. After a single generator or Generator Control Unit failure, the full electrical load is taken over by the second generator. The S-92A Rotorcraft Flight Manual Part I, Section III "Emergency Procedures" section "Electrical System Malfunctions" address failures related to the AC electrical system. Sikorsky notes that selecting the APU on before operations in a low-level DVE environment mitigates risks related to loss of both AC electrical systems.*'

The let-down procedure was briefed by the Commander, with all timings and acknowledgements by the Co-pilot presented in square brackets, as follows:

> '[Commander at 00.30:01 hrs] *okay let-down procedure, can I wait until we're abeam this alpha position* [an apparent reference to waypoint BKSDA] *here* [Co-pilot acknowledged at 00.30:05 hrs: *okay*] [Commander at 00.30:06 hrs] *and then we're going to, I'm going to select alt pre down to two thousand and four hundred feet,* [Co-pilot acknowledged at 00.30:09 hrs: *roger*] [Commander at 00.30:10 hrs] *if you're happy we're clear of everything* [Co-pilot acknowledged at 00.30:11 hrs: *understood*] [Commander at 00.30:12 hrs] *I'm going to do an approach one all the way down to two hundred feet, eighty knots,* [Co-pilot acknowledged at 00.30:15 hrs: *yes*] [Commander at 00.30:16 hrs] *eh, it might be slightly past M O* [an apparent reference to waypoint BLKMO] *at that moment so we'll see what, how we are height wise at that moment, so I think we'll just eh take a heading, continue on past there go back around and the aim is just to follow the route all the way round em and eh* [Co-pilot acknowledged at 00.30:27 hrs: *roger understood*] [Commander at 00.30:29 hrs] *getting the speed back as much as we're comfortable, we're aware we're going to have a pretty high ground speed on the way in.* [Co-pilot acknowledged at 00.30:34 hrs: *Okay*]'

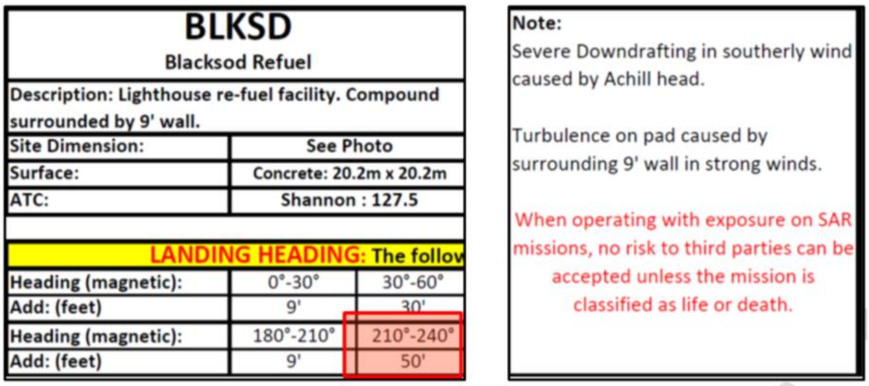
At 00.30:37 hrs the Co-pilot said '*so that's the let-down procedure*' immediately followed by the word '*fuel*', which is the next item after let down brief on the '*DVE APPROACH*' checklist. The fuel was checked by the Commander as being 3,000 lbs which was stated as being more than sufficient to get to Sligo, and that the weather at Sligo was good.

87 For item 10 on the '*DVE APPROACH*' checks (**Figure No. 10**), the position check required two separate sources. The Commander said that they could see where they were and asked whether everybody was happy with the position. The Co-pilot confirmed that he was happy, and the Winchman said that they were out over the water. At 00.31 hrs, the Commander asked the Co-pilot to call out the Helicopter's current latitude and longitude. The Winchman confirmed that this was '*bang on*'. The position of this cross-check is shown in **Figure No. 11**.

Figure No. 11: Location of position cross-check carried out at 00.31 hrs

Following this position check, the Co-pilot announced that the '*DVE checks'* were complete. The Winchman then informed the other Crew Members that R118 had five minutes to run to the FV. The Co-pilot said that this news was '*fantastic'*, and the Commander observed that they (R116) would not have to go too far.

At 00.32 hrs, the Flight Crew had an initial discussion about the arrival at the helipad at Blacksod. The Commander initially asked the Co-pilot to double check that 50 ft was to be added to the LDP[49] for their arrival heading of 210-240 degrees (highlighted with a red box in **Figure No. 12**). The Co-pilot confirmed the 50 ft addition to the LDP. The Commander replied '*fifty feet okay and anything else they're saying on that eh*'. The Co-pilot then read the note from the LSD '*eh severe downdraft in southerly wind caused by Achill Head … turbulence on pad caused by surrounding nine foot wall and strong winds … eh when operating with exposure on SAR missions no risk to third parties can be accepted unless the mission is classified as life and death*'[50]. The notes read by the Co-pilot appear on the '*Landing Site Guide'* on the '*BLKSD Blacksod Refuel'* chart (**Figure No. 12**).



BLKSD Blacksod Refuel		
Description: Lighthouse re-fuel facility. Compound surrounded by 9' wall.		
Site Dimension:	See Photo	
Surface:	Concrete: 20.2m x 20.2m	
ATC:	Shannon : 127.5	
LANDING HEADING: The follov		
Heading (magnetic):	0°-30°	30°-60°
Add: (feet)	9'	30'
Heading (magnetic):	180°-210°	210°-240°
Add: (feet)	9'	50'

Note:
Severe Downdrafting in southerly wind caused by Achill head.

Turbulence on pad caused by surrounding 9' wall in strong winds.

When operating with exposure on SAR missions, no risk to third parties can be accepted unless the mission is classified as life or death.

Figure No. 12: Extracts from '*BLKSD Blacksod Refuel*' chart

The Commander then briefed the Co-pilot that the landing at Blacksod would be a PC2 landing using a PC1 profile, that the LDP would be 175 ft and the VTOSS would be 50 kts. The Commander asked the Co-pilot to keep a close eye on her going in, and that if there were any problems that they would execute a go-around to the south and couple the aircraft controls back up again. The Co-pilot acknowledged this. Immediately following the briefing, the Commander noted that the Helicopter was approaching position BKSDA, and that there was high ground of 2,257 ft in their '*9 O'clock*' position. The Commander said that she would reduce the speed to 100 kts and requested the Co-pilot to select '*ALT PRE*' down to 2,400 ft. The Winchman advised that they were *'all clear ahead'*. The Co-pilot confirmed the selection of ALT PRE and informed Shannon ATC that they were leaving 4,000 ft and descending to make their way into Blacksod for refuelling.

At 00.35 hrs, the Co-pilot asked the Commander '*you happy with the range* [Commander's name] *at the moment yeh*'. The Commander replied '*eh yes for the moment yeh I'm just going to stick on the map if you're happy* [Co-pilot's name] *for the moment* […] *I'll let you mess about with those ranges whatever you're happy with*'. The Co-pilot then noted that the Helicopter was passing 3,400 ft for 2,400 ft.

[49] **LDP**: Landing Decision Point.

[50] The Operator informed the Investigation that this caution refers to departures from the helipad above a maximum operating weight of 24,500 lbs as described in *OMF Section 10.4.4.2.2 PC2 takeoff – With exposure (SAR missions only).*

The Commander replied that there was one thousand to level, and then the '*Approach One*' [an apparent reference to APP1]. She noted that they had four miles to run to BLKMO and asked the Co-pilot to select heading mode and said that they would '*stay here*' until they were at the height they wanted. The Commander then briefed the Rear Crew that there were four miles to run to the first waypoint, and that they would route a bit further west in order to complete the APP1 descent profile down to 200 ft.

At 00.36 hrs, there was the sound of a synthetic voice calling '*LEVEL OFF*'. The Helicopter reached 2,400 ft and the Commander requested the Co-pilot to select '*Approach One, three-cue, coupled'*. The Commander then confirmed the selection and capture of the Approach One mode, indicated airspeed with Rad Alt armed in the descent, and that they were '*in heading*' going past their '*initial point*' (BLKMO). At 00.38 hrs, there was the sound of a synthetic voice calling '*MINIMUMS MINIMUMS*'. The Commander acknowledged the annunciation and asked the Co-pilot to reset the '*ALT PRE'* to 500 ft. The Co-pilot confirmed the selection and noted that they had one mile to go to BLKMO (flying west bound) and were passing 2,000 ft for 200 ft. The Commander noted that the radar was clear and initiated a turn to the right (noted on the FDR to be ten degrees) so that they could sweep back around to the left when they levelled at 200 ft.

The Commander advised the Rear Crew that the Flight Crew were disabling the audio on the HF and FM radios as it was going to be '*busy for a bit*', and the Winchman and Winch Operator acknowledged this. The Commander asked the Crew to *'keep your eyes peeled once we get down there'*. This was acknowledged by the Winchman and the Co-pilot. At 00.40 hrs, the Cockpit Crew cross-checked that the Helicopter was passing 1,000 ft on the Rad Alt. The Commander requested that the anti-ice be turned off as the OAT was +10 degrees. The Commander then said that the plan was to reduce the speed to 90 kts to avoid any '*squawks'*[51]. Thereafter, the Co-pilot called out the height in 100 ft increments. At 00.41 hrs, passing 700 ft, the Commander requested confirmation that they were clear ahead on radar and on EGPWS. The Co-pilot confirmed that they were '*clear ahead on ten mile range*'. The Commander requested direct to BLKMO again and indicated that they would maintain their heading until they were level, and that it would then be a left turn. The Co-pilot continued the altitude callouts in 100 ft increments until passing 300 ft, which he additionally confirmed as *'100 feet to go to 200 feet'*. Thereafter, he called out the altitude in ten foot increments until the Helicopter levelled at 200 ft Rad Alt. The Commander noted the speed reducing in accordance with the Approach One profile.

The Commander announced that Approach One was complete, that the Helicopter was turning back around to the left and that, once inbound, she would be asking for NAV. The Winchman reported *'OK, clear around to the left'* and the Co-pilot called *'Clear ahead on E GYP WIZZ and radar.*' At 00.42 hrs, the Commander requested the Co-pilot to select '*NAV…or Search*', and then confirmed that '*Indicated airspeed, search, and Rad Alt captured'*. This statement would usually refer to the captured AFCS modes as displayed across the top of the Pilot's PFD, as shown in **Photo No. 14**.

[51] This appears to be a reference to potential '*nuisance*' alerts from the EGPWS system. The Investigation understand that when using APP1 to descend, if IAS is left above 100 KIAS the EGPWS can perceive a threat as the aircraft is descending towards the water; the speed will reduce with the APP1 profile, but potentially not before the EGPWS system gives an aural & visual warning. Accordingly, the Operator trains its personnel not use APP1 above 100 KIAS.

Photo No. 14: Photo of S-92A MFD 1, taken during Review Flight (**Section 1.16.1**)

At 00.43 hrs, the Commander requested the '*Before Landing*' checklist in anticipation of an increase in groundspeed. The Landing gear was confirmed as down with '*three greens*'. In response to item No. 2 '*Radar*' on the '*Before Landing*' checklist (**Figure No. 13**), the Commander replied '*It's on, we're using it*'.

	BEFORE LANDING	
1	**Landing Gear** ______________	**DN, 3 Greens**
2	Radar	A/R
3	**Parking Brake** ______________	**A/R**
4	DCP bugs	A/R
5	**Compasses** ______________	**SLAVED/DG**
6	(*)Role Equipment	A/R / Secure
7	Landing Briefing	Complete

Figure No. 13: Extract from Operator's S-92A Normal Checklist

The Commander handed over control of the collective lever while the parking brake was placed to '*ON*'. The Commander then resumed control of the collective lever and confirmed that she was happy with the Display Control Panel (DCP) bugs. The Flight Crew cross-checked the Helicopter compass on a heading of 179 degrees and the Commander stated that '*I'm going to start my left turn now'*. In reply, the Co-pilot noted '*starting to get ground coming in there at just over eight miles in the ten o'clock position*'. The Commander replied that this made sense. The role equipment was confirmed to be secure by both the Winchman and the Winch Operator. The Commander's landing briefing was '*okay again just got the surface visual there anyway which is good eh brief for landing eh I'd say it's going to be a PC two, em, landing using a PC one profile L D P one seventy five feet go-round V_{TOSS} fifty five knots'.* The Co-pilot acknowledged the brief and then stated that the before landing checks were complete. The Commander then requested the Co-pilot to '*put the speed back to seventy five* [kts IAS] *as we go round the corner*', to which the Co-pilot replied '*seventy five selected*'. There was no discussion on the CVR recording of the horizontal visibility in the Black Rock area.

The transcript of the remaining portion of the flight was included in the Investigation's Preliminary Report. Following further review of the CVR, an updated version of the transcript is included in **Appendix M** of this Report. The Co-pilot noted, at 00.45:21[52] hrs that there was 1.3 miles to run to BLKMO, and that the next waypoint would be '*Bravo Kilo Sierra Delta Alpha'*.

[52] The time format used for the remaining part of **Section 1.11.4** will be ***HH.MM:SS***.

The Commander confirmed the configuration of the aircraft as '*Indicated Airspeed, Search and Rad Alt*'. The Co-pilot noted, at 00.45:37 hrs, that there were '*small targets*[53] *at six miles 11 o'clock…large out there to the right*'. Three seconds later, a synthetic voice was heard annunciating an '*ALTITUDE ALTITUDE*' caution. The Commander acknowledged this by stating that '*there's just a small little island that's BLMO itself*'[54].

At 00.45:56 hrs, the Winchman informed the Commander that he was '*looking at an island directly ahead of us now guys, you wanna come right* [Commander's name]'. The Commander asked the Winchman '*OK come right, confirm?*' The Winchman replied '*twenty degrees right yeh*'. At 00.46:02 hrs, the Commander requested the Co-pilot to '*OK come right, select heading…select heading*'. This was in accordance with '*8.3.17.3.2* ***Autopilot – Coupler / flight director modes***' which states '*All mode selections below 500 feet at night or in IMC shall be made by the PM, on the PF's request, with the exception of selection of GA (and any other mode that may be engaged directly by buttons on the flight controls) and full disengagement of the coupler / FD.*

The Co-pilot replied, at 00.46:04 hrs, '*Roger…heading selected*'. Within one second of the Co-pilot's reply, the Winchman said '*Come right now…come right…COME RIGHT*' in an increasingly concerned tone; less than one second after this, at 00.46:08 hrs, a synthetic voice was heard annunciating an '*ALTITUDE ALTITUDE*' caution. Coincident with the second annunciation of the word '*ALTITUDE*', a sound was heard, which the Investigation believes was due to the initial impact. During the final seven seconds of the CVR recording there were no recorded identifiable verbalisations by any Crew Members or exchanges between the Crew. A synthetic voice was heard annunciating a number of caution messages prior to the end of the recording; '*SMOKE IN BAGGAGE, SMOKE IN BAGGAGE*', '*DECOUPLE*', '*TOO LOW GEAR TOO LOW GE*'. The recording ended at 00.46:19 hrs, during the second annunciation of the '*TOO LOW GEAR*' caution.

1.11.5 Cockpit Area Microphone Recordings – Content

The CVR recorded two Cockpit Area Microphone (CAM) Channels, previously described as the '*LQC*' and '*HQC*' Channels. The LQC Channel recorded 2.02:30 hrs of low quality (150 Hz to 3.5 kHz) recording of the CAM. The HQC Channel recorded 33.43 minutes of high quality audio (150 Hz to 6 kHz) from the CAM. The microphone which supplies the audio to the CVR is located on the upper part of the main cockpit instrument panel between MFD 5 and MFD 3.

The Investigation examined a spectrogram[55] of the CAM recordings (**Figure No. 14**) with the assistance of the UK AAIB Recorder Laboratory and noted that the audio frequency of the recording was consistent with the Helicopter's main rotor RPM as recorded on the FDR. In particular, the Investigation observed that there was a drop in the audio frequency of the CAM recording in the moments leading up to the initial sound of impact at 00.46:08 hrs.

[53] In Preliminary Report 2017-006, the transcript stated the phrase; '*small target at six miles*'. Subsequent review, analysis and validation of the CVR concluded that the word used by the Co-pilot was '*targets*' (plural).
[54] In Preliminary Report 2017-006, the transcript stated the phrase; '*Eh just a small little island… that's B L M O itself*'. Subsequent review, analysis and validation of the CVR concluded that the phrase used by the Commander was '*there's just a small little island that's B L M O itself*'
[55] **Spectrogram:** A graph with time on X-axis and audio signal frequency on Y-axis (also called a Sonogram). Frequency is measured in a linear vertical scale from 1,024 to 8,000 hertz.

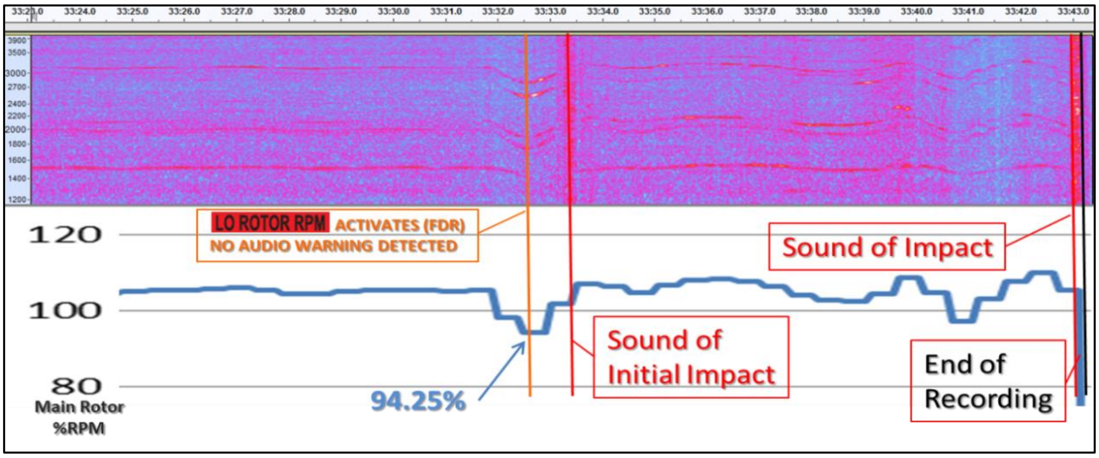


Figure No. 14: Spectrogram of final 20 seconds of ‘HQC’ CAM recording with FDR Main Rotor RPM data

The CAM audio recording indicated that there was an increase in a sound that may have been due to wind noise. While the noise was of a similar frequency to the rotor RPM noise shown in the Spectrogram, an examination of the waveform[56] of the final 10 seconds of the flight (**Figure No. 15**) indicated a gradual but considerable change in amplitude during the final five seconds of the recording.

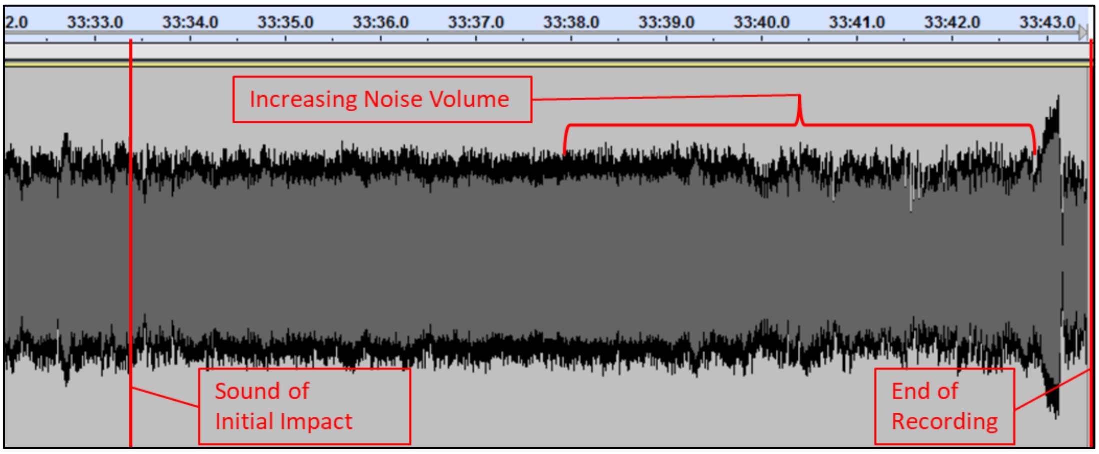


Figure No. 15: Waveform of Final 10 seconds of R116 ‘HQC’ Cockpit Area Microphone

The CAM channel did not record any sounds that would indicate the separation of any parts of the cabin structure, doors or windows prior to the end of the recording.

A sound consisting of two sequential, high-pitched, half second long, descending tones was recorded at 00.46:13 hrs, immediately following the second annunciation of ‘*SMOKE IN BAGGAGE*’, on two of the CVR channels. The sound was recorded on the ‘*CVC*’ and ‘*CV1*’ channels, but not on either of the Cockpit Crew channels (‘*CV2*’ and ‘*CV3*’). The sound was not heard again during the final six seconds of audio recording.

[56] **Waveform:** A graph with time on X-axis and audio signal amplitude on Y-axis. Amplitude is measured in a linear vertical scale from -1.0 to +1.0 units.

1.11.6 Recorded Flight Data

1.11.6.1 Position Data (Latitude and Longitude)

As noted in the Investigation's First Interim Statement, during the examination of the data recovered from the FDR, the Investigation found that the latitude and longitude position information, whilst generally consistent with the expected flight path, appeared anomalous (**Figure No. 16**).

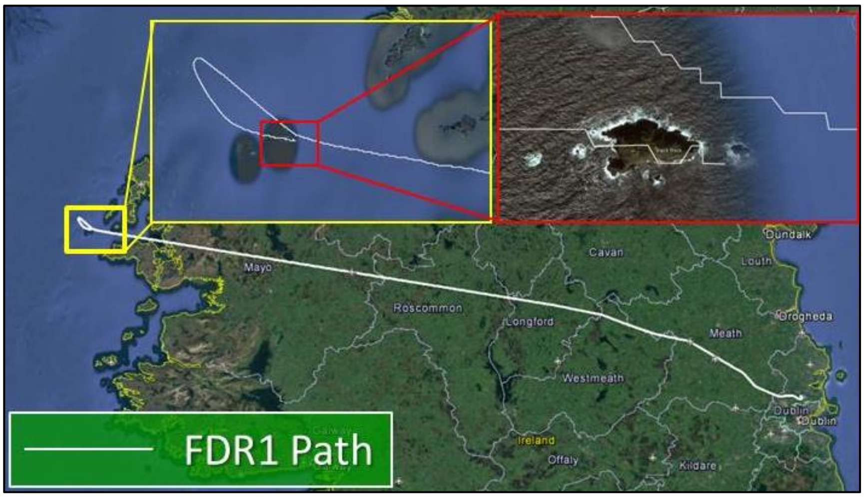


Figure No. 16: Position data from FDR1 showing the flight path of EI-ICR

It was noted that the position information recorded on FDR1 produced a jagged or '*zigzag*' flight path. The Investigation reviewed the position information for FDR2 for comparative purposes; this data also indicated a jagged flight path (**Figure No. 17**).

The Investigation reviewed the FDR positional data for EI-ICG, another IRCG S-92A helicopter. This data also produced the jagged or '*zigzag*' flight path. The Investigation informed the Helicopter Manufacturer of this finding; the Manufacturer conducted an examination of the data processing and recording system for present position on the S-92A helicopter.

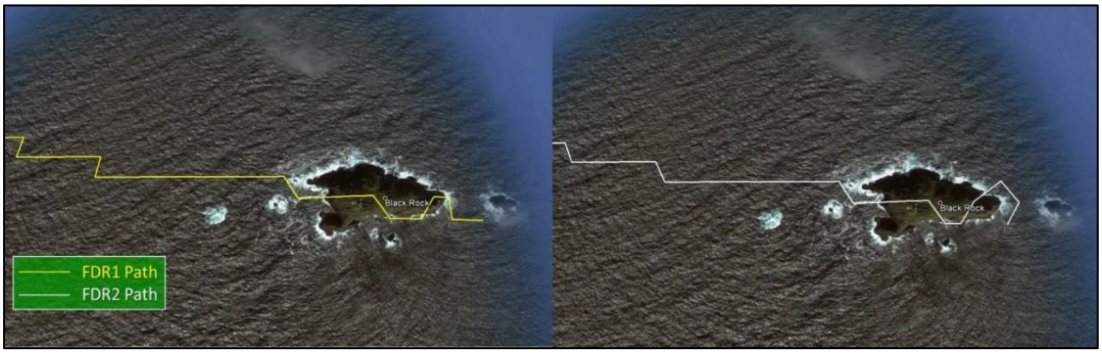


Figure No. 17: Position data from FDR1 and FDR2 showing the flight path of EI-ICR

The primary navigation interface between the helicopter and the flight crew is the FMS. Raw GPS data is received by the FMS from satellite sensors and is provided as an input to the various aircraft systems including the AHRS, and the MFDs in order to enable accurate navigation of the helicopter.

Thereafter, the position data is provided to the various recording systems on board the helicopter, such as the FDR and HUMS. This architecture is shown in **Figure No. 18**. The Helicopter Manufacturer informed the Investigation that the position data being supplied from the AHRS, to the MFD and HUMS is formatted in four parts; a *coarse* position for latitude, a *coarse* position for longitude, a *fine* position for latitude and a *fine* position for longitude. The *coarse* position is accurate to within approximately 61 ft, and the addition of *fine* position increases the accuracy of the overall position to within approximately 2 ft. It was noted by the Investigation that the MFD did not supply the four components of the position data to the FDR at all times.

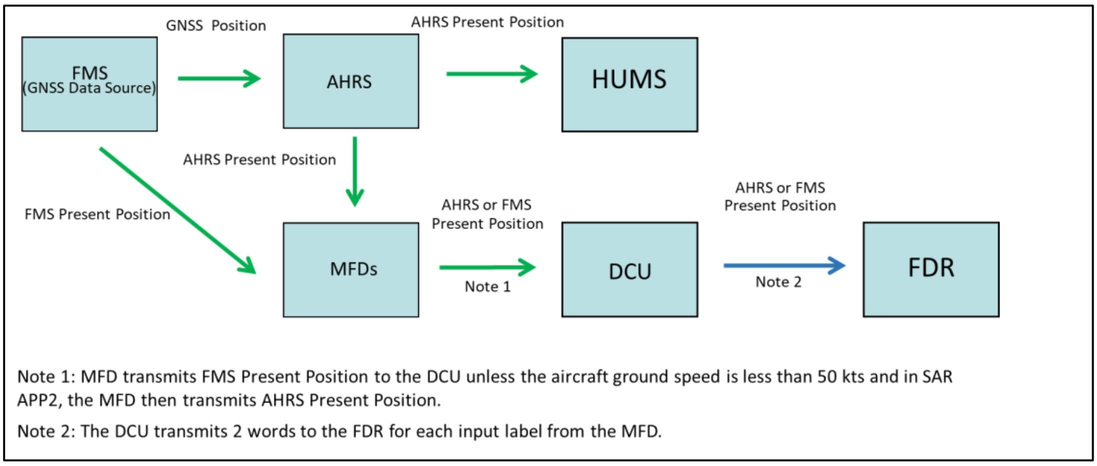


Figure No. 18: Positional Data Flow from FMS to FDR and HUMS (*Helicopter Manufacturer*)

The Helicopter Manufacturer informed the Investigation that the MFD logic was designed to provide both *coarse* and *fine* position data to the FDR if the helicopter was travelling at a groundspeed of less than 50 kts and/or in SAR APP2 (SAR Approach Mode 2). At all other times, only *coarse* data was to be provided to the FDR, which reduced the accuracy from within 2 ft to within 61 ft approximately.

During the accident flight the Helicopter departed from EIDW and accelerated to normal cruising speed. Thereafter, the FDR data indicated that it remained above 50 kts groundspeed until the end of the recording.

The Helicopter Manufacturer informed the Investigation that the difference between the *coarse* and *fine* position was insufficient to account for the jagged flight path that was recorded on the FDR of EI-ICR (and EI-ICG). The MFD supplies the position data through a Data Concentrator Unit (DCU) to the FDR. This data consists of 20 bits[57] of information for each of the two parameters (*coarse* latitude and *coarse* longitude). Following further examination of the FDR data recording process, the Manufacturer informed the Investigation that a formatting error in the data output from the MFD to the DCU caused two bits of data to be masked (hidden) from view. This error resulted in 18 bits rather than the original 20 bits of data being recorded on the FDR for the position of the Helicopter. This masking resulted in a reduction in the accuracy of the *coarse* position recorded from approximately 61 ft to 247 ft. The existence of this error has been confirmed by the Helicopter Manufacturer through laboratory and flight testing.

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[57] **Bit:** Binary Digit – a single piece of digital data, consisting of either a '1' or '0' binary value.

1.11.6.2 Safety Action – Position Data (Latitude and Longitude)

The Helicopter Manufacturer advised the Investigation that the formatting error would be addressed by a future software update. The Manufacturer confirmed to the Investigation that the error in the formatting of position data does not affect the navigation functions of the helicopter, pilot displays, AHRS, or HUMS recorded data. The error is limited to the data passed from the MFD through the DCU to the FDR. The Manufacturer also confirmed that the data processing system is unique to the S-92A helicopter and is not used in the Manufacturer's other types or variants of helicopter. Accordingly, the Investigation is satisfied that this anomaly was not a factor in the accident.

In the Investigation's First Interim Statement, the Investigation acknowledged the positive engagement of the Helicopter Manufacturer in identifying the root cause of the position data discrepancy in the FDR recordings. Notwithstanding the Safety Action commenced by the Manufacturer, *coarse* position data was (and is) being provided to the FDR of S-92A helicopters. The '*Manual of Accident and Incident Investigation (ICAO Doc 9756)*' states that '*The primary purpose of a modern FDR system is to capture all significant data related to the operation and performance of the aircraft'*. The Investigation was of the view that the most accurate available position should be recorded on the FDR, regardless of groundspeed, SAR mode or any other flight phase. Consequently, the Investigation issued Safety Recommendation **IRLD2018001** relating to the Flight Data Recording System in its First Interim Statement.

95 The Sikorsky Aircraft Corporation should make the necessary updates/modifications to the S-92A helicopter to ensure that the latitude and longitude information recorded on the Flight Data Recorder reflects the most accurate position information available during all flight regimes and mission profiles (**IRLD2018001**).

The response to date is presented in **Appendix G** to this Report.

1.11.7 Navigation Mode Data (AFCS SAR Modes)

During the course of the Investigation, it became apparent that not all of the lateral navigation modes were being recorded to the FDR. In particular, during the final three minutes of the accident flight, the FDR contained no record of an AFCS lateral navigation mode being used to navigate the Helicopter along the desired flight path until activation of the Heading mode just prior to the initial impact with Black Rock. The CVR provided the Investigation with an indication of the navigation mode requested by the crew during the flight. The Investigation was able to identify an absence of a selected lateral navigation mode on the FDR. However, this did not eliminate the possibility that the Helicopter was operating in some form of '*roll hold*' mode in the absence of any other selected lateral mode.

The Helicopter Manufacturer confirmed that not all AFCS SAR modes are recorded on the FDR. The Manufacturer informed the Investigation that the AFCS SAR modes are recorded on the HUMS card. Using the HUMS data, the Manufacturer provided the Investigation with the necessary lateral navigation parameters in use during the flight.

The Investigation was unable to find any reference to the '*SRCH*' mode in the Helicopter Manufacturer's RFM Supplement or in the Operator's operations manuals. The Operator informed the Investigation that selecting '*SRCH*' on the SAR mode menu on the MSP, coupled the helicopter to the roll channel, and that the functionality was identical to selecting '*NAV*' on the MSP. The Operator further explained that if a crew was following an FMS company route, and had the SAR menu active on the MSP, they would press the SRCH button which would couple the helicopter in roll, and the helicopter would fly the route for them.

The Helicopter Manufacturer informed the Investigation that when SRCH is engaged, the Coupled Flight Director (CFD) can only couple to the FMS, as opposed to the NAV button, which allows coupling to either FMS or VOR. It also said that use of the SRCH button provided a subset of the functionality of the NAV button. The Helicopter Manufacturer confirmed that SRCH can be used to follow FMS navigation without an active search pattern, that existing RFM documentation on NAV mode also applies to SRCH, and that there is no specific published guidance on AFCS SRCH mode.

Sikorsky S-92A RFMS No. 4 Part 1 includes the following limitation related to the use of SAR AFCS modes: '*Night or IMC SAR approaches are only permitted if the entire approach is conducted overwater'.*

1.11.8 Recorded Flight Data Timing

As previously described in the Investigation's Preliminary Report, the FDR component of the MPFR recorded the data from 952 parameters over a period of 25 hours. The MPFR recorded two copies of these parameters – one copy to each of the respective DOC modules on the CSMM (FDR1 and FDR2). The Investigation initially noted that there was a discrepancy of approximately 32 minutes between FDR1 and FDR2 recording durations. The Investigation confirmed that this anomaly did not result from corrosion during immersion in salt water or due to any pre-existing condition. The FDR data contained a series of *'random zeroes'* which were recorded to the device during routine power interruptions associated with start-up and shut-down of the Helicopter. The discrepancy occurred due to a read error by the MPFR manufacturer's proprietary software, which identified the zeroes as valid flight data, rather than as part of the power-up or power-down of the device. When the data was extracted using the AAIU's proprietary software, which correctly interpreted the *'random zeroes'* data, there was no discrepancy between the duration of the two sets of data on the MPFR (FDR1 and FDR2). This confirmed that the same flight data duration had been recorded on both of the FDR DOCs. The Investigation is satisfied that this anomaly did not affect the analysis of the data.

1.11.9 FDR Flight Data Summary

The FDR data indicated that the Helicopter departed EIDW from RWY 16 at 23.02 hrs, and commenced a climbing right turn, during which time the FMS lateral navigation (LNAV) mode was selected. This mode established the Helicopter on a course direct to Sligo. As the Helicopter passed through 1,400 ft altitude, Dublin ATC provided radar vectors for traffic separation. The Helicopter levelled at an altitude of 3,000 ft on a QNH of 1029 hPa as it crossed '*The Ward*', approximately 2 NM west-north-west of Dublin Airport, and accelerated to an IAS of 130 kts. The Helicopter resumed lateral navigation to Sligo at 23.09 hrs, and followed the track shown in **Figure No. 19**.

At 23.20 hrs, in the vicinity of Athboy, Co. Meath, the Helicopter turned left onto a course that would bring it towards Blacksod Helipad. At 23.34 hrs, the Helicopter commenced a climb from 3,000 ft using vertical speed and reduced the IAS to 100 kts as it passed south of Granard, Co. Longford. The Helicopter levelled at 4,000 ft altitude three minutes later and accelerated to 130 kts IAS. The Helicopter maintained a course towards Blacksod Helipad for an additional three minutes. At 23.39 hrs, as the Helicopter passed 6 NM north-east of Longford Town, the course was adjusted to route directly to the FMS waypoint BLKMO, which involved a left turn of approximately four degrees onto a magnetic course of 280 degrees. The Helicopter maintained this course and altitude at an indicated airspeed of 130 kts.

Figure No. 19: Flight Path of R116 from departure until on track for Sligo

At 23.43 hrs, the FDR recorded the Co-pilot's weather radar range, which had been set at 10 miles range from the start of the flight, was set to 25 mile range. The Co-pilot's MFD 2 was the only cockpit screen that displayed weather radar information during the flight (**Table No. 23**).

At 00.17 hrs, the selected IAS was reduced to 120 kts. As the Helicopter passed 2 NM south of Nephin Beg Mountain at 00.22 hrs[58], while still at 4,000 ft, the FDR recorded that the selected range on the weather radar was changed from 25 miles range back to 10 mile range. The position of this range change was 24 NM east of Black Rock, and was just prior to the Co-pilot briefing the Winchman on the intended route into Blacksod. At 00.32 hrs, the selected IAS was reduced to 110 kts.

The FDR recorded data related to the MFDs and the weather radar for the duration of the flight. The configuration of each MFD and the weather radar mode and range settings from the point at which the Helicopter commenced descent from 4,000 ft until the end of the recording are shown in **Table No. 23**. These settings did not change during the remainder of the flight.

Parameter	Status Option	MFD1	MFD2	MFD5	MFD3	MFD4
WxR Display	**ACTIVE/ NOT ACTIVE**	NOT ACTIVE	ACTIVE: 10NM Range	NOT ACTIVE	NOT ACTIVE	NOT ACTIVE
Terrain Display	**ACTIVE/ NOT ACTIVE**	ACTIVE	NOT ACTIVE	NOT ACTIVE	NOT ACTIVE	NOT ACTIVE
Display Mode	**PFD/NAV/ EICAS/VIDEO**	PFD	NAV	EICAS	TACTICAL VIDEO[59]	PFD
Display Format	**HSI FULL/ARC Dig Map/Fixed**	ARC	ARC	N/A	DIG MAP	FULL
Declutter	**ACTIVE/ NOT ACTIVE**	NOT ACTIVE	NOT ACTIVE	NOT ACTIVE	NOT ACTIVE	NOT ACTIVE
TCAS Display	**ACTIVE/ NOT ACTIVE**	ACTIVE	ACTIVE	NOT ACTIVE	ACTIVE	ACTIVE
Flight plan	**SELECTED/ NOT SELECTED**	SELECTED	SELECTED	NOT SELECTED	SELECTED	NOT SELECTED
LTNG Display	**ACTIVE/ NOT ACTIVE**	NOT ACTIVE	NOT ACTIVE	NOT ACTIVE	NOT ACTIVE	NOT ACTIVE

Table No. 23: EI-ICR MFD Configuration from Top of Descent until End of Recording

At 00.34 hrs, the Helicopter began to descend from 4,000 ft at a rate of 500 fpm using FD No. 1 Alt Pre-select mode, and the IAS was reduced to 100 kts. The flight path and significant FDR events for the remaining 12 minutes of the flight are represented in **Figure No. 20**. The Helicopter passed through 3,400 ft in the descent at 00.36 hrs, and *'Heading'* mode was selected as the active lateral navigation mode. The Alt Pre-select mode remained engaged until 00.38 hrs, as the Helicopter passed 2,400 ft in the descent. This is the altitude at which APP1 AFCS SAR mode becomes available for selection. The FDR records APP1 selection at 00.37 hrs. At 00.39 hrs, the Helicopter turned right from a magnetic heading of 277 degrees onto a heading of 291 degrees. The IAS was selected to 90 kts at 00.40 hrs, and the Commander requested the Co-pilot to select '*Direct to BLKMO'* on the FMS, and he acknowledged this. The bearing to BLKMO at this time was 137 degrees. However, the Helicopter remained in '*Heading'* mode during the descent. At 00.42 hrs, an IAS of 80 kts was selected as part of the APP1 mode requirements. The APP1 mode disengaged at 00.42 hrs. The local OAT recorded by the FDR was +10°C.

[58] The CVR recorded the cockpit Crew discussing the high ground in the vicinity of the helicopter at this time.
[59] **Tactical Video:** In this cockpit configuration, this term refers to the Euronav moving map display.

Once the Helicopter had levelled at 200 ft on the Rad Alt, the selected heading bug was turned to the left over a period of fourteen seconds from its heading of 291 degrees onto a heading of 137 degrees. This was the course required to fly direct to BLKMO when, at 00.40 hrs, the Commander had previously requested (as recorded on the CVR) *'Direct to BLKMO'*. The Helicopter began to turn to the left in '*heading*' mode. A roll angle of 12 degrees was recorded by the FDR. The turn rate shown in **Figure No. 20** appears higher than this roll angle would suggest. This was due to the effect of the prevailing wind at the time.

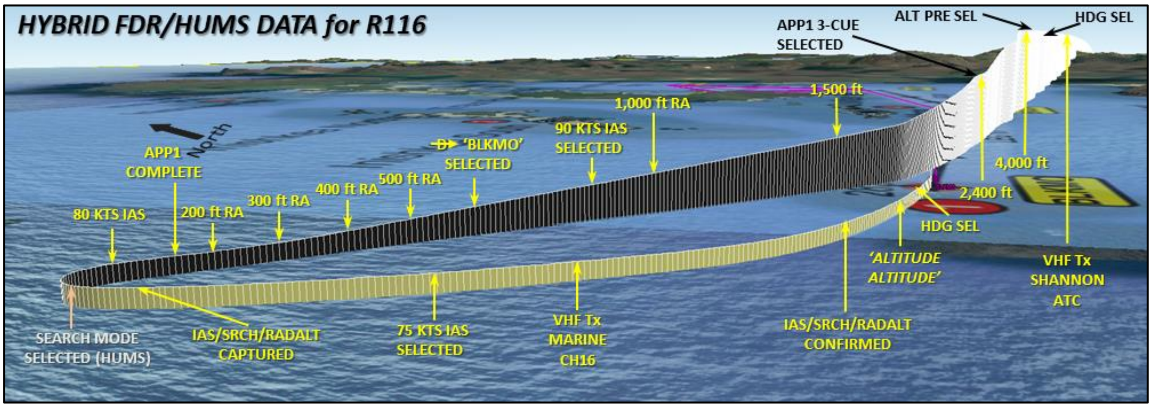

Figure No. 20: FDR/HUMS Significant Events, 00.34 hrs - 00.46 hrs

The FDR recorded the wind as coming from 230 degrees magnetic with a speed of 33 kts; the Helicopter's groundspeed was recorded as 50 kts during the turn. As the Helicopter passed through a heading of 230 degrees, the crosswind component caused the Helicopter to drift further eastwards in the turn. The Helicopter continued turning left and as it passed through 203 degrees, the FDR recorded that the FD No. 1 *'Heading Select'* mode was de-activated and the roll angle reduced to 3 degrees to the left. This reduction in roll angle coincided (00.42 hrs) with a recording on the CVR of the Co-pilot announcing '*Search selected*'. The HUMS data recorded the activation of the AFCS SAR SRCH navigation mode at this time. The Commander was heard to confirm '*Indicated Airspeed, Search and Rad Alt captured'* on the CVR.

At 00.43 hrs, the FDR recorded a change in roll angle to the right, which caused a three degree turn to the right. The Helicopter then returned to a roll angle of 1-2 degrees to the left. Although the FDR or HUMS recorded no change in lateral mode selection, this sequence of manoeuvres would be indicative of the Helicopter AFCS Flight Director transitioning from a navigation ARM mode to navigation CAPTURE mode; the NAV mode in this instance being SRCH. At 00.44 hrs, the IAS was further reduced to 75 kts, and remained at this selection until the final accident sequence.

Also at 00.44 hrs, the FDR recorded the use of the transmission button on ICS station 3 (the Winch Operator's station); this was a call to Belmullet Coast Guard, a call sign which was being used by MRSC Malin. The Helicopter continued to turn to the left and it began to reduce the rate of turn to establish on a direct course towards BLKMO. At this point *Duvillaun Mór* Island was 6 NM in the '*11 o'clock'* position and the high ground at Achill was to the right of the Helicopter's track; the recorded (Co-pilot's side) magnetic heading was 119 degrees, with a recorded drift angle of 11 degrees to the left of the Helicopter's magnetic heading.

At 00.45 hrs, the FDR recorded the Commander's Rad Alt reducing to 171 ft and the Co-pilot's Rad Alt reducing to 170 ft. This was as the Helicopter passed over an outcrop of two rocks, *Carrickduff* and *Carrickad*, which are located approximately 0.65 NM to the west of the Black Rock. These heights were below the selected minimum Rad Alt height of 180 ft, and this triggered an '*ALTITUDE, ALTITUDE*' annunciation in the cockpit. The Commander identified this saying '*there's just a small little island that's B L M O itself*'.

The FDR recorded a rate of climb of 125 fpm for two seconds as the AFCS returned the Helicopter to the selected Rad Alt height of 200 ft. Four seconds later, the Helicopter descended at 125 fpm for two seconds to recover back to 200 ft again as the Helicopter passed east of *Carrickduff* and *Carrickad*. The Helicopter rolled out of the left turn and maintained a heading of 120 degrees while in SRCH mode, 20 seconds prior to the initial impact. The FDR parameters from the Co-pilot's side of the Helicopter recorded groundspeed of 90 kts, and a drift angle of 12 degrees to the left of the Helicopter's magnetic heading of 120 degrees, which gave a track-over ground of 108 degrees. The Winchman's observation of '*an island, directly ahead*' occurred about 600 m/0.3 NM from the western end of Black Rock at approximately 12 seconds prior to the initial impact with terrain. The FDR data did not indicate any technical issues or exceedances during the flight.

1.11.10 Final Accident Sequence

A graphical representation of the FDR parameters for the final minutes of the accident flight is included in **Appendix N**. At 00.45:48 hrs, the '*selected heading*' parameter on the FDR changed instantly from 137 degrees to the Helicopter's actual heading of 120 degrees, indicating that the '*PUSH SYNC*' button was pressed on the heading knob on the Remote Instrument Controller (**Figure No. 21**) located on the right-hand side of the cockpit central console. For clarity, the '*PUSH DIR*' buttons on the controller do not function when FMS navigation mode is selected; they cause the respective left or right course indicator bar ('*the split bar*') to point at the selected navigation source. This action will not cause the Helicopter to route direct to the source unless an appropriate lateral navigation mode is selected on the AFCS. It will not change the navigation mode or waypoint selection in the FMS Flight Plan.

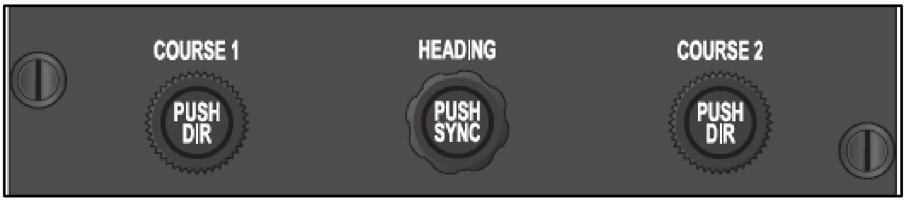

Figure No. 21: Remote Instrument Controller with Heading Synchronisation button

At 00.46:04 hrs, '*Heading HOLD ON*' was selected and captured, and one second later the selected heading changed from 120 degrees to 123 degrees.

At 00.46:06 hrs, a number of parameter changes were recorded by the FDR (unless otherwise stated, the equivalent parameters from the Co-pilot's side of the Helicopter that were recorded on the FDR were of similar magnitude in each case):

- The *Rotor Speed* reduced from 105% to 98%
- The *Pilot's Collective Stick Position* changed from -21.25% to +30%

- The *Pilot's Pitch Attitude* changed from +3° to +5°
- The *Pilot's Vertical Speed* increased to 1,000 fpm
- The *Pilot's Pitch Stick Position* changed from +12% to -27%
- The *Pilot's Roll Stick Position* changed from -1.5% to +11%
- The *Pilot's IAS* was 80 kts and the *Pilot's Groundspeed* was 90 kts
- The *Vertical Acceleration* increased from 1g to 1.9g

It should be noted that the Helicopter Manufacturer confirmed to the Investigation that the FDR records *Pitch*, *Roll* and *Collective Stick position* for both the Pilot and Co-pilot channels, but does not measure or record the magnitude of the force applied to any of the Helicopter's primary flight controls. The FDR data did not record whether any forces applied to the flight controls originated from the Commander's or Co-pilot's respective flight controls.

At 00.46:07 hrs:

- The *Rotor Speed* reduced from 98% to 94.25%
- The *Pilot's Collective Stick Position* changed from 30% to -10.25%
- The *Pilot's Pitch Attitude* changed from +5° to +29.8°
- The *Pilot's Vertical Speed* increased from 1,000 fpm to 3,000 fpm
- The *Pilot's Pitch Stick Position* changed from -27% to +29.5%
- The *Pilot's Roll Stick Position* changed from +11% to -5.5%
- The *Pilot's IAS* was 77 kts and the *Pilot's Groundspeed* was 87 kts.
- The *Vertical Acceleration* increased from 1.9g to 2.17g
- *Master Caution annunciation on the EICAS*
- *Low Rotor RPM annunciation on the EICAS*
- The *Pilot's Roll attitude* increased from 0° to 9° right
- The *Yaw rate* increased from 0° to 9°/sec to the right
- The *Co-pilots Radar Altitude reduced from 216 ft to 76 ft*
- The *Pilots Radar Altitude reduced from 216 to 85 ft*
- *Engine Ng's increased from 86% to 97%*
- The #1 *Radar Alt ON* deactivated
- The '*ALTITUDE, ALTITUDE'* annunciation was triggered
- *FD DGRD (Flight Director degraded)* annunciation on the EICAS
- *Longitudinal acceleration from 0.02g to 0.45g*

At 00.46:08 hrs, (the time of impact with terrain):

- The *Rotor Speed* increased from 94% to 107%
- The *Pilot's Collective Stick Position* changed from -10.25% to +4.75%
- The *Pilot's Pitch Attitude* changed from +29.8° to +57.6°
- The *Pilot's Vertical Speed* increased from 3,000 fpm to 3,250 fpm
- The *Pilot's Pitch Stick Position* changed from +29.5% to +2%
- The *Pilot's Roll Stick Position* changed from -5.5% to -30%
- The *Pilot's IAS* reduced to 57 kts and the *Pilot's Groundspeed* reduced to 85 kts.
- The *Vertical Acceleration* reduced from 2.17g to 1.1g
- The *Pilot's Roll attitude* increased from 9° right to 132° right
- The *Yaw rate* increased from 9°/sec to the right to 23°/sec to the right
- The *Co-pilots Radar Altitude reduced from 76 ft to 5 ft*
- The *Pilots Radar Altitude reduced from 85 ft to 11 ft*
- *Engine Ng's reduced from 97% to 94%*
- The '*Pilots Baro Corrected Altitude'* increased from 305 ft to 362 ft
- The '*Pilots Magnetic Heading'* changed from 120° to 160°

The following systems were recorded on the FDR to have changed status at 00.46:08 hrs:

- #1 & #2 Attitude Hold fail........................activated
- #1 Baro altitude mode ON........................activated
- #1 collective trim fail........................activated
- #1 & #2 Secondary SAS fail........................activated
- #1 & #2 Heading hold fail ....activated
- #1 & #2 NAV vertical mode fail........................activated
- #1 & #2 Turn Coordination fail........................activated
- #1 & #2 Weight on Wheels........................activated
- #1 Yaw trim fail........................activated
- Autopilot Channel 1 fail........................activated
- Copilot FD Couple fail........................activated
- Pilot FD Couple fail........................activated
- The '*HARD LANDING*' caution........................activated
- The '*SMOKE IN BAGGAGE*' caution........................activated
- The '*AUTOPILOT 1 FAIL*' and '*AUTOPILOT 2 FAIL*' cautions..........activated

- The '*LEFT GEAR DOWN*' indication .... deactivated
- The '*RIGHT GEAR DOWN*' indication .... deactivated
- Temp Ch6 IGB .... activated

At 00.46:09 hrs:

- The *Rotor Speed* increased from 107% to 110%
- The *Pilot's Collective Stick Position* changed from +4.75% to +14.75%
- The *Pilot's Pitch Attitude* changed from +57.6° to -30.5° and then to +29°
- The *Pilot's Vertical Speed* changed from 3,250 FPM to -8,000 FPM
- Roll attitude increased from 132° right to 172° right
- The *Yaw rate* increased from 23°/sec to the right to 60°/sec to the right
- The *Pilot's Pitch Stick Position* changed from +2% to -33%
- The *Co-pilots Radar Altitude* increased from 5 ft to 53 ft
- The *Pilots Radar Altitude* increased from 11 ft to 131 ft
- *Engine Ng's* increased from 94% to 96%
- The *Pilot's IAS* reduced to 19 kts and the *Pilot's Groundspeed* reduced to 85 kts
- The *Vertical Acceleration* reduced from 1.1g to -0.43g
103 - The *Pilot's Roll Stick Position* changed from -30% to +11%
- The '*Pilots Baro Corrected Altitude'* increased from 362 ft to 544 ft
- The '*Pilots Magnetic Heading'* changed from 160° to 091°
- The AFCS DGRD caution activated
- The AVC FAIL caution activated (AVC: Active Vibration Cancelling System)
- The EGPWS 'TOO LOW GEAR' activated
- The 'LANDING GEAR UP' Warning activated
- The '*No. 3 Hydraulic Pressure High Mode'* activated

From this time onward, the FDR recording indicated that the Helicopter had departed from controlled flight. The nature of the Helicopter's trajectory and the dynamic forces involved were such that many of the recorded flight parameters, particularly those that rely on dynamic air pressure, cannot be relied on as being accurate. The recorded Rad Alt parameters for the final seconds were 228 ft, 183 ft, 490 ft, 483 ft, and 116 ft. Since the Rad Alt measurements are based on a radar return from the ground, these parameters cannot be relied upon as the Helicopter was experiencing significant pitch and roll excursions. The barometric altitude recorded at the time indicated that the Helicopter's altitude continued to increase to a maximum of 574 ft before descending to 302 ft at the end of the FDR recording.

A number of additional parameters are included in **Appendix N**. These discrete[60] parameters were recorded on the FDR between 00.46:08 hrs, and the end of the recording at 00.46:19 hrs, and indicated the functional state of particular systems.

1.11.11 Skytrac Satellite Communication System

The Investigation was provided with a copy of the Helicopter's flight path, as recorded on the Skytrac system described in **Section 1.6**, and is shown in **Figure No. 22**.

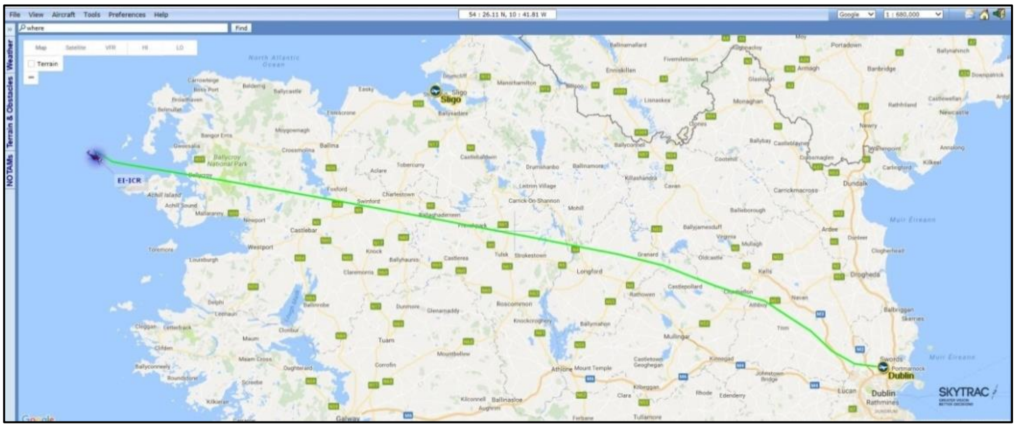

Figure No. 22: Skytrac flight path for EI-ICR, 13-14 Mar 2017

The track created from the recorded positions of EI-ICR during the flight showed a high degree of correlation with the data received from the other available position sources, such as FDR, HUMS, AIS and Shannon ATC radar recordings. However, the Skytrac System primarily provides a flight-following function and can be configured to transmit position information at any interval between 0.5 seconds and 15 minutes. In the case of the IRCG helicopters, the position was transmitted every three minutes. The last four positions received from EI-ICR are shown in **Figure No. 23**. The impact with Black Rock occurred prior to the expected position transmission at 00.47 hrs.

Figure No. 23: Skytrac final transmitted positions (white line) for EI-ICR

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[60] **Discrete:** The term '*discrete*' refers to a system parameter that is binary in nature; either ON or OFF, ACTIVATED or DEACTIVATED, FUNCTIONAL or FAILED.

The Investigation noted that while the sampling rate of the positions reported by the Skytrac System during the flight is insufficient to reproduce an accurate flight path, the positions and times provide a correlation with the other position sources.

1.11.12 AIS Data

The AIS is described in **Section 1.6**. The IRCG used a real-time display of AIS data on a large screen at MRCC Dublin, and at each MRSC. In addition to the position in Latitude and Longitude, the AIS System transmits a date and time stamp, the ground speed in knots, altitude in metres and helicopter heading in degrees. This data was transmitted at 10 second intervals (**Figure No. 24**). The final transmission was at 00.46:07 hrs.

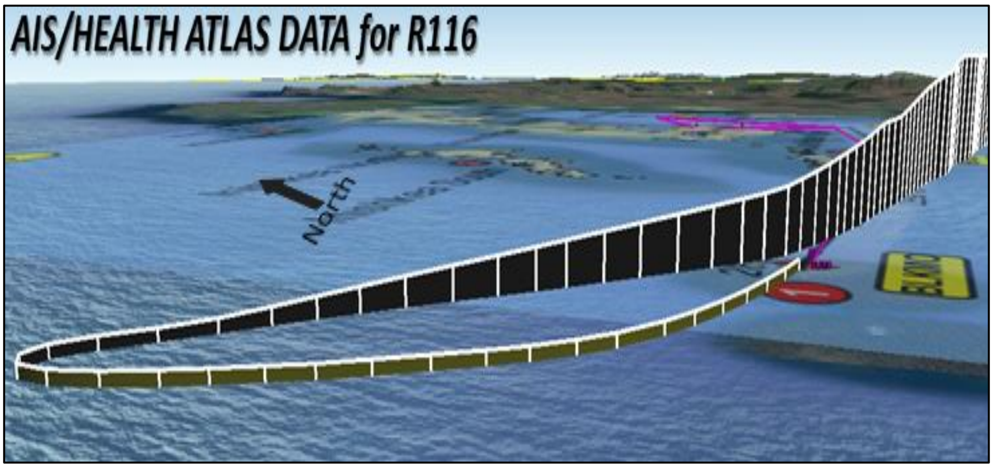

Figure No. 24: AIS Position Data, EI-ICR, 00.34 - 00.46 hrs

The AIS data is also used by the National Aeromedical Coordination Centre (NACC) of the National Ambulance Service (NAS). It is used to provide NAS staff with near real-time information of helicopter locations. In the immediate aftermath of the accident, the Health Intelligence Unit of the HSE provided near real-time AIS information for all IRCG helicopters to the Investigation (**Figure No. 25**) including the last position of the Helicopter at 00.46:07 hrs.

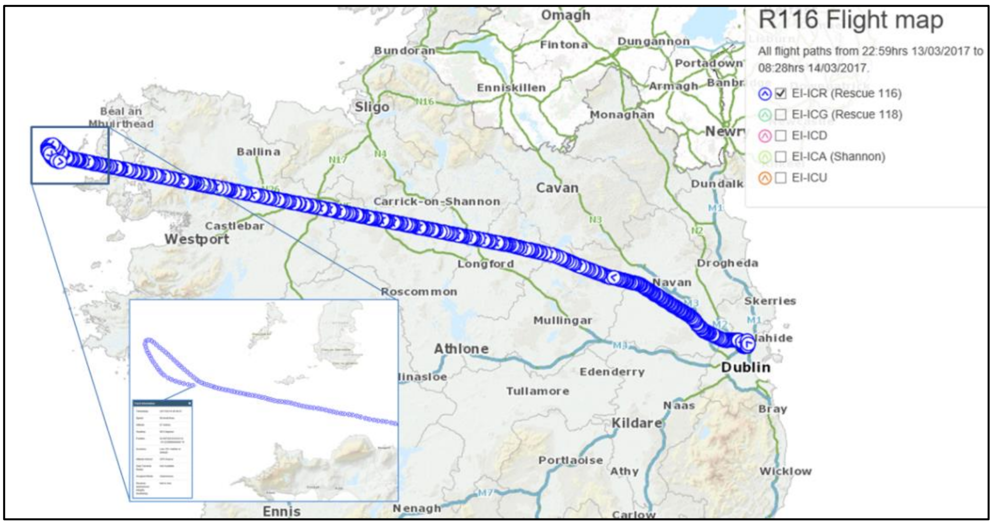

Figure No. 25: The AIS position reports from EI-ICR as shown on the HSE Health Atlas

The NAS provides a flight following service for missions that it tasks. As EI-ICR was tasked by the IRCG as part of a SAR tasking, the IRCG was responsible for flight following. The AIS information from NAS databases, based on positioning information supplied from the IRCG/DTTAS National AIS system, informed the initial search efforts for EI-ICR. The AIS data showed a high degree of correlation with the FDR and HUMS data subsequently recovered by the Investigation.

The Investigation was notified that an AIS signal apparently associated with EI-ICR had appeared on a number of occasions after the accident. In each instance, the MMSI[61] number associated with EI-ICR would appear on commercially available AIS software systems. The MMSI would appear in several different locations, including: near Black Rock, Co. Mayo; south-west of Portugal (**Figure No. 26**); and South America. However, the vessel status, speed, course, AIS source, wind speed and wind direction would remain identical regardless of the current date or place, and would be more suggestive of a surface vessel than a helicopter.

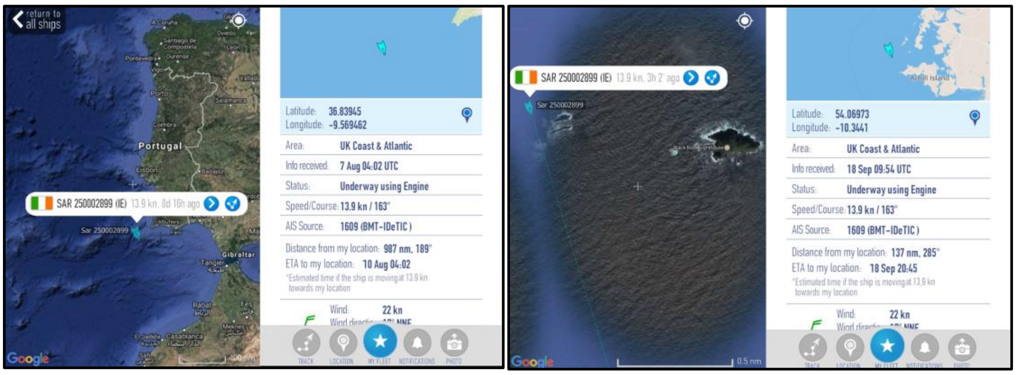

Figure No. 26: Examples of AIS displaying different Locations of EI-ICR

The Investigation requested the assistance of the UK MAIB to contact industry sources regarding the reliability of commercially available, open-source, AIS-based products. The Investigation was informed that the AIS data in question was most likely caused by an internal error in the database of received AIS transmissions, rather than due to an erroneously programmed AIS transmitter on a vessel, or a signal from EI-ICR's AIS. Accordingly, the Investigation does not consider that these were valid signals from EI-ICR.

1.11.13 EGPWS Annunciations

The EGPWS System is described in **Section 1.6.6.5**. The warning and caution annunciations that do not have an independent audio capability, but use the EGPWS '*voice*' as an audio source, are listed in **Appendix O**. The EGPWS manufacturer used the FDR data recovered by the Investigation to conduct an EGPWS simulation. With the landing gear in the DOWN position, the Mode 4b annunciation criteria were substantially reduced (10 ft at 80 kts). The activation of the LOW ALT switch by the Flight Crew at 00.28 hrs resulted in the '*look ahead'* functions of the EGPWS being substantially reduced, and the Mode 6 '*ALTITUDE, ALTITUDE*' (generated from Rad Alt inputs) callout being enabled. However, the lighthouse and terrain at Black Rock were not in the EGPWS databases, and therefore the '*look ahead*' function was redundant.

[61] **MMSI:** A nine digit number used by maritime digital selective calling (DSC), AIS and certain other equipment to uniquely identify a ship or a coast radio station. MMSI 250002899 identified EI-ICR.

The simulation indicated that there were two separate callouts of '*ALTITUDE ALTITUDE*'. These occurred at 00.45:40 hrs, as the Helicopter passed overhead *Carrickduff/Carrickad*, and at 00.46:08 hrs, as the Helicopter approached the western end of Black Rock. Both of these annunciations can be heard on all the CVR ICS channels. The simulation demonstrated that both events were due to the Rad Alt reducing below the bugged height of 180 ft in accordance with the EGPWS Mode 6 criteria.

The simulation identified an EGPWS annunciation of '*BANK ANGLE'* at 00.46:09 hrs, which was within one second after the initial impact with terrain. The EGPWS manufacturer's '*Helicopter - Enhanced Ground Proximity Warning System Pilot's Guide*' stated that '*an excessive bank angle warning is provided based upon Radio Altitude, Roll Attitude and Roll Rate*'. The Manual indicated that at a Rad Alt of 50 ft or below, the annunciation is triggered when the bank angle of the Helicopter exceeds 30 degrees. At 00.46:08 hrs, the FDR indicated a Rad Alt height of 11 ft and a roll angle of 44 degrees to the right.

The EGPWS manufacturer's *Interface Control Document* lists a number of annunciations that '*are the only voices that can interrupt*' the current EGPWS annunciation. These include the '*SMOKE IN BAGGAGE*' annunciation. The results of the simulation indicated that the '*BANK ANGLE'* annunciation was suppressed by the prioritised '*SMOKE IN BAGGAGE'* annunciation, and was therefore not heard on the CVR. The FDR recorded the activation of the *'LOW ROTOR'* warning just prior to impact as the main rotor RPM reduced below 95%, but this was not audible on the CVR. It is considered probable that this was also suppressed by the *'SMOKE IN BAGGAGE'* annunciation. The recording of the HUMS position data ended prior to the end of the CVR recordings. Therefore, it is not possible to accurately represent the
 locations of final EGPWS call-outs that were audible on the CVR.

The substantial reduction in Mode 4b annunciation criteria was based on the undercarriage being down and locked. At 00.46:08 hrs, the FDR recorded that the *'LEFT GEAR DOWN'* and '*RIGHT GEAR DOWN'* indication deactivated. This event restored the original criteria of '*150 ft terrain clearance when below 100 kts'* as stated in the '*Helicopter - Enhanced Ground Proximity Warning System Pilot's Guide*'. This triggered the EGPWS Mode 4b '*TOO LOW GEAR'* annunciation.

1.11.14 Health and Usage Monitoring System (HUMS)

1.11.14.1 General

The Helicopter was equipped with a Goodrich HUMS, also referred to as IMD[62]-HUMS. It is a commercially available, integrated airborne and ground system, designed to perform diagnostic, health and usage monitoring functions on a helicopter's drive train, propulsion, auxiliary and structural components. IMD-HUMS is intended to provide information to an operator, maintenance personnel and flight crew, about the maintenance and serviceability of the helicopter. The HUMS collects, processes, and records data from an array of dedicated sensors and independent helicopter systems on a per-flight basis. This data is made available to maintenance personnel on the ground for analysis to identify conditions that require maintenance.

[62] **IMD:** Integrated Mechanical Diagnostics.

The HUMS also detects and records individual component usage, such as the number of engine or APU starts, rotor brake applications, take-offs and landings, as well as the operating hours of various components. This information allows scheduled maintenance to be performed on the basis of actual component usage as opposed to being estimated based on airframe or engine hours.

The principal component of the on-board HUMS is the Main Processor Unit (MPU). It is designed to control the overall system by performing the following functions: acting as the communications link between all main components of the system; calculating flight regimes; calculating track and balance solutions; monitoring drive train health status; and, monitoring and processing all accelerometer, tachometer, and sensor raw data. The MPU is also designed to receive information from the drivetrain and from the *Rotor Track and Balance System* (ROTABS) accelerometers, the tachometers, blade tracker, and helicopter data buses (including Air Data Computer (ADC), AFCS, AHRS, and DCU). Raw signals from the accelerometer, tachometer, and tracker are all fed into the MPU where they are digitised, processed and sent to the MFD for display to the flight crew (**Figure No. 27**).

The MPU sends the data to a Data Transfer Unit (DTU), which records all data to a Data Transfer Memory Unit (DTMU). Typically, the DTMU card is removed after every flight to transfer data to the Ground Station. The DTU is mounted on the right hand avionics rack in the cabin.

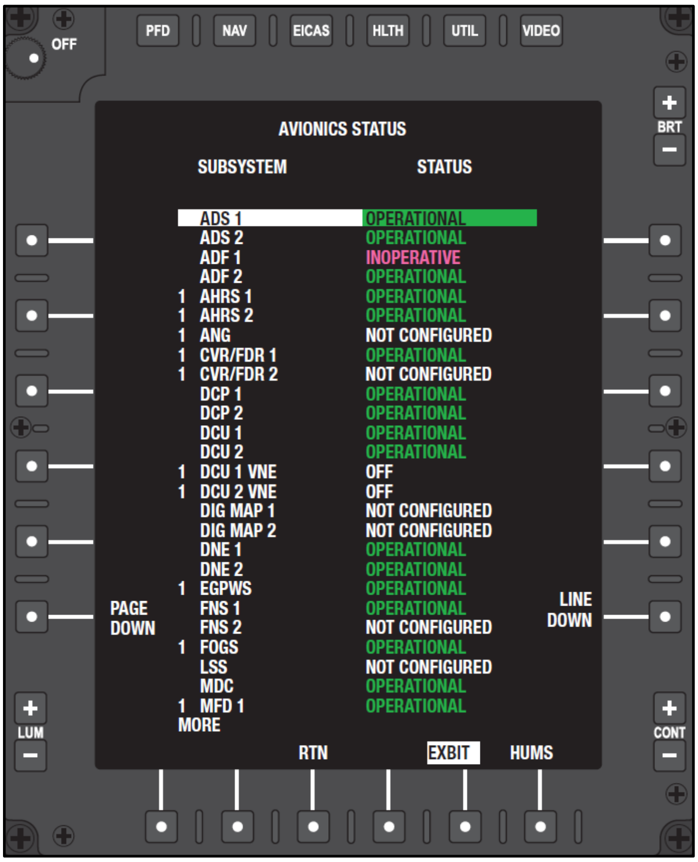

Figure No. 27: Example of the HUMS Interface displayed on MFD 5

The DTMU is a *Personal Computer Memory Card International Association* (PCMCIA) memory card, available in various capacities from 20 Megabytes (Mb) to 256 Mb. Data is typically recorded at a rate of approximately 10 Mb per hour; thus, a 20 Mb card will hold approximately 2 hours of data, while a 256 Mb card will hold approximately 25 hours of data. In terms of recording time, these capacities can be sharply reduced if a large number of exceedances have been detected. During normal operation, data is recorded on the Data Card at a rate of 1 Hz to 10 Hz. However, when an exceedance is detected, HUMS records data at a higher rate for a period of 15 seconds prior to and 15 seconds after the exceedance. A large number of exceedances can therefore fill a Data Card much faster than the average rate of 10 Mb/hour.

The DTMU from EI-ICR was located on 23 March 2018 by ROV. It was still attached to its original mounting point in the front right avionics rack. The DTMU was recovered by Irish Naval Service divers on 24 March 2017, 10 days after its immersion. The DTMU was transported under AAIU escort to the UK AAIB Recorders Laboratory in the UK. Although the HUMS is not designed or constructed to be crash-protected, the DTMU was in good condition and the data was recovered from the card (**Photo No. 15**).

Photo No. 15: HUMS PCMCIA card with top and bottom covers (UK AAIB)

The data file was in a proprietary format. The Helicopter Manufacturer converted the contents of the PCMCIA card into engineering units using proprietary software, and provided the results to the Investigation for review and analysis. As previously described in the Investigation's First Interim Statement and **Section 1.11.6** of this Report, the HUMS data was used by the Investigation to determine the flight path of the Helicopter.

The HUMS collected data from accelerometers located on the Airframe (4), Cockpit (2), Cabin (1), Tail Pylon (1), Engine (4), Main Gearbox (10), Intermediate Gearbox (1) and Tail Rotor Gearbox (1). The HUMS was also supplied by sensors located in the Engine High Speed Shaft, the Main Rotor, Tail Rotor, Main Gearbox (rotor speed), and a Rotor Blade Tracking Camera. In addition, the HUMS MPU collected data from the Pilot's and Co-pilot's AHRS, ADC and AFCS. The Maintenance Data Computer (MDC) data was collected in turn from other systems throughout the Helicopter (either directly or indirectly). These systems included Weather Radar (WxR), radio frequencies (Comm and Nav), Radio Altimeters, FMS status, Fuel Quantity, Chip Detection System (CDS) and the Auxiliary Power Unit (APU).

1.11.14.2 HUMS Data (Position)

The Investigation examined the HUMS parameters for the flight. In most cases, there was a high degree of correlation between the HUMS and FDR parameters. The discrepancy between the latitude and longitude parameters of the two devices has been described previously in **Section 1.11.6**.

The Investigation's First Interim Statement stated that;

> *'Analysis conducted by the Helicopter Manufacturer of the aircraft position recorded by HUMS revealed that HUMS position was not as precise as the AHRS, due to the resolution of the aircraft position data in HUMS. Understanding of the resolution limitation allowed the Helicopter Manufacturer to analytically correct the aircraft position data.'*

The difference between the AIS position data and the HUMS position data (uncorrected and corrected) is shown in **Figure No. 28**. The discrepancy noted in the Investigation's First Interim Statement was examined by the Helicopter Manufacturer. This included the completion of a test flight at the Manufacturer's facility to confirm the findings of the examination. Following the flight, the Manufacturer noted that the HUMS software supplier did not have the correct significance (in degrees) assigned to bits in the latitude and longitude labels recorded to the DTMU. Bit significance has been rounded down, therefore shifting the recorded position. The corrected helicopter flight path was 159 ft to the north and 18 ft to the west of the original HUMS recorded data.

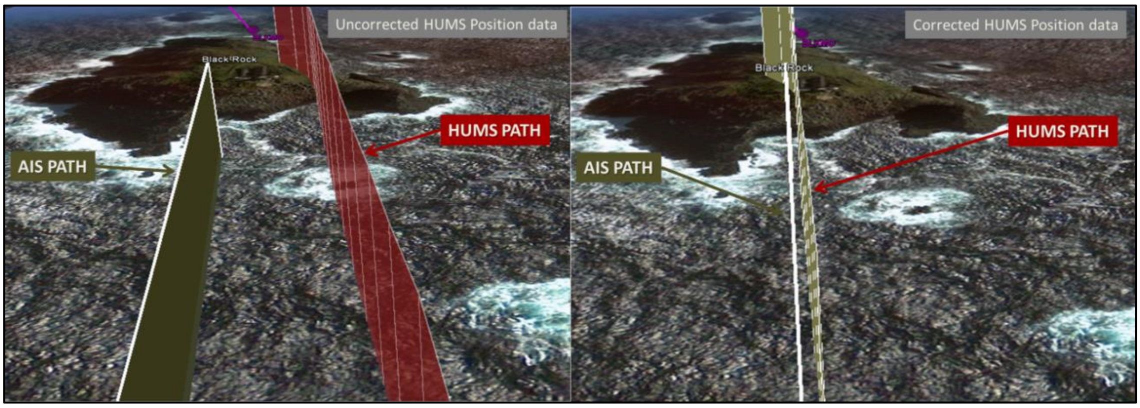

Figure No. 28: AIS Path data with uncorrected and corrected HUMS Path Data - R116

Following the completion of the Manufacturer's internal examination and identification of the error in the HUMS software, the Helicopter Manufacturer updated software version -112 with a new -114 software version which corrected the discrepancy. The corrected position data is estimated by the Manufacturer to be within a margin of error of 2 ft approximately.

Once the corrected HUMS Flight Path was established, the Investigation noted that the Helicopter's flight path recorded by the HUMS was further to the north of that indicated by the wreckage pattern found on Black Rock (**Section 1.12**). The HUMS flight path did not indicate the right turn recorded by the FDR just prior to the initial impact with the terrain.

A previous AAIU Report (AAIU Report No.: 2011-016**)** involving an aircraft conducting manoeuvres prior to impacting terrain observed that:

> *'The initial output regarding the aircraft's navigational position showed discontinuities. However, the Manufacturer indicated that the navigational position recorded by the FDR is based on the GPS, which goes into a Dead Reckoning (DR) mode if the satellite signal is temporarily lost (e.g. if obscured by terrain or during manoeuvres involving significant bank angles). In this case, the DR position then generated is an approximate position based on the last known position updated by inputs from the aircraft's air data and IRS.'*

As previously noted, the helicopter's positional information is sent from the GNSS Data Source via the AHRS, to the HUMS (**Figure No. 29**).

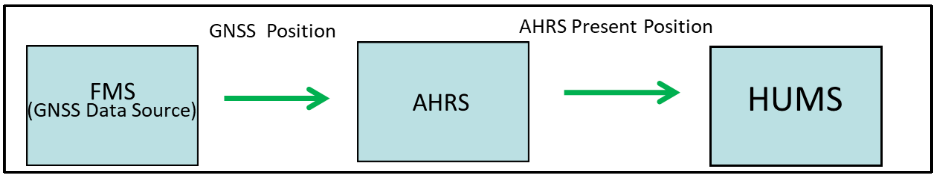

Figure No. 29: Schematic of GPS data processing

The Investigation asked the Helicopter Manufacturer to comment on whether the HUMS data could be subject to any form of DR mode or other data smoothing as a result of a loss of GPS position information. The Helicopter Manufacturer stated that:

> *'Data smoothing including DR is entirely possible. HUMS gets its data from AHRS, and AHRS, does indeed have the capability of predicting the position when GPS drops out. That's actually why* [the Helicopter Manufacturer] *uses the AHRS position data for SAR operations. …The Technical Specification applicable to that AHRS, … can be summarized as providing a "coasting" capability if GPS drops out for up to 30 seconds. During this time, an internal … filter continues to update the last valid GPS position using integrated inertial N-S and E-W velocities.'*

1.11.14.3 HUMS Data (Other Parameters)

The Investigation compared the HUMS data with the FDR data for the flight and noted that the HUMS data recording, as shown in **Appendix P**, stopped approximately three seconds after the initial impact with Black Rock, which occurred at 00.46:08 hrs. The data showed a near-exact correlation between the HUMS (blue and red lines) and FDR (jagged black lines) parameters prior to 00.46:08 hrs. The data appeared to show a divergence between the HUMS and FDR data just prior to the initial impact. This apparent divergence was caused by differences in the rate of data sampling by the HUMS and FDR systems.

An extract of the HUMS data from **Appendix P** is shown in **Figure No. 30**; the data range coloured yellow represents 0.5 seconds of flight time. The table lists the parameter values for the Helicopter's *Pitch Attitude* in degrees as they were recorded to the FDR and HUMS respectively during that time period.

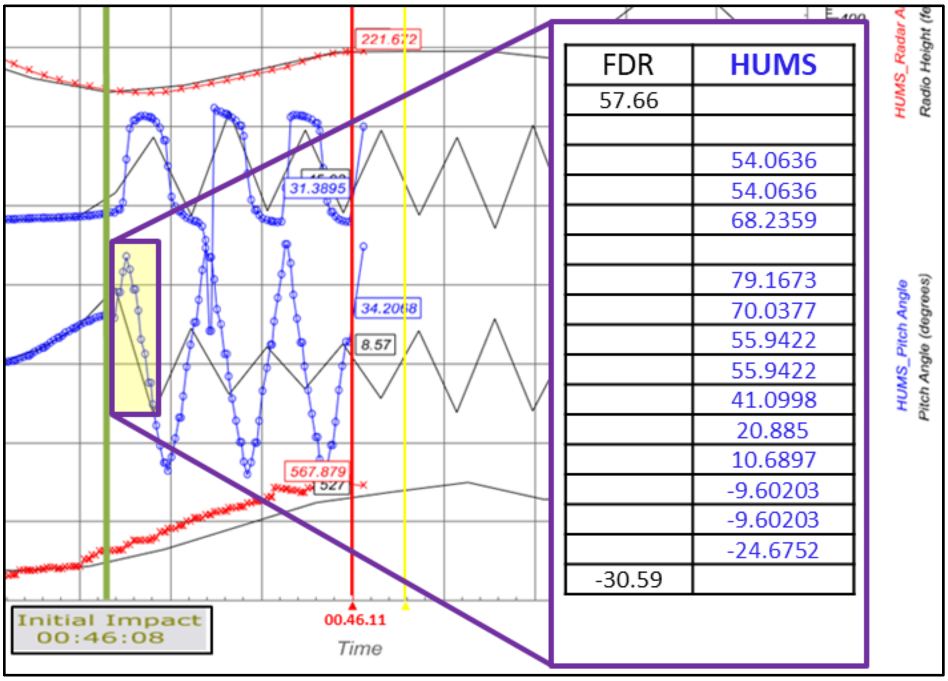

Figure No. 30: Example of Sample Rate of HUMS and FDR parameter '*Pitch Angle'*

It can be seen that the HUMS provided the Investigation with additional data as a result of the higher routine sampling rate. Furthermore, when the signals from other sensors indicated that a significant event was occurring, the HUMS automatically increased the sampling rate. **Table No. 24** shows comparative examples of the sampling rates for the parameters shown above.

Parameter Name	Units	HUMS Output Rate[63]	Output Rate[64] to FDR
HUMS_Cal Airspeed/Computed Airspeed	Knots	Up to 8.7 per second	1 per second
HUMS_Radar altitude / Radio Height	Feet	Up to 10 per second	1 per second
HUMS_Roll Angle / Roll Angle	Degrees	Up to 64 per second	2 per second
HUMS_Pitch Angle / Pitch angle	Degrees	Up to 64 per second	2 per second
HUMS_Baro Corrected Alt / Pressure Altitude	Feet	Up to 17.4 per second	1 per second

Table No. 24: Comparative sampling rates for FDR and HUMS data

The additional data provided by the more frequent sampling rate of the HUMS indicated that the Helicopter experienced a more substantial departure from controlled flight than that indicated by the FDR data.

1.11.15 Avalex Digital Video Recorder

The Helicopter was fitted with an AVR-8240-XM Digital Video Recorder (DVR) manufactured by Avalex Technologies Corporation (**Photo No. 16**). The DVR provides the capability of recording video from the Wescam MX-15i EO/IR Camera System (**Section 1.6.6.12**).

[63] **HUMS Output Rate:** Based on *'Interface Control Document for the S-92 Health and Usage Monitoring System (HUMS)'* dated 15 June 2018.

[64] **FDR Output Rate:** Based on '*S-92A FDR Parameter Definition (AMS 8.0)*' dated 10 March 2015.

The system is self-contained within the control panel in the SAR Operator's console and interfaced to the SAR Operator's mission video display for EO/IR video playback. The DVR contained 16 GB[65] of internal memory, with the capability to add either a SD Flash Card or a USB[66] Flash Drive for recording. Both memory devices were removable. The DVR was controlled by the use of a *Mode Control* knob to select PLAY, STOP or REC (record) functions, and a *Menu* button, which provided access to optional functions such as video quality selection and storage locations for the recorded video data.

Photo No. 16: Avalex AVR-8240-XM DVR

The CVR had indicated that the Winchman was using the Wescam MX-15i EO/IR Camera during the flight and observed Black Rock with the EO/IR camera prior to impact. The Investigation considered it important to recover the Avalex DVR in order to establish whether the EO/IR camera output had been recorded.

Following ROV operations in March and April 2017, a further sea bed search commenced on 23 July 2017 (**Section 1.12.5**), when the DVR (**Photo No. 17**) was recovered. The unit was damaged and both the *Menu* button and *Mode Control* knob were missing from the panel. It was not possible to determine by visual inspection of the panel which position the Mode Control knob was set to at the time of the accident. It was also not possible to determine which media (USB, SD Card, internal) was selected as the storage location for recorded data.

Photo No. 17: Avalex AVR-8240-XM DVR from EI-ICR (with Flash Drive)

The unit was brought to the NTSB Vehicle Recorder Section in Washington D.C. for analysis. The DVR was analysed by the use of both X-ray and Computer Tomography (CT) scans. In particular, the remaining parts of the *Mode Control* knob were examined to determine the position of the selector knob. These scans (**Photo No. 18**) showed that the knob was set to the '*PLAY*' mode, and not to '*RECORD'*. There was no video data found on the DVR internal storage.

[65] **GB:** Gigabyte; one gigabyte is equivalent to 1,000,000,000 bytes.
[66] **USB:** Universal Serial Bus.

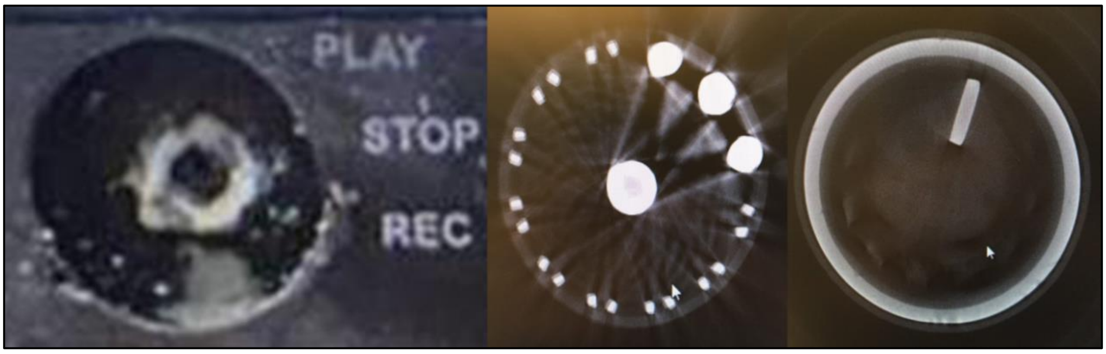

Photo No. 18: CT Scan of *Mode Control* knob showing *'PLAY'* mode selected (*NTSB*)

Three video files were recovered from a USB flash drive located in the USB slot on the front panel of the DVR. The first video file was recorded on 3 March 2017 and was of 45 minutes duration. It was a recording of search conducted by Rescue 116 in an area west of Drogheda, Co. Louth. The second video recording was dated 8 March 2017 and was of 35 seconds duration. It was a recording of a search that was conducted by Rescue 116 at Howth Head, Co. Dublin. The third video recording was dated 12 March 2017 and was of 10 minutes duration, recorded during a SAR mission. FDR data for this flight was also recovered from the MPFR (**Figure No. 31**) and showed that the helicopter routed from Dublin Airport to the scene of an accident, brought a casualty to a hospital in Dublin, and then returned to Dublin Airport.

Figure No. 31: FDR Data from Rescue 116 Mission on 12 March 2017

The three video files occupied 1 GB of space on the USB drive. There were no files relating to any flights after 12 March 2017 on the USB device, which had approximately 15 GB of free space remaining. The third video established that both the Avalex DVR and the Wescam MX-15i EO/IR Camera System were functional on the day prior to the accident and therefore the Investigation is of the opinion that the system was capable of recording if it had been switched on during the accident flight.

1.11.16 Toughbook

The Toughbook was recovered from the seabed on 23 March 2017. It had been immersed in salt water for nine days. The device was extensively damaged during the accident sequence, and significant salt corrosion was evident on many of the components upon recovery (**Photo No. 19**). Due to the extent and nature of the damage to the Toughbook, it was not possible to extract any data from the device.

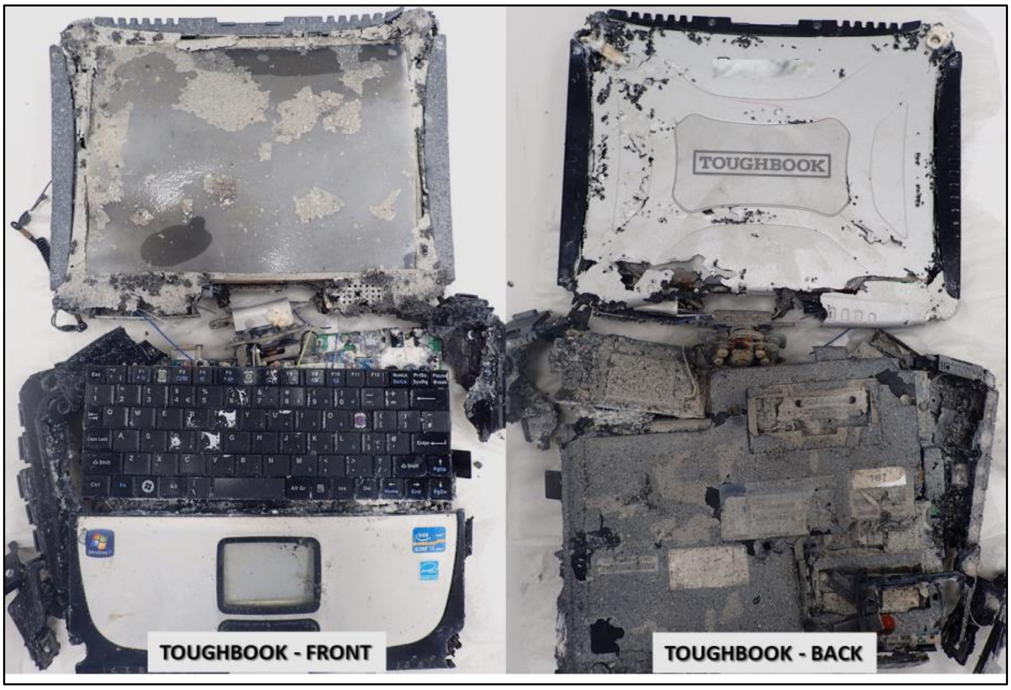

Photo No. 19: Photo of front and back of R116 Toughbook

1.12 Wreckage and Impact Information

1.12.1 Initial Observations

The accident occurred at 00.46 hrs on 14 March 2017. Later that day, an Inspector of Air Accidents participated in an aerial survey of Black Rock which identified that debris from the Helicopter was visible close to the helipad and below the steel grid at its southern edge (**Photo No. 20**).

Photo No. 20: Debris situated close to the helipad and below its steel grid

1.12.2 Debris found on Black Rock

On 15 March 2017, the day following the accident, an Inspector of Air Accidents travelled by helicopter to Black Rock and recovered several items of wreckage. On 16 March 2017, several members of the Investigation team conducted a land search on Black Rock of the areas that were safely accessible on foot. Four large pieces and several smaller pieces of the IGB fairing were found close to the helipad. Fractured sections of the IGB casing, including the oil level sensor and a portion of the chip detector were found close to the helipad. The locations of the IGB and its oil system components on the helicopter type are shown in **Figure No. 32** (**Note:** The wiring installation shown relates to a test set-up and was not the production standard for the Helicopter).

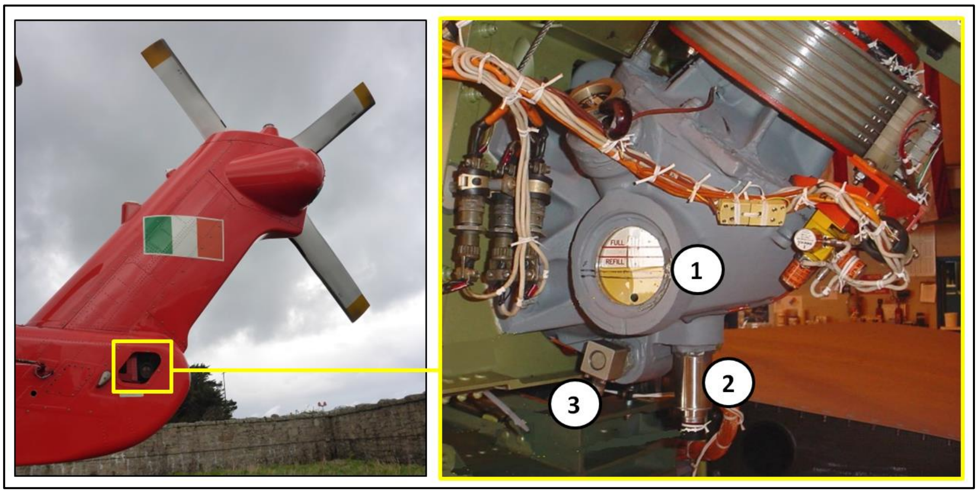

Figure No. 32: Location of IGB on the helicopter type
(1: Oil-level sight-glass; 2: Oil-level sensor; 3: Chip detector)

The Investigation reconstructed the fractured sections of the IGB casing. Gouge marks, in a direction parallel to the longitudinal axis of the Helicopter, were found on the base of the oil-level sight-glass housing (**Figure No. 33**).

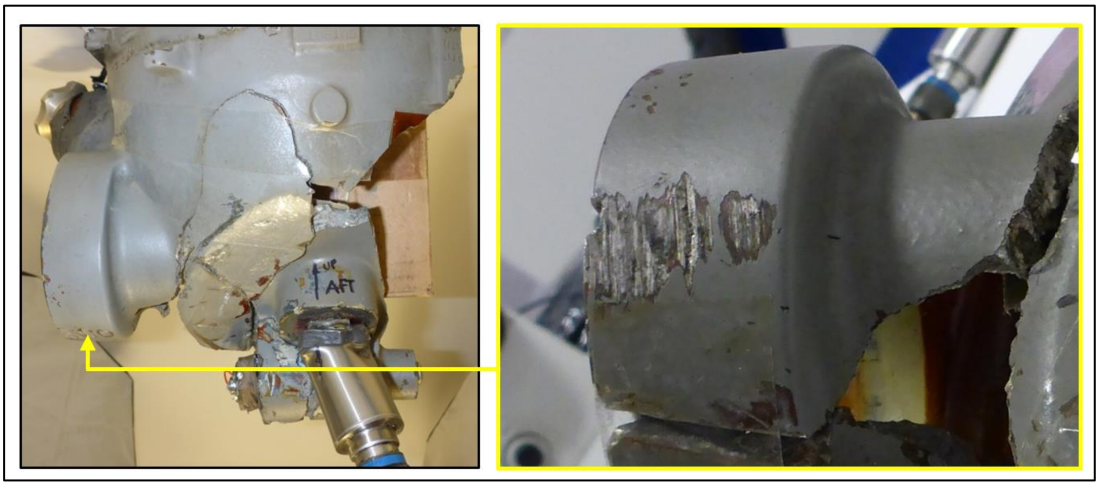

Figure No. 33: Reconstructed IGB casing and damage to base of oil-level sight-glass housing

The horizontal stabiliser separated from the tail rotor pylon in the accident sequence. The main section, approximately 2.7 m in length (circled in green in **Figure No. 34**), was found adjacent to an outhouse. Tiles on the roof of the outhouse exhibited damage (circled in yellow). A piece of what appeared to be a roof tile was embedded in the trailing edge of the stabiliser. The separated horizontal stabiliser had sustained substantial damage. A piece of trailing edge, 1 m in length (circled in magenta) from the inner part the Helicopter's horizontal stabiliser, was found on the side of a large outcrop, 3 m to the south-west of the perimeter wall at the lighthouse.

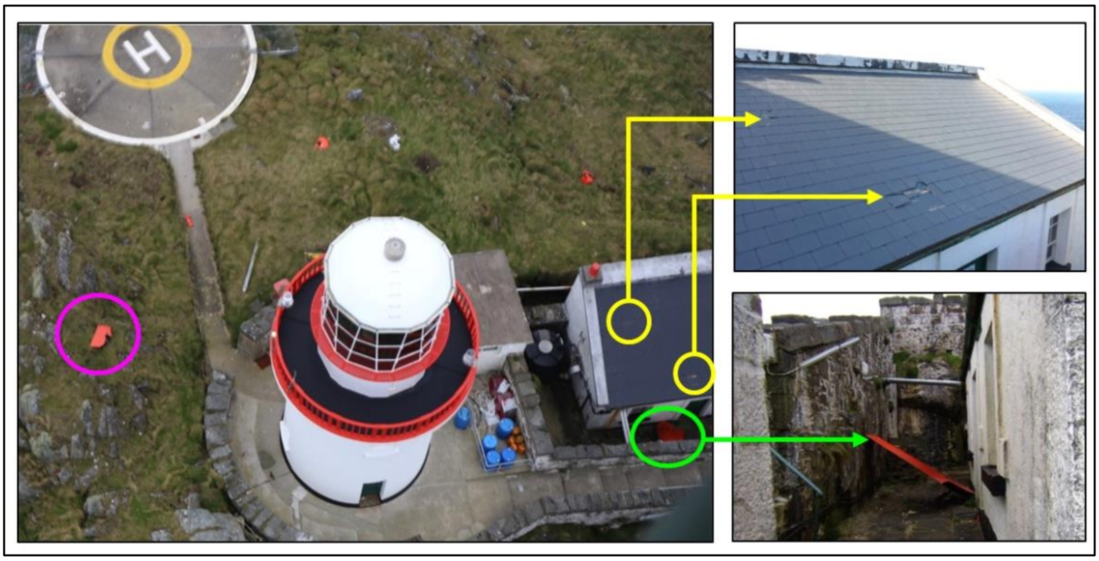

Figure No. 34: Sections of horizontal stabiliser (circled in magenta and green) and roof damage (circled in yellow)

Two pieces of aluminium alloy structure, each approximately 600 mm in length, were found to the east of the outhouses. These pieces were later identified to be forward and aft sections of the mounting structure for the horizontal stabiliser. The underside of each of these pieces was scraped and distorted.

Fragments of the tail rotor blades, including blade tips, were also recovered from Black Rock, most of which were less than 50 mm long. During the subsequent wreckage layout at the AAIU wreckage examination facility at Gormanston, a piece of metallic leading edge erosion strip from one of the tail rotor blades was found to fit into a gouge in the upper aft edge of the aft section of horizontal stabiliser mounting structure (**Figure No. 35**).

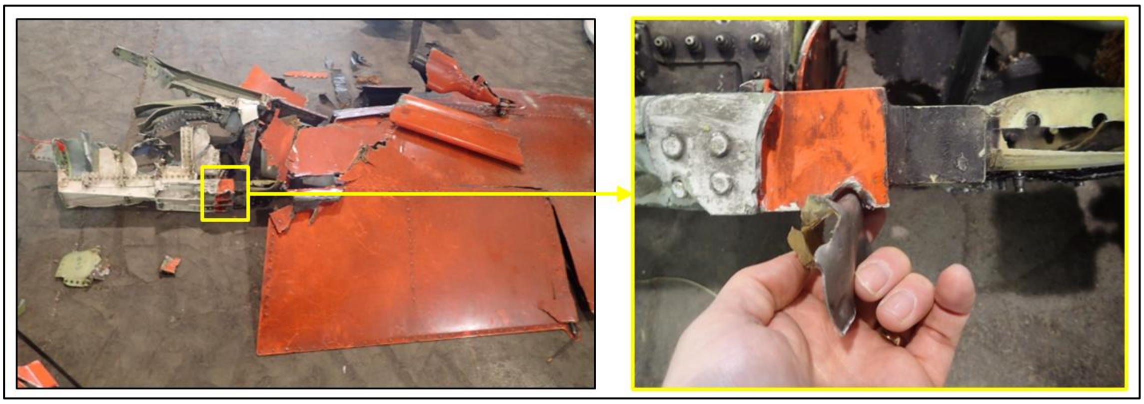

Figure No. 35: Gouge in upper aft edge of aft section of horizontal stabiliser

Two tail rotor control cable pulleys were also found on Black Rock. One of the pulleys was lying on the platform at the top of the lighthouse. Several fragments of a landing gear wheel rim were found close to the helipad. One fragment of the wheel rim and several other pieces of debris were found below the helipad grid, at its southern edge. One of the fragments of wheel rim was imprinted with a serial number. Using the Helicopter's technical records, the Investigation established that the fragment was from the number one (left-hand outboard) main wheel. The damage pattern on this rim fragment, suggested that it had been rolled outwards, which was consistent with a tyre overpressure event during the impact sequence. Parts of the Wulfsberg transceiver, which was located in the tail section of the Helicopter, were found to the east of the outhouses.

No contents from the Helicopter cabin or any personal effects were found on Black Rock.

In an attempt to locate a point of impact, further visits were made to Black Rock on 20 March 2017, and again on 21 March 2017. With the assistance of Defence Forces personnel, who provided mountaineering expertise, members of the AAIU examined large areas of Black Rock not accessible by foot. No obvious point of impact was found. A high concentration of debris was found in the area below the helipad on its southern side (**Photo No. 21**).

Photo No. 21: Location where a high concentration of debris was found

1.12.3 Items found on the Sea Surface and on the Shoreline

In the hours and days following the accident, a large number of items of wreckage were found and recovered by individuals and agencies, and were provided to the Investigation.

The centre (main) portion of the right-hand sponson (containing the right-hand fuel tank) was found floating intact on the sea surface. The fuel tank was found to contain a substantial quantity of fuel. Various pieces of the left-hand sponson, which had shattered, were recovered from the surface. Both life rafts were found floating on the sea surface. The forward cabin sliding door was recovered floating in the water. The top sliders were still attached to the structure. The door latch and pin exhibited bending. The upper ramp door (cargo hatch) was recovered in the water, separated from the structure. The locking handle was broken and the exposed honeycomb structure was visible over the entire length of the left-hand side. The main ramp itself was also recovered from the sea. The left-hand and right-hand ramp pistons had separated from the ramp. Approximately 150 mm of the ramp on the left-hand side fractured and separated. The right-hand wooden skid plate was intact; the left-hand skid plate was fractured and separated from the ramp. The APU access panel, aft upper fuselage section (‘*whale tail*’) separated from the structure. The left-hand and right-hand emergency exit panels from the aft cabin were recovered. The left-hand emergency exit panel was distorted and had fractured on the upper forward corner. A diagram of the helicopter type, with some of the pieces found on the sea surface is shown in **Figure No. 36**.

The overall pattern of damage indicated that the Helicopter suffered more impact damage to its left-hand side.

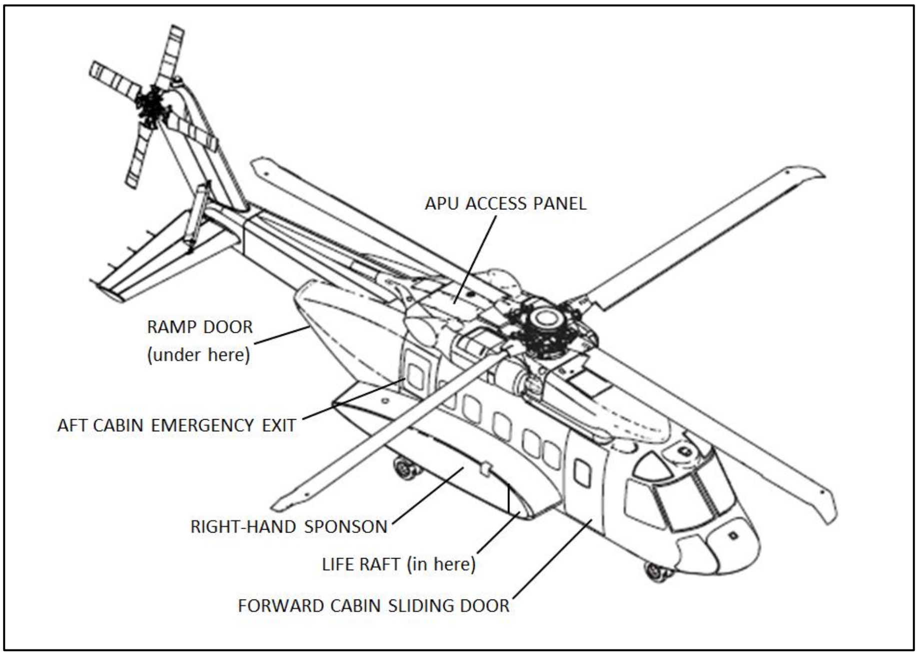

Figure No. 36: Pieces found on the sea surface

A partially filled auxiliary fuel tank (normally mounted mid-way on the left-hand side of the cabin) was recovered intact from the sea surface, having fractured at the lower attachment points.

The tail rotor drive cowling (approximately 1 m in length) separated from the drive shaft tunnel and was recovered from the sea surface.

1.12.4 Underwater Search

In addition to the extensive sea-surface and shorelines searches, which were conducted from the time of the accident, underwater searches as described below, were also carried out.

The approximate position of the Helicopter's MPFR Underwater Locator Beacon (ULB) was identified on the day following the accident (15 March 2017) by the (Irish) Marine Institute, utilising an Ultra-Short Base Line (USBL) sub-surface locating device, operated from a local fishing vessel. At the same time, sonar scans of the seabed were commenced by the Geological Survey (Ireland), supported by the Marine Institute, in an attempt to locate wreckage and to provide information for anticipated dive operations and planned ROV searches.

The Irish Lights' Vessel '*Granuaile*' positioned to the south of Black Rock on 21 March 2017, with the Marine Institute's Holland 1 ROV on board. The ROV was launched at approximately 20.00 hrs; however, due to difficult weather conditions and sea-state it was immediately recovered. Early the following morning (22 March 2017), in more favourable conditions, the ROV was launched again (**Photo No. 22**).

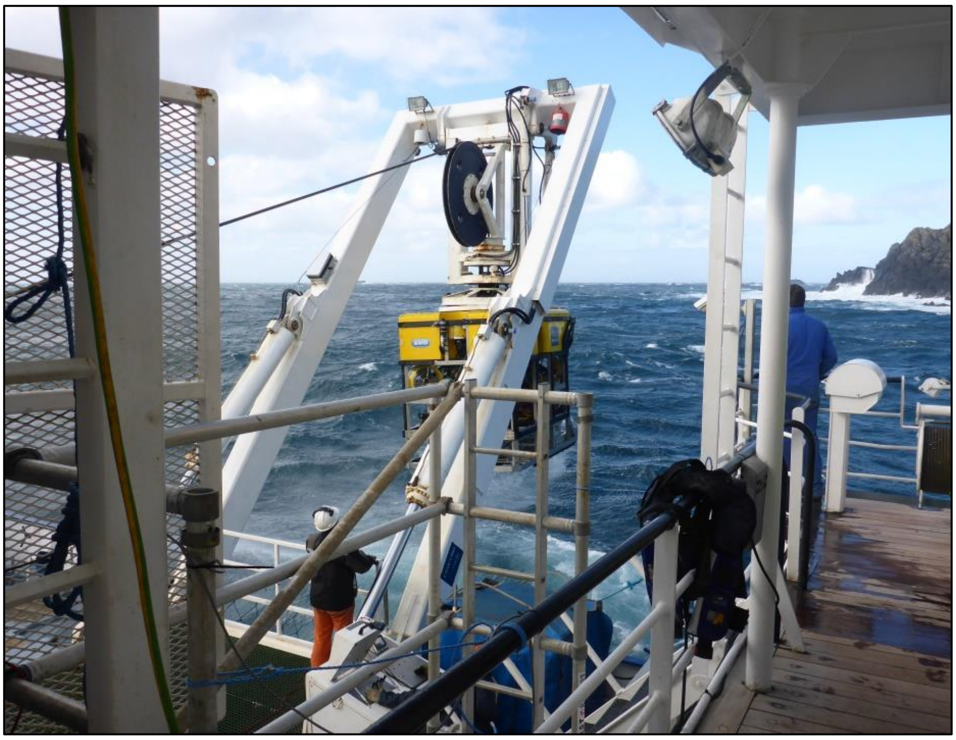

Photo No. 22: ROV launch during search operations, 22 March 2017

Within a short time of the ROV launch, the main wreckage was located on the seabed to the south-east of Black Rock at a depth of approximately 40 m (**Photo No. 23**). The main section of wreckage, comprising of the cockpit and cabin ceiling/upper fuselage was found lying on its left-hand side approximately 135° from vertical, and on a heading of approximately 140° magnetic (**Photo No. 24**).

Photo No. 23: Approximate position of main wreckage indicated by yellow arrow

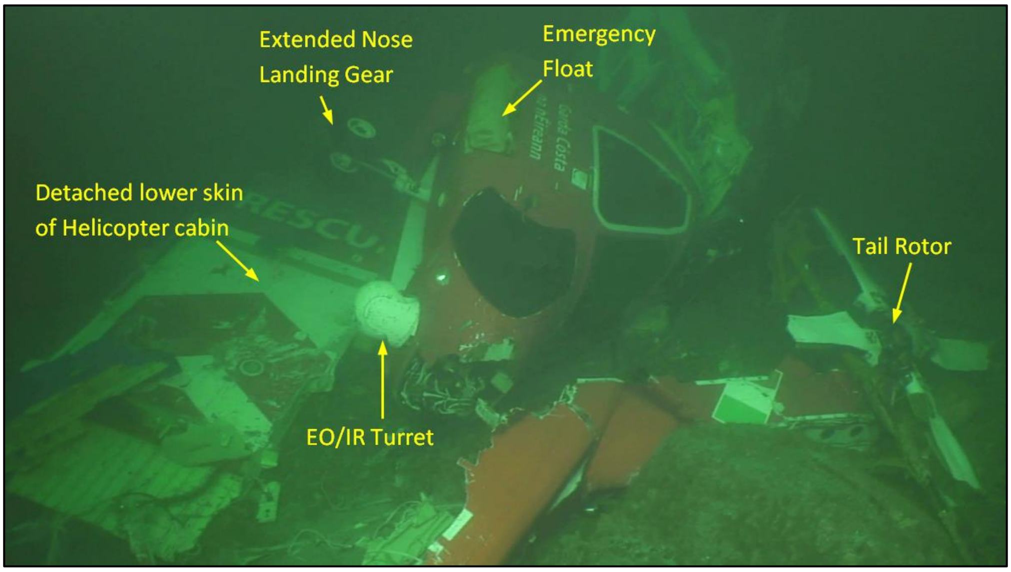

Photo No. 24: Disposition of the main wreckage on the sea bed

The right-hand side of the cockpit area was relatively undamaged. It was not possible to view the left-hand side as this side was in contact with the seabed. The deceased Co-pilot was located within the cockpit wreckage, in his seat, with his harness fastened. On 24 March 2017, divers from the Irish Naval Service attempted to remove the Co-pilot, but this was not immediately possible due to the disposition of the wreckage. Following extensive preparatory work using the ROV, the Co-pilot was recovered by Irish Naval Service divers on 26 March 2017. Extensive surface and ROV searches were carried out in attempts to locate the two Rear Crew members. Despite these efforts, the Rear Crew members were not located and remain lost at sea.

ROV surveys identified that the Nose Landing Gear (NLG) was in the extended (down) position. The EO/IR Turret '*FLIR ball*' was present below the nose. Both avionics racks were still present and intact in the cockpit entrance area. The MPFR was visible in the left-hand avionics rack. The HUMS unit and its memory card slot were also visible. The two emergency floats, situated below the sides of the cockpit area, were uninflated. Their covers had separated, and the floats remained *in-situ* attached to their mounting points.

All four main rotor blade roots were observed still attached to the main rotor hub. All the observed sections of main rotor blade exhibited damage. Two of the main rotor blades appeared to be notionally intact from the root to just inside the tip cap.

The cabin floor/lower fuselage had separated from the lower fuselage aft of the nose landing gear area and was lying forward of its normal location. The EO/IR control console, which contained the Avalex AVR-8240-XM DVR, was lying close to the cabin floor section.

The tail pylon was lying ahead of the nose of the cockpit wreckage. The inner portions of the four tail rotor blades remained attached to the tail rotor hub and gear box which was *in situ* in the tail pylon. There appeared to be substantial crushing damage to the base of the tail rotor pylon structure. The upper structure of the drive shaft tunnel was observed and was still connected to the tail rotor vertical pylon and tail rotor. Two separate sections of tail rotor driveshaft were lying close to the main cockpit and upper fuselage section.

The majority of debris was found on the seabed in close proximity to the main wreckage, which included:

- The right-hand hand jettisonable cockpit window (emergency exit).
- Both Main Landing Gear (MLG) Sponson sections, which had separated from the fuselage. The left-hand MLG sponson section appeared to have sustained more damage than the right-hand one. The upper portion of each MLG remained attached to its sponson section.
- A litter structure and several utility seats.
- The rescue hoist.
- The fractured and separated base plate of the ADELT system.

A section of the upper rear fuselage, where it transitions to the tail pylon, was lying forward (south) of the tail pylon. This section contained the aft float, which was observed to be uninflated. The float cover had detached.

1.12.5 Wreckage Recovery

A detailed photographic and High Definition (HD) video survey was conducted with the ROV, before commencement of wreckage recovery operations. The MPFR and the HUMS memory card were recovered by Irish Naval Service divers on 24 March 2017. Over the period from 22 March 2017 to 10 April 2017, several items of wreckage were recovered with the assistance of the ROV, including the jettisonable window (emergency exit) from the right-hand hand side of the cockpit; and, the Helicopter's technical log book, within its fire-retardant storage pouch.

The main wreckage section was recovered on 2 April 2017 with the assistance of a heavy lifting vessel following the installation of lifting harnesses by Naval Service divers (**Section 1.13.5**). However, during the lifting operation, which was conducted in high sea-state conditions, the cockpit section separated from the main wreckage.

On 10 April 2017, the tail pylon from EI-ICR, which included the tail rotor assembly, was recovered from the seabed by the ILV '*Granuaile*' after the ROV had attached lifting harnesses (**Photo No. 25**).

Photo No. 25: Recovered tail pylon section (on board ILV '*Granuaile'*)

The ILV '*Granuaile*', with the Marine Institute's ROV on board, returned to the area on 22 July 2017. During one of the ROV dives, the Electro-Optic and Infrared (EO/IR) control panel, including the DVR, was recovered from the seabed. The data from the DVR was subsequently downloaded with the assistance of the NTSB.

1.13 Medical and Pathological Information

Caution: This section contains sensitive post mortem information which some readers may find distressing.

1.13.1 Commander

A formal forensic post mortem examination was conducted by a Deputy State Pathologist at Mayo General Hospital, Castlebar on the 14 March 2017.

The Deputy State Pathologist's Report included, *inter alia*, the following information:

- There were bruises over the groin area on the right leg and a small number of bruises on the front of the thigh of the left leg. These may have seen sustained on exiting the aircraft during or after the accident. There were no underlying fractures of the pelvis or large bones. There was no significant underlying pathology which would have contributed to death in this case.
- Toxicology was negative for drugs and alcohol.
- At post mortem examination, there were large hyper-inflated lungs, which were overlapping the contour of the heart. The lungs exhibited congestion with frothy fluid in the larger airways. There was some '*Crepitus*'[67] on palpation of the lungs also. All these features are in keeping with death due to drowning.
- Cause of death was due to drowning. There were no contributory factors.

[67] **Crepitus:** Is the abnormal popping or crackling sound in either a joint or the lungs, which may be faint or loud enough for people to hear. Crepitus in the lungs is caused when the air sacs abruptly collapse as the lungs fill with fluid.

Because the Commander was found unresponsive on the sea surface, the Investigation considered it appropriate to seek to understand what factors may have contributed to the cause of death. In that regard, the Investigation sought assistance from a pathologist in the UK who has specialist experience in the area of diving operations.

The UK-based pathologist considered it probable that an inhalation of air occurred at the critical period of the impact with the sea. He went on to explain that, assuming an approximate lung volume at the surface being five litres, this would have been '*squeezed*' to a potential volume of two litres at 40 m on the principle of Boyle's Law[68]. During the egress and ascent the (now compressed) air would expand and may have been exhaled, or may have been retained in the lungs causing local tissue damage. The lung parenchyma[69] is not compliant to changes of pressure and there is usually tearing at the blood gas interfaces (alveoli and pulmonary vessels) developing gas embolism[70].

Detection of parenchymal damage and gas in the heart is difficult at autopsy, as is gas in the cerebral vessels, and may be artefact. This is sometimes referred to as CAGE (cerebral air/gas embolism). In the autopsy report, '*Crepitus*' of the lungs was observed which may be a useful observation to support the diagnosis of barotrauma[71].

The UK-based pathologist considered it to be possible that following egress from the Helicopter close to or on the sea bed at 40 m, the Commander made a rapid ascent to the surface and developed pulmonary barotrauma, gas embolism that could have caused incapacity, and led to drowning.

Further information is provided at **Section 1.15**, Survival Aspects.

Note: As the Commander's HEED[72] bottle was not recovered, the Investigation was unable to determine if the HEED bottle was utilised by the Commander during egress from the Helicopter.

1.13.2 Co-Pilot

A formal forensic post mortem examination was conducted by a Deputy State Pathologist at Mayo General Hospital, Castlebar on the 27 March 2017.

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[68] **Boyle's Law:** An experimental gas law that describes how the volume of a gas decreases as the pressure increases.
[69] **Lung parenchyma:** Is the portion of the lung involved in gas transfer - the alveoli, alveolar ducts and respiratory bronchioles.
[70] **Gas embolism**: Is a blood vessel blockage caused by one or more bubbles of air or other gas in the circulatory system.
[71] **Barotrauma:** Is physical damage to body tissues caused by a difference in pressure between a gas space inside, or in contact with, the body, and the surrounding gas or fluid.
[72] **HEED**: Helicopter Emergency Egress Device, a small canister of pressurised air designed to provide breathable air to assist egress from a helicopter underwater. These bottles are often referred to as STASS (Short Term Air Supply System) bottles or EBS (Emergency Breathing System). The technical specification for the HEED 3 model which was worn by the Crew states that it contains 30 breaths of air at the surface.

The Deputy State Pathologist reported, *inter alia*, that:

- At post mortem examination, this helicopter pilot was seen to have died of multiple injuries and death would have ensued rapidly.
- There was no evidence of any natural disease which would have made any contribution to the accident or his death.
- Analysis of the blood and urine for the presence of alcohol and drugs yielded negative results.

Cause of death was multiple injuries (helicopter crash). There were no contributory factors.

1.13.3 Winch Operator

Missing; lost at sea.

1.13.4 Winchman

Missing; lost at sea.

1.13.5 The Search for the missing Rear Crew

During ROV operations conducted in March, April, and July 2017, priority was given to searching for the two missing Rear Crew. During initial operations, all large sections of the wreckage, within the lifting capability of the ROV, were manipulated by the ROV to facilitate a comprehensive search of the seabed for the missing Rear Crew. Irish Naval Service divers placed lifting slings around the main section of wreckage, including the cockpit area. This section was lifted on 2 April 2017, in rough seas, by a heavy lifting vessel, while the area was monitored by a smaller ROV operated from a small boat on the surface. Other surface vessels and a SAR helicopter were in attendance to monitor the operation. The Rear Crew members were not located.

Further extensive, grid-type, ROV searches were conducted from 6 to 10 April 2017 to the south-west of Black Rock. Searches involved positioning the ILV '*Granuaile*' at a selected location and launching the ROV, which was then commanded to dive and travel approximately perpendicular to the ILV '*Granuaile*', while personnel in the ROV control room monitored the imagery from the ROV's cameras (**Photo No. 26**). The ROV was then re-positioned to permit it to travel back towards the ILV '*Granuaile*' along a new search line.

The ILV '*Granuaile*' was repositioned a number of times, and each time the search process was repeated. In addition, An Garda Síochána informed the Investigation that underwater searches were conducted by Garda divers around the shoreline of Black Rock. Local vessels, RNLI vessels, and the IRCG, also conducted searches from the sea-surface; shoreline searches were also conducted by a number of agencies and individuals including IRCG, Civil Defence and members of the public.

Photo No. 26: ROV Control Room

The ILV '*Granuaile*', with the Marine Institute's ROV on board, returned to the area on 22 July 2017, where further extensive underwater searches for the missing Crewmen were conducted until 25 July 2017. The Rear Crew members were not located.

1.14 Fire

127 There was no fire prior to, during, or after the accident. There was no evidence of fire on any of the recovered wreckage. The CVR recorded two automated callout warnings of '*SMOKE IN BAGGAGE*' but these appear to have been related to system disruption during the impact sequence rather than an actual fire/smoke event.

1.15 Survival Aspects

1.15.1 Initial Air and Sea Search for the Helicopter and its Crew

Logs kept by MRSC Malin recorded that, at 01.08 hrs, Blacksod Lighthouse personnel contacted MRSC Malin to enquire if they could see R116 on AIS, as the Helicopter had not arrived as expected at Blacksod helipad. At 01.13 hrs on 14 March 2017, MRSC Malin made a MAYDAY relay to all stations informing them that communications had been lost with R116 and requesting that any vessels with information contact Malin Head (MRSC Malin). At 01.21 hrs, MRSC Malin informed the FV, which was approximately 140 miles west of Eagle Island and being assisted by R118, that R116 may have ditched off Blacksod. MRSC Malin requested that the FV advise R118 of this. R118's crew informed the Investigation that this message was received from the FV just as winching operations were concluding. During winching operations, the winchman experienced an impact with the FV structure and fell onto the FV's deck; the winchman informed the Investigation that he felt no ill-effects or impairment from the impact and fall on the night of the accident, although in the days following the accident his ribs did become sore and he took some sick leave.

In order to maintain the Crew's focus in light of the gravity of this message from the FV regarding R116, the commander of R118 cautioned all crew members to adhere rigidly to their briefed tasks, to ensure that R118 could safely depart the SAR scene as quickly as possible. The only remaining briefed action was the HI-line recovery, which was already in progress and took approximately one minute to complete. R118 then climbed away from the FV and established flight at a safe altitude, en route to Black Rock. R118 then requested the FV to resend its message.

R118 departed the FV at 01.23 hrs and established SAT Phone communications with MRSC Malin at 01.31 hrs. At 01.46 hrs, MRSC Malin recorded communications indicated that R118 re-established radio communications on Marine Channel 16. At 01.48 hrs, R118 informed Belmullet Coastguard Radio (MRSC Malin) that they were unable to identify any signals from the locator beacons which would have been carried on R116 and on the lifejackets of individual crew members.

Recorded communications between R118 and MRSC Malin show that at 02.10 hrs, R118 was on scene at Black Rock and commencing a search. At 02.11 hrs, R118 advised MRSC Malin that strobes had been sighted in the water. The Crew of R118 informed the Investigation that shortly thereafter they identified a life raft in the water and that a casualty was floating in the water nearby. The winchman was deployed to recover the casualty.

Standard winching procedure was to deploy the winchman to a safe working height, signalled by hand between the winchman and the winch operator. The winch operator then '*patters*' (verbally directs) the helicopter closer to the casualty, with the intention of placing the winchman in the water as close as possible to the casualty. The winch operator informed the Investigation that shortly after the winchman reached a safe working height, the cable felt momentarily slack; the reason for this was that the winchman had been engulfed by a large wave and when the wave had passed, the casualty had been moved away from the winchman. The winchman informed the Investigation that due to darkness he could only make out the profile of the casualty's lifejacket and hair, and that at no time did he observe any responsiveness from the casualty. The helicopter was re-positioned several times but each time the winchman got close to the casualty, wave action separated them. Achill lifeboat arrived on scene at this time. R118 directed it to the casualty's location, recovered the winchman and withdrew a short distance so that the lifeboat could attempt to recover the casualty.

Achill lifeboat was successful in recovering the casualty at approximately 02.37 hrs. The Lifeboat crew noted that the casualty appeared lifeless, was lying on her back, with her face out of the water and with no helmet on. When recovered on deck, she was found to be unresponsive, not breathing, and there was no sign of life. R118 continued searching for other casualties, while members of the Achill lifeboat crew attempted to resuscitate the casualty. Resuscitation efforts were continued for approximately 25 minutes. The casualty was subsequently winched from the lifeboat by R115, which had arrived on scene from Shannon. The casualty, who was identified as the Commander of R116, was transferred to Castlebar Hospital.

In the intervening period, at 02.29 hrs, MRSC Malin had contacted ARCC Kinloss (in Scotland) and asked if any EPIRB[73] transmissions had been received. ARCC Kinloss replied that they had not received any EPIRB or PLB transmissions.

1.15.2 Environmental Conditions

The Met Éireann forecast for Blacksod Bay issued at 02.16 hrs on 14 March 2017 predicted that the area of Blacksod Bay would be *'rough'* (sea-state 5[74]) and that the sea temperature would be 9 °C. Data included in the Transportation Safety Board of Canada, Marine Investigation Report M90L3034[75] predicts that at 10 °C an average adult wearing a lifejacket and light clothing could survive in the water for up to 2.5 - 3 hours, but would become weak and unable to assist themselves after approximately 1.5 hours. Wearing an immersion suit[76] and appropriate clothing underneath the immersion suit can increase survival time significantly. Report M90L3034 notes that there are cases of persons wearing immersion suits surviving for up to 24 hours in water temperatures close to 0 °C.

1.15.3 Survival Clothing

During the occurrence flight, both the Commander and Co-pilot were wearing immersion suits. Underneath their immersion suits both Pilots were wearing several layers of warm clothing including short, padded jumpsuits.

The Investigation could not determine what clothing was being worn by the Rear Crew at the time of the occurrence. The Operator informed the Investigation that '*the Rear Crew's specifically allocated immersion suits were not at the Dublin base*'.

All crew members were wearing safety helmets designed to provide impact protection, sound proofing and communications. The Commander's helmet was recovered from the sea surface, while the Co-pilot was wearing his helmet when he was located in the wreckage. On inspection by the Investigation, these helmets exhibited damage to the outer surfaces but the protective shells were intact.

The helmets that were worn by the Winchman and the Winch Operator were recovered from the sea in September 2017 and July 2018 respectively. On inspection by the Investigation, these helmets exhibited surface damage and the integrity of the protective shell had been compromised.

1.15.4 Lifejackets

The Flight Crew of R116 wore RFD Beaufort Mk44 lifejackets (**Photo No. 27** and **Photo No. 28**). The Rear Crew wore RFD Beaufort Mk15 lifejackets (**Photo No. 29** and **Photo No. 30**). Both types of lifejacket were equipped with a light, a whistle, an inflation-activated strobe light and a '*buddy*' line. The Mk44 lifejacket was fitted with an integrated spray hood, whilst the Mk15 had a spray hood added by the Operator. Each Crew Member lifejacket also incorporated a number of Operator-specific accessories. These were: SARBE 6-406G PLBs, Flares and HEED 3 bottles.

[73] **EPIRB**: Emergency Position Indicating Radio Beacon.
[74] Sea state measured on the Douglas scale. Sea State 5 indicates wave heights between 2.5 and 4 m.
[75] http://www.bst-tsb.gc.ca/eng/rapports-reports/marine/1990/m90l3034/m90l3034.asp#appendix_h
[76] **Immersion Suit**: A waterproof dry suit designed to provide protection following immersion in cold water.

Photo No. 27: Mk44 lifejacket as worn (*courtesy of the Operator*)

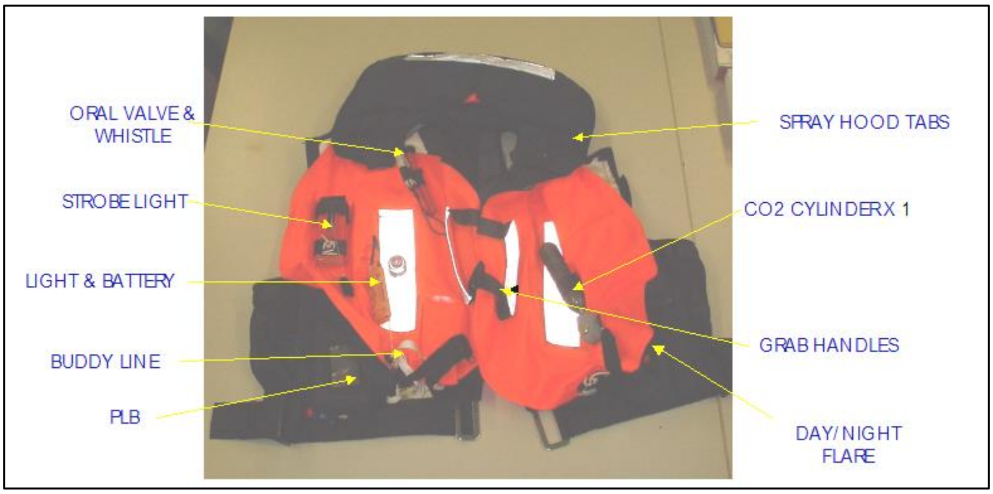

Photo No. 28: Mk44 lifejacket, partially unpacked (*courtesy of the Operator*)

Photo No. 29: Mk15 lifejacket as worn (*courtesy of the Operator*)

Photo No. 30: Mk15 lifejacket partially unpacked (*courtesy of the Operator*)

The Commander and Co-pilot were wearing their Mk44 lifejackets when recovered. A spare Mk15 lifejacket, which was carried in the Helicopter, was recovered from the main Helicopter wreckage during ROV operations. Two more Mk15 lifejackets were subsequently recovered. On 30 September 2017, the lifejacket worn by the Winchman was recovered from shallow water at Elly Bay, Clogher, Ballina, Co. Mayo, 9 NM north-east of Black Rock, and on 12 July 2018, the lifejacket worn by the Winch Operator was recovered 1 NM north-west of Achill Head, Co. Mayo. Two of the five recovered lifejackets – the Mk44 worn by the Commander and the Mk15 worn by the Winchman – were found inflated. The lifejackets worn by the Co-pilot and by the Winch Operator were not inflated.

Four of the five recovered lifejackets (the Commander's, Co-pilot's, the Winchman's and the spare Mk15 carried on the Helicopter) were examined by qualified lifejacket servicing personnel. No anomalies regarding the likely serviceability of the lifejackets were noted and all were found with PLBs installed. **Appendix Q** describes the lifejacket inspections in detail.

The fifth lifejacket (the Winch Operator's) was examined by the Investigation. This lifejacket exhibited significant abrasion damage which included the PLB pocket; the PLB was missing and was not recovered.

1.15.5 Locator Beacons

The S-92A helicopter ELT emits a continuous audible tone. The ADELT[77] transmits a twin tone on 121.5 MHz every three seconds and a 406 MHz transmission every 50 seconds approximately.

The UK Marine Accident Investigation Branch (MAIB) contacted the UK Maritime and Coastguard Agency (MCA) on behalf of the Investigation. The MCA confirmed that no signal was received from any of the on-board emergency transmitters at the time of the accident.

[77] **ADELT:** Automatically Deployable Emergency Locator Transmitter, also known as a Crash Position Indicator (CPI). This system is described in **Appendix B**.

Each lifejacket was equipped with a SARBE 6-406G PLB. When activated, SARBE 6-406G PLBs transmits on 406 MHz every 50 seconds approximately, and twin tone signals on 121.5 MHz and 243 MHz every three seconds, which can be identified by Search and Rescue Authorities and used to locate the beacon. The SARBE 6-406G's GPS position data is transmitted with factory-set COSPAS-SARSAT beacon identities, on 406 MHz at intervals of approximately 50 seconds. SARBE 6-406G can be activated manually, or automatically by a saltwater activation switch. During production the seals on SARBE 6-406G beacons are pressure tested with a pressure equivalent to a water depth of 10 m, and once activated, the battery is specified to provide power for over 24 hours at -20 °C.

Four SARBE 6-406G PLBs were recovered following the accident; these were the PLBs installed in the lifejackets of the Commander, the Co-pilot, the Winchman and the spare lifejacket carried in the Helicopter. The Investigation arranged for them to be inspected by qualified personnel.

The first three PLB units to be recovered, those carried by the Commander, the Co-pilot and the spare, were also returned to the original equipment manufacturer for detailed examination and testing. The SARBE 6-406G manufacturer's inspections found that all three PLBs showed damage consistent with submersion to a water depth greater than 10 m (the maximum certified depth for the units). The main seals remained in good condition; however, the units had sustained significant internal water damage. The ingress of water would have prevented any further operations of the PLBs even following return to the surface. During the inspection it was noted that the battery from the Co-pilot's PLB had an expiry of January 2017.

In the case of the beacon located in the Winchman's lifejacket, the antenna mount had separated from the beacon casing and this provided a path for sea water ingress, irrespective of immersion depth. Accordingly, this beacon was not subjected to further inspection.

As noted in the Investigation's Preliminary Report, the installation of the Commander's and Co-pilot's PLBs, in their Mk44 lifejackets, were not in accordance with the beacon manufacturer's operator's handbook. The PLB manufacturer's investigation report states:

> *'Life jacket integration is outside the scope of this* [the PLB] *investigation. However, it was noted that the configuration of two of the life-vests did not provide the recommended separation of the two antennas (TX and GPS) and did not provide a clear view of the sky without manual intervention. The operation of the GPS antenna, especially in this configuration, may be compromised.'*

Details of the PLB (SARBE) inspections and testing are presented in **Appendix R**.

1.15.5.1 Service Bulletin 184

In October 2008, the Mk44 lifejacket manufacturer issued SB 184 which stated:

> *'Due to the unavailability of the old model SARBE 6 Personal Locator Beacon (PLB) customers are now supplied with the new SARBE 6 406 PLB's.*
>
> *As the size of the new beacon is significantly different, they no longer fit into the existing standard beacon pocket on the Mk44 & Mk44SC Aircrew Lifejacket.*
>
> *This Service Bulletin authorises RFD Beaufort approved maintenance personnel to modify Mk44 & Mk44SC Aircrew Lifejackets, iaw* [in accordance with] *the instructions at Para 2, so that the new style PLB may be fitted, and for the aerial to be stowed securely.'*

The modification included the replacement of a pocket with a larger pocket and additional webbing to secure the aerial of the locator beacon. SB 184 instructed customers to '*Stow the PLB in the PLB pocket, with the GPS unit and connecting cable* […]*'*. This instruction is not in accordance with the SARBE 6-406G manufacturer's operations manual which directed:

> *'Place GPS antenna horizontally with green top facing the sky, and with a clear view of the sky and horizons. Keep the GPS and transmitting antenna separated by 30cm.'*

This apparent contradiction between SB 184 and the operations manual for the SARBE 6-406G was identified in a number of SQID reports, as early as 2011. These SQIDs are discussed further in **Section 1.17.4.2**.

1.15.6 Safety Recommendation IRLD2017006 – PLB Installation

The Investigation's Preliminary Report identified that the installation of PLBs in the Mk44 lifejackets worn by the Flight Crew, was a matter of concern. To address this, the AAIU issued the following Safety Recommendation in the Investigation's Preliminary Report relating to PLB Installation in the Mk44 lifejacket:

RFD Beaufort Ltd should review the viability of the installation provisions and instructions for locator beacons on Mk44 lifejackets and if necessary amend or update these provisions and instructions taking into consideration the beacon manufacturer's recommendations for effective operation (**IRLD2017006**).

As a result of this Safety Recommendation the lifejacket manufacturer re-designed the provision for SARBE 6-406G installations in Mk44 lifejackets. The modification was tested with a SARBE 6-406G installed and the SARBE was found to perform satisfactorily (**Appendix S**). The modification was issued to lifejacket customers as SB 25-147 Version 2. Further details of this Safety Recommendation (which has now been closed) and associated responses are presented in **Appendix G** to this Report.

Also as a result of AAIU Safety Recommendation IRLD2017006, the Helicopter Operator suspended the use of Mk44 lifejackets in their fleet and directed flight crew to wear RFD Beaufort Mk15 lifejackets. The Operator has since modified all Mk44 lifejackets in their fleet in accordance with SB 25-147 Version 2 and returned them to service**.**

1.15.7 Regulation of Personal Protective Equipment

Within Europe, Personal Protective Equipment (PPE) must meet the standards set out in Regulation (EU) No 2016/425. Compliance with this Regulation is denoted by a *Conformité Européenne* (CE) mark on the lifejacket itself. The lifejackets worn by the crew in this accident did not have a CE mark. The lifejacket manufacturer informed the Investigation that the lifejackets worn by the crew in this accident were exempt from Regulation (EU) No 2016/425 due to the fact that they were certified for aviation use. Article 2 of Regulation (EU) No 2016/425 states that:

> *'2. This Regulation does not apply to PPE:* […]
> *(d) for exclusive use on seagoing vessels or aircraft that are subject to the relevant international treaties applicable in Member States;'*

1.15.7.1 Initial Certification of Mk44 and Mk15 Lifejackets

The Investigation was provided with the lifejacket manufacturer's certification documents for the Mk44 and Mk15 lifejackets. Both variants of lifejacket were certified to UK Civil Aviation Authority (CAA) Specification No. 5, in July 2000. When EASA was formed in 2002, responsibility for this certification transferred from the UK CAA to EASA.

Following its formation, EASA developed a technical standard for lifejackets, designated ETSO (European Technical Standard Order) 2C504. Lifejackets that had been approved prior to the establishment of EASA retained their previous approval even if they did not comply with the complete ETSO 2C504 standard, an arrangement known as *Grandfather Rights*. Neither UK CAA Specification No. 5, nor ETSO 2C504 included requirements relating to the installation of PLBs.

One of the certification documents provided by the lifejacket manufacturer was the Declaration of Design and Performance (DDP) for the Mk44 lifejacket which refers to the lifejacket pockets stating that:

> *'The lifejacket is fitted with pocketry. Equipment to be fitted into the pocket is discretional to the User and such equipment shall be declared to the CAA for ratification according to aircraft type.*
>
> *The responsibility for declaration and obtaining subsequent ratification from the CAA of any equipment stowed in pocketry lies with the individual users.'*

The lifejacket manufacturer advised the Investigation that operators would not routinely be supplied a copy of the DDP when purchasing a lifejacket and the Operator informed the Investigation that this was the case in this instance. However, specific operator requests for modifications to the lifejacket required dialogue between the Operator and the manufacturer's sales and engineering teams. The Investigation notes that such dialogue did take place. This is discussed further in **Section 1.17.4.2**.

The lifejacket manufacturer also informed the Investigation that it was currently looking at improvements to its process and was reviewing the possibility of adding a statement on the limiting conditions of use to EASA Form One Certificates[78] and/or Component Maintenance Manuals.

1.15.7.2 Continuing Airworthiness of Personal Protective Equipment

Under EASA Regulations, minor design modifications to previously approved parts can be made without EASA authorisation by an approved organisation. The lifejacket manufacturer holds such an approval, known as an Alternative Procedure to Design Organisation Approval (APDOA) for design and approval of certain ETSOs (in this case lifejackets, immersion suits and rafts). Annex 1 of Regulation 748/2012 (certification of aircraft and related products, parts and appliances, design and production organisations) states that:

> *'21.A.611(a)*
>
> *(a) The holder of the ETSO authorisation may make minor design changes (any change other than a major change) without further authorisation by the Agency* [EASA …] *the holder shall forward to the Agency any revised data that are necessary for compliance with point 21.A.603(b).'*

EASA confirmed this to the Investigation, stating that:

> *'Minor changes following procedures agreed with the Agency* [EASA] *according to Part 21, 21.A.611(a), can be done to an approved equipment by the Authorization Holder (ETSOH) without further authorisation by the Agency. Accessories can be introduced via minor changes into the approval, provided that these do not interfere with the compliance of the equipment to the requirements of ETSO* […]*'.*

The EASA website FAQs state that:

> *'As a general criterion, a change could be classified as 'minor' if it doesn't require a complete re-investigation for assessing the compliance to the applicable requirements.'*

In the case of the Mk44 lifejacket, the manufacturer's SB 184, which modified the pockets to accommodate a new standard of PLB, was defined in the SB as a minor design change.

The Mk44 DDP document provided by the lifejacket manufacturer included an annex which contained an index of minor design variances from the original certified design. Most of the variances listed are specific to the requirements of a particular operator, and most related to the modification or addition of pockets.

The lifejacket manufacturer informed the Investigation that since the accident they had undertaken a number of actions to ensure that any integration issues with their products are identified and are addressed. The actions were:

[78] **Form One Certificate:** The EASA Form 1 is a certificate stating that a product, a part, or a component was manufactured/maintained in accordance with approved design data.

- A full review of all lifejacket installations and the beacons fitted to them.
- A change to procedure which mandates that all enquiries for commercial lifejackets requiring beacons to be fitted are reviewed. If the assembly has been supplied previously (i.e. within the last two years) the order can proceed. If not, a full review is carried out to assess the feasibility.
- A DFMEA (Design Failure Mode Effects Analysis) is completed on all new project work.

The Component Maintenance Manual (CMM) is updated, or created as appropriate, for all new assemblies entering production. The CMM is then checked as part of the initial production phase.

EASA reviewed the Interim Statement published by the Investigation (AAIU Report 2018-004) and noted that in Ireland, a National SAR Approval is '*based on the requirements of European Union Regulation (EU) 965/2012, as amended*', and informed the Investigation that:

> '*Under EU law, for operations which are governed by R965* [European Regulation (EU) No 965/2012], *responsibilities are clearly addressed* […] *and the CAT operators' responsibilities, among others, are as follows:*
>
> *ORO.GEN.200 Management system*
> *(a) The operator shall establish, implement and maintain a management system that includes:*
>
> […]
>
> *(3) the identification of aviation safety hazards entailed by the activities of the operator, their evaluation and the management of associated risks, including taking actions to mitigate the risk and verify their effectiveness;'*

EASA further explained that under the EU regulatory framework:

> *'If, as part of its management system and associated risk assessment outcome, the operator elects to use non-mandatory non-installed equipment such as PLBs for additional risk mitigation, the operator should assess whether the additional equipment is fit for purpose. In addition, it should not affect the integrity of any other equipment used eg mandatory equipment such as approved life jackets. The STC* [Supplemental Type Certificate] *for the life jacket approval classifies PLBs as a minor modification, hence not affecting the integrity of the life jacket.'*

EASA informed the Investigation of changes to the approval requirements for lifejackets and PLBs. EASA stated:

'[…] *as major outcome from this case, for any future ETSO approval of lifejackets including additional non required functionalities, like PLBs, EASA will make explicit reference to the integrated equipment (specific model, PN, etc.) in the Certificate and any change to such functionality if not notified to EASA for acceptance will consequently invalidate the approval. Last but not least, EASA intends to issue a new ETSO standard on Personal Locator Beacon by the forthcoming amendment 16 of CS-ETSO* […] *whose Minimum Performance Standards (MPS) should reflect Maritime Standard RTCM 11010.3. After publication of such new ETSO, PLB installations on lifejackets will only be accepted for ETSO approved PLBs.'*

1.15.8 Offshore Survivability Training

Acceptable Means of Compliance (AMC)[79], provided by EASA, AMC1 ORO.FC.230 a) 2 (iii) (F) require the Operator to provide all of their helicopter crews with Helicopter Underwater Escape Training (HUET) training once every three years. The training undertaken by the Crew in this occurrence was a combination of classroom and pool-based training and covered the following elements:

- Use of STASS/HEED bottle
- Egress from a simulated helicopter cabin/cockpit in a variety of scenarios; inverted, darkness, cross-cabin, with and without STASS/HEED
- Inflating lifejackets
- Boarding life rafts
- Jumping into deep water from height

For the pool-based training, crew members were required to wear immersion suits and lifejackets. The Operator informed the Investigation that since May 2016 crew members wore another manufacturer's lifejackets during training rather than the Mk44 and Mk15 lifejackets. This was because the Operator was planning to introduce an alternative lifejacket to the Irish Operation to bring it in line with the Operator's Parent Company's international operations.

An examination of the Operator's training records showed that all of the Crew of the occurrence Helicopter had current certification for HUET and STASS/HEED training.

In relation to underwater helicopter egress, the Investigation notes that a North Atlantic Treaty Organization (NATO) report, RTO-AG-341, titled '*The Requirements for an Emergency Breathing System (EBS) in Over-Water Helicopter and Fixed Wing Aircraft Operations*' stated:

'*Disorientation. Broadsmith (11)[80] has modelled various helicopters and concluded that a helicopter may rotate several times before settling on the bottom or stabilizing out.*

[79] **AMC**: EASA informed the Investigation that AMCs are not at the level of a requirement. However, if followed, they provide a presumption of compliance with the associated Implementing Rule.
[80] Broadsmith, M. Westlands Aerospace Personnel Communication. November 1989.

The survivor, under such circumstances, will be disoriented due to false cues signalled by the organs of balance in the inner ear, loss of gravitational references and darkness or, paradoxically, by bright surface sunlight reflecting off the bubbles in the in-rushing water.

[…]

Even if the survivor has made a safe exit from the fuselage, it is still necessary to breathhold until reaching the surface. As the helicopter sinks, it is not uncommon to have to make an escape in 5-10 metres of water. Due to Boyle's Law, below about 5 metres, neither the buoyancy in the survival suit or the lifejacket will bring the person safely to the surface. It is therefore necessary to swim. This requires hard work and significantly shortens breath-hold time.'

1.15.9 Life Rafts

Following the accident, the life raft that was installed in the left-hand sponson was recovered from the sea by the RNLI in a partially inflated state. The life raft, which was installed in the right-hand sponson, was recovered from the sea by a fishing trawler; it was fully inflated. It is considered likely that each life raft deployed during the accident sequence. The centre (main) portion of the right-hand sponson (containing the fuel tank) was found floating on the surface of the sea intact, whereas the left hand sponson had shattered. The nature of the damage sustained to the left-hand sponson was such that it likely adversely affected the inflation of its life raft.

1.15.10 Helicopter Emergency Beacon Detection Equipment

When activated, the locator beacons attached to Crew lifejackets, the Helicopter and its life rafts, broadcast distress signals which can be detected by an array of satellites orbiting the earth.

A single satellite, circling the Earth around the poles, eventually views the entire Earth surface. The '*orbital plane*', or path of the satellite, remains fixed, while the Earth rotates underneath it. At most, it takes only one half rotation of the Earth (i.e. 12 hours) for any location to pass under the orbital plane. With a second satellite, having an '*orbital plane*' at right angles to the first, only one quarter of a rotation is required, or 6 hours maximum. Similarly, as more satellites orbit the Earth in different planes, the waiting time is further reduced. The Cospas-Sarsat System (**Figure No. 37**) design constellation provides a typical waiting time of less than one hour at mid-latitudes.

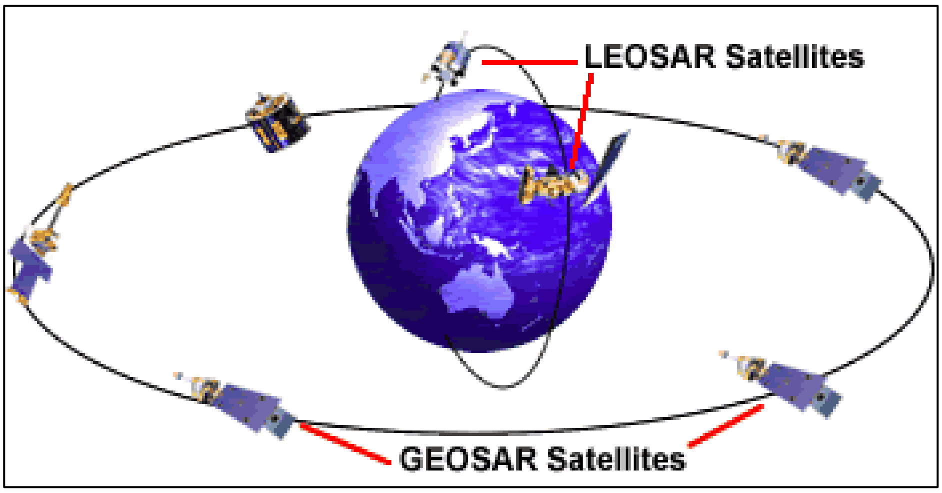

Figure No. 37: COSPAS SARSAT Satellite Coverage (*COSPAS-SARSAT*)

The LEOSAR system calculates the location of distress events using Doppler processing techniques. Doppler processing is based upon the principle that the frequency of the distress beacon, as '*heard*' by the satellite instrument, is affected by the relative velocity of the satellite with respect to the beacon. By monitoring the change of the beacon frequency of the received beacon signal and knowing the exact position of the satellite, the location of the beacon can be calculated.

The GEOSAR system consists of 406 MHz repeaters carried on board various geostationary satellites, and the associated ground facilities called GEOLUTs, which process the satellite signal. As a GEOSAR satellite remains fixed relative to the Earth, there is no Doppler effect on the received frequency and Doppler radio location positioning techniques cannot be used to locate distress beacons. To provide rescuers with beacon position information, such information must be either acquired by the beacon through an internal or an external navigation receiver and encoded in the beacon message, or derived, with possible delays, from the LEOSAR System. According to COSPAS/SARSAT, the typical time to alert from detection is up to 90 minutes for the LEOSAR and up to 5 minutes for the GEOSAR system.

1.16 Tests and Research

1.16.1 Review Flight

In order to observe cockpit displays, the operating environment, crew dynamics and the topography of the Black Rock area when operating an S-92A helicopter, the Investigation arranged for a Review Flight to be performed. With the approval of IRCG, the flight was conducted on 2 July 2018 in one of the Operator's S-92A helicopters, a sister-ship of R116, which was equipped with the same avionics suite and flight instruments as the accident Helicopter. A team of four AAIU inspectors was on board. The flight was conducted during daylight hours, in VMC. The prevailing wind on the day, approximately 030 degrees, 24 kts, was significantly different to those experienced on the night of the accident, reported as 240 degrees, 25-33 kts.

After departure from Sligo airport, the flight routed towards the Blacksod area at 4,000 ft, following which the flight was planned to follow a similar flight path to the accident flight, based on HUMS and FDR data.

The flight routed west over the Blacksod Bay area at 4,000 ft, and descended towards Black Rock, using APP1 to bring the helicopter to 200 ft. Once at 200 ft, it performed a turn back to BLKMO using heading mode initially, and then the AFCS Search Mode.

During the Review Flight, the instrument displays were selected in a manner that best reflected FDR parameters from the accident flight. This included selecting the GMAP2 radar range to 10 NM, which was the range set during the accident flight. The Investigation was able to observe and record examples of radar returns displayed on the pilots' MFDs as the helicopter tracked west towards BLKMO, descending from 4,000 ft, and then as the helicopter tracked easterly towards BLKMO at 200 ft. During the flight, the Flight Crew had programmed the FMS with the APBSS route to the Blacksod landing site.

In order to record details of the Review Flight, the Investigation used a combination of hand-held video and still cameras. The following photographs were extracted as frame captures from the video taken by the Investigation, as the Helicopter approached BLKMO (**Photo No. 31** and **Photo No. 32**).

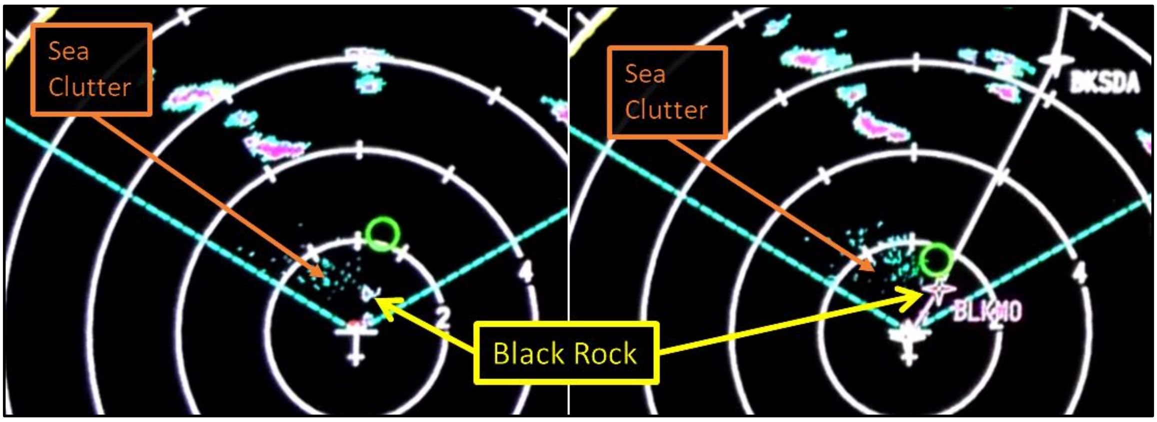

Photo No. 31 and **Photo No. 32:** Radar returns from Black Rock on 10 NM range, without and with, APBSS route overlay.

The magenta coloured, star-shaped waypoint marker (**Photo No. 32**) indicates the location of the BLKMO waypoint, and the magenta coloured track line indicates the helicopter's track to that waypoint. Comparison of **Photo No. 31** and **Photo No. 32** shows that the waypoint marker for BLKMO overlaid and obscured the radar imagery for Black Rock based on the radar returns. The radar image also shows an area of multiple smaller returns known as '*sea clutter*'[81]. These are returns from the sea surface due to wave action caused by local wind conditions, and cannot be filtered when operating the radar in GMAP2 mode.

[81] **Clutter**: In addition to the target information, radar may also detect some unwanted returns/echoes from other objects. These unwanted returns are termed as clutter. Such echoes are typically returned from ground, sea, rain, birds, insects, chaff and atmospheric turbulences, and can cause serious performance issues with radar systems. As the wind speed changes due to atmospheric disturbances, so the sea-state and wave reflectivity also changes, which will vary the amount of sea clutter observed on radar returns.

Compared to the reported weather conditions for the accident flight, the wind conditions on the date of the Review Flight were lighter, with a corresponding sea-state estimated at 2-3. The sea-state at the time of the accident flight was estimated at 5, resulting in the likelihood that more surface '*sea clutter*' returns may have painted on the radar display of the accident Helicopter.

It was not the intention of the Investigation to use the Review Flight to assess the functionality of the EGPWS alerting system as, at the time of the accident, the data for Black Rock was missing from the obstacle and terrain databases. However, as stated in **Section 1.17.11.1**, the Investigation was advised by the EGPWS manufacturer that '*Black Rock Island was added to the terrain database in release 485/585. The database was posted on Honeywell's website on June 14, 2017.*' The Operator subsequently installed this terrain database release in its helicopter fleet. Accordingly, during the Review Flight, the EGPWS system was capable of generating alerts when approaching Black Rock. As already stated in **Section 1.6.6.6**, the EGPWS manufacturer's manual states that the LOW ALTITUDE mode reduces the look ahead from 1.1 NM to 0.75 NM at 120 kts and that '*Forward airspeed will also modify the look-ahead envelope. Below 100 knots, the envelope is reduced until it is completely inhibited at 70 knots or less.'* During the Review Flight four passes were made towards Black Rock and an alert was generated on only one of those four passes. It was noted that during the Review Flight, the helicopter was slowing down and going close to or below the 70 kts threshold for EGPWS warnings, and this would explain why alerts were not generated on all passes. For completeness, the Investigation notes that the accident Helicopter had a recorded KIAS of 77 kts immediately prior to the accident and accordingly, it was within the envelope necessary to generate a warning (> 70 kts), albeit with substantially reduced '*look ahead*' sensitivity.

The Investigation also took the opportunity during the review flight of observing and recording the Toughbook display of AIS data. Graphical AIS data is displayed on the Toughbook display and on a bulkhead-mounted, 17 inch repeater screen at the SAR Operator's Station (**Photo No. 33**).

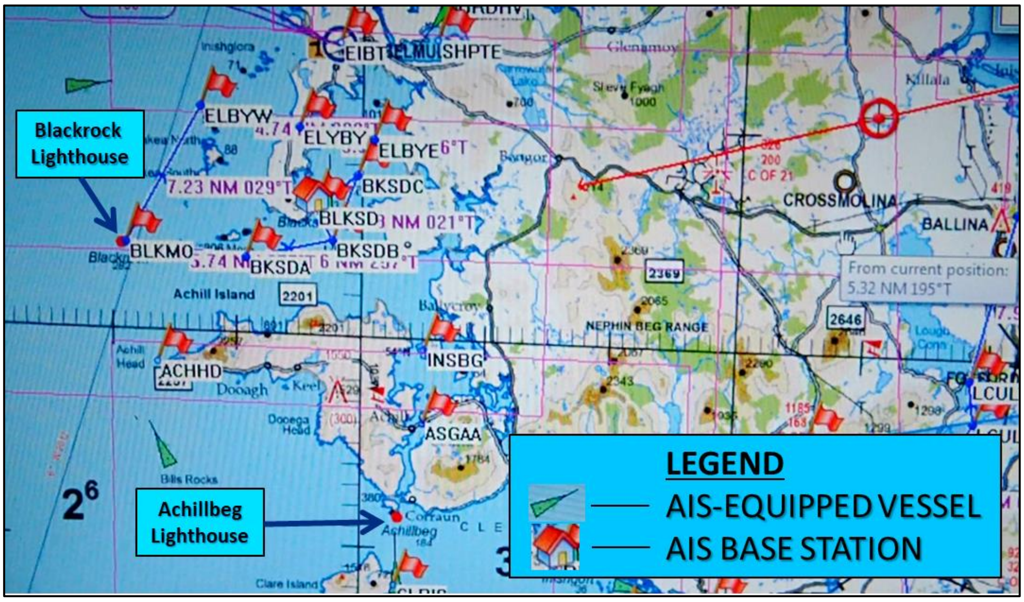

Photo No. 33: Screenshot of Toughbook AIS display during review flight (labels added)

It was noted during the flight that marine vessels with a Class 'A' AIS transponder were displayed as a green triangle symbol, and AIS Base Stations were indicated by a house-like symbol. FMS waypoints, such as those used in the APBSS Route Guide are indicated with a red flag symbol. The Investigation further noted that AtoN AIS transmissions from suitably equipped Lighthouses, such as Blackrock and Achillbeg Lighthouses in **Photo No. 33** were not displayed on the screen – the red dots shown at each lighthouse were part of the underlying chart.

The AIS transponder manufacturer informed the Investigation that AtoN messages could be received by the transponder installed on the Operator's S-92A helicopters. The Toughbook mapping-software provider informed the Investigation that the Windows PC-based AIS add-on for the mapping application did not support AtoN transmissions.

1.17 Organisational and Management Information

The Operator used the term '*Nominated Post Holder*', and defined the term Post-Holder as '*The person acceptable to the Authority who is responsible for the management and supervision of their respective area.*' One of the Operator's manuals set out roles and responsibilities for six Nominated Persons: the Accountable Manager; the Manager Flight/Ground Operations; the Continuing Airworthiness Manager (Part M); the Compliance Monitoring Manager; the Safety Manager; and, the Manager Crew Training; however, the manual did not specify roles and responsibilities for the Maintenance Manager (Part 145). Another of the Operator's manuals, issued within a month of the previously mentioned manual, provided a '*Management List*' which included the same Post-Holders, but with different nominated deputies in some cases.

1.17.1 The Operation

The Helicopter was owned and operated by a company providing SAR helicopter services in Ireland. The Operator of EI-ICR was the holder of an AOC issued by the IAA. The Operator was also the holder of a HEMS approval and the sole holder of an Irish National SAR Approval. Both approvals were issued by the IAA.

The Operator was contracted to carry out SAR operations on behalf of the then Minister for Transport. SAR is managed by the IRCG, which is a Division of the Department of Transport, under its Maritime Safety Directorate. The Minister for Transport introduced a National SAR Framework in 2010, which sets out the national arrangements for meeting the State's international SAR obligations.

The Contract[82] stipulated '*a state of readiness of not more than 15 minutes from 0830 to 2200 local time, and not more than 45 minutes from 2200 to 0830 local time for each and every day of every year.*' The Operator's OMF stated that '*SAR readiness states will be defined by the contracting agency and outlined in local instructions. In general, readiness states will fall into two categories: periods of 15-minute notice and 45-minute notice to launch on receipt of a formal request from the contracting agency. A 15-minute readiness shall be maintained from 07:30 to 21:00 local. A 45-minute readiness shall be maintained from 21:00 to 07:30 local*.'

[82] **Contract**: Between the Minister for Transport and the Operator, henceforth referred to as "*the Contract*" in this Report.

The Operator subsequently informed the Investigation that '*The Contract stipulated a launch time of 15 minutes between the hours of 0730 & 2100 and 45 minutes between the hours of 2100 & 0730. (During summer period of 01 Jun to 31 Aug, 15 minutes between 0830 & 2200 and 45 minutes between 2200 & 0830*)'.

The Operator had operating bases at Dublin, Waterford, Shannon and Sligo. The Operator's OMA set out a table of seven management positions (Post-Holders); six of the seven had nominated deputies. OMA set out detailed descriptions including responsibilities for six Nominated Persons; however, two of the Nominated Person roles said that the appointee was '*not any of the nominated persons*'. The holder of these two positions informed the Investigation that he was not aware of the OMA restriction, that it had not been brought to his attention, and that he did not know if it had been added during updates and standardisation with other AOCs within the Operator's Parent Company without his knowledge. The Investigation notes that the nomination of this Post-Holder had been verified for both roles, by the IAA, in 2014.

The Post-Holders' office locations were distributed throughout the Operator's base network. The Investigation noted that the duration of staff assignments to many Post-Holder roles seemed lower than those that AAIU staff had experienced with other AOC holders, i.e. Post-Holder turnover rates seemed higher. It appears that the IAA was also concerned about the rate of change of Post-Holders. In 2012, the IAA wrote to the Operator setting out its concern that since 2005 there had been five different operations Post-Holders.

In its 2012 correspondence, the IAA explained that it considered the Operator to be a large, complex AOC operator engaged in medium to high risk types of operations, introducing a new helicopter type into service and expanding its operation to include HEMS. The IAA said that for these reasons it needed to see in place a Senior Management Team with appropriate operational and managerial experience to ensure effective oversight of the operation. The Investigation notes that since January 2010, five different persons held the operations Post-Holder position, and all but one of the other Post-Holder positions also changed during the period.

The Investigation was informed that personnel involved in training provided assistance to the operations Post-Holder in the preparation of technical documentation, such as operations manuals.

As set out in OMA, the crew training Post-Holder had a broad portfolio of responsibilities including '*inter-base and inter-fleet coordination and standardisation of training and checking of pilots and crewmen*'. He was also responsible for '*The coordination of aircraft checklist amendments, their drafting approval and distribution of same*'. According to OMA, the operations Post-Holder was responsible for '*The content drafting, distribution, and amending of the Company operations manuals and training manual*'. OMA also stated that the training Post-Holder was responsible for '*The overall presentation of the Company's training manual, the drafting and final distribution and amendment of this document*'.

OMA stated that the operations Post-Holder was responsible for '*Supervising the activities of the safety and compliance monitoring manager in ensuring standards required by the EASA OPS, EASA FCL and the IAA are being met*.' OMA also stated that the compliance monitoring manager '*Reports and has direct access to the accountable manager in any related matters*.'

In relation to the acceptance of helicopters following maintenance by another organisation, OMA stated that the operations Post-Holder was '*(in cooperation with the technical services manager) responsible for* [...] *Performing acceptance test-flight to ensure the helicopter is within acceptable specification and operation requirement*.' Not all operations Post-Holders held an S-92A captain rating. Furthermore, the term/post of '*technical services manager*' was not defined in OMA.

The Operator's OMF states:

> '*A SAR operational flight may only be commenced at the request of, or after consultation with the contracting agency or its delegated representatives (usually an MRCC). Should a request for assistance be received from another source, it should be referred to the contracting agency for approval. The SAR crew may prepare for such a mission but are not to get airborne until tasked by the contracting agency*.'

The Investigation reviewed the statistics published for SAR helicopter taskings in Ireland since 2004. **Figure No. 38** shows the number of SAR helicopter taskings for the years 2004 to 2017.

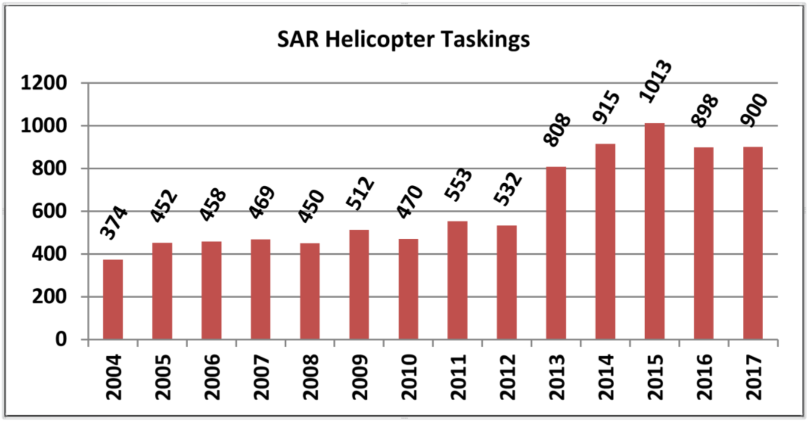

Figure No. 38: SAR Helicopter Taskings 2004-2017

With the advent of S-92A operations, SAR helicopter taskings included a significant number of HEMS taskings. **Figure No. 39** shows the breakdown between SAR and HEMS taskings for the years 2014-2016.

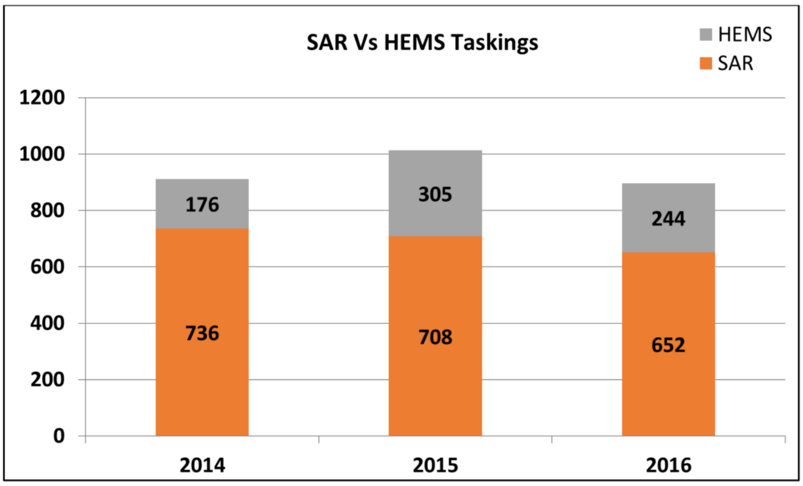

Figure No. 39: SAR Vs HEMS Taskings 2014-2016

The balance between training, taskings and non-revenue (typically maintenance-related) flights is shown in **Figure No. 40**.

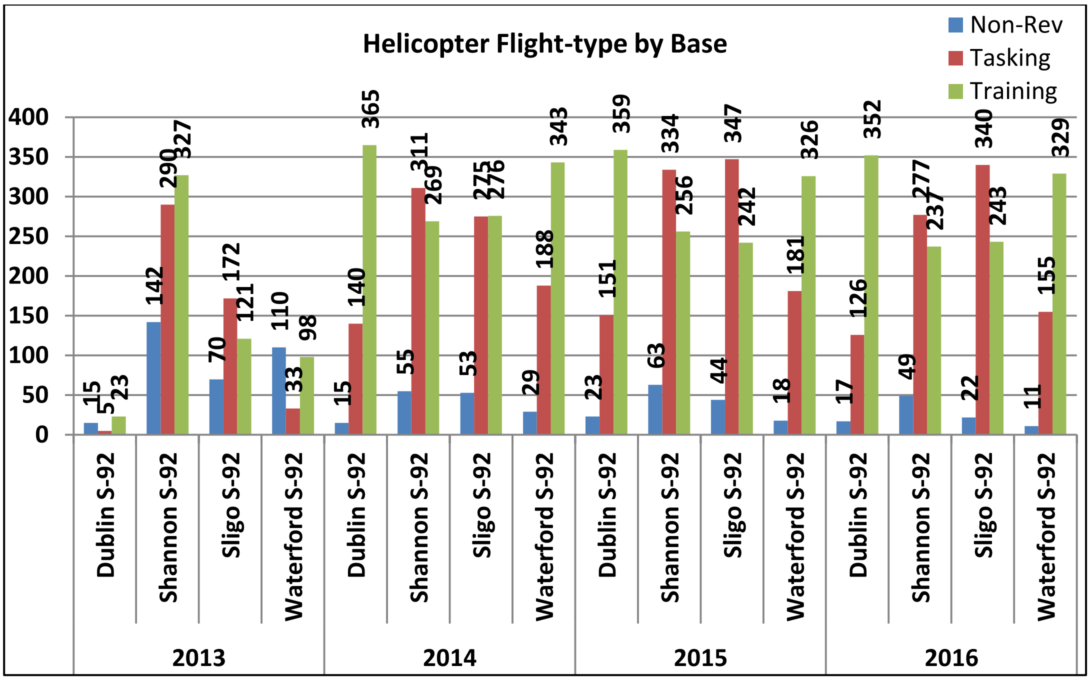

Figure No. 40: Training vs Taskings vs Non-Revenue, by Base

The data shows, that with the roll-out of the S-92A helicopter type across the Operator's base network in 2013, there was a significant increase in the number of taskings. Annual taskings peaked at 1,013 in 2015, up from an S-61N maximum of 553 in 2011. Furthermore, HEMS became a significant part of the mission workload, accounting for 30% of the taskings in 2015.

The introduction of the S-92A, the addition of the HEMS approval, and the demands of operating under both a National SAR Approval and CAT standards for HEMS, potentially within the same flight, meant that there had been a significant increase in the complexity of the operation in the years between 2012 and 2017. The data also shows that the Shannon and Sligo SAR bases received more taskings than Dublin and Waterford; and that at Dublin and Waterford, training flight numbers exceeded tasking flights.

The Investigation notes that the Operator used three different categorisations for HEMS missions; '*HEMS*', '*SAR (FTL*[83]*)*' and '*SAR (HEMS)*'. The Operator informed the Investigation that '*SAR (HEMS*)' was the wording used to record HEMS flights on iSAR (the Operator's '*electronic*' recording system) and that it was used to differentiate a mission from a SAR mission. The Operator said that '*SAR (FTL)*' was a means of annotating on iSAR a HEMS flight reclassified as SAR for crew FTL purposes, while the flight was still to be carried out in accordance with the OMG (Ops Manual Part G). The Investigation identified a number of HEMS missions which iSAR records indicated were operated at night.

[83] **FTL**: Flight Time Limitations

Many of the Operator's personnel who spoke with the Investigation remarked on the different nature of operating on the east coast versus operating on the west coast. They informed the Investigation that east coast operations usually benefitted from greater availability of ambient light sources in the littoral environment, whereas the west coast was a much darker environment in which to operate. Personnel also highlighted that the east coast bases were more proximate to their training areas and often to their operating areas; the consequence of this was that the tempo of an east coast mission could be more rapid and often involved less transit time than west coast missions.

The Investigation needed to interview a large number of the Operator's personnel. A significant lead-in time was required for these interviews, which were arranged through the Operator. This was because the personnel in question were on a rostered duty pattern, and the Investigation was anxious not to introduce additional risk or emotional upset by interviewing personnel who were on duty, or were imminently to go on duty.

1.17.2 IAA Oversight

The IAA informed the Investigation that it regulates a sector against international and European safety standards and systems in accordance with international agreements and that in this context it was subject to ongoing audit, inspection and standardisation by ICAO, EASA and the State. Furthermore, the IAA explained that it does not manage the individual activities of regulated entities; each entity is responsible for ensuring their organisation's continued compliance with the essential requirements of the Basic Regulation and the conduct of their individual organisation's operations in accordance with civil aviation regulations.

The IAA pointed out that the SI 483/2013 Irish Aviation Authority Act 1993 excluded '*Annex 12; Search and Rescue*'[84], from the IAA's remit. Furthermore, it pointed out that IAA Annex 12 responsibilities were introduced by SI 171/1995 and elaborated on within a Memorandum of Understanding (MoU) between IAA & IRCG dated 23 Feb 2010, which detailed service provision in respect of Aviation Rescue Co-ordination Centres & Sub-centres.

The IAA drew the Investigation's attention to SI 172/1995 – Annex 12 (Standards and Recommended Practices Search and Rescue) (Designation of Authorities) Order, 1995, which states:

> *'Para 2(1) The Minister shall be the authority by which any powers exercisable under Annex 12 of the Chicago Convention other than powers in relation to Rescue Co-ordination Centres and Rescue Co-ordination Sub-Centres in the State are to be exercised in the State.*

[84] Annex 12 Search and Rescue: ICAO Annex 12 contains the Standards and Recommended Practices, which in conjunction with the International Aeronautical and Maritime Search and Rescue (IAMSAR) Manual, Volume I — Organization and Management, Volume II — Mission Co-ordination, and Volume III — Mobile Facilities assists States in meeting their search and rescue (SAR) needs and obligations accepted under the Convention on International Civil Aviation. These obligations, as they relate to the provision of SAR services, are specified in Annex 12 as Standards and Recommended Practices. The three volumes of the IAMSAR Manual provide guidance for a common aviation and maritime approach to organising and providing SAR services. States are encouraged, by use of the manual, to develop and improve their SAR services and to cooperate with neighbouring States.

> *Para 2(2) The IAA shall be the authority by which any powers exercisable under Annex 12 of the Chicago Convention in relation to Rescue Co-ordination Centres and Rescue Co-ordination Sub-Centres in the State are to be exercised in the State.'*

The IAA summarised its views in relation to the regulation of SAR within the State as follows:

> *'the service provider of helicopter SAR to the State holds an EASA AOC* [[85]]*, issued by the IAA, and while the Basic Regulation excludes SAR, it also advocates that 'The Member States shall undertake to ensure that such activities or services have due regard as far as practicable to the objectives of this Regulation'. In this context,* [the Operator]*, as an AOC holder, is subject to safety oversight by the IAA in accordance with the appropriate Commission Regulation. An integral part of this programme is the issuance of an 'Aerial Works Permission', named a 'National SAR Approval', in accordance with Article 9(2) of the IAA Operations Order, 2006.*
>
> *This 'Aerial Works Permission' is an enabling document in order to facilitate* [the Operator] *to conduct SAR operational missions on behalf of the State, subject to a SAR operational tasking by the Irish Coastguard and the aircraft Captain accepting the operational SAR tasking. In all cases the sole tasking agency for operational SAR missions is a State agency; the Irish Coastguard, all operational SAR missions are completed on behalf of the State through the Irish Coastguard, operational SAR missions may involve other State aviation assets such as the Air Corps, and as a consequence, are solely a State activity. The IAA does not conduct oversight of Irish Coastguard activity.'*

According to its website, the IAA is responsible for the management of Irish controlled airspace, the safety regulation of Irish civil aviation and the oversight of civil aviation security in Ireland. A State Safety Programme (SSP) is defined by ICAO as an integrated set of regulations and activities aimed at improving safety. It includes specific safety activities that must be performed by the State, and regulations and directives promulgated by the State to support fulfilment of its responsibilities concerning safe and efficient delivery of aviation activities in the State. The stated primary purpose of the Irish State Safety Programme is to ensure the continuous improvement of safety standards in Ireland. According to the IAA, this is achieved by focusing resources in the areas that present the greatest risk to aviation safety and implementing actions that will best mitigate these risks.

As part of its State Safety Programme (SSP), the IAA produces the State Safety Plan (SSp) for Ireland. The purpose of the SSp is to outline to all stakeholders where the IAA Safety Regulation Division will target resources to fulfil the SSP objective of reducing accidents and incidents.

State Safety Plan 2017–2020 stated:

> '*Search and Rescue (SAR) is excluded from the regulatory framework of civil aviation and thus is outside the remit of the EASA or the IAA,*
> […]

[85] The Investigation notes that the AOC referred to by the IAA as the '*EASA AOC*' does not cover SAR activities because EU Commission Regulation No 965/2012 does not include SAR.

The IAA has initiated a comprehensive review of the safety oversight structure for helicopter operations in Ireland that involve both civil and State functions, in order to ensure that there are no gaps in the oversight process (New Action a) below).
[…]
[New Action a] *The IAA, in conjunction with the DTTaS* [Department of Transport, Tourism and Sport]*, will conduct a comprehensive review of the safety oversight structure for helicopter operations in Ireland that involve both civil and state functions, in order to ensure that there are no gaps in the oversight process.*'

State Safety Plan 2018-2021 stated:

'*During 2017, the IAA undertook a review of the safety oversight system for helicopter operations in Ireland that involve both civil and State functions. The review found that the legal powers and legislation available to the IAA were sufficient to enable it to implement the IAA safety oversight system in respect of a civil AOC holder organisation and permit that organisation to operate SAR missions on behalf of the State. Action a) is now closed.*'

In response to AAIU Safety Recommendation IRLD2018003 (**Section 1.17.8**), the Minister for Transport, Tourism and Sport commissioned an independent consultants' report (hereafter referred to as the '*AQE Report*') to review the oversight arrangements for SAR aviation operations in Ireland. On 21 September 2018, The Minister published the AQE Report on the DTTAS website, and the Investigation acknowledges that work is ongoing to address the 12 recommendations made in that report. The AQE Report noted that the IAA provided input for the preparation of the National SAR Framework.

The IAA input included the statement that, '*The Safety Regulation Division of the IAA is the body responsible for the regulation and oversight of aircraft operations, including aeronautical Search and Rescue, within the State*'. The AQE Report went on to say:

'*The IAA statement to AQE that 'the Framework is not an IAA document' seems to indicate that there is now a disconnect. Whilst it might be assumed that the text in the SAR Framework whereby reference is made to the SRD/IAA is in fact linked to oversight responsibilities originating from the amended 1993 IAA Act (as amended) SI 172/1995 (rescue coordination centres), it is clear from discussions with the IAA that they do not share the same understanding of the purpose of the document as the Department and the IRCG and as such, its objectives are not being delivered as intended*.'

The Investigation notes that the IAA's Annual Safety Review of Aviation in Ireland 2013 stated:

'*The Irish AOC holders who provide helicopter transport are* [the Operator and four others]. *These Operators are active within Ireland and some also operate abroad. They conduct commercial air transport operations – both onshore and offshore, carry out search and rescue (SAR) operations* […] *Currently training for SAR operations takes place under an AOC and SAR operations are conducted under an aerial works permission. During 2014 legislation will come into effect so that SAR operations will also take place under an AOC.*'

The IAA first granted an Irish National Search and Rescue approval to the Operator on 1 October 2014. This was re-issued as: Issue 2 on 12 November 2014; Issue 3 on 3 December 2014 and Issue 4 on 8 February 2017. The accident flight was being operated under this Issue 4 of the approval. On 25 April 2017 (subsequent to the accident), Issue 5 of this Irish National Search and Rescue approval was issued to the Operator by the IAA with just one change from Issue 4, the removal of the registration of the accident Helicopter. The basis for granting the Operator's Initial (and subsequent) National Search and Rescue approval was set out in the IAA's Aeronautical Notice O.76, Issue 1 of 1 October 2014; titled '*The Conduct of Search and Rescue (SAR) Operations in Ireland*'. This direction states the following:

> '*DIRECTION*
>
> *In accordance with EC Regulation 216/2008 - Article 1,(2)(a), the European Aviation Safety Agency (EASA) has deemed that the requirements of the 'Basic Regulation' shall not apply to the conduct of Search and Rescue operations and that such operations are to be classified as a 'State' activity which is to be regulated by the National Aviation Authority.*
>
> *In compliance with this regulation the Irish Aviation Authority, in accordance with its powers as set out in the Irish Aviation Authority (Operations) Order, 2006; Article 7(1) and the Irish Aviation Authority (Rules of the Air) Order, 2004; Articles 3 and 16, hereby directs that operations carried out for the purpose of Search and Rescue by a commercial operator shall be deemed to be for the purpose of Commercial Air Transport and therefore subject to the operator being the holder of an Irish National Search and Rescue Approval (SAR APP).*

> *Prior to 28 October 2014, an Approval issued for the sole purpose of SAR shall be based on the requirements set out in JAR-OPS 3. Following that date, an Approval shall be based on the requirements of European Union Regulation (EU) 965/2012, as amended. Additional requirements to be complied with by the holder of a SAR APP are set out in* ***Annex 1 to this Aeronautical Notice****.*' [Emphasis added].

There was no Annex 1 to AN O.76 published with this notice. However, the Investigation learned that in May 2013, the IAA invited DTTAS and the Operator to comment on a draft document titled '*AN O 64 – SAR AOC v3*'[86]. DTTAS passed the draft document to IRCG and advised IRCG to '*respond directly to IAA on this consultation process*' on the basis that DTTAS would '*have a look at the draft AN when it's received*'.

IRCG responded to the IAA stating:

> '*Thank you for giving us an opportunity to engage in the consultation process on AN.064. Overall we see this as a very welcomed step forward for aviation SAR.* […] *I am conscious that safety and regulation is at all times a matter between the IAA and the regulator but I have tried to make sure that the new procedures do not add any cost that could be levied on the Department and that it doesn't reduce our operational capability.*'

[86] The Investigation notes the difference in the reference numbers quoted.

The full title of the document in question was: '*Annex to Aeronautical Notice O.64, The Conduct of Helicopter Search and Rescue (SAR) in the Republic of Ireland, National Approval Guidance*'.

Under the heading '*Legal Requirements*', this document included the same first paragraph as that which was published in AN O.76:

> '*In accordance with EC Regulation 216/2008 - Article 1, (2)(a), the European Aviation Safety Agency (EASA) has deemed that the Basic Regulation shall not apply to Search and Rescue and that such operations are therefore a State activity which is to be regulated by the National Aviation Authority.*'

The unpublished '*Annex to Aeronautical Notice O.64*' went on to state that '*The Irish Aviation Authority (IAA) has oversight of the State activity of SAR within the Republic of Ireland.*' The document was based on the relevant extant regulation at the time – JAR OPS 3. It prescribed the need for IAA approval for a number of issues including:

- Procedures for SAR operational and training flights
- Persons authorised to be carried as SAR passengers
- Flight Time and Duty Time limitations scheme
- Crew composition
- Operating Minima:

  > '*An operator shall specify the minima appropriate to SAR operational flights, SAR training and any other categories of flight e.g. air tests, positioning, demonstration flights. Such minima are to be based on the requirements of JAR-OPS 3 and shall be approved by the IAA.*
  >
  > *Operating minima for the dispatch and continuation of a SAR operational flight, while set out by the Operator and approved by the IAA, remain at the discretion of the helicopter Commander.*'

- Fuel policy and refuelling procedures with passengers on board, with and without rotors running
- Training programmes for flight crew

The wording of the first paragraph of AN O.76 is almost the same as the wording of the first paragraph of another IAA Aeronautical Notice, AN O.66 (Issue 1, dated 24 April 2013), titled '*Helicopter Flights Carried out in Support of Aerial Fire Fighting Operations*' which stated:

> *'In accordance with EC Regulation 216/2008 - Article 1,(2)(a), the European Aviation Safety Agency (EASA) has deemed that the requirements of the 'Basic Regulation' shall not apply to the conduct of flights carried out for fire fighting operations and that such operations are therefore a State activity which is to be regulated by the National Aviation Authority.'*

AN O.66 also specified that firefighting flights were to be classified as aerial work and set out a range of requirements to be met by operators of firefighting flights. Given the similarity in the wording of these two notices (AN O.66 and AN O.76) it seems likely that at that time the IAA was following a specific paradigm in relation to how it regulated operators who were conducting flights outside of the scope of European Regulations, which the IAA itself said were to be regulated by the National Aviation Authority.

The IAA only issued one National SAR Approval, and that was to the Operator. It included a table of 27 items. The table set out columns titled '*Requirement*', '*Reference*', and '*Alleviation Granted*', for each of 27 '*alleviations and exemptions*'. For instance, under the requirement heading '*General Rules for VFR*', the reference quoted is '*(EU) 923/2012 SERA*[87]*.2005(a), 5001, 5005 & 5010 with the exception of SERA.5005(d) and (e). AIC Nr 12/01. AN R.02*'. The alleviation granted was '*To permit flight for the purpose of Operational SAR to be carried out in VFR minima lower than specified*'. The Approval also stated that '*the Operator's Safety Management System shall monitor and review all flights carried out pursuant to this approval*'. The National SAR Approval stated '*A copy of this Approval shall be included in the Operations Manual Supplement and carried onboard each aircraft*'; OMF as provided to the Investigation did not include a copy of the National SAR Approval.

In relation to the 27 alleviations granted, the Investigation asked the IAA for copies of the application, rationale, risk assessment, mitigations, stipulations and final granting document for each of the alleviations granted.

The IAA informed the Investigation that '*These are alleviations issued to the operator of aircraft engaged in SAR. These alleviations are necessary to allow the crew to complete the SAR mission. The final decision to avail of these alleviations rests with the aircraft commander.'* The Investigation asked the IAA if it carried out any risk assessment in relation to any of the requested alleviations. The IAA replied '*Alleviations are issued on foot of a request from the operator to allow SAR operations to operate at the 'Commanders Discretion' – Risk assessments are conducted by the crew on-site according to the situation at hand.'*

The Investigation asked the IAA what exactly were the terms of the alleviations granted. The IAA informed the Investigation that:

> '*Alleviations are issued to allow the Aircraft Commander(s) / crew to make an operational decisions* [sic] *when tasked by the Coast Guard with a SAR mission. The alleviations enable the mission to operate at the commander's discretion below the normal operational rules and rules of the air applicable to civil aircraft.*
>
> *In the case of the Rules of the Air, these alleviations are granted on request under Article 4 of Commission Implementing Regulation (EU) No 923/2012 of 26 September 2012 which foresees this need:*
>
> *Article 4*
>
> *Exemptions for special operations*

[87] **SERA:** Standardised European Rules of the Air.

1. At the request of the entities conducting the following activities, the competent authorities may grant exemptions from the specific requirements of this Regulation to those entities for the following activities of public interest and for the training necessary to carry out the activities safely:

[…]

(d) search and rescue;

(e) medical flights;'

The IAA provided the Investigation with a copy of the Operator's request for exemptions *'for SAR operations and training'*. The Investigation noted that 25 of 27 alleviations granted were restricted to SAR Operational Flights. The Investigation asked the IAA to explain why the alleviations were restricted to Operational SAR, even though the Operator had requested alleviations for training. The IAA, whilst acknowledging that Article 4 of Commission Implementing Regulation (EU) No 923/2012 of 26 September 2012 permitted exemptions for SAR training, stated *'In the normal course of events, training events do not require operational alleviations from the applicable regulations, hence the use of the term, 'operational SAR flights'.'* However, the correspondence from the Operator to the Authority indicated that the restriction to operational SAR flights adversely affected the ability of the Operator's Dublin Base to dispatch for training in less than ideal conditions.

The alleviation granted in relation to VFR flight stated *'To permit flight for the purpose of Operational SAR to be carried out in VFR minima lower than specified'*. Due to the circumstances of the accident, the Investigation asked the IAA the following questions:

- *'What were the "specified" minima?*
- *What were the VFR minima lower than specified?*
- *What evidence/safety case/control measures were provided by the Operator, or demanded of the Operator, in order for the Authority to be satisfied that granting the alleviation did not erode the operational safety margins available to crews?'*

The IAA responded stating that:

'Commission Implementing Regulation (EU) No 923/2012 of 26 September 2012 (SERA) sets the normal minima for operations of civil aircraft in the Union. The alleviations to SERA allow aircraft commanders elect to operate SAR flights in conditions which are below the normal VFR flight rules for civil traffic set out in SERA. The operational safety margins for SAR fights rest with the operator and the aircraft commander.'

The Investigation asked the IAA to reconcile statements in the IAA's State Safety Plan 2017-2020 and the IAA's AN O.76. The IAA's State Safety Plan 2017-2020 states *'Search and Rescue (SAR) is excluded from the regulatory framework of civil aviation and thus is outside the remit of the EASA or the IAA* […]', whilst AN O.76 states, '*In accordance with EC Regulation 216/2008 - Article 1,(2)(a), the European Aviation Safety Agency (EASA) has deemed that the requirements of the 'Basic Regulation' shall not apply to the conduct of Search and Rescue operations and that such operations are to be classified as a 'State' activity which is to be regulated by the National Aviation Authority.'* The IAA replied, stating that:

'*The 'Basic Regulation', (Regulation (EC) No 216/2008 of the European Parliament and of the Council of 20 February 2008 on common rules in the field of civil aviation) states that:*

2. This Regulation shall not apply to:

(a) products, parts, appliances, personnel and organisations referred to in paragraph 1(a) and (b) while carrying out military, customs, police, search and rescue, firefighting, coastguard or similar activities or services. The Member States shall undertake to ensure that such activities or services have due regard as far as practicable to the objectives of this Regulation;

The wording in Notice 0.76 attempts to set out the above exclusion of SAR from the basic regulation. […] *it is not possible to determine the origin of this wording but it appears to be consistent with phraseology used in the UK CAA's CAP 999. The IAA has reviewed the wording of AN 0.76 and will consider re-issuing with rewording to clear up any inconsistency in interpretations.*'

The National SAR Approval granted to the Operator contained a '*Requirement*' titled '*Departure Approach Procedures*'. The associated '*Alleviation Granted*' stated '*To permit non-standard and unpublished procedures to be carried out at aerodrome/heliport of departure/arrival. This will apply to Operational SAR flights only.*'

The Investigation asked the IAA, in relation to requirement 5 and the reference in '*Alleviation Granted'* to unpublished procedures, if the IAA considered that the Operator's Route Guide constituted published or unpublished procedures. The IAA said that the alleviation referred to (requirement 5) pertains to CAT.OP.MPA.125 Instrument departure and approach procedures. The IAA referred the Investigation to AMC1 ORO.MLR.100 Operations manual — general, which states:

'*(h) For the route and aerodrome part of the OM, material produced by the operator may be supplemented with or substituted by applicable route guide material produced by a specialist company.*

(i) If the operator chooses to use material from another source in the OM, either the applicable material should be copied and included directly in the relevant part of the OM, or the OM should contain a reference to the appropriate section of that applicable material.

(j) If the operator chooses to make use of material from another source (e.g. a route manual producer, an aircraft manufacturer or a training organisation), this does not absolve the operator from the responsibility of verifying the applicability and suitability of this material. Any material received from an external source should be given its status by a statement in the OM.'

The IAA said that responsibility for the applicability and suitability of the material used in the respective route and aerodrome part of the operations manual rests with the Operator and is not the subject of prior NAA Approval. The IAA further explained that changes and revisions for items not requiring prior approval are however subject to notification to the NAA and as such are reviewed and accepted by the NAA if compliant with requirements.

The Investigation notes that in 2013 one of the Operator's sister companies made an application to the IAA to operate non-SAR flights in Ireland. As part of that application the sister company, as required by regulations, submitted routes for two coastal aerodromes where it planned to operate, Waterford Airport and Cork Airport. In an email to the applicant, the IAA noted that: these Low Level Routes were the same as those used by the Operator; and, because the Rules of the Air Order imposed minimum heights of 500 ft by day and 1,000 ft by night, there was no need for the applicant to state minimum heights for each leg of the Low Level Routes.

The IAA further informed the Investigation that:

> '*The* [Operator's] *FMS Route Guide is used primarily during SAR tasking and associated training flights. There is no restriction on its use for HEMS operations providing that the operational limitations applicable to HEMS flights are observed. The SPA HEMS Guidance Material in Reg Air Operations elaborates the philosophy to risk that may be applied. One of the areas in HEMS operations where risk, beyond that allowed in Part-CAT and Part-ORO, is identified and related risks accepted is (i) in the en-route phase, where alleviation is given from height and visibility rules.*
>
> *Note also the guidance wrt the HEMS operating site as the primary pick-up site related to an incident or accident: 'its use can never be pre-planned and therefore attracts alleviations from operating procedures and performance rules, when appropriate*'.

The IAA said that the Operator's OMF, which sets out SAR operational procedures, was accepted but not approved by the Authority. The Investigation asked the IAA to clarify the difference and to say where that difference was set out for AOC Post-Holders. The IAA advised:

> '*Article 9 (2) of S.I. 61/2004 prohibits operators from conducting 'Aerial Work' without a "Permission" from the IAA. The definition of "Aerial Work" includes SAR, therefore* [the subject Operator] *applied for such an Aerial Work permission (named a 'National SAR Approval' in accordance with AN O.76, but an Aerial Work permission nonetheless). There are no "technical requirements" in Irish law for Aerial Work or ICAO SARPS*[88]*. This is due to the diverse worldwide nature of "Aerial Work". The Authority issues a number of Aerial Work permissions every year.*
>
> *Such permissions are issued against the operator's procedural manuals. Such manuals are "accepted" in support of the permission but not approved as may be required under EU regulations where technical requirements exist. Please note, many of the "Aerial Work" permissions formally issued under National law have now been replaced by a PART-SPO*[89] *Declaration under EU PART OPs regulation (See EU 965/2012). For clarity, please note that the* [the subject Operator's] *procedures manual accepted in support of the SAR Aerial Work Permission is differentiated from the procedures required to be approved for the issue of the EU PART-OPs AOC.*'

[88] **SARPS**: Standards and Recommended Practices.
[89] **PART-SPO**: The European regulation governing Specialised Operations.

Correspondence between the Operator's post holders and IRCG senior management was reviewed during the Investigation, and indicated that the distinction which the IAA makes between '*Approval*' and '*Acceptance*' may not have been appreciated by either organisation'.

On 18 November 2015, the IAA emailed the IRCG regarding questions which the IRCG had raised in relation to the Operator's '*Decision Tree*' (**Section 1.17.3**) for deciding on the nature and viability of any tasking. The Decision Tree was necessary because the Operator had two types of permission from the IAA; it had a SAR approval and it had a HEMS approval. Whilst the Operator could avail of a range of alleviations/exemptions to complete a SAR mission, HEMS missions could only avail of some HEMS-specific, minor alleviations and for the most part were conducted in accordance with standard CAT rules, in accordance with Volume '*G*' of the Operations Manual, referred to as '*OMG*'. The IAA's response to the IRCG's questions stated that SAR was not within the scope of EU operations regulations, and that the IAA did not know of any delegation of responsibility for SAR to the IAA or what technical standards were applicable. The IAA said that it was endeavouring to raise the matter with DTTAS. DTTAS informed the Investigation that it did not have aviation expertise within the Department.

On 10 June 2016, the IAA emailed the Operator, and copied the IRCG, stating that they had considered reverting the Operator's National SAR Approval back to an Aerial Works Permission (AWP) because most entities defined SAR as a form of Aerial Work.

The IAA also stated that regardless of whether SAR was undertaken under the current (at the time) National Approval or the proposed AWP, the Authority was looking for '*accepted'* standards against which to audit the Operator's SAR operation.

All versions (initial and re-issue) of the National SAR Approval stated that it was granted to the named operator because the IAA was '*satisfied that the said operator is competent to secure the safe operation of the aircraft specified* […] *on flights for the purpose of operational Search and Rescue*.' The Investigation asked the IAA to provide full details of actions taken by the Authority following the accident and prior to the re-issue on 25 April 2017 of '*Irish National Search and Rescue Approval – No. 1 of 2014*', which led the IAA to continue to be satisfied that the Operator was competent to secure safe operation of aircraft for operational search and rescue. The IAA said that during the course of ongoing liaison with the Operator, a review of the Operator's offshore procedures was discussed, resulting in the Operator publishing FSI (Flying Staff Instruction) 2017 – 030 on 14 April 2017.

The Investigation asked for full details of this discussion of the Operator's offshore procedures and how this resulted in FSI 2017 – 030 being issued. The IAA said that at the time of the accident the immediate concern was the ongoing safety of the operation, bearing in mind the increased demand on the company's management team from internal and external factors (media, regulatory agencies, etc.).

The IAA said that it asked the Operator's management if the company needed to engage any immediate actions to mitigate any '*risks unknown*', because at that stage (April 2017) the Investigation's Preliminary Report had made a Safety Recommendation (**IRLD2017005**) regarding the Route Guide, and search efforts were still underway.

The IAA went on to say that the Operator still had to meet its contractual obligations to the State. The IAA said that the Operator issued FSI 2017 – 030 as an interim measure pending new information or outcomes of the AAIU Investigation.

The Investigation was subsequently informed by a former Post-Holder that as an immediate response to Safety Recommendation **IRLD2017005** made by the AAIU in its Preliminary Report, a discussion was conducted by phone with the IAA regarding FSI 2017 – 030 which led to the '*acceptance*' of the FSI and its issue on the evening of 14 April 2017; the former Post-Holder also informed the Investigation that he did not recollect being asked by the Authority *'if the company needed to engage any immediate actions to mitigate any risks unknown.'* The Operator's responses to Safety Recommendation **IRLD2017005** are reproduced in **Appendix G**.

The Operator's FSI 2017 – 030 stated:

> *'A review of the* [Operator's] *Route Guide is currently being undertaken and pending completion and verification, temporary cloud ceiling and visibility limitations will be in operation until this process is complete.*
>
> <u>*Action to be taken*</u>
>
> *When using the routes contained in the* [Operator's] *Route Guide, the following temporary limitations for cloud ceiling and visibility minima have been introduced and are to be adhered to for all SAR operations.*
>
> *Day:*

Ceiling	*Visibility*
400 - 499 feet	*1 km*
300 - 399 feet	*2 km*

> *Night:*

Ceiling	*Visibility*
500 feet (above highest obstacle indicated on the route)	*5 km*

> *These temporary limitations will be reviewed and amended as appropriate at the end of the review period. Cloud ceiling and visibility minima for other operations (HEMS, etc.) remain unchanged.'*

The Investigation asked the IAA to clarify its comment '*mitigate any risks unknown*'. The IAA said that:

> '*with reference the* [Professor James] *Reason*[90] *Accident Causation Model, Latent Conditions are conditions present in the system well before a damaging outcome is experienced and only made evident by local triggering factors. The consequences of latent conditions may remain dormant for a long time i.e. are hidden and unknown until they become evident once the system's defences have been breached. The perspective underlying the organisational accident aims to 'identify and mitigate' these latent conditions on a system-wide basis. The Reason model informs IAA approach to safety management.*'

[90] Reason, J. (1997) '*Managing the Risks of Organizational Accidents*', Ashgate.

The Investigation notes that [James] Reason stated that '*Organizational accidents have multiple causes involving many people operating at different levels of their respective companies*. *By contrast, individual accidents are often ones in which a specific person or group is often both the agent and the victim of the accident.*' [James] Reason further explained that '*Individual accidents can, and usually do, have organizational origins.*'

1.17.2.1 Review of IAA State Safety Plan and Risk-Based Oversight

The IAA's State Safety Plan 2015-2018 (extant on the date of the accident) stated the following:

> *'The State Safety Programme of Ireland aims to ensure the continuous improvement of safety standards in Ireland. This is achieved by focussing our resources in the areas that present the greatest risk to aviation safety and implementing actions that will best mitigate these risks'*.

At a meeting with the IAA, the Investigation highlighted the above content. The Investigation asked the IAA to explain how risk was assessed in relation to each AOC holder in Ireland, whether there was an awareness of which operator presented the greatest risk, and if any additional oversight was implemented as a result of this.

The Investigation asked the IAA if the Operator, due to the nature of the missions it undertakes, was identified as an operator presenting a greater risk. The IAA said that AOC reviews were conducted every two years, that a risk profile was created, and that it did not consider the Operator a higher risk AOC holder than others in Ireland. The IAA explained that '*organisations may have the capacity to safely conduct high risk commercial operations or other operations with a higher risk exposure. This does not equate the organisation to a high risk organisation*.'

The IAA's 2014 AOC Annual Review Form contained entries about S-92A SAR operations; SAR permission requiring updating due to regulatory changes; issues between the SAR role and CAT (HEMS) role; SAR usage of certain helipads; and, FTLs regarding HEMS versus SAR and noted that the majority of flight hours were accounted for by training and the SAR role.

The 2014 AOC review recommended continuation of the EASA AOC and SAR operations. The 2015 AOC review described operations as '*SAR/HEMS small amount CAT*' and later referred to a complex operation for oversight with SAR and HEMS mix. Continuance of the AOC was recommended. Each AOC Review Form was signed off by the inspector who completed the review and by two higher layers of management.

The Investigation noted that the AOC Annual Review Forms appeared to be more suited to airline operations than emergency helicopter operations and associated training. The IAA explained that the form was based on the requirements of European Regulation (EU) No 965/2012, which did not apply to SAR. The Investigation noted that the IAA's AN O.76 stated '*an Approval shall be based on the requirements of European Union Regulation (EU) 965/2012*.' The IAA stated that the AQE Report compiled as a result of AAIU Safety Recommendation IRLD2018003 regarding the oversight of SAR helicopter operations in Ireland, as contained in the AAIU's First Interim Statement, will form the basis of a revised oversight plan. The IAA also informed the Investigation that an operational SAR helicopter flight tasked by the IRCG, and operated under a Rescue callsign, was subject to oversight by IRCG but not by the IAA.

1.17.2.2 DTTAS oversight of IAA

The DTTAS website stated that it was responsible for ensuring that aviation practices and procedures comply with best international standards and retains overall responsibility for bodies and agencies, which included the IAA, to which it had entrusted a range of operational and regulatory functions and services relating to the safety and technical aspects of civil aviation.

The Irish Aviation Authority Act, 1993, states, at Section 32:

> *32.—(1) The company shall, in the period ending 3 years after the vesting day and subsequently, whenever so required by the Minister, submit to him a report in writing specifying the general technical and safety standards in relation to aircraft and air navigation that it applies and enforces in the performance of its functions.*
>
> *(2) Whenever, after the submission of a report to the Minister under subsection (1), the Minister so requests the company shall submit to the Minister a report in writing specifying the extent (if any) to which the standards achieved and enforced by the company, since the date of the submission of the first-mentioned report to the Minister, differ from the technical and safety standards standing specified in that report.*
>
> *(3) (a) The Minister shall, at least once in the period of 3 years beginning on the vesting day and in each subsequent period of 3 years beginning on the expiration of the last previous period, appoint a person to carry out an examination of the performance by the company of its functions in so far as they relate to the application and enforcement of technical and safety standards in relation to aircraft and air navigation and to report in writing to the Minister the results of the examination.*
>
> *(b) The Minister shall submit a copy of a report under paragraph (a) to the Government and the company.*

The Investigation notes that a Section 32 examination was carried out in 2015 and that there were no Section 32 examinations between the years 2004 and 2015.

1.17.3 Approval for SAR and HEMS

The IAA informed the Investigation that the requirements for Helicopter Emergency Medical Service Operations (HEMS) are set out in European Regulation (EU) No 965/2012 on Air Operations - Subpart J. The IAA said that the Operator had been issued a specific approval for HEMS in accordance with these requirements. This approval in the AOC Operations Specifications is valid for Day and Night Operations and fully addressed in OMG.

The IAA explained that SPA.HEMS.120, HEMS operating minima, (a) sets out the HEMS operating minima for day and night operations. In certain circumstances, outlined in Table 1 (e.g. ceiling minima below 500’ in day), the operating crew may operate below the minimum heights specified in European Regulation (EU) No 923/2012 (the Rules of the Air (SERA)). To facilitate these specific circumstances, the HEMS operator may require a permission from the IAA to operate below the SERA minimum heights, specifically SERA.3105 & certain requirements in SERA.5005.

The IAA said that the Operator held a valid Permission (07 of 2015) to conduct daylight HEMS operations below the minimum heights specified in SERA.3105 & SERA.5005(f)(2) in consideration of the operating minima outlined in SPA.HEMS.120 Table 1. The IAA noted that, as the operating minima at night are higher and meet the SERA requirements, the Low Flying Permission did not apply.

The Investigation notes that the Low Flying permission contained a number of conditions which included that the pilot-in-command shall maintain a record of each flight sector operated pursuant to the permission and that the Operator was responsible for operational control and oversight of all flights pursuant to the permission.

The Operator informed the Investigation that iSAR, its electronic flight management system, did not contain information on which flights involved low flying.

The Operator held approvals from the IAA to conduct SAR missions and HEMS missions. As outlined above, under the National SAR Approval, 27 alleviations from regulations were allowed for the Operator to carry out SAR missions. The IAA informed the Investigation that the decision to avail of these alleviations for any specific mission rested with an aircraft commander. The Operator was also authorised to carry out HEMS missions in accordance with procedures in OMG, which was accepted (but not approved) by the IAA.

The complexities of differentiating between SAR and HEMS taskings were considerable; they had implications for the operational limits that applied during the mission and even for the recording of flight crew time for fatigue monitoring purposes. Detailed operations manual extracts regarding the differentiation between SAR missions and HEMS missions are given in **Appendix T.** To assist crews in differentiating between SAR and HEMS taskings, the following Decision Tree (**Figure No. 41**) was developed and promulgated in the Operators manuals:

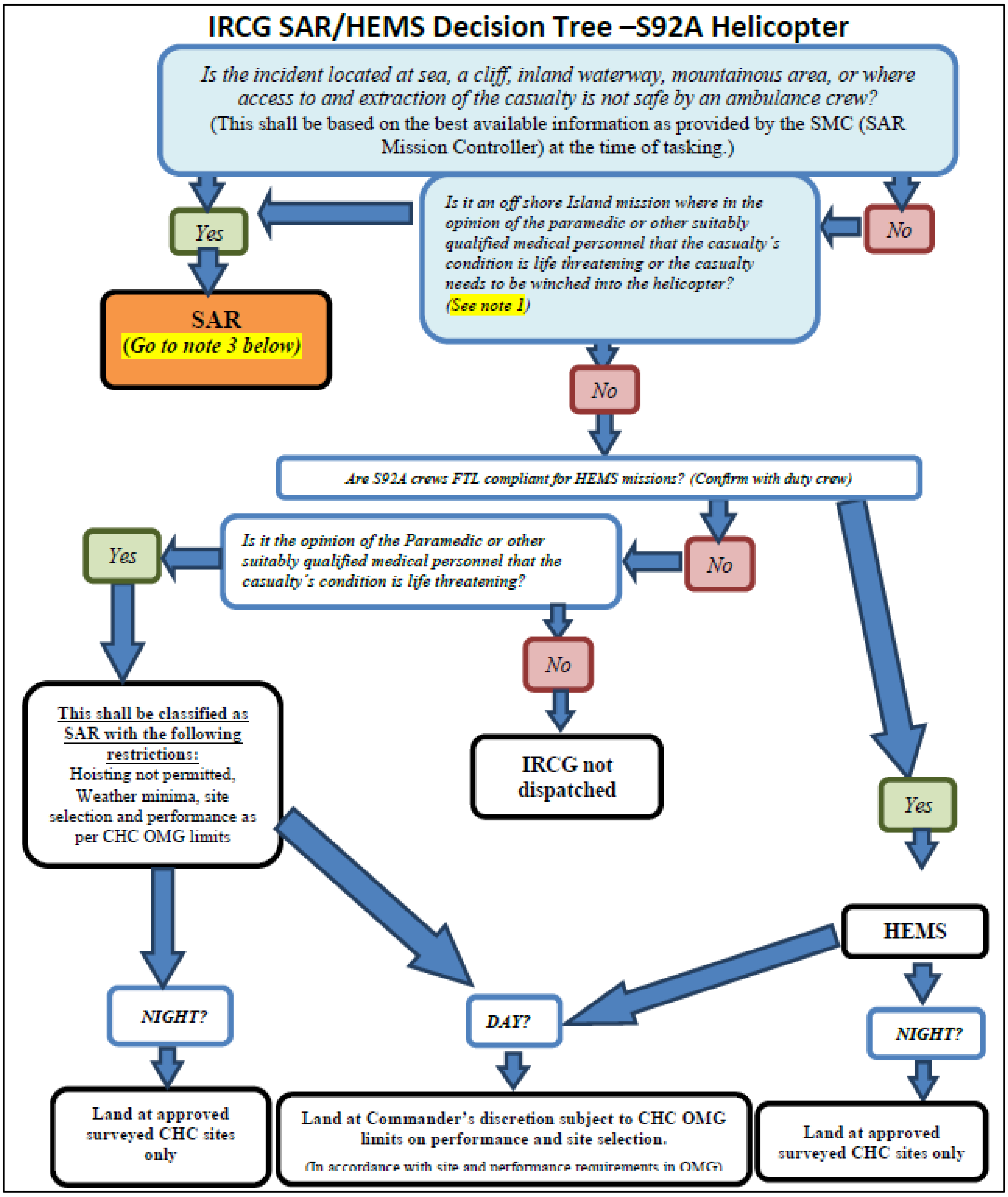

Figure No. 41: Operator's SAR/HEMS Decision Tree

The accompanying notes state:

> *'1. Island missions: If the best available information at the time of tasking indicates the casualty does not need to be winched and the condition of the casualty is not life threatening, then it will be conducted in accordance with OMG.*
>
> *2. For the purposes of night off-airport operations on both SAR and HEMS missions, night shall be deemed to begin 15 minutes prior to CET and end 15 minutes after CMT*
>
> *3. All taskings to incidents at sea, cliffs, inland waterways, mountainous areas or locations where access to, and extraction of, the casualty is not safe by an ambulance crew, shall be classified as SAR and remain so until the mission has been completed'*

Many of the Operator's Flight and Rear Crew members who spoke to the Investigation described a perceived lack of clarity about what exactly they could and could not do on any HEMS mission. The difficulty in trying to be prescriptive was summed up for many by the number of draft iterations through which the chart went (estimated to be in excess of 60, with some estimates well in excess of 100) prior to it being finalised. The Operator subsequently informed the Investigation that a previous Post-Holder estimated the figure for drafts to be 40 to 50. Some expressed the view that treating all missions as SAR missions would remove ambiguity. The Operator also informed the Investigation that its management team did not think it was appropriate to treat SAR and HEMS missions the same and undertook to produce guidance in this area to its crew.

On 4 September 2017, six months after the accident, the IRCG published SAR Ops notice 6/17 titled '*HEMS/Air Ambulance (HEMS/AA)*' whose purpose was '*to set out revised arrangements for operation of HEMS and patient transfer flights on foot of revised IAA instructions to* [the Operator].' The Notice stated that:

> '*IAA, as the regulator, has prescribed new guidelines to our contracted Helo operator* [Name]*, with regard to conduct of HEMS/AA flights. Previously such guidelines enabled certain groups of HEMS/AA missions that were deemed to be 'time critical-life at risk-life threatening' to be flown as SAR missions. Under new guidelines this discretion no longer applies and all HEMS/AA flights must be flown under CAT (Commercial Air Traffic)/HEMS/AA rules*.'

The Notice explained that:

> '*IRCG Helo services are operated on a 24 hour shift pattern. HEMS/AA rules are governed by a 12 hour shift system. When flying HEMS/AA, crew are obliged to rest on completion of a 12 hour shift. The rules as issued by IAA take cognisance of the 24 hour SAR Helo shift pattern and impose obligatory rest periods for HEMS/AA missions conducted within the 24 hour shift pattern*.'

1.17.4 Safety Management

1.17.4.1 Legislation and Guidance Material

The ICAO Safety Management Manual (SMM, Doc 9859, 3rd Edition, 2013) defines '*Safety*' as:

> '*The state in which the possibility of harm to persons or of property damage is reduced to, and maintained at or below, an acceptable level through a continuing process of hazard identification and safety risk management'*.

ICAO Annex 19 Safety Management defines a Safety Management System (SMS) as:

> *'A systematic approach to managing safety, including the necessary organizational structures, accountabilities, policies and procedures'*.

It further states that:

'…while the elimination of aircraft accidents and/or serious incidents remains the ultimate goal, it is recognized that the aviation system cannot be completely free of hazards and associated risks. Human activities or human-built systems cannot be guaranteed to be absolutely free from operational errors and their consequences. Therefore, safety is a dynamic characteristic of the aviation system, whereby safety risks must be continuously mitigated'.

The ICAO SMM provides an expanded definition of an SMS as follows:

'An SMS is a system to assure the safe operation of aircraft through effective management of safety risk. This system is designed to continuously improve safety by identifying hazards, collecting and analysing data and continuously assessing safety risks. The SMS seeks to proactively contain or mitigate risks before they result in aviation accidents and incidents'.

The ICAO SMM also states that there are four components (and 12 elements) of an SMS:

- Safety policy and objectives (Management commitment and responsibility; Safety accountabilities; Appointment of key safety personnel; Coordination of emergency response planning; SMS documentation);
- Safety risk management (Hazard identification; Safety risk assessment and mitigation);
- Safety assurance (Safety performance monitoring and measurement; The management of change; Continuous improvement of the SMS);
- Safety promotion (Training and education; Safety communication).

As noted in **Section 1.17.2**, the IAA's Aeronautical Notice O.76 states that its approvals issued for the purpose of SAR from 28 October 2014 are based on the requirements of '*European Union Regulation (EU) 965/2012* [Air Ops]*, as amended'*. Part ORO.GEN.200 ('*Management System'*) (a) of 965/2012 requires an operator to '*establish, implement and maintain a management system that includes*:

(1) clearly defined lines of responsibility and accountability throughout the operator, including a direct safety accountability of the accountable manager;

(2) a description of the overall philosophies and principles of the operator with regard to safety, referred to as the safety policy;

(3) the identification of aviation safety hazards entailed by the activities of the operator, their evaluation and the management of associated risks, including taking actions to mitigate the risk and verify their effectiveness;'

The Acceptable Means of Compliance for Part ORO.GEN.200 (a) (1) states that for Complex Operators[91], '*the management system of an operator should encompass safety by including a safety manager and a safety review board in the organisational structure'.*

[91] **Complex Operator:** An operator with more than 20 full time employees.

1.17.4.2 Operator's Safety Management System

Introduction

The Operator's SMS is described in its '*Safety Management & Compliance Monitoring Manual*' (SMCMM, Revision 3, 16 December 2016) which was extant on the date of the accident.

The IAA is included in the distribution list for the SMCMM. Whilst it is not stated in the Manual that it is subject to IAA approval, the Manual lists specific areas within it, that if amended, require IAA approval before the revision becomes effective.

The SMCMM states that it '*documents all aspects of safety management, including the safety policy, objectives, procedures and individual safety responsibilities*'. The Operator's safety philosophy is also stated in the SMCMM:

- *All accidents are preventable*
- *Management is the art of control*
- *Accidents are examples of a loss of control*
- *Accidents are a failure of management*
- *Management must do what is reasonably practicable to prevent accidents*

163 The Operator's '*Health Safety Environment & Compliance Monitoring Policy*' contained within the SMCMM, includes the following:

> '*Safety is the first consideration in all* [Operator Name] *activities. The* [Operator Name] *Safety Management System (SMS) ensures the highest levels of safety, health, environmental, Compliance Monitoring performance and security performance; it is aligned with the four components and 12 elements of the ICAO framework for an SMS, which are, in turn, reflected through this Policy and the 12 elements of our SMS'.*

The ICAO SMM describes the ICAO framework for an SMS and refers to the concept of a '*Safety Action Group*' and a '*Safety Review Board'*. The Operator's SMCMM states that '*the requirement for the Safety Action Group (SAG) are* [sic] *met by the Occurrence Review Board (ORB) & Compliance Monitoring Meeting'*. The stated purpose of the ORB is to '*review, discuss, action and close occurrences reported in SQID* [Safety Quality Integrated Database] *for the previous month and any open reports carried over from previous ORB meetings*'. The SMCMM states that the meeting is required to:

- *Review, discuss and manage occurrences and actions*
- *Identify risks involved and establish priorities*
- *Assess the impact on safety of changes*
- *Review the effectiveness of previous recommendations and promotion*
- *Ensure safety actions are implemented within agreed time scales*
- *Discuss other relevant safety matters*

The Operator's SMCMM also refers to the ICAO concept of a Safety Review Board. It states that '*the requirements of the Safety Review Board (SRB) are met by the Quarterly SMS Review'*, which '*considers strategic safety and Compliance Monitoring functions. It serves to review findings, recommendations and address major issues directed to it by the Safety & Compliance Monitoring team'*.

The SMCMM also refers to an annual SMS review meeting, which it states '*evaluates the effectiveness of the SMS and covers at least the following areas:* […] *Risk management effectiveness as measured by trends in non-conformance and in occupational health and safety events'*.

Safety Occurrence Reporting

Aviation safety occurrence reporting is subject to the requirements of European Regulation (EU) No 376/2014, which according to the Regulation, '*aims to improve aviation safety by ensuring that relevant safety information relating to civil aviation is reported, collected, stored, protected, exchanged, disseminated and analysed*'. Occurrences which represent a significant risk to aviation safety are subject to mandatory reporting requirements. The Regulation also requires that organisations establish a voluntary reporting system to facilitate the collection of details of occurrences that may not be captured by the mandatory reporting system and other safety-related information which is perceived by the reporter as an actual or potential hazard to aviation safety.

According to the Operator's SMCMM, the Safety & Quality Integrated Database (SQID) is the '*formal process for all* [Operator] *employees or contractors to report an occurrence*'. According to the SMCMM, Confidential Reports can also be entered into SQID. The manual also states that internal occurrence investigations and remedial actions are recorded in SQID.

Regarding SQID reports, the SMCMM states the following:

> '*When an individual enters a report into SQID, it is assigned a numerical identifier and the report is routed to the Safety & Compliance Monitoring team. The Safety & Compliance Monitoring team review the report and send to the appropriate people so they can consider and respond to the observations in the report*.'

The Operator informed the Investigation that it encouraged all personnel to use SQID to report occurrences. However, an email from one of the Operator's Safety Management personnel to a Senior Safety Manager with the Operator's Parent Company, in May 2017, stated '*Unfortunately, whilst the information is plentiful within the system it still remains difficult for users to access, leading to complaints and low usage*'. The Investigation spoke with a large number of the Operator's personnel and discussed, *inter alia*, their attitudes to, and usage of, the SQID system. Views offered included:

- A reticence on behalf of some personnel to file SQID reports for fear of being criticised.
- A reticence on behalf of some personnel to file SQID reports because they felt that they would simply be closed without appropriate action being taken; some even felt that management only wanted SQID reports to be submitted so that they could close them and generate impressive statistics for SQID closure rates.

- Accounts were received of SQID reports being submitted which contained compelling rationale for change, only for the report to be closed with no effective change implemented.
- Some of those interviewed pointed out that issues were being raised and discussed at base flight safety meetings which were not being raised in the SQID system, because some personnel felt that the chances of getting a successful resolution were better through the base flight safety meeting forum than through the SQID system.

Many pointed to the changed SQID system which was implemented in 2015. Personnel said that prior to the change the system provided significant feedback (and visibility) to the originator of a SQID report, and, by email, to all other personnel at the reporter's base. However, after the 2015 change, feedback and visibility for personnel was reportedly reduced. The Operator subsequently informed the Investigation that the reporting system that was introduced in 2015 continued to give personnel full access to their own reports and any amendments made to them. The Operator stated that, in addition, all personnel could search the system – the search function was different to the previous version of SQID, but was still available. Furthermore, the Operator stated that since 2018, it also circulates a summary of all SQID reports opened and closed each week to all of its employees.

Problems with the searchability and visibility of reports in the updated SQID system were reported through the SQID system itself, which was the appropriate course of action according to the SMCMM. The relevant SQID report said that:

165 '*There is no "Search All" SQID reports functionality available to SQID users. The functionality is there but the permissions are denied. In this configurations general logins can only see very limited SQID reports. This SQID has been marked as a flight occurrence as otherwise it will be not visible to users* […] *SQID is the only way Crews have of having a proper "Handover" of aircraft when we swap aircraft between bases'*.

It also highlighted that unlike the management team, crews operating at the bases did not receive an automatic email highlighting that a report has been raised. A former Post-Holder informed the Investigation that he had instituted a procedure to automatically forward messages from his SQID inbox to the relevant station if the station was mentioned in the title or subject text; however, when this Post-Holder left the Operator's employment this system ceased to operate.

SQID Processing

The SMCMM states:

'When an individual enters a report into SQID, it is assigned a numerical identifier and the report is routed to the appropriate [Post-Holder]*. The* [Post-Holder] *will be responsible for investigating and identifying corrective action as required, raising a CPA*[92] *and directing the CPA to the appropriate person for implementation. The* [Post-Holder] *will also monitor the CPA for implementation, ensure that the CPA is closed in a timely manner, and lastly, close the report in SQID when the CPA is completed.'*

[92] **CPA:** Corrective and Preventative Action.

Risk Assessment of SQID Reports

The Operator's SMCMM states:

The ORB shall:-

- *review the assigned PRR* [Preliminary Risk Rating] [**Note:** The SMCMM did not describe a process for assigning a Preliminary Risk Rating to a Safety Occurrence];
- *ensure Root Cause has been identified;*
- *confirm Corrective and Preventative actions have been implemented;*
- *agree the report can be closed;*
- *defer to next meeting items that cannot yet be closed due to lack of information or further action required;*
- *assign actions to an attendees* [sic] *to enable report closure;*
- *escalate reports that are unable to be managed;*
- *for similar occurrences, keep 'OPEN' a master report, closing and linking any subsequent reports in SQID. Refer to the linked reports on the ORB meeting minutes.*

The SMCMM also states that '*in the company Risk Assessment Matrix (RAM), an occurrence's likelihood rating multiplied by its severity rating equals the risk rating*'. Company risk assessments also use the matrix.

The SMCMM outlines Likelihood Ratings which are assigned on a five point scale (**Figure No. 42**):

	Empirical data looking backward
1	**Never heard of within your industry**
2	**Heard of within your industry**
3	**Has previously happened within the company or more than once per year in the industry**
4	**Has happened previously at that location or more than once per year within the company**
5	**Has happened at that location more than once per year**

Figure No. 42: Likelihood Ratings as provided in the Operator's SMCMM

The SMCMM sets out that the hazard severity (harm) is the extent of the injuries, ill-health or damage to the environment or assets that may be sustained if the hazard is realised. The SMCMM did not provide a severity rating scale, but it did provide an Impact Ratings table which was used as the severity rating when calculating a risk rating (**Figure No. 43**).

Rating	People	Environment	Assets	Reputation	Security
0	No injury	Zero effect	Zero damage	Zero impact	Zero risk
1	Slight injury	Slight effect	Slight damage	Slight impact	Slight risk
2	Minor injury	Minor effect	Minor damage	Limited impact	Limited risk
3	Major injury	Local effect	Moderate damage	Considerable impact	Considerable risk
4	Single fatality	Major effect	Major damage	National impact	Major risk
5	Multiple fatalities	Massive effect	Extensive damage	International impact	Extreme risk

Figure No. 43: Impact Ratings from Operator's SMCMM

SQID closure rate as a Key Performance Indicator

Regarding the ORB meetings and Key Performance Indicators (KPIs), the SMCMM states that the ORB will monitor the following KPIs and provide input into the Quarterly SMS review meetings:

> *'Closure Rates*
> *70% of reports (FOR, GOR, HESS & HID) to be closed within 60 days*
> *80% of reports (FOR, GOR, HESS & HID) to be closed within 90 days*
> *90% of reports (FOR, GOR, HESS & HID) to be closed within 180 days*
> *Proactive Reporting*
> *Increase proactive reporting by 10% per calendar year.'*

Elsewhere in the SMCMM, there is a statement signed by the Accountable Manager which sets out the Safety, Health, Environment, Quality (SHEQ) objectives for Fiscal Year (FY) 2016, 2017 and 2018. It states, *inter alia*, that the aim is to increase proactive reporting by 10%, reduce the Total Recordable Incident Rate (TRIR) by 10% with a target of 0.65 or lower per 200,000 person hours worked.

An email was circulated amongst management Post-Holders in June 2014, titled '[…] *Upcoming CPA's / Reports with 180 day expiry dates'.* It contained the following:

> *'SAR Ireland are WNS* [Western North Sea] *leaders in terms of SQID reporting and SQID Management. We never had an overdue CPA report and going forward I want to improve on this and not have any reports open in excess of 180 days.*
>
> *Can I ask that you make every effort to close out these reports* […].'

The setting of target measures can have unintended consequences. The Investigation notes that Goodhart's Law[93] identifies the risk associated with a control measure that becomes a target.

[93] **Goodhart's Law:** '*Any observed statistical regularity will tend to collapse once pressure is placed upon it for control purposes*.' This was paraphrased by Strathern as '*When a measure becomes a target, it ceases to be a good measure*' (Marilyn Strathern (1997). '*Improving ratings*': audit in the British University system. European Review, 5, pp 305-321 doi:10.1002/(SICI)1234-981X(199707)5:33.0.CO;2-4).

Occurrence Review Board and Safety and Quality Meetings

The Operator provided the Investigation with copies of the minutes from the meetings held between October 2014 and March 2017. The Operator filed these electronically as '*S Q*' Meetings.

As described earlier, the SMCMM refers to an '*Occurrence Review Board (ORB) & Compliance Monitoring Meeting'.* The meeting minutes reviewed by the Investigation from 2014 and early 2015 refer to this meeting as a '*Safety and Quality Meeting*'. From mid-2015 and 2016, the minutes refer to the meeting as a '*Safety Quality and Compliance Monitoring Meeting*'. In 2017, the meeting was referred to as a '*Safety & Quality meeting & Occurrence Review Board (ORB)*'.

The agendas for the '*Safety and Quality Meeting'* and the *'Safety Quality and Compliance Monitoring Meeting'* were the same. However, the agenda for the *'Safety & Quality meeting & Occurrence Review Board (ORB)'* was different to the agendas for the other two meetings. The '*Occurrence Review Board*' was an item on the Safety and Quality Meeting and on the Safety, Quality and Compliance Monitoring meeting agendas; it was not listed as an item on the Safety & Quality meeting & Occurrence Review Board agenda.

The Investigation notes that the Safety and Quality meetings and the Safety, Quality and Compliance Monitoring meetings were usually attended by members of what the Operator termed the '*Service Team*', which was comprised of all Post-Holders from the Accountable Manager, downwards.

The minutes from the October 2014 Safety and Quality meeting recorded the following:

> *'Again a reminder to the Service Team:-Can I ask the Service Team to give more focus to the closure of SQID reports.*
>
> *The* [Post-Holder] *has set a target of a maximum of 30 open SQID reports* […] *When a SQID report is in your area of responsibility, it is your responsibility to review the report and chase the person responsible to add closure comments, advise* [named persons*] when ready to close'.*

Some members of the Service Team informed the Investigation that they themselves had experienced difficulties using the SQID system; particularly after the change in 2015. Furthermore, some Post-Holders accepted that there had been an emphasis on closing SQID reports and that this may have compromised the effectiveness of the system to identify and rectify genuine safety concerns.

The text regarding '*a maximum of 30 open SQID reports'* appeared up to February 2015 in the meeting minutes provided; thereafter, the wording changed subtly to say '*The* [Post-Holder] *has set a target on the maximum open SQID reports* […]'. The Investigation discussed this with relevant Post-Holders one of whom informed the Investigation that despite the text which appeared in the meeting minutes, the intention was always to ensure that issues identified in the SQID system were appropriately dealt with and then closed, and that any discussions around SQID closure would have emphasised the need to appropriately deal with SQIDs.

The Investigation notes that Goodhart's Law identifies the risk associated with a control measure that becomes a target, and the Investigation found no evidence that the risk associated with setting a target for the maximum number of open SQIDs was identified and managed within the SMS.

Prior to March 2016, meeting minutes also stated that '*a Worldwide SQID summary is compiled and circulated Monthly in an effort to increase the flow of information from the* [Operator's Parent Company's] *reporting systems to all SQID users*.'

Occurrence Review Board Meetings

According to the SMCMM, ORB meetings were to be held monthly and '*a copy of the minutes will be uploaded onto SQID as a Meeting Record'*. These meetings were also attended by members of the '*Service Team'*. On 27 October 2017, the Investigation asked the Operator to provide copies of all the ORB minutes since 1 January 2010. On 3 November 2017, the Operator provided 30 files (in pdf format) and advised that they were continuing to identify the remainder and would provide these when available. On 15 November 2017, the Operator provided the Investigation with a batch of files which it said were more ORB meeting minutes. On examination, these files were in folders titled '*S Q*' meetings, and were not ORB meeting minutes. The Investigation pointed out to the Operator that these minutes were not for ORB meetings. The Operator advised the Investigation that it would re-contact a former employee to ascertain how to obtain the necessary ORB minutes.

169 On 28 November 2017, the Operator provided a second batch of 26 files (in Word and Excel format) which it said were for the period from January 2015 to March 2017. The Investigation asked the Operator why three different file formats were used for the ORB minutes. The Operator informed the Investigation that the minutes were provided in the format in which they became available. The Investigation advised the Operator that the variation in formats suggested a lack of standardisation and defined processes, and accordingly were not consistent with SMS best practice.

The earliest ORB minutes provided were from January 2011. In total, 55 sets of ORB meeting minutes were provided, for the period January 2011 to March 2017. Meeting minutes were not provided for the following months: August 2011 (which the Operator advised was actually combined with September 2011), January 2012, April 2012, May 2012, August 2012, September 2012, March 2013, July 2013, September 2013, January 2014, February 2014, March 2014, May 2014, June 2014, August 2014, September 2014, December 2014 (combined with January 2015), August 2015 (which the Operator identified as being postponed until September 2015), and November 2015 (a file was provided for November 2015, but this was found to contain a slightly modified version of the October 2015 minutes). However, the minutes from the Safety, Quality and Compliance Monitoring meetings for August 2015 and November 2015 (two of the months for which no ORB minutes were provided), state '*The ORB was chaired by* [named individual]*, all open Occurrences & CPA's were reviewed and Actions Assigned,* [named individual] *will post the review minutes on SQID.'*

On 5 December 2017, the Investigation informed the Operator that unless advised otherwise, the Investigation would conclude that the gaps in the minute sequence arose because meetings did not happen. On 7 September 2018, the Operator advised the Investigation that it was '*not sure that the assumption that the absence of the Minutes means the meetings did not happen is reasonable. All we can say for sure is that the Minutes of the various meetings held between Aug 2011 and Nov 2015 (totalling 20 sets of Minutes) could not be located at the time of asking and that they were not uploaded onto SQID.'*

Records indicate that ORB meetings were held every month in the 12 months leading up to the accident.

The Investigation asked the Operator to provide details of the ORB process because from the Investigation's reading of the SMCMM, exact responsibility within the ORB process was not clear and did not appear to be prescribed. The Operator referred the Investigation to a number of sections of the SMCMM which set out the responsibilities of various posts.

The Operator went on to say that it believed that all of the interested parties were '*comfortable*' with where the accountability/responsibility lay. The Investigation's concern, as explained to the Operator, was that in the absence of prescribed processes, it was not possible to assess whether accountability and responsibility assignments were reasonable, i.e. was the workload associated with assigned responsibilities reasonable and practical. Furthermore, without defined processes, neither management, nor its auditors, could identify actual or potential weaknesses in the processes to bring about system improvements.

The Investigation had a similar concern about a lack of prescribed process in relation to an OMF requirement to review (through a follow-up process) all post-flight medical reports, to ensure the casualty's condition was correctly diagnosed as a '*life or death*' case. The Investigation asked the Operator to explain how such reviews were conducted and what problems, if any, had been identified. The Operator advised the Investigation that the procedures were described in a cited section of OMA, and that any lessons learned would be debriefed with the crew involved. The Investigation reviewed the cited section of OMA and advised the Operator that it represented a role definition but not a procedure/process definition. Furthermore, the Investigation advised the Operator that debriefing of individual crews was inconsistent with the SMS objective of capturing and promulgating information and lessons for the benefit of all relevant personnel. The Investigation notes that suitable, prescribed processes/procedures, properly followed and documented, by appropriately trained staff, is a key concept in SMS and in aviation generally.

Quarterly SMS Review and Annual SMS Review Meetings

The Operator provided the Investigation with the agendas and the data to be discussed at the review meetings for Q3 2015-16 (quarter three – November 2015, December 2015 and January 2016), Q4 2015-16 (February 2016, March 2016 and April 2016), Q1 2016-17 (May 2016, June 2016 and July 2016) and for Q2 2016-17 (August 2016, September 2016 and October 2016).

Minutes and attendance records for these meeting were not provided; subsequently, a former Post-Holder informed the Investigation that these minutes were not available because '*these reviews usually took the form of a PowerPoint presentation to all post holders, attendance from service team was included from Q2 2016-2017 onwards.*'

Flight Safety Meetings

The contract between DTTAS and the Operator regarding the operation of the S-92A helicopter required the Operator to describe its '*safety ethos and how this will be kept vibrant for individuals at remote Bases*'. The Operator's undertaking, in response to this requirement, stated:

> '[Subject Operator] *is committed to providing safe and healthy working conditions and attitudes within the company.* [Subject Operator]*'s safety ethos is to ensure "No harm to people, property or the environment".*
>
> *The safety ethos is kept vibrant for individuals at all Bases as follows:*
>
> *All employees have a copy of the Health, Environment, Safety, and Security Handbook. (HESS Handbook) The HESS Handbook is published as a quick reference guide for all health, environment, safety, security and quality issues, and copies are provided in Volume 3 Part 5.6.*
>
> *-Monthly Safety poster Campaign.*
>
> -[company] *desk calendars, the Intranet, the Safety Boards and Posters.*
>
> *-Monthly Flight safety and health and safety meetings at all Bases.*
>
> *-Monthly management safety and Quality meetings.*
>
> *-Promoting a Just Culture.*
>
> *-Performing regular audits at all SAR Bases to verify compliance with JAR OPS 3, EASA Part 145 and Part M, Health and Safety, and* [Operator] *procedures.*
>
> *-Promoting the use of the Safety and Quality Integrated Database (SQID)*
>
> *The Integrated SMS is supported by the Safety and Quality Integrated work within* [named Operator]. *SQID is a web-based database.*
>
> *All occurrences whether aircraft or health and safety related are reported in this database.*'

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The Contract also stated:

> *'8.3.2. Safety Meetings. The Contractor* [Operator] *shall hold safety meetings and provide copies of the minutes to the* [IRCG] *SAR Ops Manager. All Contractor's Personnel who operate in Ireland and are principally assigned to the IRCG contract shall attend at least two meetings per year. The safety meetings should be a forum, where all aspects of safety can be discussed openly.'*

The IRCG advised the Investigation that it had not received copies of the minutes of Safety Meetings.

The terms ‘*Pilot focussed Flight Safety Meeting*[s]’ and ‘*Base Flight Safety Meetings’* are not defined in the SMCMM. However, the SMCMM refers to the meetings in the Duties and Responsibilities section for two separate roles. The SMCMM states: [the specified role] should:

> ‘*Ensure a pilot focused flight safety meeting is held, minuted and uploaded to SQID at least once per quarter’,* while another specified role ‘s*hould strive monthly, but at least once per quarter organise and Chair base Flight Safety meetings, and ensure that the Minutes are uploaded to SQID. Meetings should include discussion on information, actions and procedures and may be used to communicate safety matters’*.

On 20 April 2017, the Investigation requested copies of all Base Flight Safety Meetings (BFSMs) from the Operator. On 6 May 2017, the Operator provided meeting minutes for the period from January 2012 to March 2013 and advised that further information was being compiled and would be provided as soon as possible. The message was accompanied by several pdf files. These files did not follow a standard naming convention which made analysis of the files difficult. On 9 May 2017, the Operator provided a standardised index for the files and on 12 May 2017, provided several more pdf files of Flight Safety meeting minutes; these included copies of the files provided on 6 May 2017. The Operator also advised that its data trawl was not yet complete (as of 12 May 2017) and that it could not definitively state that where minutes were not provided, meetings were not held. No further BFSM minutes were provided.

The Investigation understands that BFSMs were not rostered/scheduled events; they were notified and held on an ‘*opportunity basis*’. This usually occurred at shift changeovers when there was a possibility of getting at least eight personnel (the on-going and off-going crews) to attend.

The Investigation asked the Operator why the BFSM meeting minutes were not readily available. The Operator said that:

> ‘*the process for identifying Minutes of FS Meetings includes a large element of manual review. In addition, not all Minutes had been uploaded into SQID and so we were seeking feedback from a variety of personnel as to where the Minutes may have been stored locally* […]’.

The Investigation asked why the minutes had not been uploaded onto SQID as prescribed in the SMCMM. The Operator advised that it was due to ‘*human error’*. The Investigation noted that these errors were propagated throughout the base network, involved several different staff members, occurred over a period of years, and were not detected by internal review/quality processes. The Investigation advised the Operator, on 8 June 2018, that this demonstrated a combination of ‘*systems failure*’ and ‘*corporate culture’*, rather than ‘*human error’*. The Operator subsequently informed the Investigation that it ‘*now has a specific metric to track the uploading of Minutes into SQID*.’

The Investigation asked the Operator when it was known that meeting minutes were not being recorded on SQID as prescribed in the Operator’s SMCMM.

The Operator said that it was not possible to provide a definitive date, but that if management had been aware pre-accident, action would have been taken to reinforce the need to use SQID as a central repository. On 8 June 2018, the Investigation advised the Operator that the Investigation considered management's lack of awareness was a concern and the fact that management did not have robust processes in place to identify non-compliance with the processes prescribed in the SMCMM manual was also a concern.

The Investigation carried out a review of those BFSMs minutes which were provided. **Table No. 25** sets out the number of records of minutes received by year and base:

Year	Dublin	Shannon	Sligo	Waterford	Total
2011	None	1	3	None	**4**
2012	10	10	3	6	**29**
2013	6	7	6	7	**26**
2014	10	9	6	10	**35**
2015	4	8	4	6	**22**
2016	10	1	None	7	**18**
2017 (to March)	2	None	1	1	**4**
Total	**42**	**36**	**23**	**37**	**138**

Table No. 25: Summary of BFSM minutes provided to the Investigation

The Investigation reviewed the content of all BFSM minutes provided and noted, *inter alia*:

- The standard of minute keeping varied from base to base.
- There was no BFSM held at the Sligo SAR Base during 2016. The Investigation was informed that this was due to the fact that there was no Base Flight Safety Officer for the Sligo SAR Base during that period.
- Personnel were routinely encouraged to use SQID to report issues. However, the minutes indicated that some personnel seemed to believe that SQIDs were being closed without due consideration and process. In September 2012, a senior manager and Post-Holder attended a Dublin Base Flight Safety Meeting: The minutes of the meeting noted that '[Post-Holder] *wished to avail of the opportunity to re-emphasise the importance of SQID to our Op*.' He advised that '*if you find that a SQID you submitted has been closed but you are still not satisfied with the response to feel free to SQID the same item again*.'
- Starting in the Dublin Base March 2014 meeting, there were discussions regarding inaccurate information in the '*Low Level Route Guide*' and SAR Heli-pad surveys. This discussion referenced two SQIDs which were raised nine days prior to the meeting and said that '*Both SQIDs raise serious concerns about the accuracy of the info in our official manuals*'. The minutes record that '*BFSO said that despite the gravity of these SQIDs that there had been no responses on SQID to them yet (at the time of this meeting).* [Named Post-Holder] *assured that these SQIDs are being followed up on given what they have discovered. Being dealt with at ORB level.*'

- One BFSO re-emphasised his '*old message'* that all staff should feel free to '*re-SQID items that they believe have not been rectified, or are not making sufficient progress* […] *how re-SQIDing would appear to re-focus attention on an already known issues.'*
- Other matters raised included perceived overt commercial pressure being applied to duty crew, Fatigue Risk Management (FRM), and adequacy of rest facilities
- Meetings were held with the IAA to seek to have '*false*' obstacles on the east coast, which were triggering incorrect EGPWS warnings, removed.
- From September 2016, minutes of successive meetings at the Dublin SAR Base highlighted concerns regarding interpretation of the newly revised OMF in relation to recording of duty time and possible implications for FRM. Requests for clarification persisted up to and after the time of the accident.
- Issues with the quality and adequacy of the cockpit moving map system were raised. Complaints included '*Some of the map images in aircraft are completely blurred and unreadable. For reasons of safety this system needs to be updated and of a quality that it is usable for our current operations both in Ireland and the UK*.' The minutes also recorded that the moving map system had proved inadequate during a night mission to the UK and that paper charts had to be used for navigation at all times when in UK airspace.
- The minutes recorded that *'A time line for resolution on the above issues was requested from the floor'* and that crews were '*becoming frustrated by the lack of feedback or action'.* It was also noted that *'This important safety issue has been ongoing for several months now. Items passed* […] *for management to review and issue guidance. A time line for worked examples of the FTL* [Flight Time Limitations] *system and improvements to the moving map system to be requested. Item ongoing.'*

The Investigation asked the Operator to comment on one particular entry in the February 2013 Dublin BFSM minutes. The entry read:

> '[SQID Number] *highlights an error in how we currently log Spare Duties on our FDP/FTL system.* [Initials of Individual] *as the Report Originator briefed that this was his second SQID on this topic but there had only been 1 reply to either SQID on the SQID system. He said that the discussion was being conducted through emails but believes it should be conducted on the approved Safety system for the benefit of all*.'

The Investigation pointed out to the Operator that this entry appeared to indicate that the SQID system was not being used as intended.

The Investigation asked the Operator if this particular statement quoted represented an unheeded indication of a systemic issue with the use of SQID within its operation. The Operator provided a response from a post-holder within its Parent Company which said that in the specific instance cited, it supported the principle being aired. The Operator said that it did not interpret the minuted comments as an unheeded indication of a systemic issue with the use of SQID. The Operator said that this was actually a member of the Operator's team promoting the use of SQID to formally capture key aspects of topics being dealt with.

BFSM minutes were copied (contemporaneously) to all Post-Holders within the Operator's Irish operation, to all Base Flight Safety Officers (Ireland) and to some personnel within the Operator's UK operation.

Thematic Review of ORB Minutes

As a result of the concerns raised regarding the SQID system, which arose during interviews with the Operator's personnel, the Investigation identified a need to conduct a thematic review of the contents of the SQID database and requested access to SQID from the Operator. The Operator declined this request citing data protection concerns. However, the Operator offered that if the Investigation provided the search criteria it wished to use, copies of results of those SQID searches would be provided. Furthermore, the Operator offered to supply specialist personnel to conduct searches under the direction of the Investigation and to provide those results to the Investigation. This presented a dilemma for the Investigation, as it would be necessary to review a range of SQID reports to be able to define (and refine) specific search criteria. Accordingly, whilst the Investigation specified the same search criteria for the Operator to use and the Operator provided the Investigation with the results obtained, the Investigation declined the Operator's offer to supply specialist personnel to conduct searches, and instead the Investigation decided to conduct the thematic review by using the minutes of ORB meetings.

The Investigation developed a database and devised bespoke data-loading software to aggregate the minutes which were provided for the 55 ORB meetings. The following issues are some examples of themes/issues which the Investigation noted during its review of the minutes:

- **PLBs fitted to Life Jackets**

A SQID report from November 2011 identified issues with the Mk44 lifejackets being used by the Pilots: The report stated:

> '[...] *1. The Mk15 jackets* [as used by Rear Crew members] *have been modified so that the patch antenna is on the front face of the lifejacket after it has been inflated. Essentially it is out of the water and in clear view of the sky. 2. The Mk44 are currently fitted as per the last modification from* [the lifejacket manufacturer]. *The GPS antenna is situated right beside the unit and its TX / RX*[94] *aerial* […] *will be below the buoyancy line when the jacket is inflated. ie it will be below water. WRT 2 above the PLB manual clearly states the following: 3.5 Place GPS antenna horizontally, and with a clear view of the sky and horizons. keep the GPS and transmitting antenna separated by 30cm minimum. 3.7 While operating beacon at sea, ensure that both GPS and Tx antennas are above water at all times. It is clear from the above that the PLBs in the Mk44 jackets will not receive GPS signal and therefore the 406*[95] *aspect of the beacon will not work. This leaves personnel working with Mk44s relying on homing on 121.5/243 which are no longer monitored.* [...] *I would suggest that pilots are wholly exposed in the event of a ditching until the Mk44s are modified for correct operation of the GPS antenna as is the case with the Mk15s or all personnel switch to Mk15s until the issue is sorted.'*

[94] **TX / RX:** Transmit/Receive
[95] **406:** A reference to the 406 MHz frequency used to transmit distress signals and GPS position information.

On 7 February 2012, the ORB considered the SQID report and recorded '*With Design Office and* [Named Individual][96] – *waiting reply.'* On 13 March 2012, the ORB again considered the SQID report and recorded '*Back with* [the Operator] *to discuss with* […] *Jacket Manufacturer*'.

On 12 June 2012, the ORB closed the SQID report. The ORB cited the root cause as '*Manufacturing problems. Position of the GPS antenna within the jacket would be below water level in the case of the jacket being inflated'* and recorded the corrective action as '*FSI*[97] *has been issued by MFO'* and that the lifejacket manufacturer had been contacted *'for long term fix*'.

The Investigation notes that it was actually an Operations Memorandum (Ops. Memo) and not an FSI, which was issued. The memo, designated 04/2012 and issued on 23 January 2012, stated that '*The S&Q department at* [Operator's Parent Company] *are looking for a permanent resolution by engaging the OEM*[98] *to modify the jackets'*. The Investigation asked the Operator to provide details of the Parent Company's involvement in the issue. The Operator informed the Investigation that '*It has not been possible to identify the specific discussion.'* Ops Memo 04/2012, as referenced above, advised:

> '*as an interim local solution, if Crews are required to activate their SARBE 6 while immersed in water the PLB pocket should be unzipped, the cable antenna removed and raised above the surface of the water.*
>
> *If possible, zip back up the pocket; However the PLB should remain in place due to the retaining loop over the VHF antenna.*
>
> *As an aid, below is an excerpt from the SARBE 6 manual.*
> *Place GPS antenna horizontally, and with a clear view of the sky and horizons. Keep the GPS and transmitting antenna separated by 30cm minimum.*
>
> *The red LED will flash when a GPS position is acquired. If there is no red LED flash after 20 mins, reposition the GPS antenna*'.

[96] On 6 December 2017, the Investigation asked the Operator to have the named Individual review his records and emails to provide details on his involvement and why the matter had been referred back to [the Operator]. On 20 March 2019, the named individual advised the Investigation that, '*I can (personally) recall that there was a proposal to align the jackets/beacons in use across all of the company worldwide and that this was put to each of the AOCs, including Ireland. From memory, there was a small group of crews in Ireland who were adamant that the SARBE 6 beacon and Mk44/15 lifejacket was the only one acceptable to them and so the global project was not applied to Ireland – hence the issue was 'handed back' to the Ireland team*.'

[97] **Flying Staff Instruction (FSI)**: OMA states that, '*Generally, operations manuals are revised once a year. Any changes to procedures, corrections to content of manuals, additional instructions, or essential information that need to be promulgated in between the normal manual revisions, will be published by FSI. Emergency and normal checklists will be revised when necessary and accompanied by an FSI explaining the changes and the reasons for them.*'

[98] **OEM:** Original Equipment Manufacturer.

The Investigation asked the lifejacket manufacturer to provide copies of all correspondence with the Operator that related to this SQID report. This correspondence showed that in April 2012 the Operator informed the lifejacket manufacturer of the problem. In May 2012, the lifejacket manufacturer informed the Operator that they had decided to re-issue SB 184 with an improved PLB installation. In this response the lifejacket manufacturer also expressed their willingness to assist customers with integration of new beacon types but noted that '[Lifejacket manufacturer]'s *original brief was to solely provide a stowage pocket for the beacon.'*

In 2014, and again in 2015, this issue was reported in the Operator's SQID system. The corrective action section of one of the 2015 SQIDs stated that, '*The OEM guidance for GPS antenna usage is that it is 'held' above the waterline to assist GPS tracking. This information is to be circulated again by* [designated Post-Holder].*'* The Investigation was not provided with any records of correspondence between the Operator and the lifejacket manufacturer on this matter after 31 May 2012. At the time of the accident in March 2017, SB 184 had not been re-issued by the lifejacket manufacturer.

The Investigation was provided with a copy of the Operator's presentation (last modified on 20 April 2017-Post Accident) which was used as part of all crew members' 12-monthly '*Emergency Safety Equipment*' training. This presentation did not include the information which was provided in Ops Memo 04/2012.

On 6 December 2017, the Investigation asked the Operator to provide the logic which was applied to close this SQID based on an Ops Memo that was self-described as '*as an interim local solution*', and in the absence of an identified permanent solution or indeed of a timescale for such a solution. The Investigation asked the Operator if, due to the passage of time, the logic could not be provided, please state whether current management would be satisfied to close a similar report in the same manner. On 20 March 2019, the Operator informed the Investigation that it was '*not possible to provide the logic followed by those people in place at the time*' but that '*as a result of an upgrade to the safety reporting system in May 2015, introduced a new principle that promotes Action Items and Due Dates as the focus for what needs to be done and by when. I would be confident that a similar scenario today would result in a specific Action Item being raised for a modification and that the Due Date would be tracked for completion with closure coming as a result of the work being undertaken.*'

- **GPS Navigation Software**

On 27 March 2012, when the Operator was operating the S-61N helicopter type, a SQID report titled '*Change to GPS Software to return Maritime Navigation Aids to Moving Map display*' was submitted.

It stated '*Following the recent update of the* […] *software, the maritime navigation aids that were previously displayed are now missing. The technical report dated 16th Jan 2012, Doc No: 08-030-002-002 issue 2* […] *under 'Moving Map Menu' the various options, being 'Pilot Selectable, Auto Home, OFF' etc. Under Maritime Settings, 'Navigation Aids' are selected to off, therefore marker buoys, light houses etc. are no longer displayed as previously. Would it be possible to reinstate the maritime navigation aids as they prove very useful when flying at low level over the sea.*'

The Corrective Action recorded '*Unable to correct it at this time see response from* [Named Supplier] *below…'.* This response referred to data not being available from the supplier's chart provider*.* The Root Cause was stated by the Operator as '*Supplier has left out marine navigational aids from newer versions of software*'.

- **General Issues**

In February 2015, an email titled '*Communications Initiative - Technical Updates'* was circulated amongst management Post-Holders within the Operator. It stated '[…] *Following on from Townhall meeting with Sligo it was widely discussed that top down communications irt* [in regard to] *technical issues could be better and 'that some issues that were SQIDD'ed and closed seemed to disappear into the ether with no real solution'. We obviously know this is not the case however we could be better at providing feedback and updates on where these matters lie and reassure staff that we are managing these issues and their concerns. I am therefore proposing a Bi Monthly update on raised outstanding technical issues to all staff* […]'.

Route Guide SQID Report

On 16 March 2014, which was more than nine months after the S-92A had been introduced into service, a SQID was submitted regarding the Route Guide. This Section details the processing of that SQID.

The SQID, titled '*Inaccurate Information in Route Guide*', said:

> '*On approach to Blacksod at night and in poor weather the aircraft was set up for the SGLOWBS route from Broadhaven Bay. On checking the route guide it was found that the entire Hazards / Obstacles and Coastal NDB's / lighthouses section are incorrect and appear to have data from an approach to Donegal airport approx. 70nm NE of Blacksod. On landing the route guide was looked at further to find a number of further issues throughout the route guide. Primarily these appeared to be miss numbering of the Hazards / Obstacles and some which are missing completely from either the table or the map.*
>
> *Due to the late landing time the route guide was not fully checked but examples of miss numbering can be found on routes LOWSG3, LOWSWILY, LOWTRHOS, NNLOWDW1, NNLOWDW2, NNLOWGHP, NNLOWSG, LOWBOFN, LOWEICK.'*

The Investigation notes that at the time of the accident:

- NNLOWDW2 had not been revised (the version provided to the Investigation was dated 25/02/2013) and the hazards table recorded three hazards but four were shown on the chart.

- NNLOWGHP had not been revised (the version provided to the Investigation was dated 25/02/2013) and obstacles remained incorrectly designated.

According to an email thread between 3 July 2013 and 6 July 2013, issues with LOWSG3 were identified and were to be addressed; however, nine months later issues remained with LOWSG3.

This Route Guide SQID was assigned a preliminary risk rating (PRR) of 5. The Investigation noted that there were only two ways for the ORB to arrive at a PRR of five; the ORB either considered that the Route Guide issues identified:

Could result in multiple fatalities and were never heard of within the industry

Or

Had happened at that location more than once per year and would only result in slight injury.

The Investigation asked the Operator to explain how the PRR of 5 was arrived at. The Operator said that:

'The rationale behind the PRR of 5 is difficult to provide given that it will have been allocated by the personnel involved in the management of the report. However, for reports of this nature (HID where no occurrence has taken place[99]) they will likely have aimed to strike a balance between actual risk and potential risk. From our understanding of the various discussions at the time - which are challenging to replicate completely - the Blacksod South route had no material anomalies identified with it and a minor change was made to that route involving a VHF frequency change in 2015.'

The Investigation found that on 27 March 2014, an email had been issued to base Chief Pilots, and copied to the personnel involved in updating the Route Guide. The email cited the above SQID and said:

'[…] *please issue an instruction to your crews to complete a review of routes used by your base* […] *Assign the task to one individual who will oversee and ensure all routes checked and any inconsistencies noted* […] *If there are any inaccuracies found or comments/suggestions, please forward the relevant information to* [named personnel] *who will then update the route guide.*'

The report was closed at the ORB meeting on 10 April 2014, 25 days after it was opened. The Root Cause was attributed as:

'*Transition from S61 to S92'*. The prescribed Corrective Action read '*Chief Pilots have been instructed to review all FMS routes for their base area of operation and report any inaccuracies/suggestions/comments to the FMS reps. This instruction had previously been issued last year and crew informed to use routes and waypoints with caution until proven.'*

On 30 April 2014, email correspondence indicated that SGLOWBS was still in use and that '*All hazards, obstructions and coastal lighthouse are incorrect.*'

[99] The Investigation disagrees with the Operator's characterisation of the reported event as '*no occurrence has taken place*'. The Investigation believes that this was a Flight Operations occurrence because the helicopter was on approach to Blacksod, at night, in poor weather and already set up for the SGLOWBS route, before it was realised that all the obstacle information was incorrect. The Operator informed the Investigation that the HID classification had been applied by the originator of the report.

Operator's Risk Assessments

The Safety Management & Compliance Monitoring Manual (SMCMM) describes the Operator's safety risk management processes. These include Hazard Identification and Analysis. It states the following:

> '*The Safety Risk Management process starts with identifying hazards affecting aviation safety and then assessing the risks associated with the hazards in terms of severity and likelihood. Once the level of risk is identified, appropriate remedial action or mitigation measures can be implemented to reduce the level of risk to as low as reasonably practicable. The implemented mitigation measures should then be monitored to ensure that they have had the desired effect.*
>
> *Most risk assessments, as required by legislation, require us to take "reasonably practicable" precautions. The term "reasonably practicable" allows us to make a balanced judgment about the extent of the risk and its consequences against the time, trouble (effort) and cost of the steps needed to remove or reduce it. If it is grossly disproportionate, we can say that it is not "reasonably practicable" to implement such steps. Unfortunately, there is no exact definition of "reasonably practicable"; we cannot say if a measure costs more than a certain amount it is no longer reasonable.*
>
> *All risk assessments carried out by teams from the company are undoubtedly qualitative. This means they are subjective, based on personal experience and judgment and supported by generalized data on the risk. For our normal operations and activities, this is more than adequate. Carrying out a quantitative risk assessment, which is objective and supported by accurate statistical information, is a more specialized task and should be carried out by appropriately competent individuals.*'

The Operator's '*Risk Assessment Form*' lists the '*Base*' for which the Risk Assessment refers to and the '*Competency Requirements*' of the members of the Risk Assessment team.

The form also includes columns for the following: '*Hazard/Risk*'[100], '*Threat*', '*Severity*', '*Likelihood*', '*Risk Rating*', '*Control Measures Required*' and '*Residual Risk Rating*' (**Figure No. 44** shows Page 2 of the form used for the Operator's Controlled Flight into Terrain – CFIT Risk Assessment). The form also contains the following question: '*If additional controls measures are required, can they be implemented immediately?*' The answer '*Yes/No*' is indicated on the form.

[100] **Note:** The header of '*Hazard/Risk*' is used in the Operator's risk assessment form. However, the terms are not interchangeable. A hazard is a potential source of harm, whereas risk is the assessment of the consequences of a hazard, usually expressed in terms of predicted probability (likelihood) and severity.

PAGE 2 of 5	SAFETY & QUALITY DEPARTMENT RISK ASSESSMENT FORM	

HAZARD/RISKS&THREAT			Severity S	Likelihood L	Risk Rating R	CONTROL MEASURES REQUIRED	Residual Risk Rating		
	Hazard/Risk	Threat					S	L	R
1.	Terrain separation deteriorating below normal requirements	ATCO issues incorrect/incomplete clearance.	5	1	[redacted]	Flight crew challenges clearance EGPWS Flight crew maintains situational awareness using effective monitoring (EPWS, awareness of MSA)	5	1	[redacted]
		Flight crew misunderstand clearance or instructions	3	3	9	Clearance read back Flight crew request clarification due to uncertainty Flight crew maintains situational awareness using effective monitoring	3	1	[redacted]
		Flight crew do not correctly manage aircraft to maintain or achieve clearance.	5	4	[redacted]	Flight crew maintains situational awareness Adherence to SOPs with regards to automation. Sterile cockpit (when appropriate)	5	2	10
		Flight crew set incorrect pressure altitude setting	3	3	9	Flight crew adheres to SOPs including effective monitoring. ATC detects miss-set setting via MODE "C" readout	3	2	[redacted]
		Navigation error based on incorrect content within navigation database.	3	3	9	Database provider's quality assurance process eliminates errors. Flight crew detect and report via normal reporting channels	3	2	[redacted]
		Navigation error due to incorrect FMS entry by flight crew	3	3	9	Flight crew approach/departure briefing captures the error. Flight crew maintains situational awareness	3	2	[redacted]

Figure No. 44: Extract from Operator's Risk Assessment Form

Initial '*Severity*' and '*Likelihood*' ratings are multiplied to give an initial risk rating. Instructions on how to use the '*Residual Risk Rating'* column are not contained in the '*Risk Assessment*' section of the Safety Management & Compliance Monitoring Manual. However, the completion of this column is described in the '*Safety Case*' section of the Manual. It instructs *inter alia*, to '[…] *Identify controls that reduce the effect of the consequences* […] *Complete a residual risk rating for the identified consequences with the controls in place and effective*.

The Investigation asked the Operator for copies of its Risk Assessments. The Operator initially provided four Risk Assessments, each of which had an assessment date of 13 October 2015 and an acceptance date of 14 October 2015.

The Risk Assessments dealt with:

- Controlled Flight Into Terrain (CFIT)
- Loss of Control
- Airborne Conflict
- Ground Handling

Regarding the '*Controlled Flight Into Terrain'* (CFIT) Risk Assessment (**Figure No. 44**), one hazard/risk described on the associated form was '*Terrain separation deteriorating below normal requirements'*. One of the threats listed for this hazard/risk was '*Flight crew do not correctly manage aircraft to maintain or achieve clearance'*. One of the '*Control Measures Required*' listed was '*adherence to SOPs with regards to automation'*. Another threat described was a '*navigation error based on incorrect content within navigation database'*. A listed control measure for this threat was that the '*database provider's quality assurance process eliminates errors'*.

A further threat listed was '*flight crew continue approach below MDA/DH*[101] *without visual references*'. One of the control measures listed was '*flight crew adherence to SOPs*'. Most of the risk ratings assigned to each threat included on the completed Risk Assessment Form were assigned a lower residual risk rating, yet the form does not refer to any additional measures to be implemented as a result of the Risk Assessment.

The Operator informed the Investigation that all pilots completed a computer-based-training presentation on CFIT every 24 months. Records indicated that both the Commander and the Co-pilot completed this training on 21 September 2016. The Operator provided the Investigation with a copy of the 64 page presentation that was used for CFIT training. The Investigation reviewed the presentation and noted the following extracts:

> '*There are two basic causes of CFIT accidents; both involve flight crew situational awareness*
>
> > *The lack of vertical position awareness, and/or*
> >
> > *The lack of horizontal position awareness in relation to the ground, water, or obstacles*
>
> *More than two-thirds of all CFIT accidents are the result of altitude error or lack of vertical situational awareness*
>
> *CFIT accidents occur during reduced visibility associated with instrument meteorological conditions (IMC), degraded visual environment (DVE), darkness, or a combination of conditions*
>
> *The procedure most susceptible to reduced situational awareness is the non-precision, step down approach*
>
> *Vertical position awareness is critical*
>
> *The vertical profiles* [in known CFIT accidents] *are significant, as they tend to follow a relatively constant 3° descent path until impact*
>
> *Autoflight systems can be misused, may contain database errors, or may be provided with faulty inputs by the flight crew. These systems will sometimes do things that the flight crew did not intend for them to do.*
>
> *While the Autoflight System may help to reduce overall workload, flight crew can become dependent on the automation.*
>
> *To assist flight crews, instrument flight rule enroute charts and approach charts provide*
>
> > *Minimum Safe Altitudes (MSA)*
> >
> > *Minimum Obstacle Clearance Altitudes (MOCA)*
> >
> > *Minimum Enroute Altitudes (MEA)*
> >
> > *Emergency Safe Altitudes (ESA), and in most terminal areas, actual heights of the terrain or obstacles.*
>
> *The potential for CFIT is greatest in the terminal areas.*'

---

[101] **MDA/DH**: Minimum Descent Altitude/Decision Height.

On 7 February 2018, the Investigation asked the Operator if the CFIT Risk Assessment had been updated since the accident. On 31 October 2018, the Operator informed the Investigation that the RA for CFIT '*was updated in Dec 2017 and brought into the latest RA form*.' The Risk Assessment had been updated and the Operator provided a copy dated 7 December 2017. The Operator informed the Investigation that:

'*Some of the more salient changes as part of the review were:*

- *The addition of current Accountable Manager and Safety & Compliance Manager;*
- *Ongoing change to the route guides including FSI's issued were included;*
- *The procedures for identifying and correcting any navigation system errors (charts, etc.) were added.'*

The Investigation also reviewed the three other Risk Assessments provided ('*Airborne Conflict*', '*Loss of Control leading to aircraft unintentionally deviating from normal in-flight parameters*' and '*Ground Handling leading to significant ground damage undetected prior to aircraft commencing take-off*').

None of the three Risk Assessments referred to any additional measures to be implemented as a result of the Risk Assessments. Furthermore, these three Risk Assessment Forms contained several anomalies: All three forms referred to a competency requirement for one of the Dublin-based risk assessment team members as '*Overview of Training UK'*. The Ground Handling form and Loss of Control forms contained the same anomaly. The '*Base*' section of the Risk Assessment Form for '*Ground Handling leading to significant ground damage undetected prior to aircraft commencing take-off*' refers to '*All* [named sister company's] *bases'*.

In relation to the four Risk Assessment Forms completed in 2015, the Investigation asked the Operator to provide copies of the qualifications or Competence Assessment of those conducting the Risk Assessments. The Operator informed the Investigation that '*The risk assessment is in-house and the skillsets and experience levels of those involved is well-known* [within the Operator]', and that: '*We would not routinely need to gather formal 'qualifications' or 'competence assessments' when using nominated persons who are acceptable to the IAA through their core roles.'*

Each of the 2015 Risk Assessments listed an assessment team of four or five persons. The 2015 assessment team included a Lead Assessor and the Post-Holder who signed the completed assessment. The Investigation established that other members of the assessment team had no recollection of being involved in the Risk Assessments in question. All four Risk Assessments were completed and signed off within one day.

The Operator subsequently provided copies of Risk Assessments which were carried out on earlier dates, many in 2012.

All Risk Assessments provided were on the Operator's form QAL1053, Issue 2. However, the revision date on the form used for 2012 Risk Assessments was '*7/6/2008'* while the 2015 Risk Assessments had a revision date of '*29/02/2008'*, and the two forms were different in appearance.

Safety Recommendation IRLD2018002 — Operator's Safety Management System

Based on a review of the Operator's Safety and Compliance Monitoring Manual; Minutes from 55 meetings of the Operator's ORB between January 2011 and March 2017; minutes from 130 Base Flight Safety Meetings held between January 2012 and December 2016; a number of risk assessment documents provided to the Investigation and a number of SQID reports on a range of topics, the Investigation, in its First Interim Statement, issued Safety Recommendation **IRLD2018002** relating to the Operator's Safety Management System.

> CHCI, with external input, should conduct a review of its SMS and ensure that the design of its processes and procedural adherence are sufficiently robust to maximize the safety dividend; this review should consider extant risk assessments and a thematic examination of the corpus of all safety information available to the Operator, both internally and externally (**IRLD2018002**).

The response associated with this Safety Recommendation is presented in **Appendix G** to this Report.

1.17.5 Fatigue Risk Management System

ICAO defines a Fatigue Risk Management System (FRMS) as '*a data-driven means of continuously monitoring and maintaining fatigue related safety risks, based upon scientific principles and knowledge as well as operational experience that aims to ensure relevant personnel are performing at adequate levels of alertness*'.

The Australian Civil Aviation Safety Authority (CASA), in 2010, said that while not an essential component of an FRMS, bio-mathematical models of human fatigue are a useful tool, incorporating aspects of fatigue science into scheduling through predictions of fatigue risk levels, performance levels, and/or sleep times and the provision of opportunity for rest.

OMA states '*All flight crew shall be provided with initial and recurrent fatigue risk management training in accordance with the syllabus outlined in section 'Fatigue risk management' in OMD vol 1 chapter 2*.' OMD vol 1 chapter 2 stipulates that FRM training '*shall be provided for all flight crew during initial company training and thereafter on a recurrent biennial basis'* and it goes on to outline the topics to be included in the training syllabus. All of R116's Crew members had completed Fatigue Risk Management training, as set out in **Section 1.5**.

Issues related to rostering arrangements and potential fatigue implications, were recorded in BFSM minutes and SQID reports. A recurring theme centred on personnel requesting the scientific basis for the shift patterns which were being operated.

Concerns were also raised regarding the arrangements to cover personnel shortages at one base by having a person from another base drive to that base, to complete a 24 hour rostered duty and then drive home again afterwards. The Investigation is aware that the issue had been the subject of significant correspondence between interested parties including the Operator, the Regulator, the IRCG and Operator's personnel. The Operator informed the Investigation that '*personnel covering other bases were always offered alternative accommodation in the immediate vicinity of the base prior to and following on from their shift*.'

The IAA Issued AN O.58, '*Flight Time Limitations (FTL) and Rest Requirements for crew members (Helicopters)',* which set out the parameters governing an IAA-approved FTL scheme. In 2010, the Operator requested a variation to its IAA approved FTL scheme; this variation included, *inter alia*, a factoring of standby time to allow the first six hours to be factored by a quarter (i.e. only a quarter of the time was counted), and the remainder of the standby period to be factored by a half. It appears that this variation was sought by the Operator because the IAA found that some of the Operator's personnel were in breach of the 2,000 hours maximum annual working time for any crew member as set out in Statutory Instrument 507 of 2006, '*European Communities (Organisation of Working Time) (Mobile Staff in Civil Aviation) Regulations 2006*'.

In July 2010, the IAA agreed to a temporary variation based on the Operator providing, *inter alia*, '*supporting scientific research (sleep study)'*. A study was commissioned by the Operator's staff representative associations, with support from the Operator and the IAA. The IAA was invited to attend a presentation on the study's findings, by its authors, but declined to attend; internal correspondence indicates that the IAA was concerned not to be drawn into a confrontation between the Operator, its staff and the staff representative associations. A copy of the sleep study was provided to the IAA by the Operator.

The study concluded that there was no difference in the sleep quality or amount of sleep accrued by SAR Crew members based solely on the location where they slept (i.e. on-base or at home).

The study found that SAR Crew members in the study accrued less sleep than that recommended by the US National Sleep Foundation and that this may not be enough sleep for optimal operational duty. The study made recommendations that further work be carried out; the Investigation found no evidence that these recommendations were implemented. On 29 June 2012, the IAA issued an approval for the Operator's variation of the requirements of AN O.58; this variation applied to provisions in Section 7 of the then extant OMA (which included SAR at Section 7.22), and the HEMS limitations in the then extant OMG. The IAA approval stated '*This variation shall remain in force so long as* [the Operator] *has in place a Fatigue Risk Management Programme acceptable to the Authority'*. The approval was to be re-assessed at a date not later than 12 months after the implementation of the Fatigue Risk Management Programme; no evidence was provided to the Investigation to demonstrate that such a re-assessment took place.

Fatigue management training was provided for a number of personnel in June 2012, and periodically thereafter. On 19 October 2012, the IAA asked the Operator for an overview of the implementation programme for its FRMS to date, and details of the next phase. The Operator provided a report, dated August 2012, of a study that an FRMS consultancy conducted, titled '*Enhancing Fatigue Risk Management at* [Operator's name]*: Gap analysis, FRMS Implementation Plan and Assessment of Sleep accommodation*.' The Operator said that it was meeting with the FRMS consultancy on 28 November 2012 to carry out the next phase which was a risk assessment.

The August 2012 implementation plan which was presented to the IAA incorporated a pivotal role for an FRMS manager. The Investigation notes that neither the Operations Manuals nor the SMCMM identified who the FRMS Manager was. Furthermore, the Investigation found no evidence that the Operator had implemented an FRMS.

In April 2014, an email thread between some Post-Holders indicated that there was concern that the Operator was not fully adopting FRM policy, and that this may have been an issue with regard to the Operator's HEMS approval. It also appears, at that time, that some Post-Holders were unsure who the members of its FRMS Committee were. The thrust of the email thread was focused primarily on the need to ensure that individuals received FRM training, rather than on FRMS implementation.

In 1994, the FAA published A-94-1 through -5, titled '*FAA review of accident factors and fatigue'* which found that:

> '*Prior wakefulness, characterized in this study as time since awakening prior to the accident, is one of several factors researchers have associated with increased vulnerability to fatigue. In the accidents examined in the Board's study, half the captains for whom data were available had been awake for more than 12 hours prior to their accidents. Half the first officers had been awake more than 11 hours.*
>
> *Where possible, other fatigue-related factors were explored for their possible influence on flightcrew performance. These other factors include time of day, time zone crossings, and changing work schedules.*
>
> *Of the factors regarded as contributing to an increased vulnerability to the effects of fatigue, significant differences in performance, in terms of the number and types of errors made by pilots, were observed only for the measure of prior wakefulness; that is, time since awakening. Crews comprising captains and first officers whose time since awakening was above the median for their crew position* [12 hours for captains, 11 hours for first officers] *made more errors overall, and significantly more procedural and tactical decision errors'*.

In 2013, the CASA published a report titled '*Fatigue-The Rules Are Changing'*. That report stated:

> *'On-the-job performance loss for every hour of wakefulness between 10 and 26 hours is equivalent to about a .004 per cent rise in blood alcohol concentration. Seventeen to 18 hours of wakefulness is usually considered to be equivalent to a blood alcohol concentration of about .05 per cent. In the safety-critical aviation environment, this could result in tragedy.*
> [...]
> *People are notoriously poor judges of their own level of fatigue. Asking a fatigued person if they are OK to keep working is a bit like asking someone who is drunk if they are OK to drive*.
> […]
> *There is no blood test for fatigue.*

> *A 'can-do' attitude – 'We are paid to do our job, so we can handle it' – can be very dangerous.*
>
> *You cannot train yourself to need less sleep and you cannot store sleep*.'

OMA states '*A crew member shall not perform duties in flight if he knows or suspects that he is suffering from fatigue, or feels unfit to the extent that the flight may be endangered*[102]'.

OMF states '*The commander on the support SAR helicopter should be aware of the potential for fatigue to set in quicker than on a SAR helicopter due to the somewhat monotonous nature of the mission*.'

In summary, the FAA and CASA information highlights hours of prior wakefulness are correlated with increased error rates and judgment lapses, in personnel who are awake for longer than 10 hours and that it is not possible for personnel to accurately assess their own fatigue level or to store sleep.

EASA Certification Specifications and Guidance Material for Commercial Air Transport by Aeroplane — Scheduled and Charter Operations, CS-FTL.1 states '*The operator's standby procedures are designed to ensure that the combination of standby and FDP do not lead to more than 18 hours awake time*.'

The Investigation notes that this (CS) is '*applicable to commercial air transport by aeroplanes for scheduled and charter operations, excluding emergency medical service (EMS), air taxi and single pilot operations*.'

1.17.6 IRCG Oversight

IRCG informed the Investigation that ''*Irish Coast Guard (IRCG)*' *means The Minister for Transport, Tourism and Sport of Ireland, being the Minister administering the Department of Transport Tourism and Sport, a division of which is the Irish Coast Guard.*' The Investigation notes that the Contract under which the Operator provided SAR services stated '*The Minister has responsibility for the Irish Coast Guard (IRCG), a Division within the Department. References to the IRCG and the Department shall be deemed to be references to the Minister unless the context otherwise requires*.' The Investigation interviewed members of the IRCG in relation to the operation of Irish Coastguard helicopters. The Investigation also reviewed the IRCG/Operator audits and meeting minutes for a number of years prior to the accident.

[102] The Investigation notes that this text comes directly from EASA CAT.GEN.MPA.100 c(5); EASA ORO.FTL.120 Fatigue Risk Management (FRM) requires operators to '*establish, implement and maintain a FRM*' which corresponds to '*the flight time specification scheme, the size of the operator and the nature and complexity of its activities, taking into account the hazards and associated risks inherent in those activities and the applicable flight time specification scheme*'.

1.17.6.1 Aviation Expertise and Independent Auditing

The IRCG informed the Investigation that it did not have aviation expertise available on its staff. The IRCG had for many years contracted an external consultancy to provide it with aviation expertise, advice and auditing of the Operator's bases. The contract with the external consultancy set out the contractor's responsibilities which included:

- Providing advice to the IRCG on all aspects of the operation of helicopters and aviation matters
- The development of Standard Operating Procedures (SOPs)
- Undertaking safety reviews of IRCG and the helicopter Operator
- Attending and acting as secretary at helicopter operational meetings between the IRCG and the Operator
- Overseeing the transition to the new contract with the Operator which commenced in 2012/3.

The Auditor subsequently informed the Investigation that:

> '*At the time of the accident there was no contract in place. This had expired the previous January and the IRCG had begun a process to find a replacement. This process was halted by the IRCG at the time of the accident and the external consultancy was asked to informally stand in to cover the post-accident period until a replacement was found later in the year*.'

In relation to the oversight of the transition to a new contract in 2012/3 between DTTAS and the Operator to operate SAR helicopters, the Auditor's contract stated:

> *'The Contractor will be required to oversee the transition from the current helicopter search and rescue contract to the new contract in 2012/3. Participation in the development of an agreed Transition Plan for the implementation of the rollout of services at each of the bases, assessment of aircraft, aircrew, maintenance and support services, and base and aircraft operational readiness will be required.'*

The Investigation notes that an email titled '*Sligo Final Audit – Report*', dated 21 June 2013, to the IRCG from the Auditor stated,

> '*Because of the already crowded transition programme and the loss of the final fortnight of training (ITAR*[103]*), I want* [named Post-Holder] *to declare formally that his people and facilities are ready to go live. He has to take that responsibility in the event that the now overt commercial pressure to get started has overridden safety. In my view the crews are well prepared but I only know what I feel and what they are prepared to tell me; they have their finger much closer to the pulse of the individuals. At some stage,* [Named Post-Holder] *will therefore send you a letter confirming all areas of* [the Operator] *are ready to commence S92 ops at Sligo.'*

[103] **ITAR**: International Traffic in Arms Regulations.

On reviewing the IRCG audit reports for several of the past years, the Investigation noted that some reports contained non-alpha-numeric characters, the meaning of which was unclear. When the IRCG was asked to explain these characters the Investigation was informed that these were '*unprintable*' characters. The Investigation asked how the IRCG could have reviewed these audits if these were unprintable characters and it was not known what purpose, if any, they served. IRCG accepted that it would not have been possible to fully review such audit reports. The Auditor informed the Investigation that:

> '*It is believed that these unprintable characters were tick marks that used a font that the IRCG computers seemed not to have downloaded. In any event, printed audit reports were provided to the IRCG that showed these correctly and were handed over by the external consultancy at the regular meetings with IRCG in Ireland*.'

In relation to insurance, the contract between IRCG and the Operator stipulated a nominal lower limit for insurance, in Euro, '*for each Helicopter in respect of any one accident or series of accidents arising out of one event and unlimited as to the number of claims in any one year.*' However, certificates gathered as evidence during audits indicated that, while the nominal combined single limit for any one occurrence was the same as the nominal value specified in the Contract, the insurance currency was US dollars and not Euro. The Investigation did not find any evidence that this variation (US dollars instead of Euro) had been agreed between the parties, or had been identified during any audits.

While the contract for independent auditing services called for safety reviews of IRCG to be undertaken, the IRCG informed the Investigation that no reviews of IRCG were requested.

189 The Investigation noted that IAMSAR Manual, Volume I, stated '*Appendix H contains a national self-assessment questionnaire which may be used to evaluate international and national SAR systems, to identify areas for improvement, and to assist SAR managers in assessing needs*.' The Investigation asked IRCG for copies of the last three Appendix H self-assessments undertaken by the State prior to the accident. No document following the format of Annex H was provided, although a number of documents dating from 2010 were provided. One of these was an Operational Standards Audit Report – Irish Coastguard, dated 23 February 2016, compiled by an international agency with significant expertise in coast guarding activities.

The report contained 15 findings and stated '*I would recommend that the senior management team draw up an action plan based on the initial findings and set priorities, timescales and responsibilities that are monitored until complete*.' The Investigation asked for details of the implementation plan and was provided with three documents, the earliest of which was dated June 2018, more than two years after the audit report.

The Investigation notes that '*THE NIMROD REVIEW An independent review into the broader issues surrounding the loss of the RAF Nimrod MR2 Aircraft XV230 in Afghanistan in 2006'*, undertaken by Charles Haddon-Cave QC contains findings and deliberations which have relevance and resonance for the current Investigation. In particular, Haddon-Cave identified that contracting-out must be managed carefully and that the agency which contracts-out activities must retain sufficient and appropriate expertise to allow it to be an '*intelligent customer'*. Haddon-Cave recommended that there must be sufficient numbers of suitably skilled and qualified personnel '*in-house*', to avoid routinely sub-contracting analysis and decision-making.

1.17.6.2 IRCG Safety Management System

The Investigation asked the IRCG for details of its Safety Management System. The IRCG informed the Investigation that '*the lack of a dedicated H&S Officer has precluded development of a Safety Management System'*. The Investigation notes from this response that there is a possible confusion/conflation of the functions of '*Health and Safety'* and '*Safety Management Systems'*. IRCG management completed their first aviation Safety Management course in October 2018.

The Investigation notes that a Marine Casualty Investigation Board (Report MCIB/266), published on 7 December 2018, concluded that the '*IRCG does not have an effective safety management system*'. IRCG in its response to the MCIB report stated:

> '[…] *IRCG volunteers have undertaken over a million "man-hours" on duty. In that we have had otherwise no loss of life or severe injuries, we believe these facts demonstrates a robust risk awareness culture and further reassures that the safety of staff and volunteers is integral to every operation undertaken by IRCG*'.

Social Psychologist Dr Rob Long wrote of the care that must be taken when describing safety systems, cautioning that:

> *'The use of silly and meaningless safety language matters, it creates a distraction and delusion that safety and risk are being addressed. We may feel good about speaking such words but they dumb down culture and distract people from taking safety seriously.'*

1.17.6.3 Communications between IRCG and the Operator regarding Safety

In May 2008, an IRCG audit report contained the observation that:

> '*the IRCG is recommended to support the SMS process by sending a representative from the local RCC* [Rescue Coordination Centre] *to the Safety Meeting at each base. The meetings occur monthly but a 3-monthly attendance by operations officers and controllers would enable them better to understand some of the problems facing* [the Operator] *and to make a contribution to the safety and effectiveness of their local operation'*.

The matter was subsequently discussed at an IRCG/[Operator] meeting on 30 October 2008. The Minutes record the following, '*Observation IRCG 02/08 (IRCG support of the* [Operator] *SMS process). Attendance of RCC staff at monthly base flight safety meetings was an inappropriate means of developing a strong relationship between the crews and the controllers.*' The associated action read: '*Action:* [the Operator] *would encourage captains to include the RCC in post-mission debriefs, and Chief Pilots (particularly Dublin and Waterford) to visit the RCC at monthly intervals to discuss missions and procedures. The Chief Pilots at Shannon and Sligo would be encouraged to continue the existing regular liaison with their RCCs.*'

Contractual compliance audit reports from 9 November 2012 and 10 September 2013 noted the Operator's undertaking to '*Hold safety meetings and provide copies of the minutes to the* [IRCG senior manager]. *All Contractor's Personnel who operate in Ireland and are principally assigned to the IRCG contract shall attend at least two meetings per year.'* The audit reports recorded that '*Minutes were reviewed for Shannon, Sligo, Waterford and Dublin'* but no mention was made of providing minutes to the IRCG senior manager nor of any system which the Operator had put in place to monitor that personnel were attending at least two meetings annually.

1.17.6.4 Tasking

The May 2008 IRCG audit report included the following with regard to tasking of helicopters:

> '*Observation IRCG 01/08: Last year, all RCCs were recommended to call out a helicopter at the earliest opportunity in any developing incident. Even if frequently turned back, the additional chance to practice planning and launching rescue sorties provides an important contribution to crews' training, efficiency and safety without exceeding the budgeted flying hours.*'

1.17.6.5 Fatigue Management

The topic of fatigue management was discussed at a number of meetings between the IRCG and the Operator. The minutes of the November 2008 meeting recorded the following:

> '[The Operator] *expressed concern that the Organisation of Working Time Act* [OWTA] *could remove the current dispensation to count standby time at 50% and impose a 2000 hour per year limit on crew duties; this would require the employment of 20-25% more crews. OWTA had been imposed in UK, where SAR was operated under dispensations to the regulations for Commercial Air Transportation, but the IAA approved SAR under the less stringent protections of Aerial Work.'*

In 2009, the IRCG sought legal advice on this issue. They wished to ensure that SAR aircrew were exempt from OWTA and considered seeking an amendment to S.I No. 52 of 1998 – Organisation of Working Time (Exemption of Civil Protection Services) Regulations, 1998, to achieve this. The IRCG wanted to use the OWTA limits as '*best practice*' for aircrew, but to allow crew to exceed those limits when the demands of the SAR service required it. In any event, an IAA letter of 19 February 2010 recorded that the IRCG had advised that they had requested the Minister for Transport to process an exemption to the requirements of S.I. 507 of 2006 for the Operator's personnel engaged in SAR duties on behalf of the State, but that they had been unsuccessful in achieving an amendment.

A second topic of discussion relating to fatigue management was that of the provision of accommodation for on-shift aircrews. The report of the 23 October 2015 Dublin SAR Base audit contained a finding that:

> '*There is an urgent need for 3 bedrooms and a female changing room and shower/toilet. Whilst these are planned for the new build, there is an urgent requirement for an interim solution. Crew are not getting adequate rest if called out in the night and sleeping on a sofa is not a valid option.*'

The Investigation understands that at the time of the accident, this issue had been addressed by the provision of temporary, prefabricated accommodation at the Dublin SAR Base.

1.17.6.6 Top Cover

Traditionally, Top Cover was provided by long-range fixed wing aircraft, which had greater endurance/'*persistence*' than the primary SAR helicopter. The Top Cover aircraft usually arrived on scene before the SAR helicopter (due to higher transit speed); identified the casualty vessel; established communications with both the casualty vessel and the SAR helicopter; briefed the casualty vessel's crew on communications frequencies, etc.; provided on-scene weather and navigation vectors to the SAR helicopter; and maintained over-watch until the SAR helicopter had completed its mission and was sufficiently close to shore. The roles of the Top Cover aircraft are critically dependent on it having significantly greater endurance than the SAR helicopter.

The DTTAS website published a Service Level Agreement (SLA) between the Department of Defence (DoD) and DTTAS, which was signed in August 2013. This SLA dealt, *inter alia*, with the roles of IRCG and IAC (Irish Air Corps) *vis-à-vis* SAR. The SLA stated '*Provision and tasking of Air Corps assets on an 'as available' basis*.' An annex to the SLA set out a range of areas where IAC might provide assistance, on an '*as available*' basis, to IRCG; one such area was the provision of Top Cover.

The minutes of the November 2008 meeting between the IRCG and the Operator stated:

> '*The Top-Cover Study Group (footnote) had produced a report showing that top-cover had been requested for 14 out of 179 incidents and had been available on nine occasions. On the other five, either the CASA* [an Irish Air Corps, fixed-wing, maritime patrol aircraft] *had been unserviceable or the Nimrod* [a UK Military maritime patrol aircraft, now withdrawn from service] *had arrived too late. No missions had been cancelled for lack of top-cover.*
>
> […]
>
> *In the absence of fixed-wing aircraft,* [the Operator] *agreed that the only feasible option was for another* […] *helicopter* [from the Operator's fleet] *to shadow the rescue mission, providing a limited improvement in comms and a rapid rescue service in the event of an accident to the prime helicopter.* [IRCG] *accepted that dedicating two helicopters to a single incident would reduce availability for other incidents and could impact on availability the next day. Of the other possibilities, the IAC and RAF* [Royal Air Force] *services could not be guaranteed or enhanced and the provision of a Coast Guard fixed-wing had been assessed in 2003 and was unaffordable.'*

The Investigation notes that the IRCG Helicopter Standard Operating Procedures (SOPs), state:

> '*If the scene is more than 80 miles from shore, the Duty Controller should attempt to arrange Top-Cover by an IAC Casa or French Coastguard fixed-wing. The Top-Cover's greater height improves communications with the RCC, reduces the workload on the helicopter crew, and reduces search time by directing the rescue helicopter to the scene. The Top-Cover should be designated as OSC* [On Scene Commander]*;* […]

15.2. If a fixed-wing aircraft will not be available in time, the rescue helicopter commander may request the RCC to launch a second S92 helicopter to shadow the rescue helicopter.

15.2.1. The decision to request the Shadow Helicopter will be based on the urgency of the operation, current and forecast conditions (daylight, cloud base, visibility, temperature and sea-state) and mitigations including waiting for the target vessel to steam closer, back-up by UK or French fixed wing and ships in the area.

15.2.2. The Shadow Helicopter will be positioned by the Rescue Helicopter in the optimum location to provide a communications link and to assist in the event that the rescue helicopter is ditched.

15.2.3. The Shadow Helicopter will be launched from the most appropriate base – probably Shannon for Waterford and Sligo rescues, Waterford for Shannon rescues south of N52 [line of latitude] *, and Sligo for Shannon rescues north of N52.30* [line of latitude]*. The Shadow Helicopter will launch with maximum fuel and fly for maximum endurance.'*

In contrast, the Operator's OMF states:

'Though not a mission requirement, top cover should normally be requested when operating at ranges greater than 120 nm from the coast, or at the commander's discretion depending on the circumstances of the individual mission.

Top cover

Top cover is usually provided by military organisations using suitably equipped fixed wing maritime patrol aircraft. Its assistance will speed up the rescue by minimising the search. Helicopter long range communication quality is often unreliable and the SAR helicopter crew's workload will be considerably eased by maintaining a communications link through the top cover aircraft on VHF marine.

[...]

3.17.4 Support SAR helicopter

Support SAR helicopter refers to a second SAR helicopter which is tasked to provide support for the primary SAR helicopter, which has been tasked on a long range offshore mission. A long range mission is one where a Company helicopter has been tasked beyond 120 nm from the coast. There will be a designated support SAR helicopter on 15-minute readiness for any such mission, regardless of the availability of top cover. The request for the support SAR helicopter shall be made to the MRCC by the commander of the primary SAR helicopter on accepting the mission.

[…]

Support cover sectors:

To assist crews and MRCCs in the selection of the most suitable base / helicopter, the country shall be split into four sectors by two continuous lines passing through the following points:

__a.__ Line 1 NW – SE:

__i.__ Point 1: N 56.16 W 010.00

__ii.__ Point 2: N 50.42 W 006.00

__b.__ Line 2 NE – SW:

__i.__ Point 1: N 52.40 W 010.00

__ii.__ Point 2: N 53.42 W 06.00

This provides four sectors in which two aircraft will provide mutual support cover as required.

__a.__ Northeast sector: Dublin – Sligo

__b.__ Northwest sector: Sligo – Shannon

__c.__ Southeast sector: Waterford – Dublin

__d.__ Southwest sector: Shannon – Waterford

These sectors do not preclude a commander from requesting a different aircraft if they feel it is in a better position to assist the SAR operation for any given weather conditions.

Top Cover effectiveness was one of the items on the IRCG audit checklist and the findings made varied from year to year and base to base (**Table No. 26**).

Base	2014 Audit	2015 Audit	2016 Audit
Sligo	IAC fixed wing often not available. >100nm use Waterford	IAC fixed wing often not available. >100nm use Shannon	IAC fixed wing not available. >100nm use other SAR base
Shannon	IAC fixed wing often not available. >100nm use Waterford	IAC fixed wing often not available. >100nm use Waterford	IAC fixed wing not available. >100nm use Waterford
Waterford	IAA [sic] not always available so sometimes use other IRCG Helicopter assets	IAA [sic] not always available so sometimes use other IRCG Helicopter assets	[no audit completed]
Dublin	[no entry]	[no entry]	[no audit completed]

Table No. 26: Audit Findings – Top Cover criteria

Regarding the choice of SAR base for tasking (including Top Cover) the IRCG informed the Investigation that there was an ongoing understanding between IRCG and the Operator with regard to distribution of workload between west coast bases (Shannon, Sligo) and east coast bases (Waterford, Dublin). The IRCG's rationale for this understanding was stated to be due to the higher level of operational demand on west coast helicopter operations. IRCG said that RCC staff would have been encouraged whenever practical to task east coast bases where a suitable option arose. Contract meeting minutes did reflect some of these sentiments, for example:

- *'Hospital Transfers.* [The Operator] *requested that where possible planned Hospital Transfers be assigned to Dublin or Waterford SAR Bases. This was due to the greater demands on Shannon and in Sligo. Action 16/15: IRCG.*

- *Tasking optimisation. Action 15/29: IRCG to discuss considerations for the optimum base to be tasked for SAR and HEMS call outs and a SOP covering these aspects to be drafted. Focus is to task the east coast helicopters* [to the] *west more often when time allows'.*

The Investigation notes that action item 15/29 was included in the minutes of a meeting which occurred on 8 March 2016. The same minutes included an action regarding '*Updating IRCG Standard Operating Procedures*'. The revised SOPs, dated 25 April 2016, did not reflect Action Item 15/29 regarding prioritising the tasking of east coast helicopters.

The Investigation also notes that there does not appear to have been a Safety Case or Risk Assessment completed regarding the proposal to increase the rate of tasking of east coast helicopters by tasking them to carry out more missions in the west, outside their normal area of operation.

1.17.6.7 IRCG Service Level Agreements

The Investigation notes that DTTAS had entered into a number of Service Level Agreements (SLAs) with other agencies. The SLA with the Department of Health, for the provision of an Aero-Medical service, specifically stated that the IRCG '[…] *has overall responsibility for Irish Coast Guard aviation safety and operational standards';* IRCG management completed their first aviation SMS training in October 2018. The Investigation also notes that the SLA in question refers to '*Mission compliance with Coast Guards AOC';* however, the IRCG did not, and does not, have an AOC (Air Operator's Certificate). The SLA also said '*In general the Waterford and Dublin Bases will be prioritised as HEMS and inter-hospital transfer aircraft in order to maintain Atlantic readiness on the North, West and South West approaches by the Shannon and Sligo bases.*'

The following graph (**Figure No. 45**) shows the distribution of HEMS missions by SAR base for the years 2014 to 2017 (inclusive) and indicates that the Shannon and Sligo bases carried out the majority of HEMS missions:

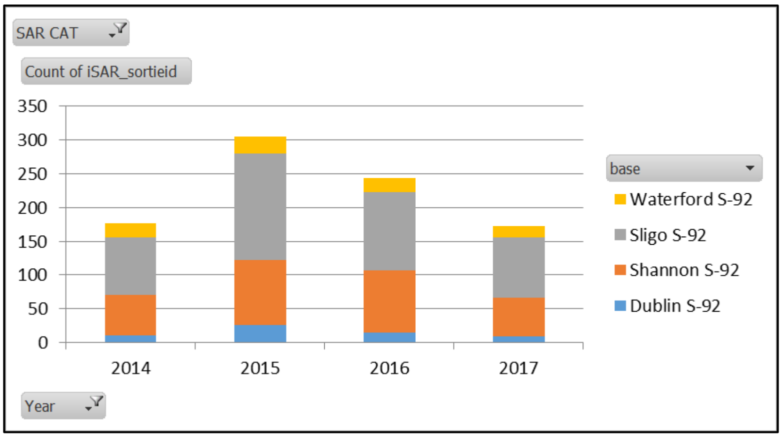

Figure No. 45: HEMS missions by base 2014-2017

1.17.6.8 Corporate Identity

During the review of the IRCG's meeting minutes and standard operating procedures, the Investigation noted the following with regard to promoting a positive public image of the IRCG:

- IRCG/[Operator] meeting minutes dated 30 October 2008 and 2 November 2011 discussed the provision of IRCG branded uniforms and an associated rank structure for aircrew. The S-92A contract also stipulated that aircrew uniforms must show the IRCG logo and must not display any corporate logos. Similar stipulations applied to helicopter liveries.

- The July 2013 meeting minutes recorded that the IRCG again impressed on the Operator that filming of rescues from cabin and head-cams was an important part of justifying to taxpayers both the role and the costs of the Coast Guard. This was a recurrent theme in the minutes of many meetings.

- The IRCG Standard Operating Procedures for Helicopter Operations stated that filming from aircraft and head-cams was an important part of demonstrating to the public both the varied and often difficult roles and the cost benefit of the Coast Guard helicopter service; and that whenever crews believed they had captured video of interest to the IRCG (and the media), the relevant section was to be downloaded and transferred to IRCG HQ or RCC as quickly as possible.

1.17.6.9 IRCG Memo Regarding Helicopter Types

In a memo to the Minister for Transport in 2011, the IRCG referred to the role of the IAA in the regulation of SAR and said that EASA would take control of the regulation of all commercial air transport operations in 2012, but that SAR was defined as a state activity regulated by National Aviation Authorities (identified as the IAA). The memo went on to say that the IAA had not allowed S-61N helicopters to provide a full national casualty recovery service on grounds of risk, and that the IAA had pressed for modern, safer helicopters to be brought in. The Investigation found no documentation to support the IRCG view that the IAA had pressed for modern, safer helicopters to be brought in.

1.17.7 European Regulation

The European Commissioner for Transport has responsibility for developing common EU standards for transport safety and security to improve the international environment for transport. SAR is an essential aspect of transport (particularly aviation and maritime) and is an obligation under international treaty.

As stated in **Section 1.17.2**, Search and Rescue is currently regulated at a national level, and is therefore not included in Commission Regulation (EU) No 965/2012 or other EU civil aviation safety regulations. However, with the adoption of European Regulation (EU) No 2018/1139 of the European Parliament and of the Council of 4 July 2018, Member States of the EU now have the possibility to apply EU civil aviation safety regulations to aircraft, organisations and personnel involved in search and rescue operations.

This Regulation explains, at Recital 10:

> *'Where Member States consider it preferable, in particular with a view to achieving safety, interoperability or efficiency gains, to apply, instead of their national law, this Regulation to aircraft carrying out military, customs, police,* ***search and rescue****, firefighting, border control and coastguard or similar activities and services undertaken in the public interest, they should be allowed to do so. Member States making use of this possibility should cooperate with the Agency, in particular by providing all the information necessary for confirming that the aircraft and activities concerned comply with the relevant provisions of this Regulation.'* [Emphasis added]

This opt-in possibility is regulated in Article 2(6) of European Regulation (EU) No 2018/1139.

The AQE Report, in response to AAIU Safety Recommendation IRLD2018003, noted this '*opt-in*' possibility and furthermore made a recommendation that DTTAS considers the potential merits of engaging with the EU/EASA and using their regulatory framework and rulemaking processes as an opportunity to develop Europe-wide guidance on creating an effective civil SAR Framework.

The Investigation also considers that there is merit in EASA being involved in the regulation of civilian SAR aviation activities and was minded to recommend that EASA should undertake such rulemaking tasks as were necessary, to devise and promulgate role-specific guidance and acceptable means of compliance for states that decided to apply 2018/1139 to Search and Rescue. EASA advised the Investigation that Article 2(6) of European Regulation (EU) No 2018/1139 established the conditions under which a Member State may decide to apply any, or any combination, of Section I, II, III, or VII of Chapter III of European Regulation (EU) No 2018/1139, to some or all activities which are normally excluded from the scope of European Regulation (EU) No 2018/1139, such as '*search and rescue operations*'. However, EASA went on to say that the provisions of Article 2(6) of the European Regulation (EU) No 2018/1139 did not mean that it was within EASA's remit to propose rules or guidance material for search and rescue operations or other activities listed in Article 2(3)(a) to which the European Regulation (EU) No 2018/1139 does not apply.

The Investigation notes that it is within the remit of EASA to certify (from an airworthiness standpoint) helicopter features suitable for SAR Operations. One such example from the S-92A is that EASA approved the FAA Rotorcraft Flight Manual which includes guidance on the use of SAR specific equipment such as the helicopter hoist. The Investigation was also informed by the Operator that the supplement to this manual which pertains to the SAR Automatic Flight Control System was first certified by EASA in 2007 because the first S-92A helicopters were operated in Europe.

1.17.8 Safety Recommendation IRLD2018003— Oversight of SAR Helicopter Operations in Ireland

1.17.8.1 Introduction

Prior to the publication of the Investigation's First Interim Statement, the Investigation engaged directly with the IAA, the Department of Transport, Tourism and Sport, IRCG, the Operator and EASA in relation to the oversight of SAR operations. Whilst the Investigation's examination of this oversight function was continuing, the Investigation believed that greater clarity regarding the individual and collective responsibilities for oversight of all aspects of SAR aviation operations in Ireland was required.

Accordingly, in its First Interim Statement, the Investigation made the following Safety Recommendation to the Minister for Transport, Tourism and Sport in relation to the Oversight of SAR Helicopter Operations in Ireland.

> The Minister for Transport, Tourism and Sport, as the issuing authority for the Irish National Maritime Search and Rescue Framework, should carry out a thorough review of SAR aviation operations in Ireland to ensure that there are appropriate processes, resources and personnel in place to provide effective, continuous, comprehensive and independent oversight of all aspects of these operations (**IRLD2018003**).

1.17.8.2 Response to Safety Recommendation IRLD2018003

The responses received prior to the issuing of the Investigation's Draft Final Report are presented in **Appendix G** to this Report. Furthermore, the Minister provided a comprehensive response which set out several measures that were taken following the accident. These were grouped under six headings (summarised by the Investigation):

1. Development of a new National SAR Plan following extensive review
2. Enhancing safety and oversight across the SAR system
3. Addressing SAR aviation oversight – nationally and internationally
4. Review and revision of all relevant Standard Operating Procedures (SOPs) and training for the IRCG personnel, particularly SAR Mission Coordinator (SMC) training with a focus on aviation tasking
5. Development of an externally accredited safety management system in the IRCG
6. Review of governance arrangements in relation to [the Operator], enhancing aviation expertise in critical areas and legislative reform of the IAA

Further details of these matters are contained in **Appendix U**.

1.17.9 Secondary Duties

The Operator relied on a '*secondary duties*' model to implement a large number of safety-critical functions (e.g. Route Guide management and updating) throughout its organisation.

The secondary duty model involves operational personnel, who are rostered for 24-hour SAR duties, being tasked with additional duties which are undertaken on an opportunity basis, when on SAR duty. The secondary duty model had certain inherent constraints: personnel were only available to carry out their secondary duties while on duty for their primary SAR role; primary SAR duties took priority over secondary duties; there was no formal back-up arrangement to ensure that the time-critical secondary duties would be carried out when the assigned person was not on duty; training for many of the roles was not prescribed.

The Operator recorded the assignment of secondary duties in a table which was to be updated at each base whenever duties changed at that base. There were approximately 95 actual secondary duty assignments, across the Operator's four bases.

SQID reports were submitted which highlighted issues with the secondary duty model, for example:

- A SQID, in December 2012, stated that 25 passenger lifejackets at a base were out of date. The root cause was attributed to *'Delay in appointment of SEO* [Safety Equipment Operative]' and the corrective action was *'SEO appointed and equipment sent for servicing'*.

- A SQID, in September 2012, highlighted that SEOs had lost access to an online system which was being used to track safety equipment, had no means of identifying equipment which was due servicing and that no safety equipment checks could be completed until the matter was resolved. The corrective action said that the reporter's access had been restored and that as this was the reporter's first shift since access had been restored he would attempt to catch up with outdated safety equipment needs.

The SQID closure text for these reports contained no recognition at a management level of the backlog issue, the outdated equipment, any support/mitigation to deal with the issue, or the systemic weakness of the secondary duty model.

The Investigation was informed that some of the secondary duties were particularly demanding. Specifically, the Investigation was informed by several of the Operator's personnel with whom it spoke that the Commander's secondary duty as the '*Pilot Roster writer*', was an onerous one which would have demanded attention, on and off duty. Many said that it would not be unusual for the Commander to be disturbed on days off because whenever short-notice issues arose with the pilot roster (e.g. a medical absence) it often fell to the roster writer to ensure an appropriate replacement was found. Indeed, a review of the Crew Members' activities in the 72-hours before the accident showed that the Commander had attended a meeting on her day off on Friday 10 March 2017 to make changes to the roster to release crews to attend the funeral of a colleague. The Operator subsequently informed the Investigation that the '*roster writer*' role is now completed by a stand-alone independent roster writer.

The Investigation was informed that role-specific training was not provided for some of the secondary duties specified (e.g. the personnel involved in Route Guide updating, Safety Equipment Crewman, Immersion Suit and Helmet servicing). The Operator informed the Investigation that '*many of the roles made best use of the core aviation/airmanship experience of those involved. While the Operator accepts that more formal training for certain positions may be beneficial, it does not agree that it needs prescriptive training for all aspects of each of the secondary roles*'. The Investigation was informed that all roles were undertaken on an opportunity basis, in addition to rostered SAR duties, and that no formal arrangements were in place to ensure that secondary duties were carried on in the absence of the assigned person. This was also identified in the 2012 SQID reports.

1.17.10 Toughbook and EO/IR Usage

The Operator explained that while there was no specific sign off for the Toughbook, it was included in a number of rear crew training syllabus items.

The Operator stated that Toughbook, by its nature, requires hands-on practice to attain competence and that this could be achieved by practice in the hangar on ground power, complemented by airborne training. Proposals had been made regarding specific Toughbook training but these were downgraded to discussion about training a trainer at each base. However, the Investigation understands that ultimately those proposals were not acted on. A detailed 82-page user guide was prepared and circulated, but a view was expressed by a number of personnel who spoke with the Investigation that detailed initial training along with regular practice and assessment would be required to ensure that appropriate standards were achieved and maintained.

The Investigation was also informed that no specific, manufacturer-provided, operational training was delivered to rear crew members in the use of the EO/IR camera system on the S-92A helicopter, although some rear crew members did attend manufacturer-provided EO/IR engineering training courses which were provided for engineering personnel. Rear crew had received manufacturer training for the FLIR system which was fitted to the S-61N. However, the Investigation was advised that the S-92A EO/IR system was more capable than the S-61N system and EO/IR manufacturer-provided training would ensure that best use could be made of the available system capabilities. On a related matter, the Investigation was advised that there was no specific rating required for rear crew before they were qualified to participate in a Radar/FLIR approach.

The Operator informed the Investigation that FLIR training is completed as part of the Winchman's Operational Conversion Course (OCC) ground school syllabus; it consists of briefing and hands-on familiarisation in the helicopter both on the ground and in the air. The Operator stated that use of the FLIR features extensively in the flying syllabus, there is an RFM supplement on the FLIR, and also a PowerPoint briefing. The Operator also stated that additional guidance on FLIR searches is given in numerous references throughout the OMF; furthermore, once a rear crew member is qualified he is required to complete Radar/FLIR approaches as part of his 90-day recency training as laid down in OMF.

1.17.11 EGPWS Database and Usage

EGPWS (**Section 1.6.6.5**) was developed from Ground Proximity Warning Systems (GPWS), a concept that originated in Europe in 1969; the intention was to give pilots an alert based on abnormal aircraft flight path and abnormal terrain clearances with respect to the ground or water. Following an accident at Washington Dulles airport in 1974, the FAA enacted an operational rule requiring all large turbo-prop and jet aircraft to be fitted with (GPWS) within one year.

As reported in the Investigation's Preliminary Report, the lighthouse at Black Rock was not in the EGPWS obstacle database, and the terrain at Black Rock was not in the EGPWS terrain database. The Investigation asked the Operator what, if anything, was known about the absence of Black Rock in the EGPWS databases.

The Operator provided the Investigation with a number of email threads from 2013. These email threads involve a number of the Operator's Flight Operations personnel, and some rear crew members. The main focus of the email threads was in relation to the updating of the Operator's Route Guide. This updating was undertaken in parallel with an updating of the Operator's internal/company database of waypoints.

The S-61N used three-character waypoint designators; however, the S-92A Flight Management System required five-character designators.

On 26 June 2013, one of the Operator's pilots emailed several other personnel, including some involved in the Route Guide/FMS updating projects, advising that the '*Blacksod South'* route (APBSS, the same route that EI-ICR was following at the time of the accident) was flown '*last night'* and it was noticed that Black Rock Lighthouse was not shown on the EGPWS. The pilot stated that at 310 feet high the lighthouse was an '*obvious hazard*' and suggested that although it was mentioned '*in the route notes*', the EGPWS issue should be *'highlighted as well'*. The pilot advised that the issue also applied to the Blacksod North route.

On June 27 2013, a different pilot emailed several of the same personnel, though not any of those involved in the Route Guide/FMS updating projects and advised, *inter alia*, that Inishmurray and Black Rock (Sligo bay) were not contained in the EGPWS databases.

On 28 June 2013, one of the Operator's pilots emailed the EGPWS manufacturer advising that '*a few Islands and lighthouses locally* […] *do not appear on the database. Is it possible to get these obstructions added to the database. If so how do we go about it?*' The EGPWS manufacturer replied the same day requesting further details. These details were provided on 2 July 2013. The email response to the Operator's pilot, on 2 July 2013, said that a '*problem report'* had been opened and that its engineering department may require further information regarding obstacle locations, but otherwise, it would '*contact you when they have an answer*'.

The manufacturer was initially unable to find any record of correspondence on the matter. However, once the '*problem report*' reference number was provided, the manufacturer was able to find its records for the matter but was still unable to confirm whether it received '*specific actionable data from the operator about what islands and lighthouses to add'.* The manufacturer asked if the Operator had any further correspondence, and the Operator advised that '*nothing further has been discovered*'. The manufacturer's database review found that '*There are no records/attachments indicating that the database group received specific actionable data on what islands and lighthouses to add. The problem report was eventually closed* [March 2015] *with no action taken by the database group.'*

Commenting on the email threads relating to the absence of Black Rock from the EGPWS database, the Operator stated, *inter alia*:

> '*The appropriate methodology for a change such as this would be to report into the company Safety Management System (called SQID) using a 'Request for Document Change (RDC)' report and this would then be managed through the company Occurrence Review Board. We have done a search of our SQID system – which was changed in May 2015 – both the pre-2015 and the post-2015 systems were searched and there are no reports pertaining to the database per se. … Management had not been aware of any discussions regarding the EGPWS database and Blackrock.'*

When interviewed, the pilot involved in the email thread with the EGPWS manufacturer said that he didn't pursue the matter at the time because there hadn't been an EGPWS on the S-61N and while it was nice to have it in the S-92A he felt that they had been safe enough without it. The Investigation notes that the pilot had informed, by copied email, eight of the Operator's personnel that he was engaging with the EGPWS manufacturer about *'getting these lighthouses added*'. The Investigation was provided with no evidence that any of those eight personnel reverted to the pilot to enquire about progress on the issue.

During the Investigation, the EGPWS manufacturer informed the Investigation that under its current (2017) business processes for customer queries, introduced prior to the accident, a notification of '*P2C*' (proposal to close) is automatically sent to the customer. If the customer accepts the proposal to close (by selecting '*yes*') then the case is closed. If the customer rejects the proposal to close (by selecting '*no'*) then the customer receives a feedback form indicating what actions are required to progress the matter.

1.17.11.1 EGPWS databases

To understand why Black Rock had not been included in the EGPWS databases at the time of the accident, the Investigation asked the EGPWS manufacturer about its processes for obtaining topographic data. The EGPWS manufacturer informed the Investigation that data was originally sourced from multiple Russian Military Topographic maps which were processed by its supplier and delivered to the EGPWS manufacturer in Digital Elevation Model (DEM) format covering Ireland.

The majority of Ireland was sourced from this data, including the area of Black Rock. The manufacturer stated that because Black Rock was not in the database, it would have been displayed as '*all blue'* on the cockpit display. The EGPWS manufacturer further explained that obstacle data is published by the IAA in the Aeronautical Information Publication (AIP) and that AIP Section ENR 5.4 lists the Air Navigation Obstacles. The manufacturer stated that its supplier gathers this data from various countries and then sells the packaged data to it and others and that it was their understanding that the lighthouse was not in the data published by the IAA. The manufacturer further advised that they checked all potential authoritative sources for Black Rock Lighthouse:

- *ENR 5.4* [Air Navigation Obstacles – AREA 1]*: As this particular lighthouse is around 50ft high it does not fit into Area 1 specification and is not listed in ENR 5.4 section. ENR 4.5 (Aeronautical ground lights – en-route, where hazard beacons and maritime beacons are usually published): is empty and redirects to section ENR 5.4. Aerodrome Document: The nearest airport – EIBT* [Belmullet Aerodrome] *doesn*'*t have aerodrome charts published, so this area is not covered.*
- *Helipad on Blackrock island is not available in AIP also.*

The IAA informed the Investigation that '*It* [Blackrock Lighthouse] *is not an Annex 15 eTOD area 1*[104] *obstacle, as the height of Blackrock lighthouse is below 100m*.'

The Investigation was advised by the EGPWS manufacturer that '*Black Rock Island was added to the terrain database in release 485/585. The database was posted on Honeywell's website on June 14, 2017.*'

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1.17.11.2 Operations Manual Guidance for EGPWS usage

Due to the fact that EGPWS was in use at the time of the accident, the Investigation examined the guidance in place governing its usage.

OMB states:

> *'1.12.6 Enhanced ground proximity warning system (EGPWS)*
>
> *a. Navigation shall not be predicated on the use of EGPWS information'*

OMF 3.18 SAR over-water DVE IMC/night let-downs states:

> *'Descent over the sea by SAR aircraft below MSA in IMC or at night when not following a published procedure may only be commenced in a safe area and must comply with the requirements of this section. Operations in airspace other than class G will require ATC clearance. Furthermore, equipment limitations detailed in the OMB should be adhered to. The purpose of this procedure is to allow the aircraft to gain VMC below or to allow the aircraft to operate in IMC low-level to close a vessel / make landfall using approved SAR mode and procedures.*

[104] **Annex 15 eTOD area 1**: ICAO Annex 15 (Aeronautical Information Services), electronic Terrain and Obstacle Databases, area 1 (the entire territory of a state).

[...]

3.18.2.1 Confirmation of position before descent

Prior to commencing any let-down below MSA over-water at night or in IMC, the aircraft position must be positively confirmed using at least one primary and one secondary navigation source. It should be remembered that a secondary navigation source may not necessarily be authorised in the OMB for aircraft navigation but may augment aircraft situational awareness.

a. Primary navigation equipment:

i. RNAV / FMS position

ii. VOR / DME position

iii. A radar position from known feature

iv. Visually identified and chart-confirmed ground feature

b. Secondary navigation equipment:

i. Independent GPS position (Memory map, cockpit moving map, GPS)

ii. ATC radar position

iii. EGPWS

iv. FLIR identified ground feature

v. AIS-GPS position

vi. SkyTrac GPS

[...]

3.18.2.2 Additional considerations

The let-down procedure, departure / escape procedure and actions in the event of a malfunction should also be considered.

Maximum use should be made of automation and SAR approach modes.

3.18.3 Procedure

[…]

f. Descent below MSA to the desired intermediate operating altitude (if required), should be commenced using a collective height hold or ALTP with the RA bug set to 20 feet below or the descent continued to final operating altitude / height; this is normally 200 feet. Below 1000 feet, the PM shall call the RADALT heights every 100 feet to 200 feet. The rate of descent shall not exceed 500 feet/min below 1000 feet. Once established at the selected final operating height, the radar should be re-optimised to ensure a good picture and cross checked against EGPWS (if available), and FLIR if the latter is available [...]’

1.17.12 MEDICO Cork

The International Aeronautical and Maritime Search and Rescue (IAMSAR) Manual, Volume II states *'MEDICO is an international term usually meaning the passing of medical information by radio. SAR agencies may provide medical advice either with their own doctors, or by arrangements with a telemedical assistance service (TMAS).'* In Ireland, the MEDICO function is managed by the Cork University Hospital Emergency Department, which provides national 24-hour Emergency Telemedical Support on behalf of the Irish Health Service Executive (HSE). The Irish service is referred to as '*MEDICO Cork*'.

MEDICO Cork documents state that it:

> *'guarantees direct access to specialist medical advice from an Emergency Medicine Registrar or Consultant through various Service Level Agreements (SLAs). A Service Level Agreement (SLA) has existed between the Irish Health Service Executive (HSE) and the Irish Coast Guard (IRCG), with support from the Irish Naval Services, since July 2001. It provides for the statutory provision of Tele-Medical support to vessels in Irish territorial waters, required for Ireland to comply with its legal responsibility towards workers at sea under European Council Directive 92/29/ECC (updated via amendment 1882/2003)'.*

The SLA extant at the time of the accident, '*Service Level Agreement Between the Irish Coast Guard and the HSE National 24 Hour Emergency Telemedical Support Unit*' was issued on 26 June 2013.

This SLA set out, *inter alia*, the following:

> *'5. ACTIVATION PROCEDURES*
> *In the event of the Irish Coast Guard requesting medical advice on behalf of a vessel the Irish Coast Guard Centre receiving the call from the vessel concerned will patch the call through to the numbers given in Annex A for Medico Cork.*
>
> *6. OPERATIONAL PROCEDURES AND COMMUNICATIONS*
> *In the event of a request from a vessel for medical advice, the Irish Coast Guard Centre will receive immediate response to the call from Medico Cork. The Irish Coast Guard staff member will at all times monitor and assist with the communications. The Irish Coast Guard will co-ordinate whatever action is advised by Medico Cork.'*

These Operational Procedures were consistent with the National SAR Framework which stated:

> *'1.6.8 The HSE through Medico Cork in Cork University Hospital provides Irelands 24/7 Radio Medical Advice Service to seafarers through the Coast Guard radio network to sick or injured seafarers on a 24-hour basis. The HSE also provide a Marine Ambulance Response Team for major emergencies. If medical advice requires the casualty to be taken off the vessel then the MRCC/MRSC providing the link will arrange for the casualty to be transported from the vessel to a hospital.'*

The MEDICO Cork Staff Guide, dated July 2014, provides guidance for MEDICO Cork personnel. It explains to staff*:*

> *'Clinical Question:*
> *This is the most important part of the conversation.*
> *To be an effective telemedicine interaction, there needs to be a complete understanding of not just the scenario the caller is faced with, but precisely what decision they are looking for help with.'*

The IRCG SOPs for helicopter operations, dated April 2016, state:

> *'10. Call-Out Procedures* [...].
>
> *10.3. Day Call-Out Procedures.*
>
> *All requests for the services of the helicopters are to be forwarded to the local RCC and confirmed in writing. The local RCC will decide if its local helicopter is the most suitable for the task, but this procedure should not be allowed to delay the launch of the aircraft for a probable task. The RCC will then:*
>
> *10.3.1. Pass relevant en-route flight information including weather forecast and mission brief to the base (See ANNEX G - FORMAT OF MET FORECAST FOR INCIDENT AREA and ANNEX H - MISSION BRIEFING).* [...].
>
> *10.3.6. Obtain the NACC assessment of the casualty (especially where life is at risk) and attempt to obtain an assessment of other casualties from a medically trained attendant on scene. Pass the assessment to the helicopter crew as part of the tasking message to help assess urgency and priority* [...].
>
> *12. Emergency Services Assistance.*
>
> *12.1. A doctor at Medico Cork is constantly available to both IRCG and* [Operator] *duty personnel to assess the urgency of the medical condition of injured survivors, to contribute to decisions on whether and when to launch, and to provide advice on the treatment of patients.* [Operator's] *crews can obtain the advice before launch or when airborne by requesting a link-call to Medico Cork through the co-ordinating or local RCC.'*

In a 2016 briefing to the IMSARC[105], MEDICO Cork presented the results of a significant research project that *'was undertaken with UCC identifying what constitutes an idealised minimal critical information dataset that should be gathered and relayed from point of injury offshore to arrival at an Emergency Department.'* The study found *'A number of critical barriers to effective information gathering and relay have been identified, including inconsistent handover procedures, information overload and message distortion.'* It noted that in 2016, MEDICO Cork was involved in *'On-going Telemedicine training for IRCG Officers, Advanced Paramedics (UCD), Military Medics and Beach Lifeguards; with a fresh emphasis on human factors and cognitive bias.'*

Further extracts from the National SAR Framework are presented in **Appendix V**.

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[105] **IMSARC**: Irish Marine Search and Rescue Committee.

1.17.13 Tasking of R118 and R116

At 21.40 hrs, on 13 March 2017, the MRSC at Malin Head, Co. Donegal received a phone call from the captain of the fishing vessel (FV) on board which a crew member had sustained an injury. The FV captain reported that one of the crew had lost '*the top half of their thumb*'; there was no discussion regarding bleeding at this time. MRSC Malin obtained the latitude and longitude of the FV and also its position in relation to a known feature (141 miles and 270 degrees from Eagle Island). The FV captain was told that the helicopter was being alerted, that the FV was within the helicopter's range and the helicopter would fly to Blacksod, and go out from there to carry out the SAR mission tasking.

MRSC Malin was staffed by two Watch Officers. While one Watch Officer continued the call with the FV captain, the other Watch Officer contacted the commander of the Sligo-based S-92A helicopter, R118, at 21.43 hrs. The commander of R118 was told that the FV had a crewman on board who had an accident '*sounds like he's lost his thumb and he's obviously bleeding quite badly there so what I'd like to do is task you to that*'. R118's commander replied '*Okay*'. R118's commander subsequently informed the Investigation that he believed that MEDICO Cork had requested that the casualty be evacuated from the FV.

MRSC Malin said that they were getting all the weather information and necessary details about the FV and would have those for the commander when he was on the base at Sligo. Malin also said '*we'll obviously organise Top Cover for you*'. MRSC Malin said that the FV was roughly one hundred and forty miles due west of Eagle Island and that they would get Blacksod and everyone '*up and running as well for re-fuelling*'. R118's commander asked if the FV had turned towards land. MRSC Malin said that they would instruct him to do so and to make best speed toward Eagle Island. The commander was informed that the FV was 78 m in length, that the FV captain was being briefed on the HI-line[106] technique and that MRSC Malin would '*get your other lads going*', meaning that Malin would alert the other three members of R118's crew via a group call on the TETRA radio system.

The phone call with the FV continued in parallel with the call to R118's commander. The FV captain provided details of the FV's structure, layout and paint scheme. MRSC Malin also obtained further details on the casualty, described as a 50 year old who had lost his thumb from halfway to the top. The FV captain said that he had the wound wrapped up and put pressure on it to stop the bleeding. MRSC Malin acknowledged this saying '*Right you've stopped the bleeding, have you given him any pain killers?*' The FV captain said that the FV carried morphine but that he was '*waiting to get some medical advice before we give him any pain relief*'. MRSC Malin said that they would put him '*through to the doctor now*' but advised him to keep the hand raised above the casualty's head. MRSC Malin then gave the FV captain a briefing on the use of the HI-line as well as a briefing on communications (radio) frequencies to be used.

[106] **HI-line**: Heaving-In line, a rope with weights attached to its end which is lowered to a vessel before a winchman is winch-lowered to the vessel. The winchman holds the other end of the line and the crew of the vessel can heave on the line to pull the winchman towards a safe position on the vessel.

At 21.53 hrs, MRSC Malin made a link call to a doctor at MEDICO Cork. MRSC Malin provided the initial brief to the doctor as follows:

> '*Good evening doctor its Malin Head coast guard here and I've a ship that needs medical advice … What has happened is he's a fisherman and he's about one hundred and forty miles northwest of Ireland and he's a crew member that has lost three quarters of his thumb ... has been amputated and we are arranging a helicopter to go out and lift him off. I have told him just to keep his hand raised at shoulder height or head height I've asked him if he's taken any pain killers and he's waiting until he speaks to a doctor before basically he does anything OK*'.

The doctor and FV captain then had direct communications, with MRSC Malin listening. The FV captain explained to the doctor that he had a casualty on board who had lost his thumb and that he was just seeking some advice on pain relief. The doctor asked what had cut the thumb. The FV captain said that he had got the bleeding stopped now. The doctor again asked '*What did he cut his thumb with?*' The FV captain explained that he (the casualty) '*jammed it between, it's squished, it's come off. He was working with nets on the aft part of the ship*' The doctor clarified '*Sorry a crush injury with a net?*' The FV captain confirmed, '*Yes that's correct the ropes on the net squashed it and it's come off*'. The doctor explained, '*OK I mean realistically he's probably going to lose that thumb ... there's not much you can do but first aid*'.

At this stage, there was a lot of background noise on the line and the doctor requested MRSC Malin to stop shuffling documents. The doctor advised the FV captain to rinse the thumb with cold water and add a compression dressing. The doctor further advised that the severed portion of the thumb '*from the knuckle up*' could be put in a saline bag with ice. The doctor again cautioned, '*but to be honest you probably won't salvage it, because you're just so far out, but anyway take the thumb, put it in as sterile a bag as possible with normal saline with a bit of ice just to kind of keep it cool and cold*'. Regarding the thumb itself, the doctor advised cleaning it, giving Tetanus if available, and just preventing it from bleeding out with a compression dressing, tight but not so tight as to lose sensation, and to keep it elevated at arm's length. The doctor again explained, '*there's really not much else you can do and chances are he's probably going to lose that thumb*'.

The FV captain asked about pain relief and the doctor said he could give paracetamol or ibuprofen. The FV captain enquired about giving morphine. The doctor said '*you can give him morphine but to be honest over time he's not going to feel it anymore. It's just going to be the initial sting of it ... during the cleaning of it that's the most painful bit*'. The doctor asked if the FV captain would be able to get an '*I.V.*' line into the casualty to administer the morphine. The FV captain said '*that would be up to the medical chief on the boat but if you tell us, clear it, we'll give him morphine*'. The doctor said to wrap it up, elevate it, and give him paracetamol or ibuprofen until the medical people get there then they can give him morphine as indicated. The doctor explained that by the time the medics got there, the casualty wouldn't be in a lot of pain. The FV captain acknowledged this and said '*OK we'll go and get it cleaned up. We did stop the bleeding but we'll go and get it clean*'. The doctor clarified that preventing the casualty from bleeding out was more important than having the wound clean and if they could clean it without blood spurting out well and good but otherwise to keep it compressed with some pressure and elevation. The doctor then asked the MRSC Malin, '*So is he going to be MEDEVACed then?*' and Malin responded '*Yeah, he's going to be MEDEVACed*'.

There was a brief discussion between the doctor and Watch Officer regarding which hospital the casualty would be brought to and MRSC Malin said that the helicopter captain would decide that. The doctor asked what the time frame for the casualty reaching hospital was and MRSC Malin said '*about three hours at least ... we'll monitor him the whole way in and as I say our helicopter's going out and we'll have him in hospital just as quickly as we can*'.

The doctor then hung-up and MRSC Malin continued to speak with the FV captain asking, 'A*re you happy enough with the advice you got?*'. The FV captain confirmed his satisfaction and reported, '*… we've stopped the bleeding … I don't think he's in excruciating pain' ... We can give him something to take the edge off it, but we won't give him anything too severe until he gets to the aircraft. I think as long as he's coping with the pain that he's in right now I think we'll wait for you guys to come out*'.

Also at 21.53 hrs, MRSC Malin rang MRCC Dublin to say '*… we're going to be doing another long range MEDEVAC … just wondering about getting Dublin up for the helicopter for Top Cover*'. Dublin asked, '*what do you want it to do, go straight to Sligo?*' MRSC Malin said, '*I would say I imagine it's a choice between yourself or Shannon I suppose really isn't it ... I suppose it would go straight to Sligo*'. Dublin raised the question of requesting a CASA maritime patrol aircraft from the IAC. MRSC Malin said that it didn't know if there would be a CASA available.

At 21.59 hrs, MRCC Dublin rang MRSC Malin. Malin asked, '*Is there a chance the Dublin Helicopter could go to this?*' Dublin enquired, '*what does the pilot want exactly*'. MRSC Malin said, '*Well I imagine it will be Top Cover I've only just tasked them to be honest*'. Dublin said, '*You have to talk to the pilot and see what he wants, does he want them to fly out after them*'. MRSC Malin said they were waiting for the R118 crew to arrive at Sligo and that they would '*find out*' what the pilot wanted R116 to do and inform Dublin about it.

At 22.02 hrs, MRSC Malin contacted the IAC Duty Officer to enquire about, '*the availability of a CASA for a long range MEDEVAC that our helicopter from Sligo is going to be conducting about 140 miles west of Eagle Island*'. The Duty Officer said that he would enquire and call MRSC Malin back.

At 22.07 hrs, the IAC Duty Officer rang MRSC Malin to advise that there was no CASA available at that time, but '*What I can offer you is something around eight o'clock in the morning*'. MRSC Malin declined the offer and said that they would make alternative arrangements.

At 22.07 hrs, MRCC Dublin phoned MRSC Malin and asked, '*Did MEDICO Cork request it* [the recovery of the casualty from the FV]'. MRSC Malin said, '*Yes! I've given them a link call to MEDICO Cork and they say yes the man needs taking off … CASA is not available*'. MRCC Dublin asked MRSC Malin what '*do they want* [R116] *to do?*' Malin responded, '*Well what we normally do is they act as Top Cover you know for the helicopter going out there, but what we can do if you like you know is we can speak to our pilot and see if he's prepared to go out without Top Cover, but it is quite a distance out*'. MRCC Dublin explained that they understood that, but that they needed to know what exactly the Sligo pilot wanted the Dublin pilot to do. MRSC Malin said that was no problem and that from Malin's perspective the mission would be to follow R118 out to the FV and wait with him until he had nearly landed.

There was some discussion around refueling in Blacksod. MRSC Malin said that they expected R118 to be airborne from Sligo in twenty five minutes time and that they would speak with the pilot about the Dublin Helicopter's role. MRCC Dublin said that they would '*Get Dublin going there anyway*'.

At approximately 22.10 hrs, MRCC Dublin called the Dublin Duty Pilot of R116 for Top Cover for R118's MEDEVAC tasking. The Commander (R116) accepted the mission and asked MRCC Dublin to alert the other crew members by TETRA radio call.

Meanwhile, at 22.08 hrs, one of R118's rear crew rang MRSC Malin. Further details were provided to the crewman regarding the FV. MRSC Malin explained that they were hoping to get the Dublin Helicopter to provide Top Cover and asked the Sligo crewman if there was anything in particular that their commander wanted the Dublin Helicopter to do. The Sligo crewman said the Dublin Helicopter could follow them out or hang about the west coast or he can go and land at Sligo or Blacksod, that R116 might have to go to Blacksod to get fuel anyway and that then it would depend on R118's communications. He said that the Dublin Helicopter could decide to come out after R118 and the normal routine was to follow out about half an hour behind. MRSC Malin then told the crewman that the casualty's bleeding had been stopped and that they (MRSC Malin) would find out what analgesics had been administered and pass the information to R118 when it was airborne.

There was a discussion about radio frequencies for communications. The crewman said (at 22.17 hrs) that R118 would be lifting in about 10 minutes and that they would make a communications check call to MRSC Malin to see which frequency worked best.

At 22.15 hrs, MRCC Dublin rang the Co-pilot (R116) directly, because he had not acknowledged the TETRA alert. The Co-pilot said that he was at the base. MRCC Dublin then briefed him on the mission to provide '*Top Cover*' for R118's mission 140 miles off Eagle Island. The Co-pilot acknowledged saying '*Right. Ok. That's grand*.'

At 22.19 hrs, MRSC Malin rang MRCC Dublin to say that '*I was on to the pilot* [R118] *there and he does request Top Cover*'. MRSC Malin said that what it would entail was following R118 about thirty minutes after it had refueled in Blacksod and that R116 could either wait off the west coast until R118 left Blacksod and then follow him or that R116 may have to re-fuel itself in Blacksod, but that there was only room for one helicopter on the pad at a time. MRSC Malin said that R118 would be lifting in 10 minutes and MRCC Dublin said that they thought R116's pilot was going to talk to R118's pilot.

Also at 22.19 hrs, while en route to the Dublin Base in her car, the Commander (R116) contacted MRCC Dublin and asked that they check if Baldonnel (a military aerodrome, located approximately 10 NM south-west of EIDW) would be open as a diversion airport. She said that bad weather was forecast for Dublin between 03.00 hrs and 06.00 hrs, and she was making enquiries before she made her fuel plan. MRCC Dublin contacted Baldonnel and was advised that no airfield services were available.

At 22.20 hrs, the Winchman (R116) rang MRCC Dublin to say that he was on his way into the Dublin Base and to confirm that the tasking was a '*Top Cover*' mission; MRCC Dublin confirmed this to him.

At 22.28 hrs, MRCC Dublin advised the Commander that Baldonnel had no airfield services. The Commander said that the flight would definitely go ahead and that she just needed to work out a diversion if the weather was bad in Dublin when they returned.

At 22.30 hrs, MRSC Malin informed Blacksod that, '*the lads* [R118] *are airborne now they'll be with you in half an hour*'.

The Winch Operator phoned MRCC Dublin at 22.35 hrs, to request an updated position for the FV. At 22.36 hrs, MRCC Dublin contacted MRSC Malin to say that the Dublin crew wanted the latest position for the FV, which Malin provided.

At 22.38 hrs, the Winch Operator phoned MRCC Dublin to say that they understood that there might be a problem (due weather) with R118 getting into Blacksod, and that if R118 wasn't able to get in, then R116 wouldn't be able to get in. Also at 22.38 hrs, MRSC Malin contacted Blacksod requesting a weather report for R118; Blacksod said they would check and revert. At 22.40 hrs, Blacksod contacted MRSC Malin and provided the weather as, '*South-westerly twenty five gusting thirty knots … a good eight miles all around easily … looking up at the sky I don't know what the cover is, but it's not bad seven, eight, nine hundred feet*'.

MRSC Malin advised Blacksod that R116 was coming to do Top Cover and may wish to re-fuel at Blacksod. MRSC Malin said that the idea was for him (R116), '*To take off from Blacksod maybe half an hour or forty five minutes … after one one eight leaves. That's the idea but it's up to the pilots of course*'.

At 22.40 hrs, MRCC Dublin Rang MRSC Malin to say, '*One one six are wondering is there a problem getting into Blacksod*'. MRSC Malin said that there was no problem and relayed the weather report from Blacksod. MRSC Malin asked why they thought there may be a problem. MRCC Dublin said, '*Because we understand that there is a problem there with one one eight getting in*'. Malin said '*not that I'm aware*'. MRSC Malin then discussed the matter and stated, '*No there's no problem we would normally furnish him with the weather anyway and there's no problem just give it to the Dublin pilot here I'll give it to you south-westerly twenty five knots gusts to thirty knots visibility eight miles but no problem.*' There was some discussion about what might have led R116's crew to think that there was a problem with the weather at Blacksod. The conversation concluded with MRSC Malin asking MRCC Dublin to tell the R116 pilot that, '*One one eight will be landing in Blacksod in about ten minutes, on the hour*', and some discussion about how long it would take to refuel at Blacksod, which was said to be about 15 minutes.

At 22.18 hrs, MRSC Malin obtained an update on the casualty's condition from the FV. During this update MRSC Malin was informed that 15 mls of Morphine had been administered to the casualty. At 23.25 hrs, shortly after it departed Blacksod, R118 contacted MRSC Malin via TETRA and was advised that 15 mls of Morphine had been administered to the casualty; the rear crew from R118 informed the Investigation that such an administration of Morphine gave rise to concern for the casualty because it could cause respiratory depression, and it also informed the decision about the most appropriate equipment selection for winching the casualty.

1.17.14 SAR Launch Guidance and Procedures

1.17.14.1 General

The following are selected extracts from relevant documents, which provide guidance and procedures for launching particular SAR assets. The Investigation has included this substantial corpus of extracts here because it is important to allow comparisons to be made and anomalies to be seen. These extracts also demonstrate the complexity and nuances involved in trying to be prescriptive about emergency response situations.

The IAMSAR Manual, Volume II, Section 1.4.4 (April 2016) states:

> *'Medical evacuation can be extremely hazardous to the patient and to the crews of the vessel and the SRU* [Search and Rescue Unit]*, because of environmental conditions and dangers inherent in transferring a patient from a vessel to another vessel or helicopter.*
> [...]
>
> *Factors to consider include:* [...] *the patient's clinical status; and the patient's probable clinical course if evacuation is delayed or not performed. A delayed evacuation, if the patient's condition permits may:* […]
>
> - *Enable a daylight evacuation;*
> - *Allow a vessel to enter port; or*
> - *Allow the weather to improve.'*

The National SAR Framework (2 March 2010) states:

> '*Search and Rescue (SAR) comprises the search for and provision of aid to persons who are, or are believed to be, in imminent danger of loss of life.*
> […]
>
> *This National Maritime Search and Rescue Framework is the standard reference document for use by all Irish Search and Rescue authorities working in the maritime domain and promulgates the agreed methods of coordination through which search and rescue operations are conducted within Ireland's SAR Region.*
> […]
>
> *In providing a search and rescue response, nothing in the content of the Framework precludes properly qualified officers from using their initiative in providing a SAR response in circumstances where these procedures are judged to be inappropriate. In so doing, however, officers' actions should conform as closely as possible to those instructions contained in the Framework most closely pertinent to the circumstances and they should keep all other parties involved informed.*
> […]

1.6.8. The HSE through Medico Cork in Cork University Hospital provides Irelands 24/7 Radio Medical Advice Service to seafarers through the Coast Guard radio network to sick or injured seafarers on a 24-hour basis. The HSE also provide a Marine Ambulance Response Team for major emergencies. If medical advice requires the casualty to be taken off the vessel then the MRCC/MRSC providing the link will arrange for the casualty to be transported from the vessel to a hospital.
[…]

1.19.2. Each SAR operation is carried out under the coordination of a SAR Mission Coordinator (SMC) designated for the purpose by the Coast Guard. The SMC is responsible for efficiently prosecuting a SAR incident using the assets available. The SMC is responsible for all stages of the SAR system. Their responsibilities include the prompt dispatch of appropriate and adequate SAR assets and the prosecution of SAR operations until rescue has been completed, or chance of success is no longer a reasonable possibility. The SMC is responsible for ensuring that the following duties are carried out depending on the SAR incident and local circumstances:

- *Obtaining and evaluating all information pertaining to the incident, including emergency equipment carried by the person or craft in distress;*
- *Classifying the SAR incident into the appropriate emergency phase (Uncertainty, Alert/Urgency, or Distress);*
- *Alerting appropriate SAR assets and SAR organisations that may be of assistance during the incident;*
- *Conducting a risk assessment;*
- *Dispatching initial SAR Units if situation warrants.*
  […]

2.1.2. IRCG provide medical link calls from ships at sea to the vessel's national medical centre and evacuation of the casualty from the vessel by helicopter or lifeboat if required. If medical advice requires the casualty to be taken off the vessel then the MRCC/MRSC providing the link will arrange for the casualty to be transported from the vessel to a hospital.
[…]

IRCG SOPs for Helicopter Operations (dated April 2016), state:

'*7. SAR, HEMS, Air Ambulance and Other Operations.*

7.1. SAR flight:

All taskings to incidents at sea, cliffs, inland waterways, mountainous areas, or locations where access to, and/or extraction of the casualty is not safe by land ambulance or its crew, shall be classified as SAR and remain so until the mission has been completed. This shall be based on the best available information at the time of tasking.

7.1.1. a. Offshore islands:

i. Missions to offshore islands will be operated as a SAR flight when designated life or death or when the casualty needs to be winched into the helicopter. When not designated life or death they will be operated as helicopter emergency medical service (HEMS) flights subject to the restrictions below.
ii. In the event the casualty does not need to be winched and the mission is not of a 'life and death' nature, then it will have to be re-categorised and conducted as HEMS or air ambulance, depending on the nature of the casualty.
[…]

8. Administrative Control.

As the appointed Contract Manager, the Director IRCG is responsible for:
8.1. Ensuring [the Operator]*'s compliance with the contract.*
8.2. The efficient running of the contract and liaison with the [Operator]*'s Accountable Manager on all matters pertaining to the contract.*
8.3. The issue of Standard Operating Procedures for IRCG helicopter operations.
8.4. The authorisation of flying-hours and the certification of flying hour charges.
[…]

10.3. Day Call-Out Procedures.

All requests for the services of the helicopters are to be forwarded to the local RCC and confirmed in writing. The local RCC will decide if its local helicopter is the most suitable for the task, but this procedure should not be allowed to delay the launch of the aircraft for a probable task.

The RCC will then:

10.3.1. Pass relevant en-route flight information including weather forecast and mission brief to the base (See ANNEX G - FORMAT OF MET FORECAST FOR INCIDENT AREA and ANNEX H - MISSION BRIEFING).
[…]

10.3.6. Obtain the NACC assessment of the casualty (especially where life is at risk) and attempt to obtain an assessment of other casualties from a medically trained attendant on scene. Pass the assessment to the helicopter crew as part of the tasking message to help assess urgency and priority.'
[…]

11. Briefing Information:
Prior to launching, the RCC Controller should provide the crew with as much of the information listed at ANNEX H - MISSION BRIEFING[107] *as possible, and equivalent information for overland rescues.*
[…]

[107] Item 4b on Annex H is titled '*Medico Cork Advice*'.

12.1. A doctor at Medico Cork is constantly available to both IRCG and [the Operator] *duty personnel to assess the urgency of the medical condition of injured survivors, to contribute to decisions on whether and when to launch, and to provide advice on the treatment of patients.* [the Operator] *crews can obtain the advice before launch or when airborne by requesting a link-call to Medico Cork through the co-ordinating or local RCC*.'

The Investigation was informed that a copy of ANNEX H was not completed on the night of the accident for the tasking of R118, although this is not expressly required once the information mentioned is obtained and available.

The IRCG has a number of checklists which serve as '*aide memoires*' which '*must be fully understood and implemented in accordance with IAMSAR Manual and Irish Coast Guard Standard Operating Procedures.'* One of these is titled '*MEDICAL ADVICE, ASSISTANCE and MEDEVAC'*. It states:

'*On receipt of a request from a vessel for medical assistance:*

- *Advise the casualty that a link call is being put through to a medical specialist;*
- *Call Medico Cork at University College Hospital Cork, of relevant Medico establishment;*
- *Advise them that you have a medical link call from ????;*
- *Advise the doctor 'We will monitor the call. At the end of the call to the ship, please hold the line so that we can discuss any arrangements and provide any further information that may be necessary';*
- *Agree Course of action with the doctor and discuss the options available for evacuation.*

[...]

The doctor will determine a course of action, which may be - to treat on board, proceed to nearest or next port, or to evacuate. Central to the Medical Advice service is dialogue between doctor and SO [Station Officer] *to take into account a course of action that matches both the medical and SAR needs of the situation;*

Consider the time scale for evacuation - in the case of evacuation, can the doctor give a time scale for getting the casualty to hospital e.g. evacuation as soon as possible, within 6 hours, 6 to 12 hours, longer than 12 hours etc. - provides a benchmark on which to base a decision, including the option to make a transfer in daylight especially if the weather is marginal;

Take into account that it may be expedient to undertake an evacuation earlier than expected due to worsening weather conditions or deteriorating light.'

The Operator's OMF states:

'*The principles and guidelines provided in the OMF will assist the SAR crew to accomplish the SAR objective, while protecting the safety of, in order of priority, the aircraft, the winchman and the casualty. In other words, the aim is not SAR at any cost and there will be limiting factors that may preclude a SAR operational flight*.'

1.17.14.2 Watch Officer Training

The Investigation interviewed the Watch Officers who manned MRSC Malin on the night of the accident. The Investigation asked them about their training. They expressed a view that senior management may not fully understand the training needs for the role of Coast Guard personnel, that training did not involve sufficient scenario-based incidents and that there was a reliance on personnel learning from each other on-the-job during actual incidents. Both of the officers had previous service with the UK Coastguard and they said that their UK training involved the use of communications simulators and a video-recorded, mock-up operations room for trainee feedback, which they found very useful. However, both Watch Officers said that they felt that their UK and IRCG training had prepared them for their roles on the night of the accident.

IRCG informed the Investigation that owing to a shortage of Watch Officers, IRCG had arrangements in place for the hiring of temporary contract staff. The SMC on the night of the accident had been employed at Malin Head Radio, and then Malin Head Coast Guard, from April 1986 until he retired on 29 July 2015. He returned to work at Malin Head Coast Guard on 7 March 2017 and completed an induction programme over three day shifts. The programme was overseen by a Divisional Controller. On-the-job training, including refreshing knowledge of SAR Operations Memos (SOPs) was carried out and the Divisional Controller then assigned him to the standard MRSC Malin roster. The Investigation asked IRCG management what scenario-based training was included in SMC courses. IRCG Management responded:

> '*Scenario based training includes case study and theoretical Incident scenarios provided by NMCI* [National Maritime College of Ireland] *Lecturing staff and is an integral element of the course. More recently peer to peer presentations by experienced SMCs have been added to the course.*
> […]
> *Practical simulator based training simulating SAR scenarios was introduced in the most recent course Jan 2016*.'

The Investigation asked IRCG management for a copy of the SMC training syllabus. The title of the syllabus document provided was '*Irish Coast Guard SMC Standard Syllabus*'. The file name included the word '*Draft'*, and the syllabus was self-described in the body of the document as a '*model course'*. The document was dated 8 January 2017. The document included a table headed '*IAMSAR Categories for SMC Course inclusion'* which listed 54 topics/skills outlined in the IAMSAR manuals. It also included a table setting out '*Course Syllabus Subject Coverage and Hours allocated'*. The Investigation noted that although '*risk assessment'* is a listed IAMSAR category, it is not mentioned in the course coverage and hours allocated table.

The Investigation asked the IRCG to explain this. IRCG Management responded:

> '*Risk Assessment is covered under SAR Operations Risks under the Three Emergency Phases as based on IAMSAR Vol II. It is included in Exercise scenarios throughout the Course. The process of Risk assessing is considered to be an integral part of SMCs work and core SMC decision making. In general the process of risk assessment is incident specific and conducted in conjunction with the SAR units whose services are being requested.*'

The Investigation asked the IRCG what exactly was the risk assessment paradigm for launching a helicopter SAR mission. IRCG Management responded:

> *'SAR Ops Notice 4/2016, Standard Helicopter Operations and 2/17 (issued post incident). Also to note Section 19.2 which states re Aircraft Commander's Responsibility. The final decision on whether the aircraft can undertake a given task lies with the aircraft commander following consultation with an RCC. The safety of the aircraft, crew and passengers will remain the responsibility of the aircraft commander and his decisions will be accepted by the IRCG as overriding in the event that they impinge on the effectiveness of any operation.'*

1.17.15 Commercial Considerations

The Operator provided SAR helicopter services to the IRCG under a commercial contract, which includes a variety of conditions relating to payments for services delivered and potential penalties for non-delivery.

Documentation provided to the Investigation showed that staff and auditors had raised concerns about what they perceived to be commercial pressure. In June 2010, one event prompted SQID reports from two members of a Dublin duty crew. These SQID reports said that having been forced to abandon a tasking in the Wicklow Mountains due to poor weather and an unserviceable radar altimeter, the helicopter had returned to base. A management Post-Holder subsequently phoned the duty captain asking about the mission. The duty captain reported that he was asked to review his decision because the S-92A contract was being signed the next day and he was of the opinion that his integrity as duty captain was being undermined. The duty winch operator who witnessed the call reported that he believed that the call was inappropriate and put commercial pressure on the duty captain and crew.

The Post-Holder reported that he often handled such requests for information about specific missions from the highest levels within the IRCG. He said that in order to maintain supervision of the operation, managers will, from time to time, make enquiries about the circumstances of a particular mission, a necessary function to maintain oversight. He said that a series of questions from a manager to ascertain the facts should not be construed as pressure and anytime he had such conversations was always mindful to remind a crew of this.

An independent investigator from the Parent Company conducted an investigation into the circumstances of this reported occurrence. His investigation report said that recent reviews of working practices, negotiations regarding terms and conditions had led to personnel being more sensitive to perceived commercial inputs and therefore could not be isolated from the overall context of this event. It recommended that appropriate protocols for customer-based enquiries should be introduced. The main focus of the report was on the systemic safety issue of air assets from different agencies working together on a given tasking and the need to introduce robust coordination procedures.

A Corrective and Preventive Action (CPA) SQID was opened to track and record accomplishment of this recommendation and the specified Corrective Action was '*Issue guidelines to the Crews*'. The CPA SQID was closed on 21 December 2010. The Investigation requested a copy of the guidelines that were issued to crews and also asked how they were issued. In response to these requests, the Operator provided a copy of a one-page document titled '*Coast Guard Enquiry Form*'. The form included boxes to enter information about the following: SAR Mission Brief; Location of Mission; Time spent on Scene; Weather en route/on-scene; Report on Casualty; Intended receiving facility; ETA at receiving facility; and briefing on any further plans or relevant details. The bottom of the form contained a note which said that the information would act as guidance for managers and crew when dealing with mission-related Coast Guard enquiries. An Administrative Memorandum was issued to Base Chief Pilots stating that '*This form can be used as a guide when a manager is required to gather operational information on behalf of the client outside of normal day to day MRCC channels*'. An Operations Memorandum was issued to all Crew advising them to raise concerns about IRCG taskings with the Flight Operations Manager or in his absence to the Accountable Manager, and reminding commanders of their responsibility for the safe conduct of any flight.

In 2013, the IRCG Auditor, in an email to IRCG management, expressed concern '*in the event that the now overt commercial pressure to get started has overridden safety'*.

In 2014, Dublin BFSM minutes recorded an alleged series of incidents where a pilot reported that during one shift senior managers made five adverse comments to him regarding his launch decisions. He said that following the fifth occasion, he had a meeting with one of the managers involved and that he believed that his concerns had been accepted and consequently the matter was not '*SQIDed*'. However, he wanted the matter recorded in the meeting minutes so that others would be aware of his experience and could '*SQID*' any such incidents they encountered.

1.17.16 Operations Manual Consistency

The Operator's OMF deals specifically with Search and Rescue Operations. The Investigation reviewed the complete Operations Manual (Parts A – G) and noted what appeared to the Investigation to be disparities within OMF, and between OMF and other sections of the Operations Manual suite.

Section 3.18 of Part F deals with '*SAR over-water DVE IMC / night let-downs'*. In this section crews are advised as follows:

> *'Descent over the sea by SAR aircraft below MSA in IMC or at night when not following a published procedure may only be commenced in a safe area and must comply with the requirements of this section. Operations in airspace other than class G will require ATC clearance. Furthermore, equipment limitations detailed in the OMB should be adhered to.'*

Section 1.12.6 of OMB, '*Enhanced ground proximity warning system*', deals with (amongst other things) the restrictions regarding the use of the EGPWS:

> *'EGPWS low altitude mode shall not be selected when operating IMC or at night except as required when performing offshore platform IMC approach procedures or SAR operations.'*

In Section 3.18 of OMF further advice is given regarding a secondary navigation source (OMF 3.18 lists the EGPWS as a secondary navigation source), which implies that the restrictions of the OMB may be ignored:

> *'It should be remembered that a secondary navigation source may not necessarily be authorised in the OMB for aircraft navigation but may augment aircraft situational awareness.'*

The EGPWS provides guidance to aircrew based on a database of information and inputs from the helicopter geographic position and altitude. In this occurrence, the installed database did not contain obstacle data for the area of the accident site, and therefore could not have augmented the aircrew's situational awareness.

Section 3.18.1 of the OMF lists the minimum equipment that must be available to carry out SAR over-water DVE IMC/night let-downs. This list includes:

> **'***3.18.1 SAR over-water DVE IMC / night let-downs*
>
> […]
>
> ***b.*** *Radar, serviceable in approved navigation modes*
> ***c.*** *Enhanced ground proximity warning system (EGPWS) or AVAD with working voice warner*'

The Investigation asked the Operator to provide details of the approved radar navigation modes and was informed that there were no approved navigation modes.

Section 3.19 of the OMF describes the procedure for carrying out Offshore/Coastal SAR Airborne Radar Approaches (SARA). OMF stated that:

> '*The offshore airborne radar approach is used to position the aircraft towards vessels at sea in conditions of poor visibility or at night. The coastal airborne radar approach is used to position the aircraft towards the coast in similar conditions. It offers a means of approaching a coastal scene of distress such as a vessel aground, or to an island or coastal LZ* [Landing Zone].'

The SARA procedure directs the crew to complete DVE Approach checks, but does not require Approach checks or an Approach Briefing as set out in yellow in **Figure No. 10**. It states:

'3.19.1 SARA procedure

a. *Aircraft to descend from MSA in accordance with section 3.18 SAR over-water DVE IMC / night let-downs*

b. *DVE checks to be completed in good time*

c. *The FMS and moving / memory map can be used to build a suitable route to the target area bearing in mind the factors above. Typically, a 'gate position' at least 2 nm downwind of the target area and clear of all obstructions will give a suitable final approach. When operating in close proximity to land, plotting the target position, gate and flyaway on a suitable scale can assist greatly in situational awareness. Additionally this enables establishment of the height of adjacent terrain in order to assist in providing adequate separation.*

d. *Speed is to be reduced to give a suitable groundspeed and the aircraft then let down under the guidance of radar, FLIR, and all navigation systems in preparation for an automatic final approach to hover at the target area*

e. *Prior to transitioning down, complete all DVE checks; landing checks are completed if a landing may be likely or is intended. A safe escape and go-around direction is to be briefed and, if appropriate, programmed into the FMS*

f. *An appropriate approach mode to the hover will be initiated at a suitable distance to the target accounting for wind, drift and radar contacts*

g. *During the approach, the PM is to operate the radar, ensuring that an accurate paint at the optimum range is maintained*

h. *The PM will also provide a commentary to assist the PF throughout the approach and trans-down*

i. *The talk-down is a running commentary designed to give the PF a full appreciation of his position in relation to the targets that he is attempting to approach. This enables him to fully concentrate on flying the aircraft accurately without feeling the need to look 'out'. No set format needs to be adhered to, as all situations will be different. Pauses in talk-down will not normally exceed 10 seconds.'*

Although OMF Section 3.19.1, subsection b, refers to '*DVE checks*', the Operator's SAR checklist calls these checks '*DVE Approach*'. The Investigation notes that the Operator's '*Normal Checklist*', '*Approach*' stipulates crossing altitudes and FAT (Final Approach Track) as two items in the Approach checklist, but these items are not in the '*DVE Approach*' checks which flight crew were required to complete[108]. Accordingly, although a SARA can be used as '*a means of approaching a* […] *coastal LZ* [Landing Zone]*'*, the SARA procedure does not require Approach checks.

However, OMA, *'General / Basic Procedures'*, Section 8.3.19.5, *'Crew Briefings'*, states that two types of briefing are mandatory:

[108] The Operator informed the Investigation that following initial input from the AAIU, the Operator introduced revised NCL [Normal Checklist] DVE Checks on 23 May 2017 with more detail, including a specific item on '*target descent heights*.'

'Mandatory crew briefings are:

a. Takeoff and departure briefing

b. Approach Briefing'

The procedure described in S-92A OMF is not the same as the equivalent procedure described in the OMF used by the Operator in 2012. Section 3.19.1, *'SARA Procedure'*, of the OMF used by the Operator in 2012 stated that:

'3.19.2 ARA Procedure

a. Aircraft to descend from MSA in accordance with 3.18 [SAR overwater IMC/Night letdowns] *above*

b. The relevant SAR and approach checks are to be completed in good time.'

OMF extant at the time of the accident also stated that:

'3.5 Follow navigation

Follow navigation provides secondary navigation information to support and confirm primary navigation and to monitor fuel planning and management. It is the process of gross error checking the progress of the flight as well as the accuracy of the primary navigation system. Follow navigation is normally carried out by the winch operator.'

221 However, OMD, which deals with training, did not contain any references to '*Follow Navigation*', nor did it contain guidance on how the crew are expected to do this task or what equipment they are expected to use.

1.18 Additional Information

1.18.1 Charts

Operations Manual Part A (OMA) Rev 1 Jul 01 2016, Section 8.1, provides flight crew with instructions regarding flight preparation. OMA requires that a flight shall not commence unless:

'e. Current maps, charts and associated documents or equivalent data are available to cover the intended operation of the aircraft including any diversion which may reasonably be expected.'

The Investigation asked the Operator if the term '*equivalent data*' could reasonably be taken to refer to Euronav and Memory Map; the Operator said that it would agree that it could reasonably be taken to be the case in the Operator's manuals.

Operations Manual Part C (OMC) Rev 1, dated Jul 01 2016, Section 2.8, details the required aeronautical charts '*that shall be available on the helicopter at all times and how to confirm their validity*'. The following were required to be carried:

- Aerodrome Approach charts
- Helicopter Operating Minima (Ireland and UK)
- En route low altitude Chart UK (L) 2e
- VFR Aeronautical Charts (1:500,000 and 1:250,000 scale)
- Landing Site Directory (Operator)

In relation to '*Night Overland Operations*' OMF stated:

> '*Memory map, with 1:50000 OSI selected, will give the required navigational accuracy and landing site detail, therefore operations without should be carefully considered. That said, in date charts of the intended area of route and landing site highlighting, wires and masts should always be used.*'

OMF went on to say:

> '*Thorough pre-flight navigation planning is essential to firstly ensure a safe transit to a landing site, and secondly in assisting with locating and identification of a landing site. Adequate time should be taken pre-flight to ensure all available information is available.*
>
> *The following is the suggested format. Navigation planning should follow:*

> *a. Plot an accurate landing site latitude and longitude or grid (converted to a lat and long) on all charts to be used. One chart, 1:250000 or 1:500000 is to be used for the en route / transit stage, and a 1:50000 OSI chart for the landing site.*
>
> *b. Select an initial point (IP) and mark the charts:*
>
> *i. **IP selection:** An IP is used as a lead-in feature to a landing site. It should be a large, easily identifiable feature positioned a minimum of 2 nm to 3 nm from the landing site. The IP will provide an accurate aircraft position prior to the run in to the landing site. Detailed route study from IP to landing site will greatly assist in locating the landing site, and if possible, a line or lead-in feature to the landing site should be used. It is not always necessary to overfly the IP. In some cases, an 'offset IP' for example, abeam a large hill or hills, may be appropriate.*
>
> *c. Plan a navigation route to the IP and then the landing site; decide on a safe transit altitude of 500 feet to 1000 feet AGL (minimum 500 feet AGL) and establish a safe en route MSA*
>
> *d. The leg from IP to landing site is particularly important to assist in the identification of the landing site. It is recommended to mark this leg on a 1:50000 OSI chart, with 1 nm distance to run to the landing site markers and any obstructions highlighted.*

e. From the chart, estimate the altitude of the landing site and establish an appropriate local MSA and safe heading

f. Mark the chart with the appropriate information to include necessary FMS waypoints, MSAs and obstruction data

[…]

Over land night navigation is challenging. Using only the FMS / Euronav will get the aircraft in the general vicinity of the landing site, however use of the appropriate charts with careful route selection and study is required to positively identify the landing site. Normal daytime navigation features will not be available, therefore large lit features such as towns or villages should be used where possible. An FMS plan will greatly assist in navigation, however, try to avoid complicating it. A recommended minimum of turning points, IP, landing site, and if appropriate, a flyaway point (on a safe heading) are to be used.'

Flight crew also use an FMS Route Guide (**Section 1.8.2**), commonly referred to as the '*Low Level Route Guide*', which is provided by the Operator, and a LSD, also provided by the Operator. The FMS Route Guide and the LSD were provided in A4 booklet formats.

1.18.1.1 Aerodrome Approach Charts

The Information contained in the charts, maps, manuals and other documents supplied was obtained from a variety of sources including instrument/flight procedures designed and prescribed by government and/or regulatory sources.

In the case of the State, the IAA Aeronautical Information Publication (AIP) is the source of data for instrument procedures, although the format and presentation of such procedures depends on the chart supplier. Prior to flight, the validity check on these charts is accomplished using the supplier's amendment record. As the Helicopter was not landing at an aerodrome with instrument procedures, no '*aerodrome approach charts*' were applicable.

The Investigation notes that in November 2012, a SQID Report recorded that out of date (approach) plates were installed in one of the Operator's helicopters and that no updates had been received since April 2012. The originator of the report said '*There is a failing in the system in that nobody noticed that we possibly have out dated plates in the Ops room and more importantly in the aircraft*.' The recorded root cause was '*bill was unpaid and no base noticed that* [the supplier's] *amendments were not being received. There was also changes at* [the supplier] *which meant* [the Operator] *were not made aware the bill was outstanding*.'

The Corrective Action was recorded as '*Complete copies of all sets of* [the Operator's supplier's charts] *ordered and distributed. CPA opened for* [a Post-Holder] *to write and implement procedures so that* [the Operator] *are to notice that approach plates have not been received*.'

The Investigation asked the Operator to provide a copy of the CPA opened and the procedures that the Post-Holder wrote. The Operator informed the Investigation that '*the original proposal (CPA opened for the MFO to write and implement procedures so that* [the Operator] *are to notice that approach plates have not been received) does not appear to have been concluded as originally planned and there is no recollection of a procedure being written*'. However, the Operator went on to say that it assumed that what was put in place was robust as there were no further occurrences of out of date plates. The Operator subsequently informed the Investigation that it now uses EFBs and [a named application that provides terminal and en route charting information], which are electronically updated.

1.18.1.2 Aeronautical Charts – Ireland

Aeronautical Charts are based on ICAO Annex 4[109] and ICAO Doc 8697[110]. Differences to these provisions are detailed in AIP GEN 1.7; topographical information is reproduced under licence by permission of Ordnance Survey Ireland (OSI). Aeronautical Charts included in the AIP are kept up to date by amendments to the AIP. Significant amendments or revisions in aeronautical information may be promulgated by notices to airmen (NOTAMs) or Aeronautical Information Circulars, as appropriate. Corrections to Aeronautical Charts are promulgated as hand amendments to the AIP and listed in Sections GEN 0.5 and GEN 3.2.8. Items of information found after publication to have been incorrect at the aeronautical information date are corrected immediately by NOTAM if they are of operational significance.

The AIP provided details of aeronautical charts available. For general VFR navigation, these comprise the series IRELAND Sheets '*2172 ABCD*'. These comprise three charts: IRELAND (1:500,000) — at the time of the accident Edition 06, dated 31 May 2013 was current; IRELAND North/South and IRELAND East/West (1:250,000), with Edition 03 dated 28 February 2013, were the extant versions.

The AIP provides the following information regarding these charts:

> '*4.2 General Description of the VFR Charts*
>
> *4.2.1 Aeronautical Chart - ICAO 1:500,000*
> *The Irish Aviation Authority has produced a visual flight rules (VFR) aeronautical encapsulated A4 folded chart Scale 1:500,000. This chart is for VFR navigation within the boundaries of the Shannon FIR. In addition to aeronautical information, the charts provide terrain contours, hydrographic, topographic, cultural and other visual features compatible with legibility at the scale of the chart - this information is supplied by Ordnance Survey Ireland and/or Ordnance Survey Northern Ireland.*
>
> *4.2.2 Aeronautical Chart 1:250,000*
> *The Irish Aviation Authority has produced a visual flight rules (VFR) aeronautical encapsulated A4 folded chart Scale 1:250,000. It comprises two charts - front and back (East & West, North & South), covering the Shannon FIR.*

---

[109] **ICAO Annex 4:** International Civil Aviation Organization, Annex 4 to the Convention on International Civil Aviation, Aeronautical Charts.
[110] **ICAO Doc 8697**: Aeronautical Chart Manual, 3rd Edition 2016.

The charts are for VFR navigation within the boundaries of the Shannon FIR. In addition to aeronautical information, the charts provide terrain contours, hydrographic, topographic, cultural and other visual features compatible with legibility at the scale of the chart - this information is supplied by Ordnance Survey Ireland and/or Ordnance Survey Northern Ireland.'

In accordance with OMC, Section 2.8, the validity of the VFR Charts should be checked against information found at the OSI website '*irishmaps.ie*'.

1.18.2 Offshore Night VMC Flying and Radar Approaches

The OMA provides the following detailed (extract) guidance for offshore night VMC flying and radar (instrument) approaches:

'8.3.21.9 Offshore night VMC flying techniques

Darkness and a lack of a distinct natural horizon, combined with the isolated nature of offshore installations, often means that external references cannot be relied upon to maintain a safe flight path during such operations. Visual contact flight at night in the offshore environment should therefore be treated as primarily an instrument flying exercise, with the view out of the cockpit forming an extra part of the pilot's flight instrument scan. To reduce pilot workload, full use should be made of the coupler, in particular altitude and heading hold modes (and airspeed hold if available), until PF is satisfied with the visual references and the aircraft is on short finals.

[…]

8.4.4 Offshore instrument approaches

CAT.OP.MPA.120, AMC1 CAT.OP.MPA.120, GM1 CAT.OP.MPA.120

With the Airborne Radar Approach (ARA) / GPS approach, the GPS / radar is used to identify the offshore installation and provide track orientation and approach setup. The aircraft radar is used to ensure obstacle clearance, confirm final approach track and range. Radar and GPS ranges shall be cross-checked throughout the approach. Once within 2 nm, the radar shall be used as the primary navigation aid to ensure adequate clearance from obstacles.

8.4.4.1 Airborne radar approach (ARA) for over-water operations – General

a) Pre-Flight Considerations:

i. Helicopter type-specific guidance, including use of automation, is in the OMB

ii. An ARA requires the GPS and the weather radar to be fully operational

iii. An approach is only authorised if the weather radar provides a clearly distinguishable radar return which confirms with the GPS / FMS that it is the correct offshore installation intended for landing

[…]

v. The landing pilot is determined by wind direction, deck orientation, obstacles and missed approach considerations. Either pilot may fly the approach. If the PM [Pilot Monitoring] for the approach becomes the landing pilot, he shall take over control at or before MAP [Missed Approach Point] provided he has the required visual references. Hand-over of control may be delayed until after MAP only when both pilots have the required visual references. The latter may be required during circling procedures.

b) En route and initial approach:

i. The initial approach fix (IAF) and / or the final approach fix (FAF) and the offshore installation should be programmed in the FMS / GPS as waypoints. If automation is available, the approach should be flown coupled to NAV (LNAV).

ii. Inside the FAF, the destination rig must be the waypoint referenced.

iii. Descent below MSA [Minimum Sector Altitude] to 1000 feet may commence when within 10 nm of the offshore installation, provided the approach path avoids all radar-identified obstacles by at least 1 nm. Separation may be reduced to less than 1 nm if the contact has been identified visually by at least 1 nm.

iv. If lateral clearance from any obstacle will be less than 1 nm, the PF [Pilot Flying] shall:

   i. Approach to a nearby target structure and thereafter proceed visually to the destination structure in accordance with the procedure for section 8.1.4.2 VFR flights operating between helidecks, or

   ii. Make the approach from another direction leading to a circling manoeuvre while using the appropriate revised minima (see section 8.4.4.2.6 Minimum descent height and section 8.4.4.2.8 Missed approach point)

c) Final approach:

i. Final approach track shall normally be into reported wind ±30°. Approaches may be flown downwind or crosswind leading to a circling manoeuvre, if weather conditions are better than the required minima for circling approach (see section 8.4.4.2.6 Minimum descent height and section 8.4.4.2.8 Missed approach point).

ii. Before reaching the FAF and descending below 1000 feet, both pilots shall confirm that a clear path is available on the inbound track and in the missed approach area. Crews shall not undertake an ARA unless the radar can provide course guidance to ensure obstacle clearance and a clear path. The clear path is an obstacle-free area extending 1 nm either side of the track flown from the FAF to the installation and the intended track of the missed approach ending once having reached MSA, or 1000 feet if radar separation of at least 1 nm from obstacles can be assured.

iii. *The helicopter should be flown coupled to NAV (LNAV) to the 10^o offset initiation point (OIP) providing the FAT* [Final Approach Track] *can be identified in the GPS / FMS, although HDG mode may be used to manoeuvre if required for obstacle avoidance. From the OIP onwards the helicopter shall be flown in HDG mode. The heading bug can be preset to the offset heading once the aircraft is level at the MDH.*

iv. *Maximum tailwind component on the final approach segment is 20 knots*

v. *Maximum groundspeed is 90 knots, recommended groundspeed by 2 nm is 70 knots. Minimum airspeed from the FAF inbound is defined in the OMB. The airspeed should be chosen based on the reported wind at the destination and may be corrected during the approach, in anticipation that groundspeed will be the anticipated value by the time the aircraft reaches OIP.*

vi. *If unable to couple to LNAV, drift compensation should be applied so that the helicopter tracks directly to the offshore installation, and that the exact heading is identified.*

vii. *Both pilots shall confirm helicopter reaching and holding MDH* [Minimum Descent Height].

viii. *At 1.5 nm (the OIP), turn 10^o to offset the heading left or right as required*

d) *Missed approach:*

Turn to the missed approach heading in accordance with the missed approach procedure as published on the ARA approach plate.

[…]

8.4.4.2.1 Airborne radar approach – Required visual references

A pilot shall not continue an approach beyond MAP unless he is visual with the destination and satisfied that the forward visibility and cloud base will permit adequate visual references to be maintained to landing.

A pilot shall not descend below MDH / MDA until he is satisfied that the visual references available are sufficient to determine that the aircraft is on the correct normal approach angle. The obstacles in the planned approach sector must be clearly visible during the visual segment of the approach, so that he can verify his position and altitude relative to the destination helideck elevation at all times. At night, these visual references should normally include elements of the helideck perimeter lighting system.

The aircraft shall remain coupled in 4-axis / 3-cue until PF is ready to descend below MDH, or until speed needs to be reduced below minimum coupled speed, if earlier. When PF is satisfied with the visual references and on the correct normal approach angle he shall call "Helideck, descending".

If visual references are lost after passing the missed approach point (in the visual portion of the approach), or in the event of a failure that does not require an immediate landing, but requires either more time to diagnose or a return to maintenance base, immediately start a climbing turn away from the destination to roll out on a safe heading and follow the briefed missed approach procedure, climbing to MSA. The coupler / FD [Flight Director] *should be used provided the aircraft is within system parameters (for example, above minimum couple speed).*

8.4.4.2.3 Offshore obstacles

Standard MSA is 1500 feet; however, an obstacle identified as being over 500 feet will require a calculated MSA.

8.4.4.2.4 Radar system errors

System errors with the radar on the 2.5 nm scale may be as much as $\pm 4.5^{o}$ *bearing error and 250 m range error. These errors are accounted for in the procedure design and limitations.'*

OMB states:

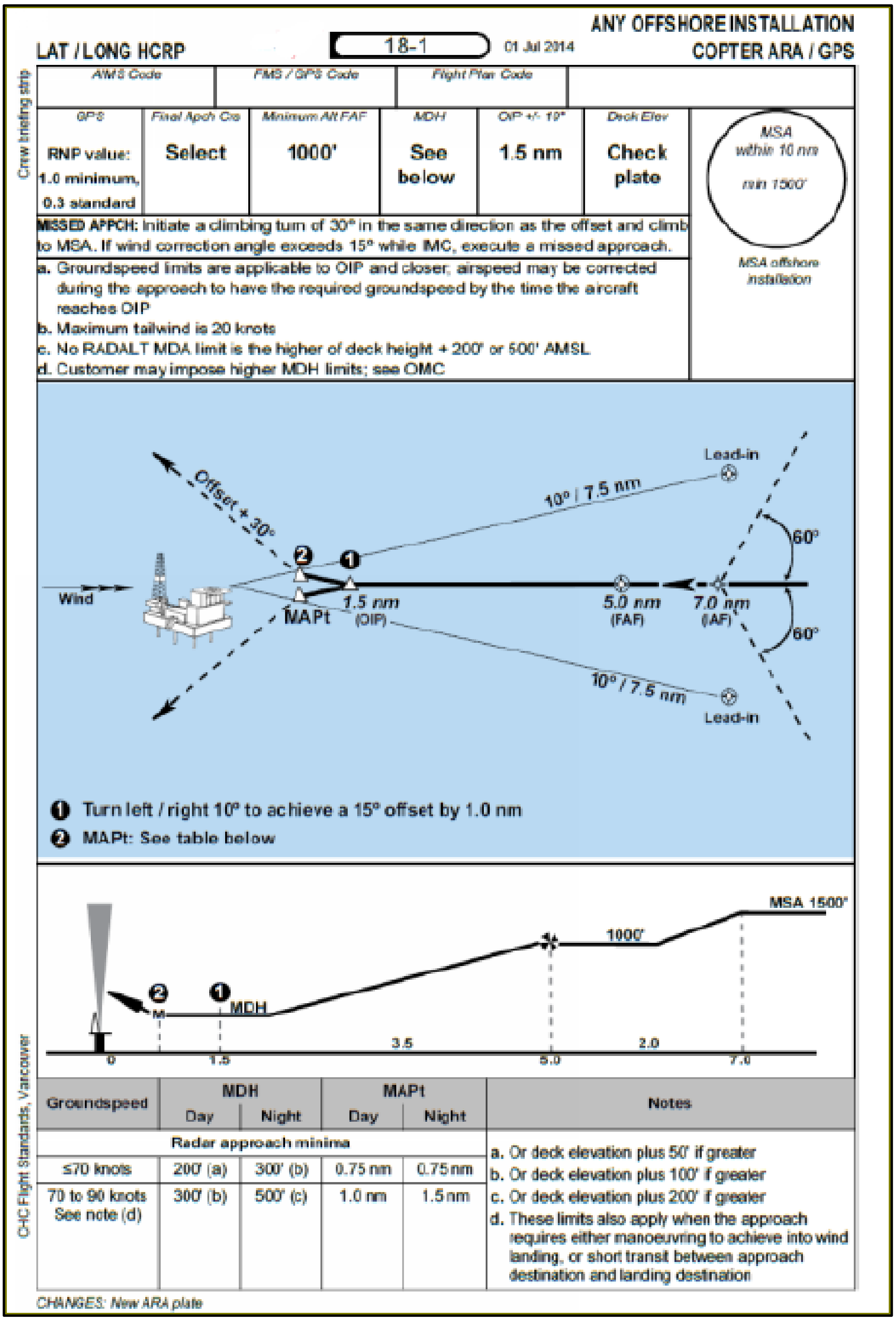
'2.12.8.6 Airborne radar approach

The ARA is performed as per OMA chapter 8.

[…]

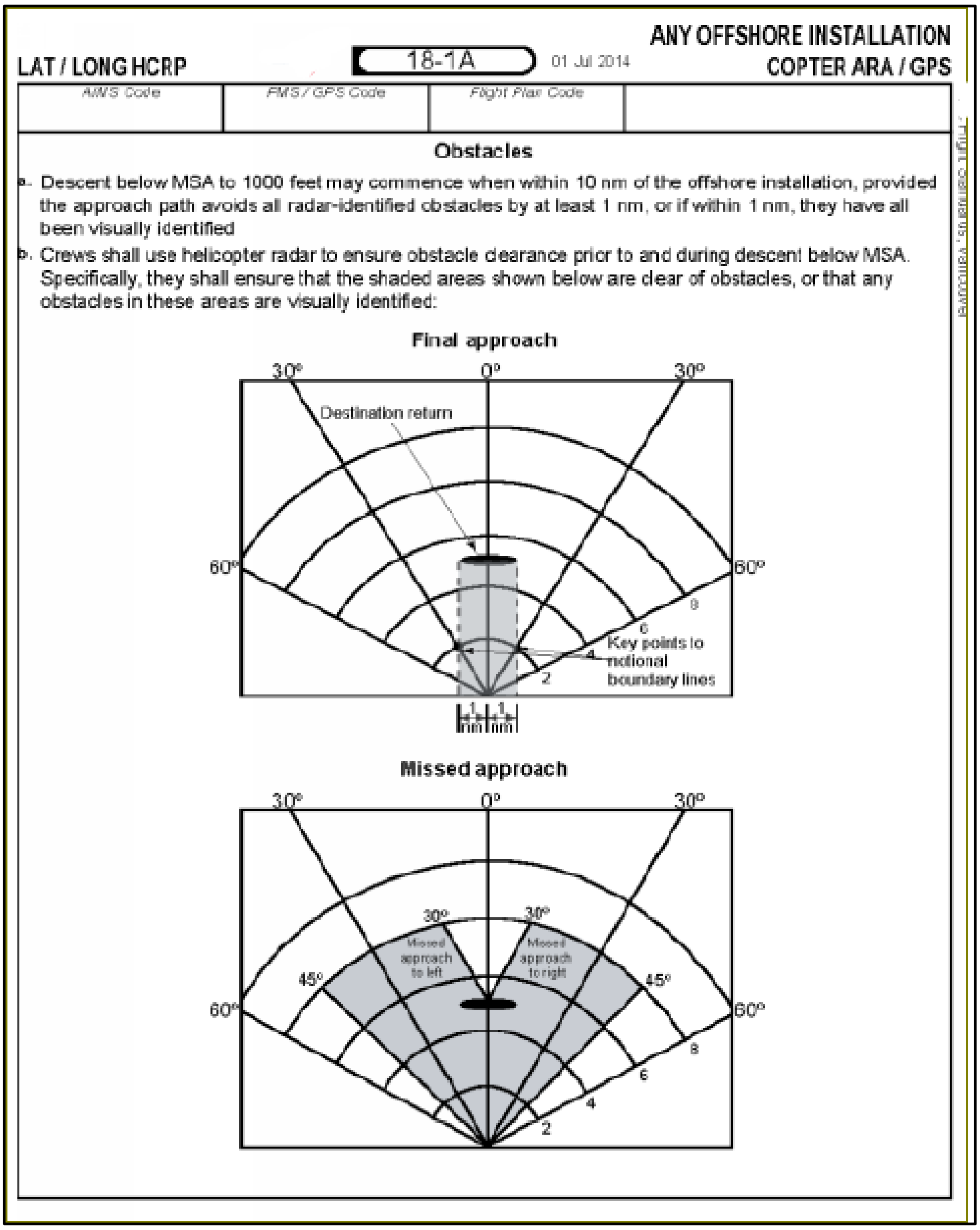
2.12.8.6.4 Radar setup
The primary reference for the approach is the radar. It shall be used for obstacle clearance and determining approach distance to target, the target being the intended landing platform. The radar range shall not be reduced below 10 nm until on final.'

Both OMA and OMC provided a copy of a Sample ARA plate which is shown at **Figure No. 46** and **Figure No. 47**.



Groundspeed	MDH Day	MDH Night	MAPt Day	MAPt Night	Notes
Radar approach minima					a. Or deck elevation plus 50' if greater
≤70 knots	200' (a)	300' (b)	0.75 nm	0.75 nm	b. Or deck elevation plus 100' if greater
70 to 90 knots See note (d)	300' (b)	500' (c)	1.0 nm	1.5 nm	c. Or deck elevation plus 200' if greater d. These limits also apply when the approach requires either manoeuvring to achieve into wind landing, or short transit between approach destination and landing destination

Figure No. 46: Sample ARA plate from OMA and OMC



LAT / LONG HCRP | 18-1A | 01 Jul 2014 | ANY OFFSHORE INSTALLATION COPTER ARA / GPS

AIMS Code	FMS / GPS Code	Flight Plan Code	

Obstacles

a. Descent below MSA to 1000 feet may commence when within 10 nm of the offshore installation, provided the approach path avoids all radar-identified obstacles by at least 1 nm, or if within 1 nm, they have all been visually identified

b. Crews shall use helicopter radar to ensure obstacle clearance prior to and during descent below MSA. Specifically, they shall ensure that the shaded areas shown below are clear of obstacles, or that any obstacles in these areas are visually identified:

Final approach

Missed approach

Figure No. 47: Sample ARA plate from OMA and OMC

1.18.3 Black Rock and its Lighthouse

1.18.3.1 General

Black Rock (**Photo No. 34**) is an island, approximately 420 m by 250 m. It is located off the west coast of Ireland approximately 9.5 NM west of Blacksod Lighthouse. The island has precipitous cliffs and is subject to prevailing westerly winds, Atlantic seas and swell, with the result that its sea cliffs are almost constantly being fringed with white water. In close proximity to the island, the water depths are in the region of 25 m, dropping away quickly to depths of approximately 42 m. A smaller rock, locally known as Parrot Rock, lies approximately 120 m to the east of Black Rock.

Photo No. 34: Black Rock and Lighthouse

Black Rock Lighthouse (**Photo No. 35**) is a circular stone tower located on the western end of the island. The tower is approximately 50 ft in height. The Aeronautical Chart extant at the time of the accident contained a lighthouse symbol (red dot) and adjacent numerals *282*, indicating a combined height of 282 ft. A number of buildings are contiguous to the tower. A concrete helipad, 9.7 m in diameter, is situated to the west of the lighthouse. The centre of the helipad is approximately 14 m from the perimeter wall surrounding the lighthouse and adjacent buildings. A steel grid, 1.7 m wide, is affixed to the outside of the helipad on its western side.

231

Photo No. 35: Black Rock lighthouse, Co. Mayo

The lighthouse marks the outer entrance to Blacksod Bay and provides a recognisable reference and turning point for marine coastal traffic.

The light has been in use since 1864 and has had various configurations since then. The most recent light configuration, a Tideland TRB-220 beacon, was installed at Black Rock on 1 July 2016. It has a published range of 18 NM (white) and 14 NM (red).The '*character*' of the light is one white (to sea) or red (to land) light flash every 12 seconds. This is created by a fixed light-source (i.e. lamp continually '*On*') within a rotating lens. The flash of 0.3 seconds duration is created using six lens panels on a carousel rotating once every 72 seconds.

The red flash is created using red material at the lantern glazing over the specified arc. The sector bearing of travel is 276°-212° or 296° for the white light and 212°-276° or 64° for the red light. The sectored white light indicates the clear water approach to Blacksod Bay, whilst delineating, in its red sector, the off-lying dangers of the Inishkea and Duvillaun More Islands. A detailed description of the characteristics of the light itself is presented as **Appendix W** to this Report.

The lighthouse station is now unmanned, but is under the care of an attendant who visits the station with technicians to carry out routine maintenance.

1.18.3.2 Black Rock/Blacksod Lighthouse System Monitoring

The monitoring of the Black Rock Lighthouse is performed using the AIS. This system sends the status of the light to a Central Monitoring System (CMS), near Dublin, every three minutes, using a VHF radio transmission. Therefore, any failure of the light will be notified within a maximum of three minutes. The status of other equipment at lighthouses is sent to the CMS every six minutes.

The Light (Lantern) has its own control and monitoring cabinet that provides digital outputs with the light state (ON, OFF and FAIL). The control and monitoring cabinet monitors the current flowing through the lamp to detect its state. The AIS unit takes these light indications and populates the relevant fields in the AIS Aids to Navigation (AtoN) Message Type 21 and the AIS GLA monitoring Message 6. These messages are transmitted out on both of the AIS VHF channels (1 & 2). Irish Lights has a network of AIS receiving stations around the mainland coast (nearest at Blacksod Lighthouse), where all received AIS messages (this will include the messages transmitted from Black Rock Lighthouse) are forwarded to Dun Laoghaire, decoded and stored. Irish Lights also has access to the IRCG AIS Network. Received AIS messages are also monitored in real-time, with the current state of the light being displayed to the monitoring officer on duty. During office hours monitoring is in Dun Laoghaire and outside office hours it is from Harwich in the UK.

AtoN21 messages (Message Type 21) are sent via AIS. They fit into two slots, and are transmitted every three minutes. Black Rock AIS transmits on the first minute of the hour, and every three minutes thereafter in Slot numbers 244 and 245 on AIS Channel 1, and in slots 827 and 828 on AIS Channel 2. This equates to transmission times of 6.5 and 22 seconds past the start of the minute, every third minute on channels 1 and 2 respectively. AtoN AIS messages are not received by AIS-equipped helicopters.

The Commissioners of Irish Lights conducted a review of all data for the lighthouses at Black Rock, Blacksod, Eagle Island and Achillbeg for the night of the accident. It concluded that the four lighthouses in the vicinity of the R116 accident location (operational area) were operational over the period of interest; the lights remained on and functioned correctly throughout the period between '*light on*' on the evening of 13 March 2017 and '*light off*' on the morning of 14 March 2017. The results of that review are summarised in **Table No. 27**.

Lighthouse	'Light on'	'Light off'
Eagle Island	13/03/2017 18.32:06	14/03/2017 06.59:06
Blacksod	13/03/2017 18.11:47	14/03/2017 07.05:01
Black Rock (Mayo)	13/03/2017 18.39:22	14/03/2017 06.45:07
Achillbeg	13/03/2017 18.33:09	14/03/2017 07.06:09

Table No. 27: '*Light on*' and '*Light off*' timings for lighthouses in operational area

All messages recorded on the CMS are time-stamped at source. The remote telemetry units at the lighthouses synchronise their clocks with the CMS every time that they communicate. The CMS is synchronised to UTC as are the AIS receiving stations that timestamp the AIS messages.

1.18.4 Cockpit Operating Environment

1.18.4.1 General

Flight deck documentation, written procedures, and cockpit displays, are an inherent part of flight operations, often specifying and dictating the actions by which the crew is expected to interact and interface with the machine and its operating environment. Not only must the crew operate the flight controls and automatic systems, but they must read flight instruments, checklists, charts, and other flight documentation. These tasks require flight crew to be able to see the instruments and documents in question with sufficient clarity. A number of factors may affect this ability to clearly see written text, and flight instrument displays. These factors include, but are not limited to:

- Cockpit Lighting
- Vibration
- Typography
- Colour of displays and graphics
- Ergonomics of cockpit layout
- Document and chart presentation and usability

1.18.4.2 CVR Comment

In **Section 1.11**, it was noted that at 23.32 hrs, while entering APBSS into the FMS, the CVR records the Commander commenting '*the lights in this thing drive me mad* …'. The Co-pilot acknowledged saying '*yeh eh they're atrocious* [Commander's name]' and the Commander's rejoinder was '*They're so annoying I'm pressing buttons here*'. Consequently, the Investigation examined cockpit lighting, and other factors which may have affected Crew ergonomics on the night.

1.18.4.3 Cockpit Lighting

Regulatory Requirements for Cockpit Lighting

Commission Regulation (EU) No 965/2012 of 5 October 2012 laying down technical requirements and administrative procedures related to air operations pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council states:

> '*CAT.IDE.H.115 Operating lights* […] *(b) Helicopters operated at night or under IFR shall* […] *be equipped with: (1) lighting supplied from the helicopter's electrical system to provide adequate illumination for all instruments and equipment essential to the safe operation of the helicopter* […]'

Operator's Cockpit Lighting

The Investigation noted that on 21 February 2015, a request for a local modification to the cockpit lighting was generated within the Operator's base network. The '*Requirement*' section of the modification request document stated:

> *'The current lighting in the aircraft cockpit has proven to be completely inadequate for night time operations. This poor lighting has led to the inability of aircrew to read checklists and approach plates which is a safety hazard.*
>
> *This has in itself led to aircrew bringing a myriad of different personal lighting systems into the cockpit in order to complete the operations. This however also poses a safety and commercial hazard as outlined by SQID […] when an aircraft was grounded due to batteries from a pilots lighting system being lost in the cockpit.*
>
> *Crews were awaiting the implementation of the overhead cockpit lighting mod but have recently been advised that the mod is not compatible with SAR configured aircraft. Therefore for safety and protection of commercial interests this mod should be considered urgent.'*

Regarding the modification which crews '*were awaiting the implementation of*', the Investigation notes an email between Post-Holders dated 20 January 2015 which said, '*This modification is only good for the Oil & Gas A/C the SAR variant has a different wiring /access config, which means we cannot fit it*.'

The locally requested modification, designated AHSE-59190 REV A, was issued by a Part 21 DOA (Design Organisation Approval) on 7 August 2015. The Investigation was informed that, in order to read documentation and checklists in-flight, the Operator's flight crew were bringing their own torches on flights.

The Investigation noted that a SQID report in April 2015 recorded that a heading mis-compare error was noted during a flight. The error was attributed to two LED torches magnetically mounted on the rear cabin walls in the vicinity of the Attitude and Heading Reference System; removal of the torches resolved the error.

The issue over adequacy of cockpit lighting continued, and on 11 July 2016, a SQID report, titled '*Aircraft Cockpit Lighting Inadequate and Mod Yet to be Completed*' was submitted.

The report said:

> '*During SAR 177/16 the issue of inadequate cockpit lighting once again caused issues with reading checklists and completing the PLOG.*
>
> *This issue has been flagged as a safety issue from the very first operation of the S92 in Ireland yet no solution has been implemented.* […] *I submitted a mod request for the provision of a wander light attachment point in the upper hand hold area of the cockpit. This mod was accepted by management, forwarded to* [specific Post-Holder] *where it was approved and has now sat for months with absolutely no progress.*
>
> *The mod itself contains very few parts and very little actual mod work meaning zero downtime to complete*[111]*. The fact that a simple resolution to a safety issue hasn't been completed 18 months after initiation should be a source of concern and embarrassment to all involved*.'

The modification, designated AHSE-59190 REV A, was incorporated on EI-ICR on 14 October 2016.

The Helicopter Manufacturer informed the Investigation that enquiries to its manufacturing facility and customer support group had not found any reports that the cockpit lighting was '*inadequate for night time operations*'. The Investigation asked the Operator if the matter had been raised with the Helicopter Manufacturer. The Operator advised that '*Initial liaison with the* [Helicopter Manufacturer's representative] *in Ireland has not led to any evidence that this particular issue was raised with him.*'

In response to a follow-up query from the Investigation about modification AHSE-59190 REV A, the Operator advised that it '*would not have sent a Part 21 approved modification to the IAA for review.*' The Investigation notes that there is no requirement to provide Part 21 Approved modifications to a regulatory authority.

Between June and August 2015 work was carried out on EI-ICR to incorporate Night Vision Imaging System (NVIS)-compatible components into the aircraft. This work was carried out under an amendment (No. 13) to the contract between DTTAS and the Operator. Components were installed as part of a planned adoption of NVGs (Night Vision Goggles) by air crew. The work had the effect of changing the lighting environment within the cockpit to optimise it for use with NVGs, in particular by altering the intensity and tone of cockpit lighting and its colour spectrum. At the time of the accident the use of NVGs by crews had not commenced.

Anecdotal reports received by the Investigation indicated a variety of views regarding the impact of the NVIS modification on the cockpit lighting environment during night operations; some thought it improved it, others felt that it had dis-improved.

[111] The Operator informed the Investigation that the assertion regarding zero downtime was incorrect.

Some commentators also said that the standard of cockpit lighting varied across the Operator's fleet, i.e. from helicopter to helicopter.

The Investigation notes that two torches were part of the Helicopter equipment fit, mounted in the cockpit abeam each pilot's outboard knee. The Helicopter Manufacturer confirmed to the Investigation that these torches are intended to be used in emergency situations (such as a loss of electrical power) and not intended for normal use e.g. reading of cockpit documentation.

The Investigation was informed by several personnel that at the time of the accident, battery-powered, personal lighting systems were being used by many flight crew members. The Investigation was also advised that personal lighting systems provided by the Operator were routinely used during simulator training. It is not known what, if any, personal lighting systems were being used by the accident Crew. However, the Investigation notes that the equipment checks conducted by the Winch Operator and the Winchman during the afternoon prior to the accident flight indicated that the torches for use in emergency situations were on board the Helicopter.

1.18.4.4 Vibration

There are two principle requirements to enable the eye to view objects with a maximum degree of visual acuity. Firstly, the image must be focused on the retina and secondly, the image should remain stationary on the retina. It is this second requirement that can be affected by vibration. Helicopter vibration has the potential to cause motion of both the eye, and the object being focussed on. Thus, if the pilot's eye is stationary, but is viewing a complex display that is vibrating, the visual acuity of the details of the display may be reduced. Also, at certain frequencies, cockpit vibration can be transmitted through the body to the eye. This relative linear motion between the eye and the object being viewed may result in retinal image motion and degraded visual acuity.

1.18.4.5 Typography

Typography can be described as the technique of arranging type (letters, numbers, symbols) to make written language legible and readable when displayed, and involves the selection of typefaces, point sizes, line lengths, line-spacing, and letter-spacing. One important aviation aspect relates to the readability of text presented to flight crew in the cockpit environment. Amongst the factors that can affect readability of text in the cockpit environment are type of font (such as Helvetica, Arial, Times New Roman), whether a font is Serif[112] or Sans Serif, size of lettering, and background colour upon which the type set.

[112] **Serif**: In typography, a serif is a small line or stroke regularly attached to the end of a larger stroke in a letter or symbol within a particular font or family of fonts.

Research on readability of text used in flight crew documentation indicates the optimal text size uses a character x-height of at least 0.10 inch and a Sans Serif font. Examination of the text page of the Route Guide furnished to the Investigation showed that the font used in the tabulated page for each route was '*Times New Roman*' – a Serif font. When a sample of a printed page of the Route Guide was examined it was noted that the '*x-height*' of text used in the table containing leg heading and distance was less than 0.08 of an inch. However, the x-height of the text in the '*Hazards/Obstacles*' table was found to be 0.10 inch.

In addition, the background colour upon which text is set can also affect its readability. Degani, (1992) NASA Contractor Report # 177605, '*On The Typography Of Flight-Deck Documentation*', noted that it is best to use black type over a white or yellow background for cockpit documentation, and to avoid using black over dark red, green and blue.

1.18.4.6 Research Articles and SIA Serious Incident Report

The above topics (Lighting, Vibration and Typography) have been the subject of aviation research over a number of years.

The Investigation notes the contents of Degani's report (1992), which stated that:

> '*Effective appearance of flight-deck documentation is effected by the correct graphical presentation and the environmental conditions that influence reading in the cockpit. These two factors should agree with the unique physical condition of the cockpit, the capabilities and limitations of the human operator, and the method of using the documentation as dictated in the standard operating procedures*'.

Degani also found that Sans Serif fonts are more legible than roman fonts, and he went on to say:

> *'a font size between 0.14 and 0.20 inches is suitable for checklists and other critical documentation used on the flight deck. However, for practical reasons of limited space on a single page (in case of a checklist) and simply because of increased volume (in case of manuals), this range (0.14-0.20) may not be efficient (Turner and Huntley, 1991). Again, one must not forget that any determination of suitable font height must be combined with accompanying typographical factors such as horizontal spacing, line width, vibration levels, color, etc., before any final judgement concerning the legibility of any typesize can be extracted.* […] *What is clear, from reviewing checklists, manuals, and these data, is that a font size below 0.10 inch for any important flight-deck document is not recommended.'*

Degani also provided research findings and guidance relating to vertical line spacing and horizontal character spacing, document colours, anti-glare plastic laminates and pilot age groups.

The Investigation also notes the contents of a March 2005 study by Kumagai, Williams, & Kline, titled '*Vision Standards for Aircrew: Visual Acuity for Pilots*' carried out on behalf of the Canadian Department Of National Defence. The authors found that:

> '*One common and critical near visual acuity task that all* […] *pilots must perform (regardless of aircraft type) is reading and understanding approach plates in order to land an aircraft at night. Again, this task is common, yet visually demanding and correct performance is critical. The SMEs* [Subject Matter Experts] *discussed extraneous factors that may be present to make this task more difficult including:*
>
> - *Poor interior lighting conditions: For example, the* [other helicopter type] *has red interior cockpit lighting and the interior lights used to view approach plates at night are generally very dim in most cockpits;*
> - *Poor environmental visibility: This task must be performed in any kind of night time environmental conditions including bright sunset, snowstorm, thunderstorm, thick cloud cover, etc. The SMEs indicated that this task is especially difficult at night because of the use of cockpit lighting which inhibits night vision adaptation and renders visibility outside of the cockpit extremely difficult;*
> - *Vibrating cockpit: This task is made further challenging by the vibration of the cockpit. Again, the amount of vibration will be dependent upon the weather conditions experienced. For example, high winds will contribute to a vibrating cockpit which will make this focused reading task extremely difficult;*
> - *Vision Enhancers: Pilots may be expected to perform this task while wearing either laser eye protection or NVGs. Again, this increases the task difficulty, as the approach plates are colour coded and NVGs inhibit colour visibility and distinction. NVGs also inhibit the visible FOV* [field of view] *available to the pilot and make the transition from near, intermediate and far vision very difficult (pilots have to look down below the NVG to see near objects);*
> - *Vision Transition: Pilots must be able to look at their cockpit instrumentation (near and colour vision), to their immediate surroundings (intermediate vision), to distant objects (far vision) for detection and identification purposes. The constant transition between these distances is a challenge to the visual system;*
> - *Combination: Reading and understanding approach plates is a commonly performed pilot task across all aircraft. The combination of any or all of the above listed extraneous factors can challenge the visual system and may render the task of approach plate reading extremely difficult.*
>
> *Any of these extraneous factors may work alone or in combination to challenge the visual system of any pilot, in any type of aircraft, at any time.'*

Johnson and Casson[113] showed that over a range of background luminance from daylight to dark room, visual acuity decreases linearly with reductions in luminance. A person with 20/20 visual acuity under high luminance-high contrast conditions will change to 20/60 visual acuity for low luminous conditions.

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[113] **Johnson and Casson**: Johnson, Chris & J. Casson, Evanne. (1996). Effects of Luminance, Contrast, and Blur on Visual Acuity. Optometry and vision science : official publication of the American Academy of Optometry. 72. 864-9. 10.1097/00006324-199512000-00004.

In addition, an issue that can arise with mesopic[114] vision is that colour perception can change under different lighting conditions. The cause of this change is complex, but in general terms, under reduced light, blue objects appear to glow, and red objects will appear darker[115].

The Investigation also notes that a recent UK AAIB Report, AAIB Bulletin: 6/2019, EW/G2018/08/12 into a serious incident where incorrect flap was used during take-off found that: '*The different flap setting was probably missed at this point* […]. *The lack of contrast in the size and font on the EFB may have contributed to this'.* The AAIB report went on to note that the aircraft operator was considering *'Changing the format, font or colour of the calculated takeoff speeds and flap setting on the EFB to make the calculated data stand out differently from the rest of the inputted data'.*

1.18.4.7 Graphics and Colours

Graphics and Colours used in Route Guide

The Investigation examined the graphic representation of the routes used in the Route Guide. The Operator produced the graphic representations for the routes by copying images from various IAA aeronautical charts. Route overlays were then applied to these images. Route graphics did not contain a scale marker; individual route graphics had different scaling; and tinting of graphics appeared different to the original charts.

The aeronautical charts which were used in Route Guide images depicted bodies of water using the colour blue, with elevations for offshore lighthouses in black italics beside a red dot. The Operator used a red disc, with a white number inside the disc, to designate obstacles. As was noted above, background colour may lead to difficulties reading and seeing text and other graphic representations. An email regarding proposed amendments to the Operator's checklist philosophy as contained in its OMA circulated in July 2015 amongst personnel from the Operator's Parent Company, and Post-Holders from the Operator, identified that a blue background made reading extremely difficult in a darkened cockpit at night. It concluded that '*The Black on Blue is too hard to read at night due to the low contrast between the text and the background*.' While the text page of the APBSS route (and other text pages within the Route Guide) contain black text on a white background, the route map for the APBSS route contained black text on a blue background.

As noted in **Section 1.18.4.6**, mesopic vision under reduced light can raise specific difficulties with colour perception, in particular with blue and red objects.

[114] **Mesopic**: Mesopic vision is a combination of photopic vision (vision of the eye under well-lit conditions) and scotopic vision (vision of the eye under low light levels but not quite dark conditions).
[115] Extract from Ernsting's Aviation Medicine, Colour Vision, Purkinje Shift Phenomenon.

Graphics and Colours used on MFD

The MFDs in the cockpit were capable of displaying different graphic presentations to flight crew, depending on the type of display selected by a pilot. In addition to the selected display option, the MFD was capable of displaying other information, such as waypoints and track line, by overlaying this detail on the MFD screen. Thus, if an MFD was set to display radar ground returns (GMAP2), flight crew could overlay a pictorial representation of a route, such as APBSS over the radar display.

When displaying radar returns, the size of an object detected by the helicopter's radar, when displayed, is dependent on the range selected on the display. Thus, an object detected at 3 NM would appear smaller when displayed on a 10 NM range versus. a 5 NM range. However, the overlay graphics of a route, including track line width, and waypoint designator, have the same thickness and size, irrespective of range selection.

The Investigation notes that the colours used for displaying information on the MFD were, in some cases, the same for different items being displayed. For instance, certain track-lines, waypoint designators, and waypoint labels, would be displayed in magenta – the same colour as some of the terrain returns used by the radar display in GMAP2 mode.

1.18.4.8 Ergonomics of Cockpit Layout & Document Presentation and Usability

The Route Guide, as described in **Section 1.8.2**, was contained in a display book consisting of a number of transparent, A4 size, polypropylene pockets. Each route was presented on two A4 pages, one landscape orientation (the route graphic) and one portrait (the route notes). To use the Route Guide, the display book was opened at the chosen route, in-flight, and held by a flight crew member. A route briefing required the integration of information from both pages, which of necessity involved rotating the book between both orientations. Furthermore, as the pages were held within transparent polypropylene pockets, it is possible that reflections and/or glare could obscure text and graphics under certain lighting conditions. Consequently, reading from such a document presented in this fashion, in the confines of a helicopter cockpit, could be challenging.

The Operator's S-92A fleet was equipped with various OSI and Aeronautical charts. These were stored in a chart locker, in the cabin, beside the Winchman's station. Although they could be used by flight crew during flight, the nature and size of such charts could make their use in the helicopter cockpit challenging. In addition, most of the charts were also available in digital version, on the Toughbook, which was not visible from the cockpit, while some were available in the Euronav imagery in the cockpit.

1.18.4.9 European Plan for Aviation Safety

Since 2018, the European Plan for Aviation Safety, published by EASA, has included '*Reduction in human-factors-caused rotorcraft accidents that are attributed to the rotorcraft design*' (RMT.0713).

According to EASA, it is widely recognised that human factors contribute either directly or indirectly to a majority of aircraft accidents and incidents and that the design of the flight deck and systems can strongly influence the crew performance and the potential for crew errors. EASA said that currently, the certification specifications for rotorcraft do not contain any specific requirements for a human factor assessment to be carried out but that large transport aircraft have benefited from human factor assessments of the design of the flight deck and associated systems. EASA said that '*the development of certification specifications for human factors in the design of rotorcraft cockpits would mitigate the probability of human factors and pilot workload issues that could lead to an accident*.'

1.18.5 Anecdotal Accounts of other Safety Related Occurrences

During interviews with a number of personnel from the Operator, the Investigation heard anecdotal accounts of other events over the years which were serious in nature and involved circumstances where safety margins had allegedly been seriously compromised. The Investigation asked the Operator's personnel who were interviewed why such events might not have been reported and various answers were provided including organisational culture, fear of retribution, embarrassment and pride. The Investigation asked the Operator to provide copies of SQID reports and any/all other documentation/emails/correspondence whatsoever, in relation to alleged safety events. The Investigation also asked for details of any/all other events involving loss of situational awareness/control or during which crews encountered unanticipated conditions which necessitated non-normal recovery strategies. The Operator informed the Investigation that it was unable to get any '*hits*' searching the SQID database for information on any of the alleged safety events. In February 2019, the Operator provided a two-page electronic scan of the '*Operations Record from the Dublin base*' for 29 and 30 November 2005. The log records the crew involved and the tasking details and the comment the following day of '*as of this morning still off line'.* There is no mention of any safety-related event occurring during the tasking. No other documentation was provided in response to this request.

The Investigation asked those who said that they had knowledge of previous events if they could provide any documentation in relation to the events. Details were provided of two events. A 2003 event involved a LIMSAR (non-auto-hover equipped) helicopter; and a 2005 event which was classified as a '*pilot disorientation*' event. Follow-up actions appear to have focused on helicopter capabilities and enhanced training. However, the Investigation notes from the details it received, that both of these events appear to have occurred at night between midnight and 01.00 hrs.

1.18.6 Flight Data Monitoring

One system which has proved valuable in providing feedback to operators and crew is Flight Data Monitoring (FDM). The Investigation notes that the SMCMM incorporated a 13-page section titled '*Flight Data Monitoring (Not currently used within* [the Operator]*)*'. The Operator informed the Investigation that at the time of the accident it did not have an FDM programme for its fleet and that there was no regulatory or contractual requirement for such a system to be used by the Operator.

The Investigation notes that the nature of SAR operations is atypical of other helicopter operations and accordingly, bespoke Helicopter Flight Data Monitoring (HFDM) triggers and interpretation would be required to make optimal use of HFDM in a SAR operation. The Investigation further notes that the HUMS data recorded for each flight may provide a comprehensive data set which could be explored as part of a HFDM programme.

1.18.7 Visibility and Weather Limits – SAR Operational Flight

Due to the fact that the Helicopter was operating in conditions of poor weather and reduced visibility, the Investigation reviewed the associated guidance provided in a number of the Operators manuals. Relevant extracts from OMB and OMF are provided in **Appendix X**.

The mission on which R116 was engaged was considered by the Investigation. OMF lays down procedures for operating a second helicopter as a Support SAR Helicopter tasked to provide support for the primary SAR helicopter, which has been tasked on a long range offshore mission. OMF sets out:

> ***'Support SAR helicopter – Mission conduct:***
>
> *The primary mission of a support SAR helicopter will be to provide assistance in the event of an occurrence onboard the primary SAR helicopter. To accomplish this, the support SAR helicopter crew will be brought to 15-minute readiness at the applicable base for the tasking area.*
>
> *a. In certain conditions, the primary SAR helicopter may request that the support SAR helicopter be positioned to the primary SAR helicopter's last landward point of departure. Factors to consider when requesting this are daylight, weather conditions, sea-state and so on.*
>
> *b) In a small number of cases, it may be prudent to further request the support SAR helicopter act as a chase helicopter. Conditions when this option shall be considered include weather, sea-state, daylight and number of casualties involved.*
>
> *Where possible, the support SAR helicopter should not be shut-down on a refuelling area that may be required by the primary SAR aircraft.'*

OMF also provided the following guidance regarding night scanning: '*The human eye becomes almost completely dark-adapted in 30 minutes in darkness or under red light, thus increasing its light sensitivity approximately 10000 times. Dark adaptation is destroyed very rapidly by exposure to bright light*.'

1.18.8 Fishing Vessel

The FV, which R118 was tasked to assist on 13 March 2017, was a pelagic[116] trawler (**Photo No. 36**) operating under the flag of the United Kingdom (GB).

The FV was built in 2016, and had an overall length of 79 m, a maximum breadth of 16 m and a gross tonnage of 3,080 tonne (t). Accommodation on the main deck was arranged with five single crew and three engineers' cabins and in the superstructure there were four single crew cabins.

Photo No. 36: Fishing Vessel

The Investigation understands that the FV was equipped with a sick-bay and that there was a '*medical chief*' aboard.

Council Directive 92/29/EEC (31 March 1992) provides provisions on the minimum safety and health requirements for improved medical treatment on board vessels. Article 2 of the Directive provides general requirements for carriage of medicines, medical equipment, a sick-bay and medically trained personnel. Specifically Article 2, 3 requires that:

> '*every vessel flying its flag or registered under its plenary jurisdiction, of more than 500 gross registered tonnes, with a crew of 15 or more workers and engaged on a voyage of more than three days, has a sick-bay in which medical treatment can be administered under satisfactory material and hygienic conditions*'.

Article 4 of the Directive provides for the allocation of responsibilities and requires under Article 4, 1, (b) that:

[116] **Pelagic:** Fish that live in the upper water column of the ocean are targeted by pelagic/mid-water trawls. The funnel-shaped trawl nets are hauled by either one or two boats (pair trawls). Pelagic boats generally fish for a single species.

'The management of the medical supplies is placed under the responsibility of the captain of the vessel; he may, without prejudice to this responsibility, delegate the use and maintenance of the medical supplies to one or more workers specially designated by reason of their competence'.

Article 5 of the Directive provides for information and training and requires under Article 5, 3. that:

'The captain and any worker or workers to whom he delegates the use of the medical supplies pursuant to Article 4 (1) (b) have received special training updated periodically, at least every five years, taking into account the specific risks and needs connected with the different categories of vessel and in accordance with the general guidelines set out in Annex V'.

1.18.9 OMC Content for Operator's Routes/Route Guide

The Operator's OMC is titled '*Route Guide(s)*' and provides '*Instructions and information needed for the area of operation. This part is issued individually for each local operating area*.'

OMA contains, *inter alia*, the following entries in relation to Route Guides:

'8.1.2.8 Provision of helideck information

AMC2 CAT.OP.MPA.105

The OMC contains a listing of those helidecks authorised for use together with a listing of the limitations applicable to each deck.

A pictorial representation or template is produced for each helideck by [Named supplier] *and the plates are contained in the Operators route guide.*

12.2.1 Visual flight rules

This section refers to the international standards rules of the air (ICAO Annex 2[117]*) which can be found in the aircraft in the Route Guide Airway Manual, in the section 'Air Traffic Control'. Where national differences from the international standards exist, these are found in the route guide airway manual, near the end of section 'Air Traffic Control'. It is important that these differences are noted when referring to ICAO Annex 2.*

Table of cruising levels is found in the route guide airway manual, section 'Air Traffic Control'. Guidance material related to vertical separation is contained in ICAO Doc 9574.

8.1.3.6.6 Category 1 and non-precision operations – Approach minima, AMC3 SPA.LVO.100, CAT.OP.MPA.110(c). The Company is not approved for category 2 or 3 operations. Specific minima for the aerodromes concerned are contained in OMC. In addition, the minimum altitude shall not be lower than the following table or state minima:'

[117] **ICAO Annex 2**: International Civil Aviation Organization, Annex 2 to the Convention on International Civil Aviation, Rules of the Air 10th edition.

Facility	Lowest DH / MDH (feet)
ILS / MLS / GLS	200
GNSS / SBAS (LPV)	200
GNSS (LNAV)	250
GNSS / Baro-VNAV (LNAV / VNAV)	250
LOC with or without DME	250
SRA (terminating at ½ nm)	250
SRA (terminating at 1 nm)	300
SRA (terminating at 2 nm or more)	350
VOR	300
VOR / DME	250
NDB	350
NDB / DME	300
VDF	350
ARA offshore	See section 8.4.4.3 Sample approach plate

In its introduction, OMC states:

'0.1.7 Other manuals

This OMC shall be used in conjunction with:

a. *The regulations*

b. *AIP*

c. *Aerads*

d. *Landing site directory (LSD)*

e. *FMS route guide'*

Furthermore, OMC states:

'*Minimum flight level / altitude*
Due to the nature of operations, [the Operator] *does not have dedicated routings, and therefore, minimum flight levels or altitudes along such routes. However, the aircraft commander should be satisfied that the flight level / altitude selected for any given flight is in accordance with the criteria contained in OMA chapter 8 'Operations procedures'.*

In addition, OMC sets out, under the heading '*Required aeronautical charts*', '*The following provides information on the charts that shall be available on the aircraft at all times and how to confirm their validity*':

Chart	Validity check
Aerodrome approach charts, Aerads	Aerad amendment record
Heliport operating minima (Ireland and UK)	Current revisions in aircraft Aerad folder
En route low altitude chart UK(L)2e	Aerad amendment record
1:500000 / 1:250000 aeronautical chart	Publication date at www.irishmaps.ie
Landing site directory	S92A: Contact CHC LSD coordinator

OMF states:

'2.9 Weather limits – SAR training flight 2.9.1 Departure [...] *Departures may be conducted under VFR, SVFR or IFR clearances. Normal SVFR minimum of 1500 m visibility and 600 feet cloud ceiling will apply in class C airspace, however, the following minima are to be used with the level routes (see route guide)* [...] *Use of the SHANNON RIVER and WAT03 routes require the radar or FLIR to be serviceable.'*

OMC also states:

'2.11 Aerodrome / operating site categorisation for flight crew competence qualification

Reserved

2.12 Special aerodrome / operating site limitations

For information on approved helipad / heliport facilities, refer to the [the Operator's] *IRE landing site directory (LSD). A copy of the LSD is located in the aircraft and in the base operations room.*

The LSD is also available via the FTP server on iPads and Company intranet.'

The Investigation was informed that on the night of the accident, as part of an Electronic Flight Bag (EFB) project, iPads were under test by flight crew. No iPads were recovered within the Helicopter wreckage, or from the sea bed and although iPads were being carried in the Helicopter there is no indication from the CVR that they were in use by either Flight Crew Member. Furthermore, as they were not yet approved for operational use, persons familiar with the two Flight Crew members informed the Investigation that they considered that it was unlikely either would have been using an iPad; the Commander was the Dublin Base representative for the EFB project and would have been aware of this restriction.

1.18.10 Crew Concept

The Operator informed the Investigation that the ethos that it taught was that the Commander would be the PM and manage the mission. The Investigation reviewed the guidance provided in the Operator's manuals and noted that OMA states:

'Crew concept

Both pilots must understand that their primary responsibility is to ensure the safe flight path of the aircraft. Pilots are vulnerable to inflight hazards stemming from inattention, distraction, high workload, startle (e.g., due to low arousal state), subtle incapacitation, disorientation, and lack of attention. To provide adequate barriers to these threats, the Company has adopted a crew concept that is based on the deployment of effective monitoring skills and use of appropriate task management. The key characteristics of this concept are:

a. Active pilot monitoring, including intervention in accordance with section 8.3.17.3.4 Deviation calls and the two-communication rule

b. Crew cross-checking the actions of each other and the aircraft response

c. Communication

d. Disciplined employment of Company SOPs and checklists

The crew concept shall be used to the highest extent possible during all flight operations.

8.3.17.1 Crew coordination and support

a. The commander shall fulfil his managing and decision making functions irrespective of being PF or PM

b. At any time during the flight, one pilot is PF and one pilot is PM

c. PF is responsible for managing and PM is responsible for monitoring the current and projected flight path and energy state of the aircraft at all times

d. Provided both crew members are trained in accordance with section 5.2.5 Pilot qualification to operate in either pilot's seat, Company policy is for all pilots to operate for approximately half the time in each seat, and to split the flight time equally

8.3.17.1.1 Pilot flying tasks

a. PF's primary task is to control and monitor the aircraft's flight path (including monitoring the autopilot systems, if engaged) and ATC radio calls as required

b. The secondary task of PF is monitoring non-flight path actions (non-ATC radio communications, aircraft systems, other crew members and other operational activities). The secondary task should not compromise the primary task of controlling and monitoring the aircraft flight path.

c. PF shall:

i. Ensure the PM is aware of his intentions at all times
ii. Respond correctly to communication and calls from the PM

8.3.17.1.2 Pilot monitoring tasks

a. PM's primary task is to monitor the aircraft's flight path (including autopilot systems, if engaged), complete checklists, perform ATC radio calls and to immediately bring any concern to PF's attention.

b. The secondary task of PM is accomplishing non-flight path actions (non-ATC radio communications, check aircraft systems, passenger briefings, flight administrative duties, and any other operational activities, etc.). The secondary task should not compromise the primary task of monitoring the flight path.

c. PM shall ensure that PF is aware of his intentions at all times and respond correctly to communication and calls from PF

8.3.17.1.3 Flight path monitoring – crew task management
Effective flight path monitoring is underpinned by a disciplined approach to cockpit task allocation between PF and PM.
[...]
8.3.17.2 Transfer of control
Transfer of control from one pilot to the other shall be distinct, using standard phraseology. Either person can initiate the procedure by the use of the terminology: "You have control" / "I have control". Unless the other pilot is incapacitated, transfer of control has not occurred until the pilot initiating the procedure has received a response from the other pilot. Pilots receiving control are to ensure that automation as applicable is also transferred.
[...]
8.3.14.5 The 'two communication' rule
The 'two communication' rule should be invoked to assist in detecting incapacitation. This states that a flight crew member should suspect the onset of incapacitation any time when a pilot does not respond appropriately to a second verbal communication associated with a significant deviation from a standard operating procedure or flight profile.
[...]
8.3.17.3.4 Deviation calls and the two-communication rule
The crew's primary functions are to control the helicopter and maintain situational awareness while executing a flight as safely and efficiently as possible. Standard crew calls are designed to stimulate early corrective behaviour in response to identified deviations from assigned flight parameters and / or stabilised flight. Any deviation beyond a given parameter shall prompt:

a. The PM to verbalise an awareness or action call to the PF, or

b. The PF to verbalise and take corresponding corrective action, even if not prompted by the PM, or

c. The PM to verbalise, take control, and return the helicopter to assigned parameters and stable flight

The PF shall make a deviation call if he is the first to recognise the deviation and, at the same time, take corrective action. Deviation calls comprise three distinct and sequential stages [Awareness Call, Action Call, Control Transfer]. *The first and second stages use the two-communication rule to identify and correct deviations from the intended flight path. The third stage involves the PM taking control and immediately correcting the deviation. Normal monitoring of the flight profile by both pilots, and in particular by the PM, should result in advisory information being given to the PF well before any specific deviation call becomes necessary.*

> [...]
> *c. Stage three: Control transfer*
> [...]
> *To start this handover of control to the PM, the PM shall state "I have control", to which the PF response is "You have control", at which moment the PF relinquishes control of the helicopter and assumes the duties of the PM.*'

OMF 3.19 Offshore / coastal SAR airborne radar approaches (SARA) stated '[…] *The commander will normally be the PM.* […]'.

1.18.11 Intuitive Judgment and Cognitive Heuristics/Bias

CVR equipment is installed by regulation for the sole purpose of assisting state safety investigations of occurrences. The CVR for the accident Helicopter provided the Investigation with important information regarding the accident flight. Despite this, there are aspects of the Crew's communications, actions and interactions that would best be studied from video; cockpit cameras were not fitted to the Helicopter, nor were they required to be fitted. However, in trying to understand the decision-making on the accident flight, it is appropriate to note the psychological complexity and difficulties associated with consistently selecting and pursuing the most appropriate course of action, under challenging conditions. The purpose of the following information is to provide a context for some of the nuanced and overlapping factors which could have affected the Crew's decision-making during the accident flight.

Nobel Laureate Daniel Kahneman, in his book '*Thinking, Fast and Slow*' (2011), presented an overview of the psychology of judgment and decision-making. Kahneman describes a model of human decision-making that views the brain as two agents, referred to as System 1 and System 2, which '*respectively produce fast and slow thinking*.' He explains that:

- System 1 operates automatically and quickly, with little or no effort.
- System 2 allocates attention to demanding mental activities, for example, complex computations.

Kahneman describes how automatic thoughts/suggestions of System 1, may go unchecked by the deliberative System 2, and lead to intuitively selected courses of action being followed, even if a System 2 deliberation could and should have rejected the course of action. Kahneman found that tiredness disposes persons to accepting intuitive, automatic System 1 suggestions, rather than using their System 2 agency to deliberately assess their options.

Kahneman describes cognitive shortcuts, called heuristics, and cognitive biases, which can affect human thought processes, particularly System 1 operations, and can result in sub-optimal courses of action being pursued. Kahneman describes how the association of ideas/associative activation can cause the conjunction of two unrelated words to be treated as representations of reality. He also found that System 1 understood sentences by trying to make them true, and selective activation of compatible thoughts produced a family of systematic errors which made individuals prone to believe too strongly in whatever thoughts they held.

Kahneman discusses the '*priming effect*' – how exposure to a particular word can cause immediate and measurable changes in the ease with which related words can be evoked. He found that an individual could be influenced by past events which might be priming their actions. Kahneman describes how the ease of '*availability*' of information could lead System 1 to select a course of action which the more deliberate System 2 might reject, if it were activated. He also described the '*sunk-cost fallacy*', whereby an individual or group, persisted with an original course of action, in which it had become invested and had '*sunk costs*' into, even if it was apparent that a preferable course of action was now available.

Furthermore, in the December 2006 edition of '*Aviation Safety World*' (pp. 28-33), Berman, B. A., & Dismukes, R. K., in an article titled '*Pressing the Approach*', described '*plan continuation bias*' (also known as '*get-there-itis*'), as '*a deep-rooted tendency of individuals to continue their original plan of action even when changing circumstances require a new plan*'.

Kahneman also describes a phenomenon called '*WYSIATI*', an acronym for '*what you see is all there is*' – a reliance on information presented without seeking out absent information which might improve understanding and decision-making. Kahneman said that WYSIATI could be invoked to explain a long and diverse list of biases of judgment and choice, one of which was over-confidence.

1.18.12 Automation Bias

In 1998, The International Journal of Aviation Psychology, published a paper (8:1, 47-63) by Kathleen L. Mosier, Linda J. Skitka, Susan Heers & Mark Burdick titled '*Automation Bias: Decision Making and Performance in High-Tech Cockpits*'. Mosier, et al, described (page 49) how:

> '*The availability of automation and automated decision aids feeds into the general human tendency to travel the road of least cognitive effort. Typically, people try to engage in the least amount of cognitive work they can get away with (Fiske & Taylor, 1994), will prefer strategies that are easy to justify (and do not involve analyzing relative weights or numerical computations) and will often utilize heuristics (or cognitive shortcuts) to reduce effort and information load. To be successful, heuristics must provide quick and simple ways of dealing with a great deal of information and must be reasonably accurate most of the time*'.

In their '*Discussion*' (page 59), Mosier, *et al*, found that:

> '*Results of this study suggest that automation bias is a significant factor in pilot interaction with automated aids, and that pilots are not utilizing all available information when performing tasks and making decisions in conjunction with automation. Pilots exhibited the same overall rate of automation-related errors as the student population in the Skitka et al. (1996) study, demonstrating that expertise does not insulate individuals from automation bias. In fact, experience and expertise, which might be predicted to make pilots more vigilant and less susceptible to automation bias, were related to a greater tendency to use only automated cues. One possible explanation for this may be that, because automated systems tend to be highly reliable, more experience with them reinforces the notion that other cues are merely redundant and unnecessary.*

Additionally, the higher-experienced pilots in this study tended to be those more senior within their airline, and were currently flying as captains. They may be used to delegating the cross-checking role to their first officers rather than doing it themselves […] *Pilots may not ever be aware that they are using automated information as a short cut, either because the automated cues are in fact consistent with other information (and no error results), or because errors are not traced back to a failure to cross-check automated cues.*'

Complaints documented in BFSM minutes suggest a bias/preference for moving map systems over paper charts, when navigating in unfamiliar areas such as UK airspace. The Dublin BFSM minutes included: '*Some of the map images in aircraft are completely blurred and unreadable. For reasons of safety this system needs to be updated and of a quality that it is usable for our current operations both in Ireland and the UK*.' The minutes also recorded that the moving map system had proved inadequate during a night mission to the UK and that paper charts had to be used for navigation at all times when in UK airspace. The Operator informed the Investigation '*that paper charts are there as a back-up and are not 'unsafe*''.

1.19 Useful or Effective Investigation Techniques

The Helicopter Manufacturer used a simulator to fly a profile closely matching the final minutes of R116's recorded parameters and provided a video of the cockpit displays to the Investigation.

The Operator, with approval from IRCG, facilitated a Review Flight (**Section 1.16.1**) in one of R116's sister ships. This allowed the Investigation to review a number of issues relating to cockpit displays and the Toughbook, when operating in the area of Black Rock using waypoints derived from the final minutes of R116's recorded parameters.

Both the simulator flight and the Review Flight were of assistance in clarifying the Investigation's understanding of events during the accident flight.

2. ANALYSIS

2.1 Introduction

In this Section, factual information is analysed in order to identify findings and to support the making of safety recommendations, where appropriate. A safety recommendation made in this Report shall in no case create a presumption of blame or liability.

The Dublin-based Helicopter (operated as '*Rescue 116*') was tasked to provide Top Cover for the Sligo-based helicopter (operated as '*Rescue 118*'), which had been tasked to recover a casualty from a Fishing Vessel, situated 140 miles from Eagle Island. The accident occurred when R116, which was routing to Blacksod to re-fuel, impacted with terrain at the western end of Black Rock, and departed from controlled flight. The Investigation considered all aspects of the Helicopter's flight including: mission planning; the flight path selected for the mission; why Black Rock was not identified as an obstacle on the Helicopter's flight path; and, why its presence was not detected in time to conduct an effective avoidance manoeuvre. In addition, the Investigation must consider the context within which the mission was undertaken, the arrangements in place for the management and oversight of such missions by the Operator and the oversight of SAR helicopter operations in general.

SAR flying is an activity that may be conducted outside of normal aviation limitations as prescribed in regulations; this is recognised in the National SAR Approval. However, it is for this very reason that rigorous efforts must be made, and systems put in place, to ensure that risk is reduced to as low as reasonably practicable for SAR crews. In this regard, the Operator's OMF states '*The principles and guidelines provided in the OMF will assist the SAR crew to accomplish the SAR objective, while protecting the safety of, in order of priority, the aircraft, the winchman and the casualty. In other words, the aim is not SAR at any cost and there will be limiting factors that may preclude a SAR operational flight*.'

The Investigation evolved from the initial on-site phase when the search for missing persons was the main priority. Thereafter, activities included location and recovery of wreckage and recorders, data analysis, organisational considerations and oversight arrangements. The Factual Information presented in Section 1 of this Report follows the template set out in ICAO Annex 13. This Analysis section integrates the factual information to develop the fullest possible understanding of the accident flight and of the wider context within which that flight was being operated, including, but not limited to, the Helicopter itself, the Operator, the tasking agency, and the oversight arrangements.

The Analysis will be presented under five main headings: The Accident Flight; Organisational Aspects; Oversight; Survivability; and Human Factors. The Analysis will conclude with a Summary. In dealing with specific topics, it will not always be possible for the Analysis to follow the temporal sequence of events on the accident flight, i.e. events may be dealt with out of sequence and, when necessary, certain matters may be addressed under more than one heading.

2.2 The Accident Flight

2.2.1 Mission Planning Prior to Departure

The Co-pilot, who was staying at the SAR base at EIDW, was alerted by MRCC Dublin at 22.10 hrs via a group TETRA radio call. At 22.15 hrs, MRCC Dublin rang the Co-pilot directly and briefed him on the mission. The Commander was at home when alerted about the mission, and travelled by car to the Dublin SAR Base. While en route, the Commander was in phone contact with MRCC Dublin to request information about a possible weather-alternate airfield (in the Dublin area) in order to inform her decision-making and fuel planning. Also, while travelling to the Dublin SAR Base, the Commander contacted the Sligo SAR Base and spoke to the R118 winch operator, at which time he assumed the Commander would be routing to Blacksod. Subsequent to arriving at the Dublin SAR Base, the Commander briefed a Sligo engineer (by phone) that R116 would conduct a rotors-running refuelling at Sligo. The Commander arrived on the Dublin SAR Base at approximately 22.35 hrs, followed shortly afterwards by the two Rear Crew, who had also travelled from home.

The four Crew Members had a crew meeting in the Operations Room. The Winch Operator contacted MRCC Dublin by phone, seeking an updated coordinate position for the FV. In a recording of the phone call, the Commander could be heard in the background delivering a briefing, although it was not possible to determine the specific contents of the briefing from the recording. The Winch Operator contacted MRCC Dublin by phone a second time to enquire if R118 was having trouble getting into Blacksod. When MRCC rang the Dublin Base to provide the requested position update, the phone was answered by the Co-pilot, who handed it over to the Winch Operator. The Co-pilot must have left the Operations Room shortly afterwards, as the CVR recording shows that he attended the Helicopter for refuelling.

An engineer at the Sligo SAR Base recalled that after R118 had departed, the Commander (of R116) called the Sligo Base. The Sligo engineer believed that this call was made from a landline. The Commander and the engineer knew each other and having exchanged pleasantries, the Commander briefed the engineer that R116 would be coming into Sligo for a rotors-running refuelling because the weather at Blacksod was unsuitable. The exchange of pleasantries indicates that the Commander did not feel under inordinate time pressure. The Commander's intention at that time was to go to Sligo, which is why she pre-warned the Sligo technical staff so that they could prepare for a rotors-running refuelling. The fact that the Commander believed that the weather in Blacksod was unsuitable indicates that she had carried out a weather check.

The Co-pilot arrived at the Helicopter at approximately 22.47 hrs, and told the engineer that the Commander had requested a total fuel on board of 5,000 lbs; this indicates that the fuel load had been discussed and decided by the Commander. CVR recordings indicated that the two Rear Crew members were next to arrive at the Helicopter. The Commander was first heard on the Helicopter's CVR recording at 22.53 hrs. Prior to departure, the Commander had expressed doubts (to MRCC Dublin) about the weather in Blacksod and indicated that R116 would route to Sligo.

At 22.53 hrs, the Co-pilot informed ATC '*four persons on board ah just eh four hours endurance it's for departure from the field eh west bound eh either to Sligo or Blacksod we're not sure at the moment* […]'.

The CVR records that the Commander raised the issue of how long it had been since she had been in Blacksod and asked the Co-pilot how long it had been since he had been there; he replied that it had been a while for him too. In flight, the Commander asked for the '*three books*' to select FMS waypoints and a route for Blacksod, which indicates that the Commander was not familiar with the waypoint designator or routes for Blacksod. Accordingly, it seems that the Commander and Co-pilot had not discussed Blacksod in detail prior to R116's departure and consequently, that there was no detailed planning or route familiarisation for Blacksod prior to R116's departure. This may have been due to the fact that it was originally intended to route to Sligo. It may also have been because, as SAR practitioners, they were accustomed, and routinely trained, to accept an unplanned tasking whilst in-flight and to carry out the necessary planning en route. In this regard, OMF stated, '*The nature and complexity of the SAR operational flight will dictate the extent of the briefing. An initial brief prior to launch may be augmented by a more detailed brief en route to the scene as more information comes to hand.'*

At 22.53 hrs, the Commander advised the Co-pilot, '*just giving you direct to Sligo there we'll put everything in en route*'; this was a reference to the Commander's entry into the FMS system. R116 departed Dublin at 23.03 hrs, which was outside the target time of 45 minutes from tasking to get airborne during night hours. However, there was no indication that this target was weighing heavily on the Crew because the CVR does not contain any indication that it was discussed in flight. Notwithstanding this, the Crew were aware that R118 was already airborne and the intensity of R116's Crew's efforts to contact R118, during the flight, indicates that R116's Crew was keen to provide timely support. The number of Winch Operator communications engagements (114 in total, comprising 79 that were mission-related and 35 that were R118-related) and overall duration (28 minutes and 49 seconds) had the potential to cause distraction. However, the Investigation notes that during the descent at approximately 2,000 ft the Commander advised the Rear Crew that the Flight Crew were disabling the audio on the HF and FM radios as it was going to be '*busy for a bit*'.

The Investigation was provided with photographs of a number of Operations Room screens and documents, but these were taken some hours after the accident and while useful for the Investigation, because the Operations Room was in use in the intervening period, they could not be relied upon to indicate the exact nature of pre-mission planning.

2.2.2 Decision to proceed to Blacksod

At 23.06 hrs, the Commander learned from the Winch Operator that R118 was about to land in Blacksod. The Commander acknowledged this saying '*oh great thanks you might just find out what the conditions are like there as well*'. At 23.07 hrs, the Commander remarked '*we'll just get out of Dublin* [airspace] *and then we can start to have a look at everything*'. At 23.12 hrs, the Winch Operator, based on a TETRA call from R118, advised the Commander '*conditions good at Blacksod*'. At 23.15 hrs, the Commander began comparing the options of going to Sligo or Blacksod in terms of flight time and fuel required. She requested the '*three books*' which were provided by the Rear Crew.

The Winchman inquired '*Do you want Blacksod in*' and the Commander asked '*what's the designator for that?*' The Winchman said '*B L K S D*', and the CVR indicated that the Commander entered this designator into the FMS. At 23.20 hrs, the Commander concluded that it made more sense to go to Blacksod. The Rear Crew expressed their agreement and the Commander asked the Co-pilot '*what do you think*' and he agreed '*yeh*'. The Commander said '*We're going to have a good bit of clag around but we've got time'*; the Co-pilot agreed saying '*we've got time*'. The Commander continued '*We're not under any pressure so … eh … happy enough with that and look if we don't get in we've got plenty of fuel to*'; the Co-pilot interjected '*get us to Sligo*' and the Commander continued '*get back so I'm just going to give you a direct to em Blacksod now. You'll get a left turn*' and the Co-pilot answered '*alright*'.

Therefore, having initially told the Sligo engineer that weather at Blacksod was unsuitable and that she would be coming into Sligo for rotors-running refuelling, the Commander re-evaluated the options. The catalyst for this re-evaluation appears to have been the report from the Winch Operator that R118 had landed in Blacksod and that conditions there were good. The fact that, in flight, the Commander did not initially know the waypoint designator for Blacksod (BLKSD) indicated that she probably had not used it for mission planning purposes prior to launching from Dublin. The CVR dialogue shows that the Commander and the Co-pilot had expected poor weather in Blacksod ('*a good bit of clag around')* but that they felt that they were '*not under any pressure*', had '*plenty of fuel*' and agreed '*we've got time*'.

2.2.3 Route Selection

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At 23.36 hrs, the Helicopter had levelled at 4,000 ft, and the Commander said '*Just going to re-familiarise myself with Blacksod … south*'. It seems likely that the Commander was looking at the Route Index at the front of the Route Guide. The index listed the 29 routes in the guide, with APBSS Blacksod South as the first route and APBSN Blacksod North as the second. The Co-pilot noted '*what's the wind doing? From the west okay*'. The Commander acknowledged saying '*yeh … reduce the speed as much as we can, there's the northern one, but I'd rather not*'. The Co-pilot added '*showing forty knots from the west*' and the Commander acknowledged '*yeh shouldn't be too lumpy as well … APBSS … Just going to pop that* [APBSS] *in now*'.

The Investigation notes that the Co-pilot made two observations about the wind; it is not possible to know whether he was merely providing information to assist the Commander, or whether he believed it warranted further consideration in the route selection process. However, the Commander acknowledged both of the Co-pilot's inputs, and when she selected APBSS, the Co-pilot did not raise any objection. It is also noted that the Commander's method of re-familiarising herself with the Blacksod South route was to '*pop that in*' (to the FMS), i.e. it did not seem, at that stage, to involve a detailed study of the Route Guide; this may indicate an automation bias — a tendency to rely on the validity of automated systems, without additional checking.

The Commander then asked the Co-pilot '*k .. just double check this yeh Black Rock eh M O that's the first one*' and the Co-pilot acknowledged '*yeh*'. The Commander continued '*S D A, S D B, S D C … D B and then the rest is out*'; the Co-pilot acknowledged '*Thank you*'. The Commander said '*ah sending you direct to the ... this one*', the Co-pilot acknowledged '*Okay*' and the Commander continued '*this offshore one … going direct to L M O'*. The reference to '*this offshore one … going direct to L M O'* suggests that the Commander was briefing the Co-pilot from an image of the route, because it would only be clear from an image that a particular waypoint was offshore. It seems likely that the image used for briefing was the image from the Route Guide, given that the 1:250,000 Aeronautical Chart, Euronav imagery did not extend as far west as Black Rock.

At 00.22 hrs, while still at 4,000 ft, the selected range on the weather radar was changed from 25 NM to 10 NM at a position 24 NM east of Black Rock, and remained on the 10 NM setting for the remainder of the flight. With a selected radar range of 10 NM or greater, once direct to BLKMO was selected, indications of Black Rock on the radar screen could have been obscured, partially or fully, by an overlaid waypoint marker, as was observed on the Investigation's Review Flight. Therefore, for the remainder of the flight, unless the route symbology was disabled or a shorter radar range was selected, radar returns from Black Rock could have been obscured, as was the case on the Investigation's Review Flight. The CVR recording did not contain any discussion about de-selecting symbology and the FDR does not record route symbology selections.

The Commander continued '*we'll just stay up here and we can and once we're happy and we're clear … no point in rushing unless we … or we're going to be sitting there*'. The Co-pilot acknowledged this saying '*Do our let-down out there*'; the Commander agreed '*Okay*' and the Co-pilot acknowledged '*no problem*'. This exchange indicates that the Flight Crew intended to maintain a safe altitude ('*stay up here*') until they were '*clear*' of land, and then '*let-down out there*', i.e. offshore, over what they believed was open water. At 23.40 hrs, the Commander stated that '*I'm planning to go around the houses*', an apparent reference to following the route in its entirety, and gave an arrival estimate of 00.40 hrs, which the Co-pilot noted as being in one hour.

At 23.52 hrs, the Commander commented '*God I'd say I haven't been in Blacksod in about fifteen years*', the Winchman replied '*yeh it's been a while for me too alright*'. The Commander then asked the Co-pilot '*How about you* [Co-pilot's name] *have you been in recently?*' to which he replied '*No not recently* [Commander's name] *been a while*'. The Commander's motivation for this '*fifteen years*' comment is unknown; it may be that she appreciated that a lack of familiarity with the route and the landing site was a disadvantage, which would explain why she specifically asked the Co-pilot about his recency. However, the lack of familiarity on behalf of either Flight Crew member did not prompt further discussion, suggesting that neither the Flight Crew, nor the Rear Crew who contributed to the exchange, considered or appreciated that the lack of familiarity was a risk factor that required further discussion.

Later in the flight, at 00.24 hrs, when the Winchman was being briefed on the approach, he observed that there was going to be a strong tailwind; the Commander commented '*yeh we're just going to bring the speed back em we'll just we'll keep it coupled the whole way keep the speed back and it's much more manageable as we go around the corner there*'. The Commander went on to say '*it's been donkey's years since I've been in here but we'll stay nice and controlled*'. This again suggests that the Commander was aware of the Flight Crew's lack of recent experience operating at Blacksod and intended to mitigate any associated risk by staying '*nice and controlled*'. Furthermore, the Commander's comment at 00.26 hrs, '*off Eagle Island, wherever that is…Where's Eagle Island?*' indicates that she was not familiar with the topography of the area into which the Helicopter was descending, to operate at 200 ft.

These comments, allied with the Commander's earlier comments that they were '*not under any pressure*' and had '*plenty of fuel*', and the Co-pilot's agreement '*we've got time*', suggests that the Flight Crew believed that the lack of perceived pressure and the availability of time were factors in their favour which could mitigate risks such as their lack of familiarity with Blacksod.

During the briefing, at 00.24 hrs, the Winchman acknowledged that he understood the plan. He also remarked that the high ground was '*obviously in here somewhere*', and the Commander replied '*Down here…this is our first point here; we go S.D.A., that's kinda when we're abeam Achill*'. The Investigation notes that the Winchman was the only member of the Crew to raise the issue of high ground/terrain in relation to the APBSS route, when he said the high ground was '*obviously in here somewhere*'; and that the Flight Crew seemed content that it did not warrant detailed consideration. The Investigation notes that the Commander mentioned keeping the speed back five times: twice during this briefing with the Winchman, once during the briefing to the Co-pilot at 00.10 hrs, once during the Descent Brief ('*getting the speed back as much as we're comfortable'*), and after the landing checks were complete when the Commander requested the Co-pilot to '*put the speed back to seventy five* [kts IAS] *as we go round the corner*'. Accordingly, it seems that reducing speed was also a risk mitigation tactic being employed by the Commander.

At 23.55 hrs, the Commander asked '*can you guys take that one there that book out of the way it's kind of annoying me I need to do this*'. It seems likely that the book the Commander referred to was the RNAV (Area Navigation) Waypoint Listing, because the Route Guide and LSD were subsequently available in the cockpit and referred to by the Flight Crew.

At 00.05 hrs, approximately a half hour after the Commander selected APBSS as the route in the FMS, the Commander said '*just going to double check that route em* [Co-pilot's name] *to see if … we need to do any overflys'* and 38 seconds later she followed-up with *'yeh it does say here em severe turbulence may be experienced during this approach due to proximity of Achill Island*'; this is the text of the '*General Comments*' in the APBSS route description. The Co-pilot acknowledged, and the Commander went on '*in strong winds from the south south westerly direction so*' to which the Co-pilot responded '*Okay*'. The Commander continued '*we're kind of there but more westerly*', the Co-pilot acknowledged, and the Commander continued '*eh use of A B P S. Blacksod north....sure we'll give it a go if we don't like it we'll just go north*' which the Co-pilot acknowledged '*Yeh Okay*'. The Investigation notes that the Commander did not verbalise the last two words of the '*General Comments*', i.e. '*is advised*'.

The exact reason for her preference for APBSS over APBSN is unknown; it may have been because of the greater length of APBSN, or because APBSN crossed terrain at Elly Bay; or it may have been due, at least in part, to a '*plan continuation bias*', that having initially selected APBSS, and briefed it, she wanted to try it before opting to try the northern route.

The Commander verbalised the '*General Comments*' section of APBSS as part of a '*double check*' of the route; the '*General Comments*' section is the only general text (as opposed to tabular) entry on the Route Guide, was located three quarters of the way down the page and came after tables titled '*Navigational Plan; Hazards/Obstacles; Coastal NDBs/lighthouses; Comms*'.

Mosier, et al, found that automation bias is a significant factor in pilot interaction with automated aids, and that pilots were not utilising all available information when performing tasks and making decisions in conjunction with automation. Mosier, et al, also found that people prefer strategies that are easy to justify (and do not involve analysing relative weights or numerical computations) and will often utilise heuristics (cognitive shortcuts) to reduce effort and information load. Kahneman explained that the easy '*availability*' of information (for example, in this case, a route), may lead to its unquestioned selection.

It is therefore possible that automation bias, '*availability*' of the route for loading in the FMS, and the belief that it was a '*low level*' route all played a part in the Commander not verbalising tabulated, numerically dense, data and instead she relied on the one piece of plain text provided in the '*General Comments*' section. Also, it should be noted in a further possible biasing effect, the '*General Comments*' section of the Dublin Low Level routes with which the Flight Crew were familiar, did provide specific operating altitude information; so the absence of altitude information in the '*General Comments*' section of APBSS may have led the Crew to believe that flying the route at 200 ft would not be a particular safety issue.

The Commander conferred with the Co-pilot about the use of '*overfly*' and '*smart turn*' for the route waypoints to maintain terrain separation. Initially the Commander said '*keep them all overflys … might be away far enough from the land aren't we'.* However, in relation to a route waypoint, which the Investigation believes was BKSDC, the Commander said '*that one we'll probably make a smart turn though*.' The Co-pilot agreed saying '*it's quite tight for an overfly*' and the Commander concurred saying '*we'll cancel overfly that one*'. This exchange indicates that the Commander believed that all the waypoints except BKSDC, which she made a '*smart turn*', were '*away far enough from the land'.* Therefore, it appears to the Investigation that the Flight Crew's focus was on using overfly and smart turn selections to ensure that they maintained the lateral separation which they appear to have believed the route was designed to provide. Such a belief regarding lateral separation being provided by route design would explain why, in relation to the APBSS route, the crew did not discuss safe altitudes for the legs or the route.

Further evidence that the Commander believed that lateral separation was provided by the route and consequently obstacles/vertical clearance was not a consideration when following the route (with the FMS) can be found in the Commander's brief to the Co-pilot; at 00.10 hrs, the Commander said '[…] *we'll do the approach one all the way down* [to 200 ft]*, let it just fly the route, get the speed back until we're comfortable and literally just let it fly all the way round* […]'. The Investigation notes that as the waypoint BLKMO was positioned in the water just off the eastern end of Black Rock, the obstacle was not on the route, i.e. the accident occurred as the Helicopter was manoeuvring to start following the APBSS route at BLKMO, but before the Helicopter had actually commenced the route itself.

It should also be noted that the Commander had considered safe altitudes several times during the cross-country transit:

- At 23.14 hrs, R116 advised Dublin ATC that 4,000 ft will be required '*at some stage*'.
- At 23.27 hrs, R116 confirmed to Shannon Information (ATC) that it would be climbing to 4,000 ft in approximately 20 NM.
- At 00.16 hrs, the Commander observed that they were passing over the high ground at the Nephin Mountains, '*There is a two six four five which is past Nephin isn't it*'. The Winchman replied that they had '*all the Nephins there*' and quoted a figure of '*630*' [metres].
- At 00.21 hrs, the Commander commented that Achill was to the South of their
259 track with a height of 2,267 ft, and that they were to be sure that they were clear of it before they descended.
- During the DVE Approach checks, at 00.27 hrs, the Commander's let-down procedure briefing included '[…] *I'm going to do an approach one all the way down to two hundred feet,* […] *continue on past there go back around and the aim is just to follow the route all the way round* […]'.
- Following an initial discussion, at 00.34 hrs, about the arrival into Blacksod, the Commander noted that the Helicopter was approaching position BKSDA, and that there was high ground of 2,257 ft in their '*9 O'clock*' position; and the Winchman advised that they were '*all clear ahead*'.

At 00.13 hrs, the Co-pilot asked to see the map of their route and the Commander assumed control of the Helicopter telling him it was on the '*first page*'. The Co-pilot asked the Commander about the intended escape route, if they did not become visual. The Commander's reply was '*direct to back down here or even just head south* […] *there's a mast up there somewhere they're saying on the west*'. The phrase '*they're saying*' suggests that the Commander was referring to something that she had read. The Investigation believes that this was probably a reference to APBSS '*Hazards/Obstacles*' entry 5 which read '*Aerial west of Blacksod 250'*. The Investigation notes that the LSD for Blacksod lists at Obstacle 6, '*Boat Mast behind house*', but as the comment '*they're saying*' was part of a route discussion the Investigation does not think that the Commander was referring to Obstacle 6 from the LSD.

Although the CVR did not record the Commander verbalising the hazards/obstacles for APBSS, the comment '*they're saying*' suggests that the Commander had read, and recalled, at least some of the hazards/obstacles information. The Investigation notes that 38 seconds elapsed between the time the Commander said '*just going to double check that route em* [Co-pilot's name] *to see if … we need to do any overflys'* and the time she verbalised the '*General Comments*' section of the APBSS route. It is possible that in those 38 seconds the Commander scanned the '*Navigational Plan*', '*Hazards/Obstacles*' and '*Comms*' tables of the APBSS route. The fact that the Commander's only reference to an obstacle was when discussing the '*escape route*' is a further indication to the Investigation that the Commander considered that while the Helicopter was following the APBSS route, obstacles were not a concern, but that once it departed from that route, as would be the case when following an escape heading, then the obstacle environment had to be considered. This would explain why the comment about the mast on the west was only made in relation to selecting south as the escape heading.

The Co-pilot asked for an opportunity to independently self-brief APBSS when he requested '*wouldn't mind just getting a look at the map of it there*'. During his self-briefing he did not verbalise any hazards/obstacles information, nor did he raise it at any other time during the flight. Therefore, it would seem that he may also have believed that the obstacle/hazards listed were not concerns when following the route. This is a further indication that it is possible that both Flight Crew members believed that the APBSS Route, by design, provided lateral terrain separation.

It appears to the Investigation that the Flight Crew may have believed that if a specific altitude was required for a route or leg this would be specified in the '*General Comments'* section, as was the case with the Dublin SAR Base routes that the Flight Crew were familiar with, which specified that over water legs were to be flown at 500 ft. In this regard, the Investigation notes that, at 00.05 hrs, the Commander did verbalise the '*General Comments'* section of APBSS and discussed it with the Co-pilot.

The Investigation considers that a belief that the APBSS Route provided lateral terrain separation, and that if altitude restrictions applied to a leg or route these would be specified in the '*General Comments'* section, could explain why the Flight Crew was content to descend to 200 ft prior to commencing their route (APBSS) into Blacksod. It could also explain why the Flight Crew did not have a detailed discussion about each obstacle listed for APBSS.

At 00.32 hrs, the Flight Crew briefed for the arrival at the helipad at Blacksod. The Commander initially asked the Co-pilot to double check that 50 ft was to be added to the LDP for their arrival heading of 210-240 degrees according to the LSD chart (**Figure No. 9**). The Co-pilot confirmed the 50 ft addition to the LDP. The Commander replied '*fifty feet okay and anything else they're saying on that eh*'. The Co-pilot then verbalised the entire '*Note*' section, which was located at the bottom of the LSD page, without any reference to the '*Obstacle*' table located between the *'Landing Heading*' increment table and the '*Note*'. The Investigation notes that the Flight Crew, individually or collectively, appear not to have considered the LSD obstacles.

The Flight Crew's operating procedure was to use the table to calculate a safe LDP for the approach heading and then they appear to have expected anything else of importance to be stated in the text of the '*Note*' section. This may be an indication of an automation bias due to the availability of the route in the FMS. It could also be an indication of a cognitive bias with a preference for avoiding tabulated, numerical obstacle information and instead relying on the plain text entries. The Flight Crew's approach to using the LSD was similar to their approach to using the Route Guide, where they appeared to use the route image to brief themselves and only verbalised the plain text '*General Comments*' section of the associated page.

Earlier in the flight, the Flight Crew had discussed fuel planning for Dublin and for Sligo and the Co-pilot requested the weather for Sligo from ATC. When ATC provided the Sligo weather update the Commander commented, at 00.16 hrs, '*okay we'll get in on that on that low route*'. The Investigation believes that this suggests that the Commander considered the routes in the FMS Route Guide were '*low*' routes and that use of these low routes informed her decision-making even if a landing at another company base, located at a regional airport, was planned.

The reference to '*that low*' route indicates that the Commander had a route in mind and that she believed that the Co-pilot would understand which route she was referring to, as there were three '*low*' routes for Sligo in the FMS Route Guide. Therefore, it seems possible that, as part of their pre-flight briefing, the Flight Crew had discussed using a particular low route to get into Sligo for a rotors-running refuelling.

The general issue of the FMS Route Guide being referred to as the '*Low Level Route Guide'* may also have been part of the reason that the Flight Crew appears to have believed that APBSS could be safely flown at 200 ft. The Investigation found that there was no shared definition or understanding amongst the Operator's pilots and rear crew (with whom the Investigation spoke) about what exactly '*low level'* meant. Kahneman found that exposure to a particular word can cause immediate and measurable changes in the ease with which related words can be evoked. So it is possible that using the term '*low level*' carried certain connotations for the Flight Crew members. At 23.24 hrs, the CVR records what may have been another priming effect, when the Winchman asked the Commander '*Have we an approach into Blacksod?*' to which the Commander replied '*Yeh we do, we'll just pop it in*'. As the Crew considered APBSS to be an approach, and as it was contained in the '*Low Level Route Guide*', they may have believed that it could be used to safely navigate to Blacksod, while operating at 200 ft.

In addition to the specific issues around the Flight Crew's use of APBSS, there was no common understanding of the term '*low level*' in relation to routes. It is possible that this was because there was no standard document to describe how a Route Guide was to be constructed or maintained, nor were those involved trained in route design. The Route Guide was converted from the S-61N helicopter type for S-92A use in 2013, yet at the time of the accident it still contained a warning to use routes with appropriate caution until proven; however, there was no plan to prove the routes nor was any one post-holder responsible for ensuring the routes were proven.

In addition, there was no formal procedure or training for how to use a Route Guide and Routes were not available for use in the simulator. In the simulator, the Operator's crews did fly self-created routes during slot #2 Line Oriented Flight Training ('*LOFT*') mission. Had the Low Level Routes been available (or entered manually) in the simulator, there would have been an opportunity to observe how crews briefed and flew them.

2.2.4 Briefings

R116's flight involved a cross-country transit. This meant that the tempo of the mission was not typical of missions carried out by east coast crews and, while east coast crews were accustomed to moving quickly from briefing for one phase of flight to briefing for the next, on the accident flight there were long intervals between briefings. This unusual mission tempo for an east coast crew may have compromised briefing effectiveness in that the briefing for going to Blacksod was conducted in a piecemeal fashion, throughout the flight, rather than in a single briefing near to the time when the route was to be used.

2.2.5 Operating Altitude

The Helicopter descended to 200 ft over the water, before commencing its turn inbound to join the APBSS route.

The APP1 mode on the helicopter's AFCS is designed to descend the helicopter to 200 ft over the water. Pilots can interrupt APP1 and automatically level the helicopter at any other intermediate altitude between 2,400 ft and 200 ft. However, OMF gave clear instructions to crews that '*Maximum use should be made of automation and SAR approach modes*.' Whilst such advice is understandable when approaching a stricken vessel in open water, it risks encouraging automation bias (Mosier et al) with the result that, as in this case, pilots might not utilise all available information before deciding to use an automatic mode (APP1) to descend to 200 ft.

The latest weather information which the Flight Crew had available to them was for Blacksod, 37 minutes before the accident and 9 NM away. It was provided by personnel at Blacksod Lighthouse, at 00.09 hrs, when visibility at sea level, at Blacksod, was assessed as two miles with a cloudbase assessed as '*three four five hundred feet*'. The CVR indicates that when the Commander heard this, she noted the lowest cloudbase figure, i.e. 300 ft. At 00.27 hrs, as part of the DVE Approach Checks, when discussing the setting of altitude bugs, the Commander said '*if we get visual below we said three hundred feet at the moment so we'll aim just to go down to the two hundred*'. Therefore, the Commander's decision to descend to 200 ft was based on the 300 ft cloudbase estimate, provided 14 minutes earlier, for Blacksod, which was 9 NM away from the area the Helicopter was descending into.

Later in the DVE Checks, the Commander's let-down brief was '*I'm going to do an approach one all the way down to two hundred feet, eighty knots, eh, it might be slightly past M O* [an apparent reference to waypoint BLKMO] *at that moment so we'll see what, how we are height wise at that moment, so I think we'll just eh take a heading, continue on past there go back around and the aim is just to follow the route all the way round*'.

The Low Level Significant Weather Chart indicated that the frontal system affecting the Blacksod area was moving south-eastwards at 25 kts. The Blacksod Lighthouse personnel informed the Investigation that at 01.15 hrs, approximately 29 minutes after the accident, the visibility at the viewing point one mile west of Blacksod was 20 metres and the cloud base was 200 ft. Given that the wind was west-south-west, 25-30 kts, the visibility and cloudbase at Blacksod at 01.15 hrs would suggest that the conditions near Black Rock at the time of the accident could have been poorer than two miles visibility and a 300 ft cloudbase. It is noted that the Commander commented, at 00.43 hrs, '*okay again just got the surface visual there anyway which is good*', which indicates that the sea surface was in sight at that time and location, from the Helicopter's altitude of 200 ft. Although it was not verbalised on the CVR recording, the Commander may have been conscious from the Operator's CFIT training presentation that '*More than two-thirds of all CFIT accidents are the result of altitude error or lack of vertical situational awareness* […] *The procedure most susceptible to reduced situational awareness is the non-precision, step down approach* […] *The vertical profiles* [in known CFIT accidents] *are significant.*' If this was a concern for the Commander, it could explain why the vertical manoeuvring phase was completed (down to 200 ft) prior to commencing manoeuvring to join the APBSS route at BLKMO.

OMF provided the following guidance regarding night scanning: '*The human eye becomes almost completely dark-adapted in 30 minutes in darkness or under red light, thus increasing its light sensitivity approximately 10000 times. Dark adaptation is destroyed very rapidly by exposure to bright light*.' On the accident flight, prior to descending from 4,000 ft, the Commander opted to turn on all external lights except the NIGHTSUN (which was armed). The associated external white light, radiated and reflected, could have adversely affected Flight Crew members' night vision, compromising their ability to operate visually at 200 ft, in a dark environment.

2.2.6 DVE Approach Checks

OMF prescribed that '*DVE approach checks* […] *should be completed prior to the initial SAR approach / descent in a degraded visual environment*.' R116 was carrying out DVE Approach Checks prior to a descent to 200 ft, to a position the Flight Crew believed was over open water, from where they intended to manoeuvre to follow a route from the Operator's Route Guide, which was available to them for selection in the Helicopter's FMS.

In relation to item 8 on the DVE Approach checks, '*Let down procedure*', OMF provided an expanded list of items to be included in the let-down brief. The Investigation compared the Commander's let-down brief narrative with the expanded list (**Table No. 28**).

Expanded List	Commander's Narrative
Tracks and waypoints	*the aim is just to follow the route all the way round*
Use of FD: APP modes and altitudes; roll channel use	*I'm going to select alt pre down to two thousand and four hundred feet, if you're happy we're clear of everything I'm going to do an approach one all the way down to two hundred feet* […] *we'll just eh take a heading, continue on past there go back around*

Expanded List	Commander's Narrative
Capture speed	*eighty knots* […] *getting the speed back as much as we're comfortable, we're aware we're going to have a pretty high ground speed on the way in*
Decision point	Not referred to in the let-down brief. Note: a decision point on leg 4 of APBSS was implicitly identified during the briefing to the Winchman at 00.24 hrs; the Winchman asked the Flight Crew to show him the route so that he would *'have an idea with the, eh, FLIR when we get into it'*. The Co-pilot replied '*so it's to here, in, overfly, overfly, overfly, smart turn, here, not visual, back to here*'.
Go-around heading and altitudes	Not referred to in the let-down brief. Note: Go-around heading had been discussed, at 00.13 hrs, when the Co-pilot was self-briefing the route. The Co-pilot asked what the '*escape route*' was if they did not become visual. The Commander replied '*direct to back down here or even just head south* […] *there's a mast up there somewhere they're saying on the west*'.
Use of APU	Not referred to

Table No. 28: Let down brief comparison

With the exception of the APU, all items were addressed during the let-down brief, or in earlier briefings. The Investigation also notes that the Flight Crew was using the DVE Approach checklist to descend to 200 ft prior to manoeuvring to commence an FMS route, whereas the DVE Approach checklist was actually designed to descend to a SAR scene; this is evident from the expanded item 9 description in OMF which requires crews to consider the '*Fuel burn on scene*'. This meant that the Flight Crew did not do the '*Approach*' checks set out in the Operator's S-92A Normal Checklist. The Operator said that this was normal because the Helicopter was not approaching an airport. However, **Figure No. 10** (**Section 1.11.4**) shows that unlike '*DVE Approach*' checks, the '*Approach*' checks included crossing altitude checks which '*DVE Approach*' checks did not. Crossing altitude checks would usually include reference to any obstacles in the vicinity of a crossing point; if conducted, crossing altitude checks may have prompted the Flight Crew to refer back to the obstacles section of the APBSS route. Furthermore, '*Approach*' Checks may have been appropriate as the Helicopter was landing at a helipad – from the point of view of helicopter operations this was similar to landing at an airport.

OMA 8.3.19.3 '*Using the checklist system*' states '*Steps that require dual pilot action and / or verbal confirmation are signified in bold with a solid line connecting the challenge and response.*' The Investigation notes that '*Let down procedure*' was not marked with such a bold line.

2.2.7 Black Rock not Observed on Radar

OMF stated that '*The coastal airborne radar approach is used to position the aircraft towards the coast in similar conditions* [poor visibility or at night]. *It offers a means of approaching a* […] *coastal LZ* [Landing Zone].' The accident Crew appear to have been using the APBSS route as a basis for a SARA (SAR Airborne Radar Approach) to a landing site. However, APBSS was not designed as an ARA as per OMA and OMC, which required ARA routes to be designed to avoid all obstacles laterally and vertically, and to take account of radar system tolerances in their design. The Investigation was not provided with any formal statement to preclude a crew from using a route as a basis for a SARA.

The Operator, as part of its National SAR Approval, had an exemption from general rules for VFR to fly below VFR limits for Operational SAR Flight. However, the pictorial representations of routes in the Route Guide were based on IAA Aeronautical Charts, which were intended to be used for VFR flying. The fact that APBSS incorporated a waypoint (BLKMO), which was effectively coincident with the terrain and lighthouse at Black Rock, meant that obscuration of radar returns could occur. During the Investigation's Review Flight, the magenta waypoint marker and the magenta trackline to the next waypoint (BLKMO), obscured radar returns from Black Rock on the MFD, at the 10 NM range. BLKMO's waypoint label also obscured radar returns from Black Rock due to the presentation of the radar cross-section of Black Rock at the 10 NM range scale which was selected at that time.

During the Investigation's Review Flight it was observed that '*sea clutter*' (**Photo No. 31**), even in the relatively benign sea conditions (as experienced during the Review Flight), can make interpretation of radar imagery more challenging. On the accident flight, the radar was being operated in GMAP2 mode. Selection of GMAP2 mode gives a high sensitivity terrain mapping mode and the reflected signal from various surfaces is displayed as magenta, yellow, or cyan (most to least reflective). However, GMAP2 mode has no clutter reduction feature. The sea conditions and associated '*sea clutter*' during the accident flight were likely more challenging than those prevailing during the Investigation's Review Flight, imposing an additional workload for radar adjustment and interpretation.

The reliability and accuracy of the picture provided by the radar system is dependent on the manual adjustment of the tilt and gain settings; this required continuous adjustment to optimise the picture painted in the cockpit. The Co-pilot had identified '*small targets at six miles 11 o'clock…large out there to the right'*. These appear to have been the Duvillaun Islands and Achill head; and as these were the identified targets closest to the Helicopter, it is likely that the Co-pilot adjusted the radar tilt and gain to optimise the picture of these targets. It is also likely that these targets attracted the Flight Crew's immediate attention as the next known '*threats*' for their flight path. At 00.22 hrs, while still at 4,000 ft, the selected range on the weather radar was changed from 25 NM to 10 NM at a position 24 NM east of Black Rock, and remained on the 10 NM setting for the remainder of the flight.

Furthermore, with the radar operating on 10 NM range, the extent and conspicuity of any return from Black Rock would likely have been adversely affected by the magenta-coloured waypoint star designator, and the magenta-coloured track line (direct to the next waypoint). Imagery from the Investigation's Review Flight showed that it was possible for this obscuration to take place (**Photo No. 31** and **Photo No. 32**). Such obscuration arises from the proximity of the waypoint, BLKMO, to the adjacent terrain at Black Rock, and would have reduced, and possibly negated, the Flight Crew's likelihood of detecting the presence of Black Rock by radar on the 10 NM range setting.

While this obscuration would have been a consideration when approaching Black Rock from any direction, including the outbound leg, the particular, inbound direction to join the route on the night was especially problematic because the magenta '*direct to*' track line could have overlaid radar returns from Black Rock if not already obscured by the waypoint designator. In summary, the selection of a waypoint so close to terrain, which would only provide a limited radar return, meant that the likelihood of detecting the presence of that terrain, from its radar return, was significantly reduced, if not negated.

The radar was operated on the 10 NM range throughout the descent and manoeuvring onto the APBSS route. At 00.35 hrs, the Co-pilot asked the Commander '*you happy with the range* [Commander's name] *at the moment yeh*'. The Commander replied '*eh yes for the moment yeh I'm just going to stick on the map if you're happy* [Co-pilot's name] *for the moment* […] *I'll let you mess about with those ranges whatever you're happy with*'.

The map the Commander was referring to appears to be the Euronav system; **Photo No. 6** (**Section 1.6.6.11**) shows that 1:250,000 Aeronautical Chart, Euronav imagery did not extend as far as Black Rock. Therefore, the Flight Crew could not have detected the presence of Black Rock from the 1:250,000 Aeronautical Chart, Euronav imagery. Furthermore, even if the Euronav imagery had a representation of Black Rock, it might have been obscured by a waypoint marker in the same way as the radar paint.

OMF guidance says '*During the approach the PM is to operate the radar, ensuring that an accurate paint at the optimum range is maintained*'. The Helicopter was operating approximately 9 NM offshore and the Flight Crew was unaware of any terrain proximate to their position. Therefore, the choice of 10 NM range was understandable. When the Commander requested (00.41 hrs) '*confirm we're clear ahead on radar and on E GYP WIZZ*' the Co-pilot confirmed '*you are…you are clear ahead on … ten mile range*'. At 00.43 hrs, the Co-pilot advised the Commander, '*starting to get ground coming in there at just over eight miles in the ten o'clock position*' to which the Commander replied '*copied that makes sense*'. The fact that the first terrain detection was at just over eight miles may have indicated to the Flight Crew that the selection of the 10 NM range was appropriate at that time. The Commander's response indicates that she was comparing the Co-pilot's input with another source of information, probably the Euronav. At 00.45 hrs, the Co-pilot said '*so small targets at six miles 11 o'clock … large out to the right there*'; here again, the six mile distance to expected targets (the Duvillaun Islands) would require a 10 NM range selection. The Investigation notes that the size of a radar target's returns is affected by the range selected – selection of a shorter range will result in a larger target representation, for targets that are within the reduced range.

OMF required '*Once established at the selected final operating height, the radar should be re-optimised to ensure a good picture and cross checked against EGPWS (if available), and FLIR if the latter is available.'* The Flight Crew verbalised this cross-check twice: once at 00.41 hrs, as mentioned above, and again at 00.42 hrs, when the Co-pilot said '*clear ahead on E GYP WIZZ and radar*'. However, the Flight Crew was not aware that the EGPWS databases did not contain either the terrain or the obstacle (lighthouse) at Black Rock. These absences from the EGPWS databases could have adversely affected the likelihood that the Flight Crew would identify a radar return at Black Rock, even if it was not obscured by route symbology, i.e. the fact that the EGPWS was not showing anything at Black Rock meant that the Flight Crew was less likely to identify a (small) return even if it were visible. Also, because the nearest identified radar targets were six miles away, the Flight Crew's attention may have been focused on that area of the radar paint.

2.2.8 Black Rock not Detected Visually

The Operator indicated that the routes in the Route Guide were '*visual*' routes. However, the Operator did not say where or how crews were advised of this. During the descent, having initiated a turn to the right to allow APP1 to finish, the Commander exhorted the Crew to '*keep your eyes peeled once we get down there'*, which indicates that the Commander expected that she would be operating with visual references by the time the Helicopter reached the final operating height of 200 ft, approximately 9 NM from land, at night, in poor weather over the Atlantic Ocean. Therefore, the Investigation, considered the extant guidance and procedures which may have informed the Flight Crew's thinking in this regard.

As part of its National SAR Approval, the Operator had exemption to fly in minima less than VFR minima. However, there was no precise definition of what exactly these new minima were. OMF includes a number of references to visibility including:

- *'Visibility sufficient for the requirements of the task and to satisfy any OMB requirements for system modes being used*.'
- *'Clear of cloud and in sight of the surface with visibility sufficient to allow safe aircraft manoeuvre at selected airspeed / groundspeed*.'
- *'Visibility is to be assessed by the aircraft commander as sufficient for the task*.'

Elsewhere, under '*Guidance for operations without AFCS SAR modes'*, OMF refers to '*minimal visual reference'* and '*adequate visual references*' but goes on to say '*Such visual references cannot be easily quantified'* and *'assessment of what may be achievable prior to launch will be based on many variables such as: a. Forecast or reported ambient light. Such light may be natural or artificial, for example, moon light, light from coastal towns, light from adjacent vessels / installations or indeed flares deployed by top cover aircraft'.* The Investigation acknowledges the difficulty in being prescriptive about required visibility in SAR operations. However, in the absence of defined limits, and a reliable method of assessing visibility, flight crew are left to make subjective assessments.

At 23.11 hrs, the Commander received the report from R118 that conditions were good at Blacksod and this seemed to prompt her to compare fuel and flight time for Sligo and Blacksod and ultimately to conclude that it made more sense to go to Blacksod. At 23.54 hrs, the Commander received a report from MRSC Malin that visibility was down to three miles at Blacksod, in response to which she requested a figure for the cloud base. At 00.08 hrs, Blacksod Helipad provided a wind direction of west-south-west, a wind speed of 25 to 33 kts, a visibility of two miles at sea level and a cloud base of '*three, four, five hundred feet*'. However, the CVR shows that the Commander acknowledged receiving this transmission (to the Winch Operator) as '*three hundred feet and whatever*'. This suggests that the Commander prioritised cloud base over horizontal visibility, even though the transmissions to the Helicopter of '*visibility down to three miles*', at 23.54 hrs, and '*two miles*', at 00.08 hrs, indicated a deteriorating horizontal visibility trend. The reasons why the Commander did not appear to be concerned with the trend of deteriorating visibility, and no other Crew member raised it, are not known. It may have been part of their SAR operational culture, or it may have been because the Crew believed that radar and EO/IR would compensate for a lack of forward visibility.

At 00.43 hrs, the Commander commented '*okay again just got the surface visual there anyway which is good* […]'. This indicates that the Commander had visual contact with the surface at that time. However, the assessment of horizontal visibility requires, by definition, that a known feature at a known distance can be seen. But, when operating at 200 ft, approximately 9 NM from shore, over the Atlantic Ocean, at night, in poor weather, there was no known, or discernible, feature to be seen. Furthermore, none of the potential sources of ambient light mentioned in OMF, '*moon light, light from coastal towns, light from adjacent vessels / installations or indeed flares deployed by top cover aircraft*' would have been available to the Crew. Accordingly, horizontal visibility could not be determined, and consequently it was not possible for the Flight Crew to know that they had '*visibility sufficient to allow safe aircraft manoeuvre at selected airspeed / groundspeed*', as required in OMF. In effect, the Crew was in a situation where they could not see whether there was an obstacle in their path.

The fact that Black Rock was detected by EO/IR when the Helicopter was approximately 600 m/0.3 NM from Black Rock indicates that, in theory, the visibility was at least 0.3 NM because, although EO/IR provides image enhancement, it cannot '*see*' through cloud or other obscuration. However, there is no indication that the Crew detected Black Rock visually even after they were aware that it had been detected on EO/IR. This may be because, as stated in OMF '*the FLIR detection range will be far in excess of the visual detection range*'. Another factor could be that the Flight Crew may have misinterpreted the Winchman's comment, at 00.45:56 hrs, '*an island directly ahead of us*', to have been a reference to the targets (likely Duvillaun Islands) which the Co-pilot identified on radar 19 seconds earlier, as '*small targets at six miles*'.

The Flight Crew's response to the Winchman's direction to come right was in keeping with the OMA, which directed '*All mode selections below 500 feet at night or in IMC shall be made by the PM, on the PF's request*'. In this case, the PF asked the PM to '*Select Heading*' and the PM responded '*Heading selected*'.

Recorded data indicates that the lighthouse at Black Rock was functioning correctly at the time of the accident. The Investigation notes that at no time on the CVR was there a mention of a lighthouse beam being seen. Additionally, except for the NIGHTSUN searchlight, all available external lighting had been turned on which could have reduced the likelihood of the Crew detecting the lighthouse beam, even if it was visible, because of reflected light from the Helicopter's own external light sources, including its strobe lighting.

2.2.9 Black Rock Missing from EGPWS Databases

Black Rock was not in the EGPWS terrain databases; this had been noticed in 2013, during the introduction of the S-92A helicopter type. The Operator was the only operator using its Route Guide, and the frequency of operations along each route is not known nor recorded. Accordingly, nobody but the Operator would know of, and could report, missing terrain or obstacles affecting the Operator's helicopters when operating low level off the west coast of Ireland. There were gaps in dealing with this issue on the parts of both the Operator and the EGPWS manufacturer. For the Operator's part, the fact that '*The appropriate methodology for a change such as this would be to report into the company Safety Management System (called SQID)* […]' was not followed requires consideration of the systemic and cultural factors relating to usage of the SQID system; these are documented in **Section 1.17.4.2**.

An email suggestion in 2013, that a note be added to APBSS and APBSN highlighting that Black Rock terrain and lighthouse were not in the EGPWS databases, was not acted on. In the absence of further communications from the EGPWS manufacturer, the pilot who emailed the EGPWS manufacturer enquiring about adding lighthouses to the EGPWS databases did not pursue the matter at the time, because there hadn't been an EGPWS on the S-61N and he felt that the operation had been safe enough without it. Furthermore, there was no evidence that any of the eight people who were made aware by email that the EGPWS manufacturer had been contacted about adding lighthouses, followed up on the matter. Accordingly, it would seem that, in 2013, the pilot who had contacted the EGPWS manufacturer was not alone in thinking that the EGPWS was nice to have but that gaps in the obstacle database would not pose a significant safety hazard.

However, over the period since the S-92A introduction, organisational and individual attitudes to EGPWS, its accuracy and its use within the operation appear to have changed. This change is reflected in the apparently contradictory guidance provided in OMB and OMF regarding the use of EGPWS. OMB is emphatic in saying '*Navigation shall not be predicated on the use of EGPWS information*'. In relation to SAR over-water DVE IMC/night let-downs, OMF states that '*equipment limitations detailed in the OMB should be adhered to*' before going on to say '*It should be remembered that a secondary navigation source may not necessarily be authorised in the OMB for aircraft navigation but may augment aircraft situational awareness*' and then describes the EGPWS as '*Secondary Navigation Equipment*'.

Furthermore, the Investigation was informed that during simulator training, the Euronav mapping system was not available and that the standard simulator cockpit screen configuration was for the PF to set his inboard MFD to EGPWS in full mode. Some pilots reported to the Investigation that in the simulator, because Euronav was unavailable, they operated with EGPWS on both the lower half of their PFD and their inboard MFD.

The Investigation acknowledges that there are warnings given in the RFM and the OMB regarding use of the EGPWS for navigation. However, this reliance on the EGPWS for mapping in the simulator could, inadvertently, encourage automation bias and lead crews, incorrectly, to rely on, and have confidence in EGPWS, to an inappropriate extent given the system's reliance on the accuracy of its databases.

The OMF assertion that EGPWS, as a secondary navigation source, could '*augment aircraft situational awareness*' contained an implicit assumption that the EGPWS databases were both accurate and complete. Such an implicit assumption did not acknowledge that if there were terrain features or obstacles, which were not in the EGPWS databases, then flight crew situational awareness could actually be degraded, i.e. a flight crew's perception of the terrain and obstacle environment could actually be incorrect and lead to a false sense of safety. Moreover, as was the case with Black Rock, obstacles with a height less than 100 m (330 ft) could pose a significant hazard to SAR helicopter flights, which were exempt from the Rules of the Air altitude limitations, although such obstacles did not meet the criteria to be identified and published as potential obstacles in the documents (e.g. AIP) that were used as sources to gather obstacle data for incorporation in EGPWS databases.

The implicit assumption that the EGPWS databases were both accurate and complete may have been reinforced by the fact that the Operator was engaging with the IAA to arrange to have '*false obstacles*' removed from the IAA's AIP, but no evidence was found that the Operator was engaging with the IAA to have real obstacles (e.g. Black Rock Mayo, Black Rock Sligo, Bull Lighthouse) added to the AIP. The fact is that '*false obstacles'* are more likely to be detected (and reported) because they generate spurious warnings, whereas missing obstacles, which generate no warnings, may persist as a latent hazard, as Black Rock did.

OMF required flight crew to cross-check radar with EGPWS. Degraded situational awareness, resulting from reliance on EGPWS databases, which might not contain all relevant obstacle information, particularly when operating away from airports, could also compromise the use of the radar. As already discussed, if a pilot believes that there is no obstacle on his flight path, because no obstacle is visible on the EGPWS display, then cross-checking with the radar could be adversely affected and consequently the radar picture could be misinterpreted.

The EGPWS LOW ALT mode was selected as part of the DVE Approach checks. The selection of LOW ALT reduces the EGPWS warning thresholds for known obstacles and terrain, i.e. those in the EGPWS databases. However, Black Rock Lighthouse and terrain were not in the EGPWS databases and consequently there were no warning thresholds to reduce.

Notwithstanding the absence of Black Rock terrain and lighthouse from the EGPWS database, the EGPWS manufacturer's manual states '*The pilot must maintain visual contact with all terrain and obstacles at all times when using the Low Altitude mode*', but this was not possible in the circumstances that R116 was operating in as it approached Black Rock at 200 ft, at night, in poor weather. Accordingly, the Investigation makes the following Safety Recommendation:

> CHCI should review its guidance, operating and training procedures in relation to the use of EGPWS in its operations, ensuring crews are aware of the limitations of the system and that the EGPWS manufacturer's guidance on the use of Low Altitude mode is followed (**IRLD2021003**).

The Operator informed the Investigation that '*Since the accident, the LOFT mission profile was changed; one LOFT mission profile is specifically "route" related, the other is open water related but with emphasis on low level malfunction handling. Every simulator session is preceded by four hours of briefings including TKI and operational briefings. The Operator used the EGPWS PPT as one of these briefings in first 6 months of 2018; it remains available to all crews along with all other TKIs and operational briefings.*'

For the EGPWS manufacturer's part, it is noted that the customer support query was closed without reverting to the originator. However, the EGPWS manufacturer informed the Investigation that under its current business processes for customer queries, introduced prior to the accident, a notification of '*P2C*' (proposal to close) is automatically sent to the customer. If the customer accepts the proposal to close (by selecting '*yes*') then the case is closed. If the customer rejects the proposal to close (by selecting '*no*') then the customer receives a feedback form indicating what actions are required to progress the matter. In light of this revised business process, no Safety Recommendation is made to the EGPWS manufacturer in this regard.

2.2.10 Euronav and Toughbook Imagery

271 The only hard copy chart information which the CVR indicates the Flight Crew consulted was the Route Guide. However, OMA stated, under flight preparations, '*Current maps, charts and associated documents or equivalent data are available to cover the intended operation of the aircraft including any diversion which may reasonably be expected*.' The Investigation asked the Operator if the term '*equivalent data*' could reasonably be taken to refer to Euronav and Memory Map; the Operator said that it would agree that it could reasonably be taken to be the case in the Operator's manuals. It is therefore not unreasonable that crews might have come to consider Euronav and Memory Map as being equivalent to '*Current maps, charts and associated documents',* particularly in light of the greater utility of automated mapping systems over paper-based maps and charts. The 1:250,000 Aeronautical Chart, Euronav imagery did not extend as far as Black Rock, and consequently the lighthouse symbol which identified Black Rock on the Aeronautical Chart was not represented.

In relation to '*Night Overland Operations*' OMF stated '*Memory map, with 1:50000 OSI selected, will give the required navigational accuracy and landing site detail'*. It appears from CVR recordings that the Winchman was using the 1:50,000 Toughbook imagery during the overland, en route phase of flight; this imagery did not show terrain or a lighthouse at Black Rock, in fact it appeared to show open water. Consequently, from the Toughbook imagery, the Winchman would not only have been unaware of the Black Rock Lighthouse and terrain, he may actually have been convinced that there was open water in the Black Rock area.

At 00.34 hrs, just prior to R116 commencing its descent from 4,000 ft, the Co-pilot announced that the DVE checks were complete, and as the Helicopter passed abeam the navigational waypoint '*BKSDA*', '*Alt Pre*' was selected and the Helicopter commenced descent. At this time, the Commander commented on the high terrain at Achill, in the Helicopter's '*nine o'clock position*', and the Winchman announced '*all clear ahead*'. Whilst Black Rock was represented on other imagery (Marine charts and Aeronautical charts) on the Toughbook, once out over open water, the intention was to return to Blacksod for fuel, and accordingly it would not be unreasonable for the Winchman to continue using the 1:50,000 imagery while the Helicopter was manoeuvring to commence following the APBSS route, in addition to monitoring EO/IR imagery.

OSI explained that the imagery it was requested to provide, and did provide, was from its Discovery Maps series, and that this imagery did not extend beyond the Irish Grid Easting co-ordinate 52,000, which is approximately 4 kilometres east of Black Rock Island. The Operator said that it did not have a formalised approval process for map data loaded onto the Toughbook, but that procedures were being developed. The Operator said that as the OSI data originated from the State Agency responsible for the official, definitive surveying and topographic mapping of the Republic of Ireland, it was not considered necessary to systematically check the supplied map image files for accuracy. The Operator also stated that the mapped terrain on the digitised maps appeared to be identical to the paper maps carried, and that prior to the accident there had been no reports of inaccuracies in the digitised maps.

The Operator had no approval process for the map data loaded onto the Euronav, and an updating of Euronav imagery in 2015 was prompted by the quality of the imagery rather than the geographical extent or completeness of the imagery. The Investigation asked if any guidance was provided to crews for operating outside the areas covered by Euronav imagery. The Operator said that no guidance about the use of Euronav when operating outside of the areas provided in the map imagery had been provided; however, the Operator noted that Euronav was not to be used for primary navigation. The Operator also informed the Investigation '*that paper charts are there as a back-up and are not 'unsafe*''; accordingly, it is not clear to the Investigation what information source the Operator intended to be used for primary navigation.

In summary, the Operator said that Euronav and Toughbook could reasonably be considered to be equivalent to '*Current maps, charts and associated documents'.* The Operator's OMF stated that Euronav and Toughbook independent GPS positions could be used as secondary navigation equipment. However, neither the Toughbook 1:50,000 OSI imagery (which OMF stated was the recommended imagery for the cross-country transit) nor the Euronav (1:250,000 Aeronautical Chart), which OMF stated will get the aircraft in the general vicinity of the landing site, had an indication that Black Rock island and lighthouse were at the location of the BLKMO waypoint. OMF stated that '*The Euronav alone should not be used for primary navigation*', however the Operator stated that '*paper charts are there as a back-up and are not 'unsafe*''. OMF did state that Euronav could be used in conjunction with primary navigation sources (a low-level route available in the FMS, and a radar picture with the route overlaid) and other secondary navigation sources (Toughbook with 1:50,000 imagery, and EGPWS). As is now known, Black Rock was not on the EGPWS databases, or the 1:50,000 OSI imagery, or on the 1:250,000 Aeronautical Chart Euronav imagery. The Operator did not have formal processes in place to validate the map/chart imagery used in its helicopters.

Accordingly, the Investigation makes the following Safety Recommendation:

CHCI should ensure that it has in place processes to ensure that mapping imagery used in its Euronav and Toughbook are suitable, current and sufficiently comprehensive for its intended uses, and that appropriate guidance for the use of such systems is provided in the operations manual (**IRLD2021004**).

2.2.11 Black Rock Light

Data provided by the lighthouse operator confirmed that the four lighthouses in the vicinity of the R116 accident location and in particular Black Rock light, were operational over the period of interest; the lights remained on and functioned correctly throughout the period between '*light on*' on the evening of 13 March 2017 and '*light off*' on the morning of 14 March 2017.

Lighthouse beams are designed to provide a nominal range of light for surface craft as an aid to marine navigation. The nominal range of a light is its luminous range in a homogeneous atmosphere in which the meteorological visibility is 10 sea-miles (nautical miles). In the case of Black Rock Light, the nominal range published is 18 NM (white) and 14 NM (red), when the meteorological visibility is 10 NM, i.e. in clear weather.

A light of 18 NM nominal range will only have a luminous range of approximately 3 NM when the meteorological visibility is 1 NM. The local visibility on 14 March 2017 at 00.45 hrs UTC, was noted as being 2-3 km (1-1.6 NM) with mist and drizzle. However, the actual

prevailing conditions at the time of the accident may have been worse than the aftercast report and thus the luminous range may have been less than 3 NM.

The cloud base was reported as being '*three, four, five hundred feet*' at 00.08 hrs, and 200 ft at 01.15 hrs. The height of the lighthouse quoted on the Aeronautical Chart was at 282 ft, therefore, it cannot be ruled out that the light itself was in cloud around the time of the accident.

When R116 was on its outbound leg it passed just to the north of Black Rock when travelling from east to west, at an altitude of 1,300 ft. At this altitude, the Helicopter would have been above the beam of light. Furthermore, the cloud base (at Blacksod) was estimated around that time to be between 300 and 500 ft; therefore, the Helicopter was probably in IMC and thus would not have seen the light below as it manoeuvred in proximity to the red sector of the lighthouse.

On passing north of Black Rock, the Helicopter took up a north-westerly heading and commenced a descent to 200 ft ASL. The turn back towards the south-east commenced approximately 3.5 NM from Black Rock and the prevailing wind conditions were such that the Helicopter's magnetic heading was 11-12 degrees to the right of the Helicopter's track. This means that the lighthouse itself would have been positioned to the left side of the cockpit as the Helicopter approached Black Rock.

Under clear visibility conditions in the last 1.5 NM of flight, the light would potentially have been visible six times with a flash of 0.3 sec. Any reduction in visibility would have an impact on an observer's ability to see the light.

At a distance greater than 1,000 m, the angle between the observer and the light would have been less than 1.75 degrees, but would still have been in the reduced intensity portion of the beam. It is not until approximately 2,000 m from the light that a reasonable intensity of light (44% of peak) would be expected. In other words, the intensity of light would have reduced as the Helicopter approached the lighthouse. On the final flight path, with the Helicopter at a distance to run of 1,000 m or less, the Helicopter was effectively below the beam of light and thus, irrespective of the prevailing weather conditions, the beam could not have been observed by the Flight Crew.

The CVR contained no recorded reference to a lighthouse beam by any of the Crew Members of R116, either as the Helicopter routed outbound initially towards Black Rock, or as the Helicopter tracked inbound towards Black Rock. In addition, the CVR confirms that all external lighting on the Helicopter was on, with the exception of the NIGHTSUN. Such external lighting in low cloud, mist and drizzle conditions can adversely affect external visibility from the cockpit.

The reduced luminous range of the light due to the prevailing weather conditions, the Helicopter's drift angle as it approached Black Rock, and the Helicopter's height of 200 ft AMSL, all militated against the Flight Crew being able to observe the lighthouse beam as R116 approached Black Rock.

2.2.12 Route Familiarisation

It is noted that SAR missions routinely involve ad-hoc approaches to locations that crews have not approached before. In these circumstances crews '*build*' their own route based on a review of available charting information and in so doing conduct their own terrain/obstacle review from first principles and undertake their own risk assessment before deciding on the route to be followed. However, when using a route from the Route Guide, it is unclear what assumptions a crew might make.

A crew from Dublin, who landed in Blacksod at night six days prior to the accident, began a briefing to fly the APBSS route at 500 ft, unaware of the presence of Black Rock on the route. That crew's co-pilot, who had previously been based at Sligo, was aware of the presence of Black Rock, and when he raised it, the flight crew briefed for a higher altitude (900 ft). This demonstrated the value of local knowledge in identifying potential hazards and managing risk on certain routes.

Email correspondence indicated that routes were viewed as base-centric, and in one case even identified that it was important that local (Dublin) pilots were aware of a particular obstacle (a wind turbine), and that the base brief for visiting pilots should also include the obstacle; yet there was no suggestion that the Route Guide be annotated to include a warning. This suggests that the culture within the Operation was that safety in the use of routes was achieved by crews using local routes with which they were familiar, supplemented with local knowledge, rather than formal briefings from the Route Guide. This email correspondence also highlighted a reticence to add a waypoint for the wind turbine to the FMS waypoint database, because it might be flown towards using the '*Direct To*' (DTO) FMS function. Indeed, it was noted that there were only three waypoints in the company database that crews actively sought to avoid as opposed to aiming towards them – these three waypoints indicated the locations of three wind turbines on the low level route for Cork Airport.

The base-centric view of routes reflected an unstated assumption that routes were for the use of the base which '*owned*' them and may have led to the route descriptions assuming a level of local knowledge and familiarity on behalf of the user, which might not be a valid assumption if a crew from another base was using a particular route. Another complication was the marked difference between operating on the east coast and operating on the west coast, particularly at night, in poor weather, with very little littoral lighting. Furthermore, the frequency of operations of crews, away from their main operating areas, would not be high, and individual crew familiarity with an area whilst operating away from their usual base, would similarly not be high.

The mission conducted six days prior to the accident demonstrated that the significance of obstacle information in the Route Guide could be over-looked. Although Black Rock was discussed and viewed on the EO/IR system during that earlier mission, according to the CVR recording for the accident flight, the Winch Operator, who was on the earlier mission, did not mention Black Rock during the accident flight. It appears likely that on the earlier flight, as on the accident flight, the Winch Operator was heavily engaged in trying to communicate with R118, and also communicating with IRCG and Blacksod personnel. Indeed, during the accident flight, when asked if there was rotors-running refuelling available at Blacksod, the Winch Operator had to pause to think before he remembered what had been done previously; and rotors-running refuelling is an activity in which he would have been directly involved. Therefore, it is not unreasonable that he did not recall the significance of Black Rock when he returned to Blacksod on the accident flight.

Recording of crew familiarisation with routes is prescribed in OMD, although it seems that this familiarisation was not recorded as set out in OMD. Furthermore, the Operator informed the Investigation that OMD familiarisation requirements only applied to CAT flights, i.e. the Operator did not apply the requirements to SAR flights. The accident flight was being operated under a Rescue call-sign and accordingly could operate in accordance with OMF and the exemptions available under the National SAR Approval. However, given that SAR missions could operate in poor weather, at night, it would be prudent to familiarise all crew members with the routes into and out of the two refuelling bases (Blacksod and Castletownbere) on the west coast.

2.2.13 FMS Route Guide

The Route Guide contained a warning that it was '*a work in progress and should be used with the necessary caution until all routes/waypoints are proven*'. The Operator did not have defined processes for designing and proving routes, or selecting waypoints. In the absence of such defined processes there was no standard methodology for route design or presentation of route information. For example, some routes, including '*APBSS*' and the Dublin routes, had '*General Comments*' sections of plain text, but other routes did not. Also, the Dublin routes' '*General Comments*' directed the altitude at which over water legs were to be flown, whereas APBSS did not. Furthermore, there was no documented procedure for how flight crew were to use the Route Guide. Prior to the accident, the FMS routes were not available for use in the simulator, which the Operator used for training its flight crew.

The Operator's statement that its *'routes are VFR routes, not IFR'* is complicated by the fact that, at the Operator's request, the IAA-issued National SAR Approval granted the Operator permission for '*flight for the purpose of Operational SAR to be carried out in VFR minima lower than specified'*. In practice, if conditions are suitable for VFR flight, and there is no other air traffic in the area, then outside of an air traffic control zone a prescribed route would not be needed. The IAA charts on which the Route Guide was based were only intended for use in VFR conditions. Under VFR conditions, any obstacle or terrain incorrectly depicted or absent from a chart, should have been visible in time to take effective avoiding action, i.e. if charting errors existed, they should not have presented a significant hazard to low level flight in VFR conditions. However, when the Operator requested, and the IAA granted, approval to operate outside of normal VFR flight limitations, consideration should have been given to what reliable data sources would be used for navigation and for example, Route Guide construction. Accordingly, the Investigation makes the following Safety Recommendation:

The IAA should require operators who have exemptions from Rules of the Air, to provide a full safety case, including details of the acceptable navigation data sources to be used, as part of the exemption application and review processes (**IRLD2021005**).

For Dublin-based crews who normally used LOWDUB1 and LOWDUB2, which provided specific directions regarding overwater leg altitudes, the absence of altitude guidance in the '*General Comments*' section of APBSS may have been misleading regarding safe altitudes on the route legs. Furthermore, LOWDUB1 included an instruction in the '*General Comments*' table to fly overwater legs (Legs 3 and 6) at 500 ft, within 0.5 NM of a 1,000 ft obstacle. Therefore, during routine training and operational flights, Dublin crews flew route legs at altitudes lower than adjacent obstacles, secure in the knowledge that the LOWDUB1 route design provided lateral separation from those obstacles. Indeed, the Operator informed the Investigation that '*This entry identifies a hazard (in this case a populated area) which is proximate but not on the route over which crews should not fly below 1000 ft*.' The Operator's comment about an Obstacle/Hazard being '*proximate but not on the route*' is a fundamental point – Dublin crews knew that if the route was faithfully followed, the hazard/obstacle was not a problem i.e. although a hazard/obstacle was identified, the route, by design, provided lateral separation from it.

The Investigation spoke with a number of the Operator's personnel, both flight crew and rear crew, and found that there was no shared understanding prior to the accident about what the term '*Low Level Routes*' meant; attitudes to the Route Guide varied and it was unclear whether it might have been assumed that routes from the '*Low Level Route Guide*' could be safely flown at 200 ft.

The Investigation notes the Operator's comments that the routes were merely there as a framework on which to build a plan for entry/exit to a number of known sites and that routes were a guide as opposed to a prescriptive approach plate. However, the Operator informed the Investigation that '*APBSS*' was an acronym for '*Approach Blacksod South*'; and the '*General Comments*' section of the APBSS route, which the Commander verbalised on the CVR, said '*Severe turbulence may be experienced during **this approach***' [emphasis added].

Furthermore, a route that is intended to be used by crews to land at a refuelling facility could reasonably be considered to be a form of approach, and therefore it should provide the instructions necessary to allow crews to maintain adequate horizontal and vertical terrain separation to safely navigate to the refuelling facility, under all conditions. The Operator informed the Investigation that the use of the word '*Approach*' in naming some of its routes such as '*Approach Blacksod South*' (APBSS) was intended in a dictionary definition of the verb meaning to '*come near or nearer to (someone or something) in distance or time*' as in to approach (get nearer to). The Investigation believes that this non-aviation use of the word '*approach*' in the title of a route could lead to ambiguity.

The Operator provided detailed guidance in OMF for night overland navigation planning and one-off route design. This guidance said that '*an IP* [initial point] *is used as a lead-in feature to a landing site. It should be a large, easily identifiable feature positioned a minimum of 2 nm to 3 nm from the landing site. The IP will provide an accurate aircraft position prior to the run in to the landing site. Detailed route study from IP to landing site will greatly assist in locating the landing site, and if possible, a line or lead-in feature to the landing site should be used. It is not always necessary to overfly the IP. In some cases, an 'offset IP' for example, abeam a large hill or hills, may be appropriate*'. Since the Operator's guidance for flight crews contemplated an '*offset IP*' in the case of large hills, it would not be unreasonable for a crew to expect that if a large obstacle, such as Black Rock, was being used as an IP, then the route would incorporate an associated '*offset IP*'.

OMF guidance for night overland navigation planning also considered the need to decide on a safe transit altitude of minimum 500 ft AGL. Accordingly, this guidance would suggest that
277 if the IP was not offset from Black Rock, then the APBSS route guidance should have prescribed a minimum safe altitude of 800 ft AMSL (500 ft AGL) for Leg 1 of the route. However, APBSS did not incorporate either an '*offset IP*' or a minimum safe altitude.

The IAA did consider two of the Operator's Low Level Routes when they were submitted by a sister company of the Operator for use in a non-SAR, commercial operation. The IAA concluded that because the Rules of the Air Order imposed minimum heights of 500 ft by day and 1,000 ft by night, there was no need for the sister company to state minimum heights for each leg of the Low Level Routes. Given that the Operator has an exemption from these minimum altitude requirements, the Investigation believes that it would be prudent to require the Operator to state minimum heights for each leg of its Low Level Routes. Accordingly, the Investigation makes the following Safety Recommendation:

The IAA should require an operator that has exemptions from Standard Rules of the Air to state the minimum height at which each leg of its company routes can be flown (**IRLD2021006**).

The routes in use at the time of the accident did not include vertical profile information, visibility limits or indications whether or not a given route could be used as the basis for a SARA. The Investigation notes that OMC provides a sample ARA approach, which includes a '*Crew briefing strip*', provides a vertical profile and minimum altitude at the final approach fix, maintains 1,000 ft until within 5 NM of the intended landing location, gradually descends to a specified minimum descent height (for day or for night) at approximately 2 NM from the landing location, and provides go-around instructions. The Investigation believes that the Operator should provide as much of this information as possible, in a standardised format, to be used in a prescribed manner.

Due to the issues identified with the Route Guide, and notwithstanding the fact that Safety Recommendation IRLD2017005, from the Investigation's Preliminary Report, related to the Route Guide, the Investigation makes the following Safety Recommendation:

CHCI should develop and promulgate procedures/processes for all aspects of Route Guide management including route design, review, approval, updating, usage, briefing, operational limitations (to include at a minimum, visibility & altitude limits and ARA compatibility), crew training and periodic familiarisation requirements (**IRLD2021007**).

2.2.14 Tasking

While the accident occurred when the Helicopter was flying towards the first waypoint of the Operator's APBSS route in order that it could land in Blacksod for refuelling, and while acknowledging that the decision to accept a mission rests with a helicopter commander, the Investigation must consider the tasking of the Helicopter.

The nature of SAR is such that missions may need to be conducted in challenging environments and uncertain circumstances. For example, when Shannon ATC asked R116 if it was planning to go all the way to the FV, the Commander advised the Co-pilot '*eh no idea*' and the Co-pilot advised ATC that it was a possibility but that they were having problems contacting R118 and intended to land at Blacksod to refuel and '*we'll figure it out from there*'. This reflects the nature of SAR generally, and the particular mission that R116 was engaged in; the final destination/objective was uncertain, depended on circumstances and events, and would only become clear in time. Furthermore, the level of risk associated with SAR operations, particularly at night, can be higher than that experienced during non-SAR flight operations. However, while SAR is a vital and commendable service to the State, it must be conducted in as safe a manner as possible and at minimum risk to the specialist personnel providing the service. Tasking information is a crucial element in any commander's decision to launch, or not to launch, on a SAR mission.

An SLA has existed between the HSE and the IRCG, with support from the Irish Naval Services, since July 2001. It provides for the statutory provision of Tele-Medical support to vessels in Irish territorial waters, required for Ireland to comply with its legal responsibility towards workers at sea under European Council Directive 92/29/ECC (updated via amendment 1882/2003). MEDICO Cork, on behalf of the HSE, provides Ireland's Radio Medical Advice Service (utilising an Emergency Medicine Registrar or Consultant) to sick or injured seafarers through the IRCG radio network, on a 24-hour basis. A doctor is constantly available to both the IRCG and the Operator to assess the urgency of the medical condition of casualties, provide a direction on the category of the medical emergency, contribute to decisions on whether and when to launch, and provide advice on the treatment of patients.

On the night of the 13 March 2017, there were detailed recorded communications between MRSC Malin, MRCC Dublin, IRCG station Sligo, MEDICO Cork and the FV that influenced the specific tasking of R118. MEDICO Cork's protocol for its staff was clear and was followed on the night – that protocol required staff to clarify the clinical question being asked and then answer that question. Staff are trained to be sensitive to bias that may affect accurate communication.

On the night in question, the doctor in MEDICO Cork was advised by MRSC Malin; *'I've a ship that needs medical advice* […] *we are arranging a helicopter to go out and lift him off* […]*. I've asked him if he's taken any pain killers and he's waiting until he speaks to a doctor before basically he does anything OK'.* During the telephone call, the doctor explained on three occasions that it was unlikely that the injured party's thumb could be saved. As requested, the doctor provided advice on pain relief, which was the reason that the FV's captain contacted MRSC Malin in the first place.

In the initial communication from MRSC Malin to MEDICO Cork, the scenario was framed for the doctor. Prior to any clinical consultation with the FV's captain, the doctor was advised that the casualty was going to be lifted off the FV. Following the clinical consultation with the FV's captain, the doctor asked MRSC Malin, *'So is he going to be MEDEVACed then?'* and MRSC Malin responded, *'Yeah, he's going to be MEDEVACed'*. At no time during the phone call was the doctor asked to assess the urgency of the medical condition of the injured seaman or to contribute to the decisions on whether and when to launch, as was required by procedure.

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When MRCC Dublin asked MRSC Malin, '*Did MEDICO Cork request it* [the Recovery of the casualty from the FV]', Malin said, *'Yes! I've given them a link call to MEDICO Cork and they say yes the man needs taking off'*. MRSC Malin told the R118 commander that *'*[…] *he's obviously bleeding quite badly there* […]*'.* However, at the time that this comment was made there had been no discussion between MRSC Malin and the FV regarding bleeding. Therefore, it seems that there was a misunderstanding at MRSC Malin regarding the casualty, which affected the Sligo commander's perception of the casualty's condition. As it transpired, the bleeding had already been stopped by the actions of the FV's crew. This was relayed to, and acknowledged by MRSC Malin, *'Right you've stopped the bleeding* […]*'* prior to transferring the call to MEDICO Cork. It was restated by the FV's captain to the doctor in MEDICO Cork, who advised that the wound could be cleaned but that preventing bleeding was a greater priority; it was restated again by the FV captain to MRSC Malin after the link call to MEDICO Cork ended. The commander of R118 took it in good faith that a MEDEVAC was required, and as it was being requested by MRSC Malin, he believed that MEDICO Cork had said that the casualty should be MEDEVACed. Consequently, he did not question that request or seek clarification that MEDICO Cork had provided clinical advice in that regard.

The Investigation acknowledges the overriding statement in the National SAR Framework that, '*No provision of this Framework is to be construed as an obstruction to prompt and efficient action to relieve distress whenever and wherever found'.* However, it seems that in this case certain assumptions were made regarding bleeding, and the need for a MEDEVAC.

The sequence of events on the night of the accident highlights the need to guard against assumptions and bias in tasking decisions, to understand and follow protocols, particularly when dealing with third party agencies, and to continuously re-evaluate earlier decisions in light of new or changed information. The Investigation notes that the Watch Officers at MRSC Malin on the night of the accident believed that their training could be improved by the inclusion of more scenario-based training. The Investigation noted that the IRCG SMC Standard Syllabus did not include specific training for risk assessment.

The Minister for Transport had responsibility for the IRCG. As described in **Section 1.17.8.2** and **Appendix U**, the Minister for Transport, Tourism and Sport advised the Investigation that following the accident several measures were taken, which were grouped under six headings. One of the headings (No. 4) was directly related to training for tasking personnel:

> *'Review and revision of all relevant Standard Operating Procedures and training for the IRCG personnel, particularly SAR Mission Coordinator (SMC) training with a focus on aviation tasking'.*

The Minister's response outlined that the IRCG's Heli OPs SOP contains the operating criteria under which IRCG helicopters can be tasked by IRCG RCCs, for different mission types and the associated constraints and limitations that apply. It also outlines that the SOP was re-issued in 2018 following a review between the IRCG and the Operator. However, to ensure that the SOP takes cognisance of all relevant aspects in relation to the tasking of the subject Helicopter, the following Safety Recommendation is made to the Minister for Transport:

The Minister for Transport should ensure that the training syllabus for personnel involved in the decisions to launch SAR helicopter missions includes the following: information regarding the protocols used by other agencies with whom they work, so that it is clear where responsibilities lie, and how to make best use of each agency's expertise; recognition of and strategies to address cognitive bias which could affect decision-making/risk assessment regarding the initiation and continuation of SAR missions; the potential for in-flight communications with helicopter crews to adversely affect crew effectiveness; and practical scenario-based exercises (**IRLD2021008**).

2.2.15 Summary – Accident Flight

R116 was tasked to provide Top Cover for R118 which had been tasked to carry out a MEDEVAC mission from an FV, 140 miles from Ireland, in the Atlantic Ocean. R116's Crew initially routed towards Sligo and it does not appear that a specific brief for Blacksod was carried out prior to departure. This is probably because the Commander initially believed that the weather at Blacksod would be unsuitable. Furthermore, it is not uncommon for SAR crews to receive changed/new taskings while airborne, and to carry out the necessary briefing(s) while en route. When the Commander was advised that R118 had landed in Blacksod and that conditions were good there, she carried out a comparison of the options of going to Sligo or Blacksod in terms of fuel and flight time, and concluded that it made more sense to go to Blacksod; all Crew members were in agreement. Neither the Commander nor the Co-pilot had been to Blacksod for some time, and although they anticipated that weather there would be poor, they seemed content to try to get into Blacksod on the premise that they had time and could always go to Sligo if they couldn't get into Blacksod.

The CVR did not record any discussion of route obstacles, and the only part of the APBSS Route Guide text page that was directly read out was the '*General Comments*' section. The Co-pilot requested an opportunity to self-brief the route, apparently from the Route Guide, and when he asked the Commander what the escape heading would be, the Commander mentioned an obstacle to the west of Blacksod, which indicates that she had probably read at least some of the obstacle information for APBSS.

During the overland en route phase, the Commander verbalised a number of altitude checks to ensure adequate terrain clearance. However, it appears that the Flight Crew believed that once they were over open water they could descend to 200 ft and that the FMS route would provide adequate lateral terrain separation to allow the Helicopter to safely operate into Blacksod. This belief may have been supported in their minds by the fact that historically, routes such as APBSS were referred to in the Operator's community as '*Low Level*' routes, although the Investigation found that there was no common understanding of the term '*Low Level*'. Furthermore, there was no formal, standardised training in the use of '*Low Level*' routes; structured route briefings were not carried out as part of training; routes were not available for use in the simulator; there were no design standards for route construction; routes were viewed as being base-centric; routes did not incorporate vertical profile; minimum altitude information was generally not documented; Route Guide issues which had been raised in the Operator's Safety Reporting System (SQID) were closed prior to or without resolution; and, the Route Guide contained a warning that routes and waypoints had not been proven.

281 The mission tempo was atypical of primary SAR missions at the Dublin SAR Base and this may have affected the Flight Crew's briefings. Furthermore, the west coast operating environment was significantly different to the east coast operating environment, although no risk assessment had been carried out prior to the adoption of a policy of tasking east coast crews to operate in the west whenever time allowed.

Prior to descent, the Flight Crew completed DVE Approach checks. However, these checks are designed to allow a helicopter to approach a SAR scene and carry out a rescue, and they did not include crossing altitudes, which the Operator's Normal Checklist Approach checks did include. Such crossing altitude checks require crews to specifically consider and determine an appropriate altitude for crossing predetermined points on an approach.

The Commander opted to continue APP1 down to 200 ft, apparently because the reported cloudbase at Blacksod was as low as 300 ft. The Commander appeared to expect that at 200 ft it would be possible to operate visually, although the paucity of littoral light sources 9 NM from Blacksod, and the operation of external Helicopter lighting (which would have adversely affected the Crew's night vision), meant that while the Commander could see the surface, it appears that the Flight Crew could neither know the available horizontal visibility, nor see Black Rock on their flight path. There was no mention at any time of the lighthouse beam. This may have been due to several factors, individually or in combination, including: the lighthouse being in cloud; the Helicopter being below the lighthouse beam; or because the intensity of the lighthouse beam was insufficient to be noticed when the Helicopter's external lights were on.

The radar was operated on the 10 NM range throughout the descent and manoeuvring to commence APBSS. At no stage did the Flight Crew comment on a radar target in the vicinity of Black Rock; this was likely due to obscuration of radar returns by the magenta coloured waypoint (BLKMO) symbol at Black Rock and the magenta coloured track line to the BLKMO waypoint. The 10 NM range probably appeared to the Flight Crew to be an appropriate range because the nearest identified terrain threats were at 6 and 8 NM. Furthermore, the Flight Crew cross-checked EGPWS with radar, as required by OMF. However, the EGPWS databases did not contain information about the terrain and lighthouse at Black Rock. Consequently, the likelihood of the Flight Crew detecting Black Rock on the radar may have been adversely affected.

In the parlance of OMF, the Flight Crew was using two primary navigation sources: the FMS, to follow the APBSS route, and the radar, on which a route overlay would obscure radar returns from Black Rock. Four secondary navigation sources were also used: the 1:250,000 Aeronautical Chart Euronav imagery, which did not extend as far west as Black Rock; the EGPWS, which did not have Black Rock or its lighthouse in its databases; the Toughbook, which, on the 1:50,000 OSI imagery, appeared to show open water in the Black Rock area; and, the FLIR (EO/IR), which detected Black Rock when the Helicopter was approximately 600 m away from it.

Having analysed the proximate factors in the accident sequence, the Investigation will now consider the Organisational aspects which emerged during the Investigation.

2.3 Organisational Aspects

2.3.1 Tasking Agency Risk Assessment

According to the IRCG, its risk assessment paradigm for launching a SAR helicopter mission was to rely on the helicopter commander’s final decision on whether or not to undertake a given task.

While commanders must always risk assess taskings which are assigned to them, and will exercise final launch authority, the SAR Framework and the IAMSAR Manuals require the SMC to carry out a risk assessment. Notwithstanding the IRCG’s assertion that ‘*the process of Risk assessing is considered to be an integral part of SMCs work and core SMC decision making*’, it appears that neither the SMC training course nor the IRCG SOPs set out a requirement or methodology to be used by SMCs to carry out such a risk assessment. Accordingly, the Investigation has included tasking agency risk assessment processes in an earlier Safety Recommendation (**Section 2.2.14**) to the Minister for Transport.

2.3.2 Operator's Organisation and Structure

The Operator relied on its secondary duty model to discharge a large number of safety-critical tasks including Base Chief Pilots, updating of navigation plates and Route Guides, and safety equipment management. Reliance on personnel whose primary duties were as rostered SAR first responders and whose shift patterns meant intermittent attendance at the workplace, often outside normal commercial hours for suppliers, was sub-optimal. Furthermore, training for some secondary duties was neither prescribed nor provided.

The secondary duty model also resulted in a diffusion of responsibility and authority throughout the base network, without organised cover for times when secondary duty post-holders were off base/on leave. Management of this diffused authority was, at best, very challenging. Safety gaps associated with the secondary duty model were identified in SQID but appear to have been treated as isolated events rather than related to a systemic weakness.

The Investigation identified a number of issues relating to consistency in the Operations Manuals. The Operator's Flight Operations Post-Holders for several years appear to have relied on training personnel to provide assistance with the preparation and editing of operational materials, e.g. manuals. The Investigation believes that this was not optimal due to the broad portfolio of other responsibilities assigned to those training personnel. The Investigation believes that the Operations functions should have sufficient resources within their own departments to prepare and update operational documentation. In addition, the Investigation notes that the IAA expressed concern at the turnover of operations Post-Holder personnel, who were key personnel in the management and maintenance of operational documents.

The Investigation had a concern about a lack of a prescribed process in relation to an OMF requirement to review (through a follow-up process) all post-flight medical reports, to ensure a casualty's condition was correctly diagnosed as a '*life or death*' case. The Investigation asked the Operator to explain how such reviews were conducted and what problems, if any had been identified. The Operator advised the Investigation that the procedures were described in a cited section of OMA, and that any lessons learned would be debriefed with the crew involved. The Investigation reviewed the cited section of OMA and advised the Operator that it represented a role definition but not a procedure/process definition. Furthermore, the Investigation informed the Operator that debriefing of individual crews was inconsistent with the SMS objective of capturing and promulgating information and lessons for the benefit of all relevant personnel.

Essential tenets of effective management include suitable, prescribed processes/ procedures, properly followed and documented, by appropriately trained staff. The Investigation believes that the Operator’s management processes could be strengthened by a review, and where necessary, enhancement of processes in place: to allow those tasked with roles to better understand their functions; to allow management to assess the demands of each role; to ensure that systems are being used as intended; and to allow auditors and management to understand and address areas where extant processes could/should be improved.

Some of the Post-Holder responsibilities as described in OMA involved different posts having the same responsibility. OMA set out detailed descriptions, including responsibilities, for six Nominated Persons. OMA also stated, in respect of two of these Nominated Person roles, that the appointee ‘*is not any of the nominated persons*’. These two roles were fulfilled by the same individual; the holder of these two positions informed the Investigation that he was not aware of the OMA restriction. Furthermore, OMA did not contain a description of the roles and responsibilities of the Maintenance Manager (Part 145) Post-Holder (Nominated Person). The Investigation believes that clarity of purpose and responsibility at the management level is essential for effective management. Accordingly the Investigation makes the following Safety Recommendation:

CHCI should, with input from its parent company, ensure that OMA assignment and alignment of Nominated Persons' responsibilities is appropriately defined; that limitations regarding assignments are appropriately set out and adhered to; and that appropriate processes, procedures and training enable staff to discharge assigned responsibilities in a transparent and auditable manner (**IRLD2021009**).

The Investigation also notes that the IAA was concerned about the rate of turnover of Post-Holders. The IAA said that it considered the Operator to be a large, complex AOC operator engaged in medium to high risk types of operations, which needed to have in place a Senior Management Team with appropriate operational and managerial experience to ensure effective oversight of the operation. Accordingly, the Investigation makes the following Safety Recommendation:

CHCI should, with input from its parent company, review its organisational structure, secondary duty model, staffing levels and personnel training, for its operations and support functions, to ensure that there are sufficient resources available to discharge all necessary responsibilities, safety management oversight, and the drafting, approval and management of documentation (**IRLD2021010**).

At the time of the accident, the Operator did not draw on the services of its parent company's standards department when preparing the Route Guide or the Landing Site Directory. The Operator has since informed the Investigation that the FMS Route Guide had been moved under the auspices of the Content Management System and will now be an integrated part of the Operations Manual Volume C.

The Operator did not have a SAR standards pilot. The Operator informed the Investigation that there was '*no regulatory or contractual requirement for the Operator to have a SAR standards pilot function and that there is no regulatory or contractual basis against which such a role could be assessed*.' In the absence of a SAR standards pilot function, the Investigation believes that LOSA could play a similar role in assessing crew standards on the flight line and providing feedback to the training department regarding training needs. The Investigation notes the Operator's response regarding a SAR standards pilot, but also notes the Operator's parent company's statements that '*LOSA provides a chance to observe crews in a natural and relaxed state to better understand threats and errors in a real environment, so is much more than a checklist or audi*t', and that LOSA will move to Ireland in 2020. Notwithstanding this, for certainty and traceability, the Investigation makes the following Safety Recommendation:

CHCI should consider implementing a LOSA programme within its SAR operation which can routinely review operational standards for flight and technical crew, and provide reports on these reviews to the Accountable Manager for actioning by the relevant function (**IRLD2021011**).

2.3.3 Commercial Considerations

Commercial considerations at the Operator's organisational level are an inescapable reality. The Investigation agrees with the management team member's premise that to maintain supervision of the operation, managers will from time to time need to make enquiries about the circumstances of a particular mission – a necessary function to maintain oversight. The 2011 internal Operator's investigation into two SQID reports regarding alleged commercial pressure recommended that guidelines be issued to crews. The Operator provided the Investigation with a copy of a one-page document titled '*Coast Guard Enquiry Form*'. The form included boxes to enter information about the following: SAR Mission Brief; Location of Mission; Time spent on Scene; Weather en route/on-scene; Report on Casualty; Intended receiving facility; ETA at receiving facility; and briefing on any further plans or relevant details.

The bottom of the form contained a note which stated that the information would act as guidance for managers and crew when dealing with mission-related Coast Guard enquiries. An Administrative Memorandum was issued to Base Chief Pilots stating that '*This form can be used as a guide when a manager is required to gather operational information on behalf of the client outside of normal day to day MRCC channels*'. An Operations Memorandum was issued to all Crew advising them to raise concerns about IRCG taskings with the Flight Operations Manager or in his absence to the Accountable Manager, and reminding commanders of their responsibility for the safe conduct of any flight.

In 2013, the IRCG's Auditors expressed concern '*in the event that the now overt commercial*
285 *pressure to get started has overridden safety*'. In 2014, Dublin BFSM minutes highlighted a separate case where senior managers made remarks to a pilot about his Go/No-Go decisions. If the experience of the front line crews is such that they will face questioning if they decline a mission, this could induce a subtle pressure to dispatch and try to complete a mission rather than decline it.

From a management/oversight perspective, the fact that the senior Post-Holders would handle requests for information pertaining to specific missions from the highest levels of the IRCG raises a concern about the alignment of organisational interfaces and the potential for micro-management. One of the conditions of the Operator's National SAR Approval is that the Operator's Safety Management System shall monitor and review all flights carried out pursuant to the approval. The Investigation believes that such a system should facilitate management asking the questions necessary for effective oversight, whilst avoiding a perception by crews that they are being second guessed. Accordingly, the Investigation makes the following Safety Recommendation:

> CHCI should formalise its monitoring of all SAR flights to ensure that use of any exemptions allowed under the National SAR Approval is monitored, that minimum horizontal visibility is always recorded and that missions and decision-making are routinely reviewed with crews to maximise safety margins and standardise launch criteria (**IRLD2021012**).

As stated earlier, the Minister outlined several measures that have been taken since the accident (**Section 1.17.8.2** and **Appendix U**). The response described the governance arrangements extant at the time of the accident which were designed to '*avoid any perception that IRCG may be exerting undue pressure – commercial or otherwise – on day to day decision-making of* [the Operator's] *crews*'. However, the Investigation considers that in order to ensure that crews are insulated from perceived commercial pressure in relation to mission launch decisions, the Department of Transport, and its contracted SAR helicopter operator should devise an appropriate protocol for reviewing decisions, when necessary, away from the front line/duty crew operation. Accordingly, it is recommended that:

> The Minister for Transport should implement a procedure for IRCG to engage, at an appropriate level, with its SAR helicopter operator in relation to mission launch concerns in a manner that minimises any impact on duty crews and avoids creating a perception of competition or commercial pressure (**IRLD2021013**).

2.3.4 The Management of Safety

2.3.4.1 Introduction

According to ICAO:

> '*An SMS* [Safety Management System] *is a system to assure the safe operation of aircraft through effective management of safety risk. This system is designed to continuously improve safety by identifying hazards, collecting and analysing data and continuously assessing safety risks. The SMS seeks to proactively contain or mitigate risks before they result in aviation accidents and incidents'.*

Regulation (EU) No 965/2012, which the IAA stated that the Operator's SAR Approval was based on, mandates such a management system.

The Operator's Safety Management and Compliance Monitoring Manual (SMCMM) contains the Operator's '*Health Safety Environment & Compliance Monitoring Policy*' and describes the Operator's SMS, which it states is aligned with the ICAO framework.

2.3.4.2 Safety Meetings

Flight Safety and Base Flight Safety Meetings (BFSMs) were not defined in the Operator's SMCMM. Minutes for BFSMs were not readily available and when provided to the Investigation, it was established that meetings were not regularly held at all bases. Inconsistencies were also found with the records of the Occurrence Review Board (ORB) and Compliance Monitoring meeting; in particular, the ORB element did not appear to be always held monthly as required. Furthermore, while the Operator provided the Investigation with the agendas and the data to be discussed at several Quarterly SMS review meetings, minutes and attendance records for these meeting were not provided.

The Investigation found that there was no time allocated in the roster for personnel to attend BFSMs, which meant that BFSOs were left trying to hold meetings at shift handovers in order to involve the ongoing and off-going crews in the meeting. Without rostering for BFSM attendance, the Operator could not achieve its contractual obligation to ensure all personnel attended two BFSMs each year.

BFSOs encouraged SQID usage at BFSMs; however, BFSM minutes recorded a number of safety concerns, which were not entered in SQID, and also that personnel believed that SQID closure was occurring without problem resolution. The Investigation notes that the SMCMM required BFSM and ORB meeting minutes to be uploaded to the SQID system. However, this did not occur in all cases. On the face of it, the existence of a variety of minutes for the ORB and Compliance Monitoring meetings and for BFSM meetings suggested that significant safety-oriented activity was taking place. However, when the Investigation probed the detail of these minutes and carried out a thematic review, it appeared that the robustness and co-ordination of these processes was sub-optimal.

The Investigation therefore makes the following Safety Recommendation regarding Safety Meetings:

CHCI should ensure that appropriate time is provided within the roster to facilitate staff attendance at safety-related meetings and that the minutes of all safety-related meetings are stored in a manner that facilitates their incorporation into the knowledge base of safety information within the company (**IRLD2021014**).

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2.3.4.3 Safety Reporting

According to the Operator's SMCMM, SQID is the '*formal process for all* [Operator] *employees or contractors to report an occurrence*'. One of the aims of an occurrence reporting system is to capture information regarding hazards in order to contain or mitigate associated risks before they result in an accident or incident. This places a responsibility on an operator to develop a positive safety culture in which personnel fully support the SMS and have confidence in one of its principal elements – the SQID system, that the Operator used for safety occurrence reporting.

The Investigation analysed the ORB meeting minutes which were provided by the Operator and identified occasions when SQID reports were closed at an ORB meeting without an implemented, permanent solution; examples included Mk44 lifejacket SARBE installation and Route Guide issues. Furthermore, analysis of ORB minutes suggested that opportunities for systemic learning were not recognised.

Some of the personnel interviewed by the Investigation said that they were reticent to submit reports into the SQID system, believing reports would be closed without appropriate action being taken. The statement in the SMCMM that '*the aim is to increase proactive reporting by 10%*' was one of a number of issues with the SQID system that may have led some staff members to lack faith in, and limit their engagement with, the system.

These targets for increased reporting, allied to unchanged targets for closure rates, without any increase in resources for dealing with SQID reports, led to staff concerns that management wanted SQID reports to be submitted so that they could close them and generate favourable statistics for SQID closure rates. Such concerns/beliefs could undermine staff confidence in, and usage of, the SQID system. Indeed, management was aware (as far back as 2012) that such a perception existed and was contrary to the best interests of safety; this was demonstrated in a Post-Holder's contribution to the Dublin BFSM in September 2012 '*if you find that a SQID you submitted has been closed but you are still not satisfied with the response to feel free to SQID the same item again*'. A related issue was commented on again in 2015 when a Post-Holder proposed a communications initiative to address staff perceptions that some SQID reports were being closed with no real solution.

The phrasing of the SMCMM, which treated SQID Closure Rates as a KPI rather than a KSI (Key Safety Indicator), was unfortunate. According to Goodhart's Law, measuring SQID closure rates risked the unintended consequence of making SQID closure the target rather than the intended target of effective management of reported safety issues. The Investigation found no evidence that the risk of this unintended consequence, i.e. of the emphasis shifting to SQID closure and away from effective SQID management, was identified and managed within the SMS. The SMCMM placed an emphasis on, and measured, the percentage of SQID reports to be closed, rather than placing an emphasis on the percentage of safety issues to be resolved within specified time frames; this subtle difference may have set the tone for SQID processing, and for the staff's perception of the SQID system.

The SMCMM wording may have inadvertently primed those involved in SQID processing to view SQID reports as an administrative activity to be measured, rather than a critical safety function to be undertaken in a considered manner, irrespective of the time it might ultimately take to resolve certain reports. Indeed, reports which remained open for a long time could have served to alert management to safety issues requiring additional resources, whereas premature closure of reports deprived management of this cue. Furthermore, the setting of a target, in safety meeting minutes, for the maximum number of open SQIDs, could have had the unintended effect of encouraging staff to close SQIDs in anticipation that actions already in train would adequately address the identified safety issue. However, if SQIDs were closed before all necessary actions were completed, then there was no certainty about the effectiveness of the solutions implemented. Monitoring for re-entered reports in SQID and analysing why earlier SQIDs had not resulted in a permanent resolution of the issue raised could have alerted management to areas of concern within its SMS, but the Investigation found no evidence that such monitoring occurred.

2.3.4.4 Route Guide and Black Rock

In June 2013, one of the Operator's pilots emailed several other personnel, including some involved in the Route Guide/FMS updating projects, advising that while flying the APBSS route (the same route that R116 had planned to follow at the time of the accident), it was noticed that Black Rock Lighthouse was not shown on the EGPWS. The pilot stated that at '*310*' feet high, the lighthouse was an '*obvious hazard*' and suggested that although it was mentioned in the route notes, the EGPWS issue should also be highlighted. The pilot advised that the issue also applied to the Blacksod North route. However, no such note was added to the Route Guide.

Commenting on this email thread, the Operator stated, *inter alia*, that '*The appropriate methodology for a change such as this would be to report into the company Safety Management System (called SQID)*' using a '*Request for Document Change (RDC)*' report and this would then be managed through the company ORB. However, in March 2014, a SQID report was submitted regarding the Route Guide. This SQID provided information that even without the Route Guide being fully checked at the time, at least 9 out of 29 routes had anomalies and none of these anomalies, including an entirely wrong set of obstacle information, had been detected or reported during at least nine months of using the revised S-92A compatible Route Guide at the Operator's four bases.

The March 2014 SQID would suggest that personnel were not using the Route Guides in the manner which management asserted it believed that they were, i.e. methodically and exhaustively reading through every tabulated entry and assessing its importance for the planned usage of the route. It would also suggest that SQID reports were not being submitted for issues with the Route Guide. Regarding the APBSS route, the Operator informed the Investigation that it believed the tabulated information adequately identified the terrain hazard at Black Rock. However, the March 2014 SQID could have challenged the Operator's belief that crews were reading through every tabulated entry and assessing its importance for the planned usage of the route, and prompted action which could have made the Route Guides, and their usage, safer. In fact, given that an error in the length of one of the APBSS route legs had gone undetected since at least 1999, and that the magnetic headings of the APBSS route legs had not been adjusted for variation in magnetic declination since at least 1999, it would seem that even those involved in reviewing and updating routes at a base level were not reading the Route Guides in the way management believed they
289 were.

The Investigation found that on 27 March 2014, an email had been issued to base Chief Pilots, and copied to the personnel involved in updating the Route Guide. The email cited the above SQID and said '[…] *please issue an instruction to your crews to complete a review of routes used by your base* […] *Assign the task to one individual who will oversee and ensure all routes checked and any inconsistencies noted* […] *If there are any inaccuracies found or comments/suggestions, please forward the relevant information to* [named personnel] *who will then update the route guide.*' The SQID was closed at the ORB meeting on 10 April 2014, 25 days after it was opened. The closure of this SQID shows that appropriate and necessary feedback and monitoring procedures (i.e. checking that the routes had been updated before closing the SQID) were not being used. It demonstrates that the ORB was not adhering to SMCMM procedures to monitor the addressing of the original SQID; in this case, opening a Corrective and Preventative Action (CPA) for each affected route would have been appropriate. Whilst acknowledging that an earlier instruction for Chief Pilots to review all FMS routes for their base area of operation and report any inaccuracies to the FMS representatives had not achieved the necessary effect, the ORB re-issued the staff instruction and closed the SQID without feedback. In short, the ORB appears not to have appreciated the opportunities for proximate and systemic learning and improvement which this particular SQID report offered.

2.3.4.5 Email as a Safety Tool

The possibility of losing valuable information by using email instead of SQID had been highlighted in the February 2013 Dublin BFSM minutes, which said in relation to one SQID '*the discussion was being conducted through emails but* [the originator] *believes it should be conducted on the approved Safety system for the benefit of all*.' The Operator said that it did not interpret this comment as an unheeded indication of a systemic issue with the use of SQID, but instead said that this was actually a member of the Operator's team promoting the use of SQID to formally capture key aspects of topics being dealt with. The Investigation found other examples of information in emails that should have been in SQID, including Route Guide information.

The Investigation acknowledges that email is an important tool in the conduct of business generally, and can be an effective medium for distributing information, including safety information, directly to an individual, group or entire workforce. However, by its nature email is only intended to be seen by selected individuals/groups whereas safety management requires that safety information, communications and deliberations to resolve identified safety issues, should be captured in an information repository that is available to all and readily searchable.

2.3.4.6 Risk Assessments

Identification and containment or mitigation of risks through the use of an effective Risk Assessment process is a mandated, essential, pro-active element of an SMS.

Several of the Operator's Risk Assessments reviewed by the Investigation contained inconsistencies regarding who was actually involved in the Risk Assessment processes, what their role was, and the bases that the Risk Assessments referred to. Furthermore, Risk Assessments (in accordance with Regulation (EU) No 965/2012 and as stated in the Operator's Safety and Compliance Monitoring Manual) require that '*once the level of risk is identified, appropriate remedial action or mitigation measures can be implemented to reduce the level of risk to as low as reasonably practicable*'. The four Risk Assessments from 2015 were completed on the same day and accepted by a member of the Risk Assessment team the following day. None of these four Risk Assessments specified any remedial actions or mitigation measures to be implemented. One of these Risk Assessments related to what the Operator described as the risk of a Controlled Flight Into Terrain.

The Operator informed the Investigation that regarding the skillsets and experience levels of those involved in the Risk Assessment process, it would not '*gather formal 'qualifications' or 'competence assessments' when using nominated persons who are acceptable to the IAA through their core roles*'. However, the Investigation believes that it would be prudent to review skill sets of personnel prior to undertaking safety-critical tasks (such as completing risk assessments) rather than relying on a once-off, IAA, Post-Holder/nominated person acceptance process. Furthermore, the acceptance of a Risk Assessment by a member of the assessment team meant that in effect an individual was checking and accepting their own work. The Investigation considers that this was sub-optimal.

2.3.4.7 Reporting of Other Events

For air operators, the reporting and investigation of events in which safety margins have been compromised during flight operations is an essential component of an SMS. Such a component is intended to provide operators and their personnel with the opportunity to learn from these events and also to provide regulators with an accurate understanding of an operator's risk profile.

During interviews with a number of personnel from the Operator, the Investigation heard accounts of events over the years, which were allegedly serious in nature and involved circumstances where safety margins had allegedly been seriously compromised. The Investigation asked the Operator's personnel who were interviewed, why such events might not have been reported and various answers were provided including organisational culture, fear of retribution, embarrassment and pride.

The Investigation asked the Operator to provide copies of SQID reports and any/all other documentation/emails/correspondence whatsoever, in relation to such alleged safety events. The Investigation also asked for details of any/all other events involving loss of situational awareness/control or during which crews encountered unanticipated conditions which necessitated non-normal recovery strategies. The Operator informed the Investigation that it was unable to get any '*hits*' searching the SQID database for information on any of the alleged safety events. The '*Operations Record from the Dublin base*' for 29 and 30 November 2005 was provided by the Operator. The log records the crew involved and the tasking details and the comment the following day of '*as of this morning still off line'.* There is no mention of any safety-related event occurring during the tasking nor any reason as to why the crew was '*still off line*' nor any reason as to why the crew were '*off line*' in the first instance. No other documentation was provided in response to this request.

The Investigation asked those who said that they had knowledge of previous events if they could provide any documentation in relation to the events. Details of two events were provided. A 2003 event involved a LIMSAR (non-auto-hover equipped) helicopter; and, a 2005 event which was classified as a '*pilot disorientation*' event. Follow-up actions appear to have focused on helicopter capabilities and enhanced training. However, the Investigation notes from the details it received, that both of these events appear to have occurred at night between midnight and 01.00 hrs.

The nature of flight operations means that safety events do happen from time to time, some of which may be deemed serious if safety margins were compromised. The fact that the Operator was unable to provide copies of SQID reports or other documentation, in relation to alleged safety events is of some concern to the Investigation, as is the fact that flight crew who had first-hand knowledge or were aware of such events, may not have reported the events in the SQID system. Furthermore, it is unfortunate that the Operator was unable to locate any information in relation to such events within its own archives despite the fact that it appears that at least two such events had been the subject of follow-up action.

Ensuring that organisational culture and safety climate are conducive to the reporting of such events is crucial to the success of an SMS. Events that are reported, investigated and learned from (feedback) are a critical component of safety management.

2.3.4.8 Summary — SMS

A clearly defined SMS, with an accurate description of the structure of all safety meetings used by the Operator and the processes to ensure all such meetings are held when required; an effective safety reporting and follow-up system, which is trusted and supported by all staff; a Risk Assessment process that results in the identification and containment or mitigation of risks; and effective methods by which all relevant data can be collected, analysed and used appropriately, is essential for the management of safety risk. However, as outlined in the paragraphs above, the Investigation identified several anomalies with the Operator's SMS and consequently had concerns regarding the system's ability to effectively manage safety risk. The following Safety Recommendation was issued in the Investigation's First Interim Statement:

> CHCI, with external input, should conduct a review of its SMS and ensure that the design of its processes and procedural adherence are sufficiently robust to maximize the safety dividend; this review should consider extant risk assessments and a thematic examination of the corpus of all safety information available to the Operator, both internally and externally (**IRLD2018002**).

The action taken by the Operator in relation to this Safety Recommendation is contained in **Appendix G**.

2.3.5 Visibility and Weather Limits — SAR Operational Flight

On the night of the accident, R116 was tasked by MRCC Dublin to provide Top Cover for R118 and was using a '*Rescue*' call sign; the IAA informed the Investigation that based on these two factors the flight was considered to be a SAR flight and, at the Commander's discretion, could avail of the alleviations/exemptions contained in the National SAR Approval.

The CVR indicates that the Commander's decision to go to Blacksod for fuel rather than Sligo was based on a concern to save thirty minutes flight time following R118 out, and also on the return journey; furthermore, the Commander received a report '*conditions good at Blacksod*'. The CVR indicates that the Commander later noted that reports from Blacksod indicated a cloud base as low as 300 ft and APP1 was used to bring the Helicopter down to 200 ft over open water before turning inbound to follow the APBSS route. This flight profile was in accordance with OMF which allows a minimum height of 200 ft with the helicopter's collective axis coupled to RALT, and an absolute minimum of 50 ft helicopter hover with collective coupled to an AFCS SAR mode height hold.

However, OMF also requires visibility sufficient for the requirements of the task and to satisfy any OMB requirements for system modes being used. Although not a system mode requirement, OMB says '*DVE is defined as visibility less than 4000 metres or no distinct natural horizon. Circuits shall be flown at 500 feet with reference to the RADALT with speed at least V_Y. Once established on the final approach track inside 2 nm at 500 feet, couple or remain coupled to RALT, HDG and IAS and beep down to 300 feet (or deck elevation plus 50 feet, whichever is the higher), to be level by around 1 nm to run*.'

The Crew completed DVE Approach checks, indicating that they expected that they would be operating in DVE conditions. However, in descending to 200 ft, whilst it allowed the Crew to obtain COCISS conditions (clear of cloud, in sight of the surface), it eroded a safety barrier – height above the surface – without a definite improvement in terms of horizontal visibility. Furthermore, at 9 NM from Blacksod and 200 ft above sea level, operating just below the cloud base, at night, there were no external visual cues available (e.g. identifiable light sources or discernible features), to allow the Crew to assess horizontal/forward visibility.

Apart from a comment on the CVR that the Commander could see the surface, operating visibility for the route into Blacksod was not discussed. When the Helicopter commenced its left turn back towards BLKMO the Winchman commented '*clear around to the left*', although it cannot be known what inputs informed this comment. Accordingly, while the Crew was content to continue the approach based primarily on their radar picture, cross-checked with EGPWS and supplemented when possible by the EO/IR, there was no way for them to reliably assess the horizontal visibility and hence to know if it was sufficient for the requirements of the task in hand.

Indeed, the task in hand itself must be considered. By descending down to 200 ft where it did, the Helicopter was essentially embarking on a 9 NM '*en route*' phase, over water, at night, in adverse weather. This significantly increased the risks facing the Crew. While accepting that the Helicopter was on a SAR mission, it was not the primary SAR asset, and it was proceeding to a refuelling facility, not to carry out a rescue.

The Investigation notes that OMF required commanders to consider the medical category of
293 the casualty when determining a decision point. Furthermore, OMF reminded commanders that the application of weather minima should be based on the urgency of each particular mission. The wisdom of these requirements merits consideration for fear that it could encourage emotion to encroach on aviation decision-making. In addition, if a SAR helicopter is not the prime SAR asset, i.e. if it is a Top Cover/SAR Support/Chase helicopter, then it may be prudent to consider whether such missions should automatically be classified and operated as SAR missions.

In light of the foregoing, the Investigation makes the following Safety Recommendation:

> CHCI should review its OMF procedures in order to: remove consideration of casualty condition from flight crew dispatch/continuation criteria for SAR missions; require crews of support SAR helicopters to specifically consider when/whether it is appropriate to dispatch under SAR criteria; and provide specific guidance to crews about the assessment of visibility under conditions of darkness and or poor weather (**IRLD2021015**).

2.3.6 Top Cover

The Investigation notes that the IRCG Helicopter SOPs stipulated that Top Cover was required '*If the scene is more than 80 miles from shore*'. The Operator's OMF stated '*top cover should normally be requested when operating at ranges greater than 120 nm from the coast*'. This discrepancy in procedures, although sub-optimal, was not relevant in this case as the Fishing Vessel was 140 NM from the coast and therefore exceeded both thresholds.

The Operator's OMF, as extant on the night of the accident, stated '*There will be a designated support SAR helicopter on 15-minute readiness for any such mission, regardless of the availability of top cover*', i.e. in addition to R116 providing Top Cover, a third base should have been brought to 15 minute readiness. This did not happen.

Traditionally, Top Cover was provided by long-range, fixed wing aircraft which had greater endurance/'*persistence*' than the primary SAR helicopter. The Top Cover aircraft usually arrived on scene before the SAR helicopter (due to higher transit speed); identified the casualty vessel; established communications with both the casualty vessel and the SAR helicopter; briefed the casualty vessel's crew on communications frequencies, etc.; provided on-scene weather and navigation vectors to the SAR helicopter; and maintained over-watch until the SAR helicopter had completed its mission and was sufficiently close to shore.

The roles of the Top Cover aircraft are critically dependent on it having significantly greater endurance than the SAR helicopter. Accordingly, a second SAR helicopter which follows the primary asset, but has similar endurance provides few, if any, of the traditional Top Cover functions. Notwithstanding that a review of the existing SLA with the Department of Defence/Air Corps in relation to issues such as Top Cover is planned (**Section 1.17.8.2** and **Appendix U**), the Investigation considers that a broader review is appropriate. Consequently, the Investigation makes the following Safety Recommendation:

The Minister for Transport should, in conjunction with the relevant agencies, review processes regarding the requesting/tasking of Top Cover assets, fixed wing or helicopter, and should ensure that terminology is well-defined and consistently used (**IRLD2021016**).

The Investigation notes that a proposal to increase the rate of tasking of east coast helicopters by tasking them to carry out more missions in the west, outside their normal area of operation, was not the subject of a risk assessment or a safety case; and the proposal was not reflected in revised IRCG SOPs, which were promulgated at the same time. Accordingly, the Investigation makes the following Safety Recommendation:

The Minister for Transport should ensure that proposed changes to IRCG operating procedures are the subject of a risk assessment or safety case, that any mitigations required are in place prior to implementing the changes, and that SOPs are updated in a timely fashion to reflect any such changes (**IRLD2021017**).

2.3.7 Radar Usage

In relation to the Decision Point, i.e. the point at which a flight crew must decide that there are adequate visual cues available to facilitate a safe landing or else abandon the attempted landing and go around, OMF stated, '*it is imperative that no doubt exists on whether collision avoidance is being provided visually, or by radar'*. For '*Low-level offshore night or IMC flights'*, OMF stated '*As a general working guideline, separation from unidentified radar contacts should be at least 0.5 nm by radar unless the mission requirement / profile mandates closer proximity*.' However, the Investigation notes that the radar manufacturer's manual states:

> '*WARNING*
> *THE SYSTEMS PERFORM ONLY THE FUNCTIONS OF WEATHER DETECTION OR MAPPING. IT SHOULD NOT BE USED OR RELIED UPON FOR PROXIMITY WARNING OR ANTI-COLLISION PROTECTION*.'

Furthermore, OMF referred to '*permitted navigational radar modes*', but the Operator informed the Investigation that there was no such permission. Accordingly, the Investigation makes the following Safety Recommendation:

> CHCI should review its policies, manuals, training and guidance in relation to the operational use of radar in the SAR role and ensure that manuals and training accurately reflect the limitations of the systems used (**IRLD2021018**).

2.3.8 Toughbook and EO/IR Usage

The Operator said that Toughbook training was included in a number of rear crew training syllabus items, and that it required hands-on practice which could be achieved by practice in the hangar on ground power, complemented by airborne training. Proposals had been made regarding specific Toughbook training but these were downgraded to discussions about training a trainer at each base. However, the Investigation understands that ultimately those proposals were not acted on. A detailed 82-page user guide was prepared and circulated, but the predominant view from personnel who spoke with the Investigation was that detailed initial training, along with regular practice and assessment, would be required to ensure that appropriate standards were achieved and maintained.

The Investigation was also informed that no specific, manufacturer-provided, operational training was delivered to rear crew members in the use of the EO/IR camera system on the S-92A helicopter, although some rear crew members did attend EO/IR engineering training courses, which were provided for engineering personnel. Rear crew had received manufacturer-provided, operational training for the '*FLIR*' system which was fitted to the S-61N. However, the Investigation was advised that the S-92A EO/IR system was more capable than the S-61N system and EO/IR manufacturer-training would ensure that best use could be made of the available system capabilities.

The Operator informed the Investigation that FLIR training was completed as part of the Winchman's Operational Conversion Course (OCC) ground school syllabus; it consists of briefings and hands-on familiarisation in the helicopter both on the ground and in the air. The Operator stated that use of the FLIR features extensively in the flying syllabus, there is an RFM supplement on the FLIR, and also a PowerPoint briefing. The Operator also stated that additional guidance on FLIR searches is given in numerous references throughout the OMF; furthermore, once a rear crew member is qualified he/she is required to complete Radar/FLIR approaches as part of his 90-day recency training as laid down in OMF.

Regarding the Toughbook and EO/IR camera system, the Investigation considers that OMF guidance and extant personnel training should be augmented. In particular, the Investigation notes that OMF states that the moving/memory map can be used to build a suitable route to the target area; this means that Toughbook operators must be explicitly trained in route design considerations. Accordingly, the Investigation makes the following Safety Recommendation:

> CHCI should ensure that rear crew members receive operational EO/IR training and periodic, formal training and rating(s) to operate the Toughbook, with particular emphasis on approaches and construction of routes to target areas, the limitations of the databases and software in use; and that OMF and other documentation for both systems should be reviewed and updated (**IRLD2021019**).

2.3.9 Document Management

The Operator's OMA describes OMC as '*Route Guide(s)*'. OMA also states '*A pictorial representation or template is produced for each helideck by* [specialist supplier] *and the plates are contained in the route guide*.' OMA goes on to say '*This section refers to the international standards rules of the air (ICAO Annex 2). The rules can be found in the aircraft in the route guide airway manual, section 'Air Traffic Control'. Where national differences from the international standards exist, these are found in the route guide airway manual, near the end of section 'Air Traffic Control'. It is important that these differences are noted when referring to ICAO Annex 2. Table of cruising levels is found in the route guide airway manual, section 'Air Traffic Control'. Guidance material related to vertical separation is contained in ICAO Doc 9574*.' Thus, the Investigation is of the opinion that the Route Guide references in OMA are actually intended to mean a '*route guide airway manual*' or at the least a document produced by a specialist supplier, rather than to the Operator's own Route Guide.

For its part, OMC states '*This OMC shall be used in conjunction with:* […] *e. FMS route guide'*. However, OMC goes on to say '*2.1 Minimum flight level / altitude* […] *Due to the nature of operations,* [the Operator] *does not have dedicated routings, and therefore, minimum flight levels or altitudes along such routes*.' However, the Operator did have dedicated routings as provided in the Low Level Route Guide and the FMS, and accordingly, '*minimum flight levels or altitudes*' for those routes should have been specified.

The only reference to Route Guide in OMF is '*2.9 Weather limits – SAR training flight 2.9.1 Departure* […] *Departures may be conducted under VFR, SVFR or IFR clearances. Normal SVFR minimum of 1500 m visibility and 600 feet cloud ceiling will apply in class C airspace, however, the following minima are to be used with the level routes (see route guide)* […] *Use of the SHANNON RIVER and WAT03 routes require the radar or FLIR to be serviceable*.' The reference to '*level routes'* is unclear, but may be a misnomer for '*low level routes'* which is a phrase in common usage amongst the Operator's personnel. Such an interpretation might be consistent with the phraseology '*SHANNON RIVER and WAT03 routes'*, except for the fact that neither of those documents/routes exist in the Route Guide that was provided to the Investigation. The Investigation notes that this sole OMF reference to the Route Guide relates to training flights rather than operations.

The Investigation also notes that there is no reference to the Route Guide in the table of '*Required Aeronautical Charts*' in OMC. Furthermore, the validity check prescribed on the OMC table for the Landing Site Directory (LSD) ('*S92A: Contact* [the Operator's*] LSD coordinator'*) is not the same as the advice in the LSD itself ('*To check you have the latest update see* [specified drive location on the Operator's servers]').

Specifically in relation to the LSD, the Investigation noted that the revision date on the document provided was 08/09/2015 but the document actually contained two sets of site details which were updated after that date, i.e. Drogheda Athletics Ground (dated 01/02/2016) and Phoenix Park (dated (01/02/2016).

In addition, the Risk Assessment Forms used in 2015 were actually of an earlier standard than those used in 2012. In light of these issues with the Route Guide, the LSD and the Risk Assessment Forms, the Investigation believes that it would be appropriate for the Operator to review its document management methodologies and thus makes the following Safety Recommendation:

CHCI should review its document management and updating methodologies and the robustness of its practices to ensure that current documents are readily apparent, that older revisions are appropriately archived and that staff members are provided with a uniform method for confirming the latest revision state of any document (**IRLD2021020**).

2.3.10 Helicopter Flight Data Monitoring

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The Investigation notes that the SMCMM incorporated a 13-page section titled '*Flight Data Monitoring (Not currently used within* [the Operator]*)*'. The Operator informed the Investigation that at the time of the accident it did not have an FDM programme for its fleet and that there was no regulatory or contractual requirement for such a system to be used by the Operator.

The Investigation notes that the nature of SAR operations is atypical of other helicopter operations and accordingly bespoke HFDM triggers and interpretation would be required to make optimal use of HFDM in a SAR operation. Notwithstanding the challenges of operating a HFDM programme for helicopters employed in a SAR role, the Investigation believes that it would be prudent and appropriate for the Operator to introduce a HFDM programme to assist the Operator's management in enhancing their knowledge of the operation and its inherent risk areas. The Operator informed the Investigation that it '*has already commenced the process of implementing a FDM programme and is utilising the extensive experience its parent company has of FDM. The Operator has opened discussions with the relevant trade unions which it hopes will be supportive of the programme as used elsewhere*.' Notwithstanding this, for certainty and traceability, the Investigation makes the following Safety Recommendation:

CHCI should introduce, and regularly review, a Helicopter Flight Data Monitoring programme, to support its SMS and personnel in identifying and addressing operating issues and trends to optimise safety margins within its operation (**IRLD2021021**).

2.3.11 AFCS SAR modes

During the course of the Investigation, it became apparent that not all of the lateral navigation modes were being recorded to the FDR; the Helicopter Manufacturer confirmed this. The Manufacturer informed the Investigation that the AFCS SAR modes are recorded on the HUMS card. Using the HUMS data, the Manufacturer provided the Investigation with the necessary lateral navigation parameters in use during the flight. However, the Investigation believes that information on the lateral navigation modes should be recorded in the FDR, the primary source of recorded data for investigation purposes, and accordingly makes the following Safety Recommendation:

> The Sikorsky Aircraft Corporation should make the necessary updates/modifications to the S-92A helicopter, when configured for SAR operations, to ensure that the active lateral navigation mode information, including AFCS SAR modes, are recorded on the Flight Data Recorder during all flight regimes and mission profiles (**IRLD2021022**).

Whilst manoeuvring to join the APBSS route, the Commander requested Search ('*SRCH*') mode be selected and the Co-pilot acknowledged the request. The Investigation was unable to find any reference to the '*SRCH*' mode in the Helicopter Manufacturer's RFM Supplement (No. 4 Part 2) or in the Operator's operations manuals. The Operator informed the Investigation that selecting '*SRCH*' on the SAR mode menu, on the Mode Select Panel (MSP), coupled the helicopter to the roll channel. The Operator went on to say that the functionality was identical to that which is obtained when '*NAV*' is selected from the MSP. The Operator further explained that if a crew is following an FMS company route, but has the SAR menu active on the MSP, they would press the SRCH button which would couple the helicopter in roll and the helicopter would fly the route for them.

The Helicopter Manufacturer informed the Investigation that when SRCH is engaged, the Coupled Flight Director (CFD) can only couple to the FMS, whereas the NAV button allows coupling to either FMS or VOR. It also said that use of the SRCH button provided a subset of the functionality of the NAV button. The Helicopter Manufacturer confirmed that SRCH can be used to follow FMS navigation without an active search pattern, that existing RFM documentation on NAV mode also applies to SRCH, and that there was no specific published guidance on AFCS SRCH mode.

Sikorsky S-92A RFMS No. 4 Part 1 includes the following limitation related to the use of SAR AFCS modes: '*Night or IMC SAR approaches are only permitted if the entire approach is conducted overwater.*'

Given the stated differences between NAV and SRCH modes in the S-92A helicopter, the Investigation makes the following Safety Recommendation:

> The Sikorsky Aircraft Corporation should make the necessary updates/modifications to the S-92A Helicopter Rotorcraft Flight Manual Supplement No. 4 Part 2, to include a description of the operational usage of the AFCS SAR SRCH mode (**IRLD2021023**).

2.3.12 Summary — Organisational Aspects

Whilst acknowledging the dynamic nature and urgency of SAR helicopter tasking, the Investigation notes that there was no risk assessment process carried out at IRCG level prior to tasking R118, and requesting that R116 provide Top Cover.

The Operator relied on a Secondary Duty model which meant that personnel whose primary role was as SAR First Responders, and whose shift patterns meant that their workplace attendance was intermittent, were tasked with safety-critical support functions, without formal back-up arrangements or personnel training.

The Investigation has made Safety Recommendations in relation to the Operator's SMS; guidance for visibility assessment; radar usage; Toughbook and EO/IR usage; and Document Management. Finally, the Investigation recommended that the Operator introduce a programme of Helicopter Flight Data Monitoring and that the Helicopter Manufacturer provides details in the Rotorcraft Flight Manual Supplement of the operational usage of the SAR AFCS 'SRCH' Mode. Having considered these Organisational Aspects, the analysis will now consider Oversight of SAR Helicopter Operations in Ireland.

2.4 Oversight

2.4.1 IRCG Oversight

The IRCG informed the Investigation that it did not have aviation expertise available on its staff and had for many years contracted an external consultancy to provide it with aviation expertise, advice and auditing of the Operator's bases; this external consultancy is referred to in this Report as the IRCG Auditor.

In 2013, the IRCG Auditor identified overt commercial pressure during the transition from the S-61N helicopter type to the S-92A helicopter type; his recommended solution, which IRCG adopted, was '[Named Post-Holder] *will therefore send you a letter confirming all areas of* [the Operator] *are ready to commence S92 ops at Sligo'*. It was appropriate that the Auditor raised this issue, and such letter(s) were provided. But this was, in effect, a case of self-assessed competence, and the longer it took the Operator to determine and state that they were ready to commence S-92A operations, the greater the commercial pressure it faced, which is exactly what the Auditor was trying to avoid. The Investigation notes that one of the terms of the Auditor's contract was to '*oversee the transition from the current helicopter search and rescue contract to the new contract* […] *assessment of aircraft, aircrew, maintenance and support services, and base and aircraft operational readiness will be required*.'

Furthermore, a report dated June 2018 was the earliest follow-up report provided to the Investigation in response to findings from a February 2016 external audit (carried out by a different audit agency) of IRCG Operational Standards. The Investigation believes that it should have been recognised from the Auditor's email that increased oversight resources were needed, and a response time of over two years to findings of an external audit report is not considered satisfactory. **Section 1.17.8.2** and **Appendix U** outline enhancements in relation to auditing by external consultants which the Minister for Transport, Tourism and Sport instituted. Notwithstanding this, for certainty and traceability the Investigation makes the following Safety Recommendation:

The Minister for Transport should ensure that the IRCG's internal processes are sensitive to warnings from its process auditors, and that mechanisms are in place to ensure that appropriate and necessary actions are expeditiously implemented in response to any such warnings (**IRLD2021024**).

Regarding Top Cover launch criteria, the figure of 100 NM, which was mentioned in the Sligo and Shannon IRCG audit reports in 2014, 2015 and 2016, was not set out in the extant OMF, IRCG SOPs, or elsewhere. Furthermore, the reference to the '*IAA*' in the Waterford 2014 audit report appears to be a misnomer for the '*IAC*'; however, this misnomer was replicated in the 2015 report. The different answers provided in different years in the Sligo audit reports regarding the base-of-origin of a '*Top Cover*' helicopter, suggests that the policies set out in the IRCG SOPs and the Operator's OMF, were either not known or not being adhered to. Furthermore, there is no evidence that these reported anomalies were detected or commented on by either the IRCG or the Operator, each of which received copies of the audit reports.

The Investigation notes that the Auditor's contract specification stated that the Auditor '*will be required to undertake aviation safety reviews of the IRCG*'. IRCG informed the Investigation that no reviews of the IRCG were requested. Furthermore, the Investigation believes that having an auditor carrying out safety reviews of the IRCG while answering to the IRCG was a sub-optimal arrangement.

The IRCG sought legal advice to exempt its Contractor's personnel from the provisions of the Organisation of Working Time Act without a rigorous scientific analysis of the implications. In an operation as demanding as SAR, it is imperative that any changes to working time arrangements, and the associated safety implications for personnel, must be fully analysed and understood prior to change implementation.

Section 1.17.8.2 and **Appendix U** outline that a full time Aviation Manager will be appointed. Notwithstanding the Minister's response, in light of the issues identified above, and for certainty and traceability, the Investigation makes the following Safety Recommendation:

The Minister for Transport should review the provision of aviation expertise to the IRCG to ensure that the IRCG is effective and structured to support appropriate governance arrangements and that IRCG operating procedures are risk assessed and maintained current (**IRLD2021025**).

The IRCG was a Division of DTTAS (now the Department of Transport); however, it appeared to operate with significant autonomy. The Investigation considers that it would be appropriate that corporate governance structures within the Department be reviewed to ensure that IRCG is subject to routine operational and management oversight. The Investigation notes that the Marine Casualty Investigation Board Report MCIB/266 recommended regular reviews of the IRCG management system. The Investigation believes that the Department should ensure that regular, external reviews of the IRCG are carried out. As stated earlier, the Minister outlined several measures that have been taken since the accident (**Section 1.17.8.2** and **Appendix U**). These measures make provision for external reviews and the associated reporting mechanisms.

However, the Investigation considers that the departmental governance arrangements of the IRCG could be further strengthened, particularly in relation to how the Department provides oversight of the activities of the IRCG. The Investigation therefore makes the following Safety Recommendation:

The Minister for Transport should ensure that appropriate departmental governance arrangements are in place to oversee the functioning of the IRCG and to ensure that issues identified are addressed so that the systems in place will be sufficiently comprehensive and robust (**IRLD2021026**).

The IRCG informed the Investigation that '*the lack of a dedicated H&S Officer has precluded development of a Safety Management System*'. The Investigation notes from this response that there is a possible confusion/conflation of the functions of '*Health and Safety*' and '*Safety Management Systems*'. The Investigation notes that, in response to MCIB Report 266, the IRCG cited '*a million 'man-hours' on duty* [...] *have had otherwise no loss of life or severe injuries'* as evidence of *'a robust risk awareness culture*'. The Investigation also notes that '*no loss of life or severe injuries*' should not be interpreted as an indication of a safe system of management and working. Safety management is much more than a risk awareness culture. Safety management is an iterative, multi-faceted, data-driven process, which requires dedicated processes and structures to ensure that awareness is developed and maintained at a suitable level, feedback is gathered and analysed, and personnel are part of a learning organisation, which seeks and uses feedback at all levels to strengthen its procedures and defences. It must be an integrated part of both the organisation and its procedures, at all levels. Irrespective of the apparent level of safety achieved, effective safety management demands continuous, probing examination and re-examination, in an incessant search for hazard identification, hitherto unforeseen sources of danger and safety improvement, in a dynamic, continuously changing environment.

Section 1.17.8.2 and **Appendix U** outline measures which the Minister for Transport, Tourism and Sport advised the Investigation were taken following the accident. One of the measures outlined is the commitment to '*the development and implementation of an effective and functioning Safety Management System* [SMS], *applicable to the specific needs of the IRCG*'. The Investigation considers it imperative that such an SMS is implemented as soon as possible and that it encompasses matters regarding aviation safety. Accordingly, the Investigation makes the following Safety Recommendation:

The Minister for Transport should ensure that the IRCG fully implements a Safety Management System which encompasses all aspects of its air operations and which includes all stake holders in those operations (**IRLD2021027**).

The Investigation notes that DTTAS entered into an SLA with the Department of Health (in January 2013 and revised on 9 June 2014) for the provision of an Aero-Medical service which stated '*The* […] *Irish Coast Guard has overall responsibility for Irish Coast Guard aviation safety and operational standards*.' The Investigation believes that a prerequisite for responsibility for aviation safety is appropriate training and experience in aviation safety. However, on 2 November 2018, IRCG management advised the Investigation that its members had just completed their first ever aviation SMS course. The Investigation also notes that the SLA in question referred to an IRCG AOC which doesn't exist.

The Minister advised the Investigation that '*the IRCG has commenced a review of all its Memoranda of Understanding / Service Level Agreements to ensure respective roles and responsibilities are articulated clearly and understood by the respective parties*' (**Section 1.17.8.2** and **Appendix U**). Notwithstanding the Minister's response, for certainty and traceability, the Investigation makes the following Safety Recommendation:

> The Minister for Transport should review extant service level agreements involving IRCG air operations to ensure that they are suitably robust and complete, and to ensure the viability of statements of responsibility provided in such service level agreements (**IRLD2021028**).

As the *THE NIMROD REVIEW* conducted by Haddon-Cave found, contracting-out of services in safety-critical areas presents particular challenges, which must be recognised and addressed through appropriate structures and arrangements. The Investigation believes that whilst contracting out of aviation support services (including auditing) is a matter for the Department of Transport, it is imperative that the Department has sufficient in-house expertise to allow it to remain an '*intelligent-customer*'. The Minister outlined several measures that have been taken since the accident (**Section 1.17.8.2** and **Appendix U**), including the planned appointment of a full time Aviation Manager. The Investigation notes this response; however, for certainty and traceability, the Investigation makes the following Safety Recommendation:

> The Minister for Transport should periodically review the availability of in-house expertise, to ensure that the Department retains the necessary technical capabilities to intelligently oversee and review all activities associated with SAR aviation operations (**IRLD2021029**).

2.4.2 IAA Oversight

The IAA's State Safety Plan extant on the date of the accident noted that its resources would be focussed on *'the areas that present the greatest risk to aviation safety'* and that actions would be implemented *'that will best mitigate these risks'.* However, the Operator was not subject to an increased level of oversight. Furthermore, there appeared to be confusion amongst agencies (IAA, DTTAS and IRCG) regarding oversight responsibilities and mandates. Notwithstanding the benefit of hindsight, the Investigation considers that due to the nature of SAR operations, it would be reasonable to treat SAR as an area that presented a degree of risk that warranted a greater level of oversight.

In its 2013 Annual Safety Review, the IAA announced that it was introducing legislation to move the regulation of SAR operations from an Aerial Work basis to an AOC basis, and Aeronautical Notice (AN) O.76 was introduced in 2014. It seems contradictory therefore, that in 2018, the IAA said a National SAR Approval granted under AN O.76 was an Aerial Work permission. Furthermore, the IAA drew a distinction between approval (against existing technical standards) and acceptance (based on, for example, an operator's procedures manuals). It also seems contradictory that a SAR operator would be granted a '*National Search and Rescue Approval*' based on a procedures manual which the IAA says it did not approve but only accepted, i.e. the Authority's '*approval*' was predicated on a document which the Authority said it did not approve.

The IAA's 2014 AOC Annual Review Form (for the Operator) recommended continuation of the EASA AOC and SAR operations. The IAA's 2015 AOC Annual Review Form (for the Operator) only recommended continuance of the AOC. This was consistent with the introduction of O.76 in October 2014, which the IAA said would move regulation of SAR operations onto an AOC basis. Therefore, pre-AN O.76, SAR operations were off-AOC and required separate recommendation for continuance, but post-AN O.76, SAR operations were on the AOC and consequently only an AOC continuance recommendation was required (and made).

The IAA drew the Investigation's attention to S.I. 172 of 1995 – Annex 12 (Standards and Recommended Practices Search and Rescue) (Designation of Authorities) Order, 1995, which states:

> '*Para 2(1) The Minister shall be the authority by which any powers exercisable under Annex 12 of the Chicago Convention other than powers in relation to Rescue Co-ordination Centres and Rescue Co-ordination Sub-Centres in the State are to be exercised in the State.*
>
> *Para 2(2) The IAA shall be the authority by which any powers exercisable under Annex 12 of the Chicago Convention in relation to Rescue Co-ordination Centres and Rescue Co-ordination Sub-Centres in the State are to be exercised in the State*.'

However, the AQE Report, commissioned by the Minister for Transport, Tourism and Sport, in response to the Investigation's Safety Recommendation IRLD2018003, stated that the IAA had made an input to the drafting of the 2010 National SAR Framework that '*The Safety Regulation Division of the IAA is the body responsible for the regulation and oversight of aircraft operations, including aeronautical Search and Rescue, within the State*'. The Minister signed and issued the National SAR framework. Therefore, it would appear that the IAA was aware of the provisions of S.I. 172 of 1995; made a submission to the Minister's 2010 National SAR Framework working group, advising that the IAA was '*responsible for the regulation and oversight of aircraft operations, including aeronautical Search and Rescue';* and that, when he issued the 2010 National SAR Framework, the Minister concurred with the IAA's input that oversight of '*aircraft operations, including aeronautical Search and Rescue'* was the IAA's responsibility.

Furthermore, the IAA informed the Investigation that the IRCG was responsible for operational SAR missions and that it did not conduct oversight of the IRCG. However, the November 2015 email between the IAA and IRCG indicated that there was concern within the IAA regarding the IAA's authority to regulate SAR operations and what standards should be used.

This seems to conflict with the IAA's AN O.76, published in 2014, which said that Search and Rescue '*operations are to be classified as a 'State' activity which is to be regulated by the National Aviation Authority.*' The IAA's June 2016 email to the Operator indicated that the IAA considered the National SAR approval was not an Aerial Works Permission, since it was proposing to revert from the former to the latter. The email also indicates that the IAA was looking for an appropriate standard against which it could audit the Operator's operation, irrespective of the SAR approval/Aerial Works Permission distinction.

In 2010, the IAA informed the Minister's working group that it was responsible for the regulation and oversight of '*aircraft operations, including aeronautical Search and Rescue'* and the Minister reflected this in the 2010 National SAR Framework. Later, in 2015 and 2016, the IAA appears to have been uncertain of its mandate or the applicable standards for auditing purposes. However, it did not revoke or curtail the National SAR Approval, either at that time or on 25 April 2017, six weeks after the accident and two weeks after the AAIU published the Investigation's Preliminary Report. At that time, the IAA re-issued a National SAR Approval to the Operator with just one change, the removal of the registration of the accident Helicopter.

Furthermore, though the IAA stated in State Safety Plan 2017–2020 that '*Search and Rescue (SAR) is excluded from the regulatory framework of civil aviation and thus is outside the remit of the EASA or the IAA',* State Safety Plan 2018-2021 stated:

> '*During 2017, the IAA undertook a review of the safety oversight system for helicopter operations in Ireland that involve both civil and State functions. The review found that the legal powers and legislation available to the IAA were sufficient to enable it to implement the IAA safety oversight system in respect of a civil AOC holder organisation and permit that organisation to operate SAR missions on behalf of the State. Action a) is now closed.*'

All versions of the National SAR Approval stated that it was granted to the Operator because the IAA was '*satisfied that the said operator is competent to secure the safe operation of the aircraft specified* [...] *on flights for the purpose of operational Search and Rescue*.' The Investigation asked the IAA to provide full details of actions taken by the Authority following the accident and prior to the re-issue on 25 April 2017 of '*Irish National Search and Rescue Approval – No. 1 of 2014*', which led the Authority to continue to be satisfied that the Operator was '*competent to secure safe operation of aircraft for operational search and rescue*.' The IAA said that during the course of ongoing liaison with the Operator, a review of the Operator's offshore procedures was discussed, resulting in the Operator publishing Flying Staff Instruction (FSI) 2017 – 030 on 14 April 2017. The Investigation asked for full details of this discussion of the Operator's offshore procedures and how this resulted in FSI 2017 – 030 being issued. The IAA said that at the time of accident '*the immediate concern was the on-going safety of the operation, bearing in mind the increased demand on the company's management team from internal and external factors (media, regulatory agencies etc.). The IAA asked* [the Operator's management] *if the company needed to engage any immediate actions to mitigate any risks unknown. (At this stage, the preliminary report from AAIU made a SR (SR No.1) against the SAR Route Guides and the search efforts were still underway. Additionally, the company still had to meet their contractual obligations to the State). The company issued FSI 2017 – 030 as an interim measure pending new information or outcomes of the AAIU investigation.'*

The Investigation was subsequently informed by a former Post-Holder that as an immediate response to Safety Recommendation IRLD2017005 made by the AAIU in its Preliminary Report, a discussion was conducted by phone with the IAA regarding FSI 2017-030 which led to the '*acceptance*' of the FSI and its issue on the evening of 14 April 2017; the former Post-Holder also informed the Investigation that he did not recollect being asked by the Authority *'if the company needed to engage any immediate actions to mitigate any risks unknown.'*

The Operator's FSI 2017 – 030 stated:

> *'A review of the* [Operator's] *Route Guide is currently being undertaken and pending completion and verification, temporary cloud ceiling and visibility limitations will be in operation until this process is complete.*
>
> ***<u>Action to be taken</u>***
>
> *When using the routes contained in the* [Operator's] *Route Guide, the following temporary limitations for cloud ceiling and visibility minima have been introduced and are to be adhered to for all SAR operations.*
>
> ***Day:***

Ceiling	*Visibility*
400 - 499 feet	*1 km*
300 - 399 feet	*2 km*

> ***Night:***

Ceiling	*Visibility*
500 feet (above highest obstacle indicated on the route)	*5 km*

> *These temporary limitations will be reviewed and amended as appropriate at the end of the review period. Cloud ceiling and visibility minima for other operations (HEMS, etc.) remain unchanged.'*

305 The Investigation considers that asking the Operator's management if the company needed to engage any immediate actions to mitigate any risks unknown was inappropriate, as unknown risks, by definition, cannot be mitigated. However, it appears that the IAA was concerned to identify if any latent conditions in place prior to the accident, had been identified since the accident. The Investigation also considers that the Operator's contractual obligations to the State should not have been a factor in the Regulator assessing whether it was still '*satisfied that the said operator is competent to secure the safe operation of the aircraft specified* […] *on flights for the purpose of operational Search and Rescue*.'

The Investigation notes that as a result of AAIU Safety Recommendation IRLD2018003 in the Investigation's First Interim Statement, the Minister for Transport, Tourism and Sport commissioned and is acting on the AQE Report reviewing SAR aviation operations in Ireland to ensure that there are appropriate processes, resources and personnel in place to provide effective, continuous, comprehensive and independent oversight of all aspects of these operations. Notwithstanding the AQE consultants' consideration of the IAA's internal processes, the Investigation makes the following Safety Recommendation:

> The IAA should review its arrangements, guidance and procedures for overseeing civilian operators providing SAR services within the State, to ensure that they are sufficiently robust and transparent so that all parties involved have a full understanding of the scope and limits of their responsibilities and that agency interface arrangements are designed for optimal clarity and shared understanding (**IRLD2021030**).

The Investigation notes that the IAA asserted that it regulates a sector, against international and European safety standards and systems in accordance with international agreements and that in this context it was subject to ongoing audit, inspection and standardisation by ICAO, EASA and the State. Within the State, the Department of Transport (formerly DTTAS) has responsibility for ensuring that aviation practices and procedures comply with best international standards. DTTAS informed the Investigation that it did not have specialist aviation expertise within the department to discharge such oversight. Furthermore, the Investigation notes that examinations as prescribed in the Irish Aviation Authority Act 1993 were not completed between the years 2004 and 2015. While noting that the Minister informed the Investigation that a full time Aviation Manager will be appointed (**Section 1.17.8.2** and **Appendix U**), for certainty and traceability, the Investigation makes the following Safety Recommendation:

The Minister for Transport should ensure that the Department has sufficient specialist aviation expertise to enable it to discharge effective oversight of the full range of IAA activities (**IRLD2021031**).

The AQE Report stated that '*The IAA statement to AQE that 'the Framework is not an IAA document' seems to indicate that there is now a disconnect.*' The Investigation notes that the IAA had made an input to the drafting of the National SAR Framework which said '*The Safety Regulation Division of the IAA is the body responsible for the regulation and oversight of aircraft operations, including aeronautical Search and Rescue, within the State*'.

It was not clear to the Investigation what changed after this input from the IAA in 2010, or the publication of the Annual Safety Review for 2013, or AN O.76 in 2014, that led the IAA to think that it was not responsible for regulating SAR helicopter operations. In light of this disconnect, and noting that the IAA seemed to be pursuing a regulatory approach similar to its SAR approach in at least one other area (aerial firefighting), the Investigation is concerned that there may be other areas where the IAA's regulatory activities and/or published regulations need to be reviewed and possibly strengthened. The Investigation notes the IAA's statement that '*The IAA has reviewed the wording of AN 0.76 and will consider re-issuing with rewording to clear up any inconsistency in interpretations*'. The Investigation considers this statement does not reflect the unequivocal nature of the IAA's AN O.76 opening paragraph, which stated that Search and Rescue was to be '*regulated by the National Aviation Authority*'. The IAA's view that it was not responsible for regulating SAR only came to light in the wake of the accident. Accordingly, the Investigation believes it would be prudent to proactively consider if there are other areas where the IAA's perception of its role is at variance with that of its regulated entities, or of the Department of Transport which the IAA said oversees it.

Section 32(3)(a) of the Irish Aviation Authority Act 1993 requires the Minister for Transport, at least every three years, to appoint a person to carry out an examination of the performance by the company of its functions in so far as they relate to the application and enforcement of technical and safety standards in relation to aircraft and air navigation. The Minister informed the Investigation (**Section 1.17.8.2** and **Appendix U**) that the possibility of including a review of the IAA's regulatory oversight (i.e. that it is sufficiently robust, and that there is a clear understanding of responsibility with regard to functions of the IAA) will be considered during the current examination required by Section 32(3)(a) of the Irish Aviation Authority Act, which is being carried out by Independent Consultants. Notwithstanding this, for certainty and traceability, the Investigation makes the following Safety Recommendation:

The Minister for Transport should institute a detailed review of the IAA's regulatory and oversight mechanisms to ensure that they are sufficiently robust and comprehensive, and that interfaces and delineation of responsibilities are clearly defined and understood by the IAA and the entities it regulates (**IRLD2021032**).

2.4.3 European Oversight

As stated in **Section 1.17.7** Search and Rescue is currently regulated at a national level, and is therefore not included in Commission Regulation (EU) No 965/2012 or other EU civil aviation safety regulations. This means that EASA does not have a legal remit to provide guidance or to propose regulatory measures for SAR. However, European Regulation (EU) No 2018/1139 introduced a provision (Article 2(6)) allowing member states to decide to apply any, or any combination, of Sections I, II, III, or VII of Chapter III of Regulation (EU) 2018/1139, to some or all activities which are normally excluded from the scope of Regulation (EU) 2018/1139 such as '*search and rescue operations*', provided that these provisions, as they are, can be effectively applied to SAR. In addition, EASA has historically certified design features specifically and solely for use in SAR operations; for example, by certifying the SAR AFCS modes for the first S-92A helicopters in operation. This was not a peculiarity of the S-92A and occurred because the first operational S-92A helicopters were based in Europe. However, it does indicate that EASA was satisfied that it had an appropriate level of competence to address the specific requirements of SAR equipment and operations.

In light of the fact that many of the SAR aircraft operated in Europe are EASA-certified and that they are providing a vital service to European citizens, the Investigation believes that it is desirable to have an effective European civil SAR regulatory framework.

There are a number of areas of SAR regulation which all member states need to consider. Examples include:

- How the member state intends to manage SAR
- If the member state currently intends to opt-in to any elements of the Regulation (EU) No 2018/1139 for SAR based on Article 2(6)
- Analysis of accident/incident data for SAR aircraft within the EU
- Where commercial operators are used, the nature of the commercial arrangement between the state and the operator
- Where SAR aircraft are used for other roles (such as HEMS), the methods and procedures that are used to manage this interface

Some member states may already have the expertise and resources to do this, while other member states may not. In this regard, the Investigation believes that it is incumbent on the European Commission and EASA to provide expertise and guidance, which would ensure a uniform level of safety for SAR operations across the EU. Accordingly, the Investigation makes the following Safety Recommendation:

The European Commission should carry out a review of how SAR is managed in EU member states with a view to identifying best practice/minimum safety standards and, as appropriate, promulgating guidance for SAR operations using civil-registered aircraft, which at the moment are excluded from Regulation (EU) No 2018/1139, so that an appropriate and uniform level of basic safety will apply in civil SAR operations throughout Europe (**IRLD2021033**).

In addition, due to the lack of clarity that has existed in Ireland regarding the regulation of SAR, the Investigation believes that the possibility of opting-in to European Regulation (EU) No 2018/1139 for SAR based on Article 2(6) of that Regulation, should be carefully assessed and considered by the Irish State. As outlined in **Section 1.17.8.2** and **Appendix U**, the Minister '*sought and received legal advice that primary legislation is required for Ireland to exercise the EASA opt-in under Article 2(6) of the European Regulation 2018/1139*', and that DTTAS is seeking further Counsel advice concerning a possible draft Heads of Bill for this purpose. Notwithstanding this, for certainty and traceability, the Investigation makes the following Safety Recommendation:

The Minister for Transport, should engage with EASA and the European Commission to ensure that an appropriate SAR regulatory framework, and associated guidance material are in place whether by opt-in to Regulation (EU) No 2018/1139, or otherwise (**IRLD2021034**).

2.4.4 Approval for SAR and HEMS

The Investigation notes that the Decision Tree for discriminating between HEMS and SAR taskings was ambiguous in that, if the casualty's condition was not life-threatening, the second central blue box would be exited as a '*No*', meaning it was not a SAR mission. However, thereafter if crews were not FTL compliant, meaning that the mission could not be conducted as a HEMS mission, the assessor was again asked to consider if the casualty's condition was life-threatening in another attempt to classify the mission as a SAR, albeit with restrictions. This ambiguity could have the effect of encouraging personnel to exercise maximum latitude in assessing and accepting taskings, even to the extent of reconsidering factors which had already precluded acceptance. This could lead personnel to feel that there was an implied expectation that taskings should only be rejected in exceptional circumstances and that maximum latitude was to be exercised to accept taskings. Furthermore, reclassifying a HEMS mission as SAR had the effect of circumventing the FTL limitations that applied to HEMS missions. The Decision Tree is published in both the IRCG Helicopter SOPs and in the Operator's operations manuals.

Many of the Operator's crew members who spoke to the Investigation described a perceived lack of clarity about what exactly they could or could not do on any HEMS mission. The difficulty in trying to be prescriptive was summed up for many by the number of draft iterations through which the SAR/HEMS Decision Tree went prior to it being published. Some expressed the view that treating all missions as SAR missions would remove ambiguity. However, the Investigation considers that such an approach would be inappropriate. The Investigation believes that the distinction is essential, and that it is imperative that HEMS and SAR missions are conducted within the limits of the associated approvals for those activities.

There were organisational/cultural factors, which reflected, and potentially added, to the ambiguity around the SAR/HEMS differentiation. For example, the same flight was used to carry out pilot competence checks for both roles (SAR and HEMS), and '*SAR (FTL)*' was used to classify a HEMS flight as SAR, thereby allowing crews to use the more liberal SAR FTL scheme. The IAA AOC review in 2014 had identified issues between the SAR role and CAT (HEMS) role and FTLs regarding HEMS versus SAR.

The fact that SAR missions can operate with significant exemptions from extant regulations, while HEMS missions are essentially considered to be CAT missions has the potential to introduce ambiguity for crews and tasking personnel in relation to a number of matters including FTLs and call signs. Operational flight crew should be shielded, as much as possible, from this ambiguity.

The Operator informed the Investigation that its electronic flight tracking system did not contain information on which flights involved low flying. This meant that the Operator did not have a system in place to ensure compliance with the conditions of its Low Flying permission, i.e. pilots-in-command did not have a system to record flight sectors that involved Low Flying, and the Operator did not have the information needed to exercise operational control and oversight of all flights pursuant to the permission. Furthermore, the Investigation found no evidence that a copy of the Low Flying permission had been included in the Operations Manual.

SAR flights operate under exemptions from the normal requirements, including FTL requirements, whereas HEMS flights primarily operate under CAT rules. Therefore, it is essential that flights are operated as SAR flights only when absolutely necessary. The Minister outlined to the Investigation (**Section 1.17.8.2** and **Appendix U**) that the IRCG's Heli Ops SOP, which includes the SAR/HEMS decision tree, was re-issued in 2018 following a review between the IRCG and the Operator. However, to ensure that all relevant aspects of this accident have been considered in relation to the SAR/HEMS decision tree, the Investigation makes the following Safety Recommendations:

The Minister for Transport should review the SAR/HEMS Decision Tree and all arrangements regarding the tasking of SAR helicopters to ensure that there is maximum clarity in the tasking process and that HEMS missions are not conducted under provisions which should only apply to SAR missions (**IRLD2021035**).

The IAA should ensure that its review procedures, for operators that carry out multiple mission types, particularly where different regulatory regimes are in place, consider and address all aspects of mission differentiation, to ensure that operators are applying full, appropriate regulatory rigour to all flights (**IRLD2021036**).

2.4.5 Summary — Oversight

The Investigation found that IRCG relied on external consultants for aviation expertise and auditing services and that there had been a warning of commercial pressure and anomalies regarding practice versus SOP, which were not appreciated at the IRCG level. Furthermore, the IRCG did not have a Safety Management System in place; IRCG management completed their first aviation SMS training in October 2018; and, DTTAS had entered into an SLA which said that IRCG had responsibility for aviation safety and operational standards.

There was significant confusion regarding responsibility for, and the discharge of, aviation oversight of SAR operations. The Investigation made a Safety Recommendation in this regard in the Investigation's First Interim Statement, and the Minister for Transport, Tourism and Sport appointed a team of consultants to assist in resolving the issues and implementing an effective regulatory framework. In order to ensure a uniform level of safety across Europe, the Investigation believes that (civil) SAR regulation should be led at the European level, and has also made Safety Recommendations in that regard.

Finally, the Investigation identified that anomalies can arise when SAR assets and personnel, who operate under a National SAR Approval with a significant number of regulatory exemptions, are tasked with HEMS missions that are operated primarily in accordance with Commercial Air Transport regulations. Safety Recommendations to address these anomalies have been made.

2.5 Survivability

FDR data indicates that just prior to initial impact with Black Rock, the Helicopter was in straight and level flight, travelling at approximately 90 kts, over water. The Operator's normal flight checklist (final checks, memory items) specified that the Emergency Flotation System (EFS) could be armed once the airspeed was below 80 kts (indicated airspeed). Both the CVR and FDR data indicate that the EFS was not armed at the time of the accident. However, helicopter EFS are not designed to withstand the impact of an uncontrolled descent into water, as occurred in this case.

The FDR data and the items and distribution of wreckage found on Black Rock, floating in the sea, and on the sea bed, and subsequent wreckage examination suggests that the lower part of the tail section and the main landing gear made contact with Black Rock to the south-west of the helipad.

The flight path information obtained from the corrected HUMS data, when synchronised with the MPFR recorded flight data related to the Helicopter's pitch, roll and yaw, indicated that the Helicopter was likely in a nose high attitude at the time of terrain impact. Items of wreckage found on Black Rock included components from the tail rotor and the tail structure of the Helicopter. Once the tail structure/tail rotor was compromised, control of the Helicopter would no longer have been possible; the Helicopter continued in an uncontrollable state until it impacted with the sea to the east of Black Rock.

A detailed search of Black Rock found no items from the Helicopter cabin or cockpit, indicating that the main fuselage/cockpit structure did not suffer a substantial in-flight break-up, and consequently the Investigation considers that it is probable that the four Crew members were on board the Helicopter when it impacted the sea.

2.5.1 Commander

The Commander was seated in the right side of the cockpit, an area which was not compromised during the impact. The post mortem report states that the Commander sustained some bruising but no fractures. The Commander's emergency exit jettisonable cockpit window was found on the sea bed, in close proximity to the main wreckage of the Helicopter.

Post-accident inspection and testing of the Commander's PLB, indicated that it was subjected to water depths in excess of 10 m. The Investigation is therefore of the opinion that the Commander egressed the Helicopter at a depth greater than 10 m and possibly as great as 40 m.

NATO research regarding egress from submerged helicopters determined that:

> '*Even if the survivor has made a safe exit from the fuselage, it is still necessary to breathhold until reaching the surface. As the helicopter sinks, it is not uncommon to have to make an escape in 5-10 metres of water. Due to Boyle's Law, below about 5 metres, neither the buoyancy in the survival suit or the lifejacket will bring the person safely to the surface. It is therefore necessary to swim. This requires hard work and significantly shortens breath-hold time*.'

Notwithstanding the fact that the Commander had experienced a very traumatic event and the subsequent effects of disorientation, cold-water shock and night-time darkness, it appears that she was able to unfasten her seat harness, egress by jettisoning her cockpit window (emergency exit) and inflate her lifejacket. It is not possible to determine the time that elapsed before she arrived at the surface. The Commander's life jacket was fitted with a HEED bottle. This was not recovered, and therefore it was not possible to determine if it was used. However, the Commander was familiar with the use of the HEED bottle and underwater egress, having carried out HUET training less than one week prior to the accident.

The Commander was recovered, unresponsive, from the sea surface with her life jacket inflated and without her flying helmet. However, she had not used a neoprene hood carried in the leg of her immersion suit or a storm hood fitted to her lifejacket. The Commander's post mortem report states that the cause of her death was drowning. Whilst the Commander managed to egress the Helicopter at a depth greater than 10 m, it appears that the combined adverse circumstances of water depth, cold-water shock, darkness and overall sense of shock militated against her survival.

2.5.2 Co-Pilot

The deceased Co-pilot was located within the cockpit wreckage, in the left seat, with his harness fastened. On 24 March 2017, divers from the Irish Naval Service attempted to remove him, but this was not immediately possible due to the disposition of the wreckage. Following extensive preparatory work using the ROV, the Co-pilot was recovered by Irish Naval Service divers on 26 March 2017.

The post mortem examination Report stated that the Co-Pilot suffered multiple injuries and death '*would have ensued rapidly*'. The condition of the items of wreckage recovered, indicated that impact damage was more pronounced on the left hand side of the Helicopter. With regards to survivability, the severity of the Co-Pilot's injuries were such that the accident was not survivable.

2.5.3 Rear Crew

At the time of the accident the two rear crew members were in the rear cabin attending to their duties. Normal procedure is for rear crew to be seated and restrained during approach, landing and take-off. If the crew were not restrained by seat harnesses, it is likely that they would have sustained serious injuries during the uncontrollable phase of flight, and impact with the sea. The wreckage, as found on the sea bed, showed that the cabin area was destroyed. Following the accident, an extensive search of the wreckage field and the general area surrounding Black Rock (both sub-sea and surface) was undertaken, but neither rear crew member was located.

The lifejacket and helmet worn by the Winchman was recovered on 30 September 2017, from shallow water at Elly Bay, Clogher, Ballina, Co. Mayo, 9 NM north-east of Black Rock. It was not possible to draw any definitive conclusions from this evidence. However, the Investigation noted that although the external part of the lifejacket showed signs of damage commensurate with being in the sea for several months, the stole of the lifejacket exhibited less damage. The manual inflation handle was also missing. The Investigation believes that this may be because the lifejacket was not inflated at the time of the accident but, appears to have inflated and risen to the sea surface shortly before it was found. This could suggest that the Winchman became incapacitated during the accident sequence and was unable to activate his lifejacket.

The PLB carried by the Winchman was also recovered from the sea in September 2017. Examination of this PLB indicated internal water damage similar to that seen on the Commander and Co-Pilot's PLB. However, in this case, the GPS antenna and mount had broken away from the PLB unit. This means that water ingress would occur regardless of the water depth. Therefore, it is not possible to conclude at what depth of water the Winchman became separated from the Helicopter.

The lifejacket and helmet worn by the Winch Operator were recovered on 12 July 2018, in a fishing vessel's nets, 1 NM north-west of Achill Head; the lifejacket's pocketry had significant tearing and no PLB was present. Examination of the inflation cylinder, which was still in place on the jacket, revealed that it had not been pierced, indicating that the lifejacket had not been activated. Both the lifejacket and helmet exhibited significant damage and had been in the water for a significant period of time.

2.5.4 PLB Integration into Mk44 Lifejackets

Early in the Investigation it was discovered that the PLB carried on the Mk44 lifejacket could not work due to the manner in which it was installed. A Safety Recommendation was issued to address this problem in the Investigation's Preliminary Report.

The lifejacket manufacturer has addressed the specific issue with the Mk44 lifejacket, has carried out a full review of all of their lifejackets, and introduced process improvements to ensure that integration issues are addressed at the design stage. For these reasons the Investigation does not deem it necessary to issue any further Safety Recommendations to the lifejacket manufacturer. However, the Investigation notes that the National SAR Approval in Ireland is based on European Regulation (EU) No 965/2012 as amended. Part of this Regulation, '*ORO.GEN.200 Management system',* requires an operator to assess whether non-mandatory, non-installed (on an aircraft) items of equipment, such as PLBs, are fit for purpose, and will not affect functionality of mandatory items. Specifically, EASA informed the Investigation that:

> *'If, as part of its management system and associated risk assessment outcome, the operator elects to use non-mandatory non-installed equipment such as PLBs for additional risk mitigation, the operator should assess whether the additional equipment is fit for purpose. In addition, it should not affect the integrity of any other equipment used eg mandatory equipment such as approved life jackets. The STC* [Supplemental Type Certificate] *for the life jacket approval classifies PLBs as a minor modification, hence not affecting the integrity of the life jacket.'*

Correspondence between the Operator and the Lifejacket manufacturer regarding the integration of the SARBE 6 406G into the Mk44 lifejacket, which was provided to the Investigation, did not indicate that a solution to the issues raised in SQID reports had been tested and implemented. The associated SQID reports were closed without the implementation of a viable technical solution. In addition, mandatory offshore survival training, which is carried out by operational crews every three years, could not identify this issue because crew members do not necessarily wear or test PLBs during this training.

Therefore, the Investigation is of the view that the Operator's procedures in this area could be strengthened and accordingly makes the following Safety Recommendations:

CHCI should review and update its offshore survival training procedures to ensure that all helicopter crews carry out their mandatory training wearing the safety clothing and types of equipment that would be worn during day-to-day operations, and to ensure that the correct functioning and compatibility of all safety clothing/equipment is verified during this training (**IRLD2021037**).

CHCI should review and update its procedures relating to the introduction into service of non-mandatory equipment generally, and safety equipment in particular, to ensure that the procedures are sufficiently robust to identify and resolve integration issues before equipment is introduced into operational service (**IRLD2021038**).

2.5.5 Beacon Tones Heard on the CVR CAM Channel

A sound consisting of two sequential, high-pitched, half second long, descending tones was heard on the '*CVC*' and '*CV1*' channels, but not on either of the Cockpit Crew channels ('*CV2*' and '*CV3*') of the CVR. This indicates that 121.5 MHz was not tuned on the VHF radios in the cockpit, and that the Commander had muted the cockpit audio from the HF and FM radios. Consequently, the Investigation believes that this descending tone recording originated from the Wulfsberg transceiver (**Section 1.6.6.10**), normally located in the tail section of the Helicopter, which was recovered from the terrain at Black Rock.

The S-92A helicopter ELT emits a continuous audible tone; as the recorded sound was not continuous, the Investigation does not believe that it emanated from the ELT. The Lifejacket SARBE 6-406G beacons and the Helicopter's ADELT transmit a descending twin tone on 121.5 MHz every three seconds, and a 406 MHz transmission every 50 seconds. The Investigation believes that the signal heard on the CVR was a descending tone transmission on the 121.5 MHz frequency. The ADELT and the Lifejacket SARBE 6-406G beacons, transmit the same tones on the same frequency; consequently, the Investigation was unable to be definitive about the source of the tones.

The Investigation notes that although the descending tones are transmitted every three seconds, the tones were not heard again during the remaining six seconds of the CVR recording. Consequently, the Investigation believes that the Wulfsberg transceiver, which was recovered from the terrain at Black Rock, ceased to function within three seconds of the descending tones being recorded on the CVR, due to the disruption of the Helicopter's tail area during the initial impact.

2.6 Human Factors

2.6.1 Cockpit Operating Environment

During the flight, both Flight Crew members commented adversely on the cockpit lighting. A February 2015 Modification Request document cited the helicopter's lighting as '*inadequate for night time operations*'. The Investigation notes that a July 2016 SQID report stated that '*the issue of inadequate cockpit lighting once again caused issues with reading checklists and completing the PLOG*.' Personnel had requested the incorporation of a lighting modification which was available in S-92A helicopters in Oil and Gas operations; however, this modification was not compatible with the Operator's SAR helicopters. Consequently, a locally designed modification, designated AHSE-59190 REV A was proposed as an alternative, and was incorporated on EI-ICR on 14 October 2016. The Investigation notes that the Helicopter Manufacturer informed the Investigation that it had no reports of a problem with the helicopter's lighting as being inadequate for night time operations. The Investigation also notes that the cockpit lighting did not appear to prevent the Flight Crew from reading at least some of the FMS Route Guide and Landing Site Directory as aspects of each were verbalised by the Flight Crew.

Degani's research shows that '*the correct graphical presentation and the environmental conditions that influence reading in the cockpit* […] *should agree with the unique physical condition of the cockpit, the capabilities and limitations of the human operator, and the method of using the documentation as dictated in the standard operating procedures*'.

EASA has recognised that the design of the flight deck and systems can strongly influence crew performance and the potential for crew errors. Optimal SAR-helicopter cockpit ergonomics is a complex function of several parameters some of which are helicopter-specific, some environment-specific and some crew-member specific. As outlined earlier in this Report, a number of interrelated factors affect the cockpit operating environment including: cockpit lighting, vibration, typography, colour of displays and graphics, ergonomics of cockpit layout, and document and chart presentation and utility. Accordingly, the Investigation makes the following Safety Recommendation:

CHCI should engage with all relevant parties to conduct an in-depth study and review of the cockpit environment of its S-92A helicopter to ensure that safe operations can be achieved under all ambient lighting conditions and that all aspects of information presentation (colour schemes, typography, size, font, surface reflectivity, etc.) used in the presentation of Route Guides, Landing Site Directories and other information provided for use by flight crew, are optimised for use in the cockpit environment (**IRLD2021039**).

Furthermore, EASA's RMT.0713 has proposed the development of certification specifications for human factors in the design of rotorcraft cockpits to mitigate the probability of human factors and pilot workload issues that could lead to an accident. Notwithstanding EASA's RMT.0713, which will affect future helicopter design assessments, the Investigation believes that it would be prudent for EASA to provide guidance to operators of existing helicopters which would assist these operators in identifying, managing and mitigating flight deck/system configurations, which have a higher probability of causing a human factors/pilot workload issue. Accordingly, the Investigation makes the following Safety Recommendation:

EASA should carry out a safety promotion exercise, in parallel with the development of certification specifications for human factors in the design of rotorcraft cockpits, to provide operators of in-service helicopters with a best practice guide to mitigate the risks associated with human factors and pilot workload issues (**IRLD2021040**).

2.6.2 Crew Performance, CRM and Error-Trapping

One issue which was mentioned by family members and also by colleagues of the Crew Members, was that there had been a bereavement within the Operator's staff community in the week preceding the accident. Funeral ceremonies for this person, a Post-Holder of long service with the Operator, were held on Saturday, 11 March 2017 and on Monday, 13 March 2017. Not all of the members of the accident Helicopter's crew were able to attend the ceremonies. Staff at the Dublin Base informed the Investigation that when the Winch Operator came on duty at 13.00 hrs on 13 March 2017, his mood was quite subdued which they attributed to the fact that he had been unable to attend his colleague's funeral ceremonies on either Saturday or Monday. However, there was no discussion of this issue recorded on the CVR and consequently, there is no evidence that it adversely affected Crew Performance.

At 23.11 hrs, the Commander received the report from R118 that conditions were good at Blacksod, following which she compared fuel and flight time for Sligo and Blacksod, and opted to proceed to Blacksod. At 23.54 hrs, the Commander received a report from MRSC Malin that visibility was down to three miles at Blacksod, in response to which she requested a report of the cloud base and the wind. At 00.08 hrs, Blacksod Helipad provided a wind direction of west-south-west, a wind speed of 25 to 33 kts, a visibility of two miles at sea level, and a cloud base of '*three, four, five hundred feet*'. However, the CVR records that when the Commander acknowledged receiving this transmission (to the Winch Operator) she said '*three hundred feet and whatever*'. This suggests that the Commander prioritised cloud base over horizontal visibility. But the transmissions to the Helicopter of '*visibility down to three miles*', at 23.54 hrs, and '*two miles*', at 00.08 hrs, indicated a deteriorating horizontal visibility trend. It is not possible to know exactly why the Commander did not discuss this deteriorating trend although she did ask the Co-pilot to get weather for Sligo and Dublin. However, it may have been a cultural factor that as a SAR commander she was used to descending to 200 ft to operate in limited, sometimes unknown, visibility. This would also explain why no other Crew member raised the issue; the difference in this case being that on arrival at 200 ft (the normal final operating altitude), the Helicopter was 9 NM from where it was going to land.

Item 10 on the '*DVE APPROACH*' checks – the position check – required two separate sources. The Commander said that they could see where they were and asked whether everybody was happy with the position. The Co-pilot confirmed that he was happy, and the Winchman said that they were out over the water. At 00.31 hrs, the Commander asked the Co-pilot to call out the Helicopter's current latitude and longitude. The Winchman confirmed that this was '*bang on*'. The Commander prompting the Co-pilot to call out the current position for a cross-check demonstrated effective CRM and error trapping.

The Commander's route brief and discussion of over-fly/smart turn selections, did not explicitly mention an escape route or a decision point. The omission of an escape heading was trapped at 00.13 hrs, when the Co-pilot was self-briefing the route and asked the Commander what the '*escape route*' was if they did not become visual. Whilst there was no explicit discussion of a decision point, it appears to have been implicitly understood, because when briefing the Winchman the Co-pilot said '*here, not visual'*.

The Commander also participated in briefing the Winchman and therefore it would seem that the Commander and the Co-pilot had a shared understanding of the location of the Decision Point. The Investigation also notes that the Winchman asked the Flight Crew to show him the route so that he would *'have an idea with the, eh, FLIR when we get into it'.* This appears to be another error which was trapped, in that the Investigation understands that custom and practice was that a winchman would receive such a briefing. Indeed, such a briefing was essential given the importance of EO/IR (FLIR) in the prevailing conditions, and would normally have been forthcoming without a specific request from the Winchman. Furthermore, it is noted that the Winchman was the only Crew member to ask about the location of the high ground, in relation to the route into Blacksod, and the Commander's reply '*Down here…this is our first point here; we go S D A, that's kinda when we're abeam Achill*', indicated that she believed she had adequately considered it.

The Investigation notes that, at 00.45:21 hrs, the Co-pilot commented that there was 1.3 miles to run to BLKMO; 19 seconds later a synthetic voice was heard annunciating an '*ALTITUDE ALTITUDE*' caution, which the Commander rationalised as '*there's just a small little island that's BLMO itself*'. It is possible that the Crew was not unduly concerned about this caution because routes could, and did, cross terrain and obstacles e.g. '*Route SGLOWBS (Sligo to Blacksod)*' crossed the Glash Island Lighthouse (chart height 89 ft, tabulated obstacle height 100'). However, the Helicopter could not have travelled 1.3 miles in 19 seconds at a groundspeed of 90 kts approximately; and the cockpit systems would have indicated that there was still approximately one mile to run to BLKMO. Neither Flight Crew member commented on this disparity, which may have indicated some degradation in the Flight Crew's situational awareness. Furthermore, it is not clear why the Commander expected '*BLMO*' to be a little island, but the Investigation notes that the obstacle designator for the obstacle at Black Rock was actually located 0.6 NM to the west of Black Rock, and when she made the comment the Commander may have believed that R116 was actually passing over the location of the Black Rock obstacle marker (Obstacle 1).

The Investigation notes the Commander's comments '*stay nice and controlled*' and keep '*the speed back*'. However, the Investigation considers that the comments that she hadn't been in Blacksod '*in about fifteen years*', and later '*it's been donkey's years since I've been in here*', warranted further discussion and consideration. It is possible that, as the Co-pilot was an experienced and rated SAR captain, the Commander may have felt that when he didn't object, it validated her decision to go to Blacksod despite their lack of familiarity. For his part, the Co-pilot may have felt that as the Commander, an experienced SAR captain, was not unduly concerned by either pilot's lack of familiarity, it wasn't a matter to be pursued further. Two experienced commanders flying together reduces the '*authority gradient*'[118] and could lead to neither pilot wanting either to contradict the other or to appear unduly concerned about a matter with which the other seems happy.

The Investigation notes that the roles of PF and PM changed during the flight. The Commander was PF for the departure out of Dublin. At 23.15 hrs, the Commander requested the Co-Pilot to become PF, so that she could do fuel calculations. The Commander subsequently decided to go to Blacksod (a decision that the other Crew members agreed with), selected the route and told the Co-pilot she was sending him direct to '*L M O*'. At 00.05 hrs, the Commander double-checked the route and took '**overfly**' off one waypoint (which the Investigation believes was BKSDC) before briefing the Co-pilot for the approach into Blacksod. The brief referred repeatedly to '*we*' with one exception, '*if we're happy with the visuals on the first run-in it'll be on my side so it'll be my landing'.* The Commander then confirmed that the Helicopter would be at 22,400 lbs on arrival, which would allow them to do a PC1 arrival. The nature of the Commander's decision-making, route selection, and briefing, were consistent with a PM's monitoring and management role. Furthermore, it would not be unreasonable for the Co-pilot to have believed that he would be PF until such time as they were '*happy with the visuals*' at which time, because the landing site would be on the Commander's side, she would have assumed the role of PF and carry out the landing.

[118] **Authority Gradient**: The established, and/or perceived, command and decision-making power hierarchy in a Team, Crew or Group situation, and also how balanced the distribution of this power is experienced within the Team, Crew or Group. Concentration of power in one person leads to a steep gradient, while more democratic and inclusive involvement of others results in a shallow gradient.

At 00.13 hrs, the Co-pilot requested an opportunity to look at the map [of APBSS] and the Commander became PF. At 00.14 hrs, the Co-pilot offered '*to come back on the sticks*' but the Commander declined saying '*I'm happy enough there if you are actually … I'll stay on it*'. Accordingly, when the Commander was acting as PM, she had developed the plan for arriving into Blacksod; later, when she became PF, she would be briefing the Co-pilot, who was then in the PM role. However, the Co-pilot had limited involvement in the development of the plan or how the Commander intended to fly the descent, route/approach and arrival into Blacksod. OMA prescribes protocols for transfer of control, but it does not address the issue of transfer of roles. Furthermore, the Operator's ethos in training was that the Commander would be PM and manage the mission, as she had been doing since 23.15 hrs, when she requested the Co-Pilot to become PF so that she could do fuel calculations.

The fact that the Co-pilot offered to resume the PF role when he had completed his self-briefing of APBSS, indicates that he expected to be PF until the Commander had sufficient visual cues to assume control and safely land the Helicopter at Blacksod. Therefore, it is possible that safety margins for the conduct of the flight were eroded by this transfer of roles, and the fact that the Commander (PF) was subsequently briefing the Co-pilot (PM) on how she intended to fly a flight profile that she herself had planned. Accordingly, the level of independent review/management of the flight/plan may have been adversely affected by the transfer of PF and PM roles. The Investigation acknowledges that there will always be occasions when it is appropriate and necessary to briefly transfer control, and the Operator's Crew Concept as set out in OMA provides significant guidance on the transfer of control. This however, is not the same as an in-flight re-assignment of PF and PM roles. Therefore, the Investigation makes the following Safety Recommendation:

CHCI should provide explicit guidance in its Operations Manual on the protocols and briefing requirements for transfer of PF and PM roles during a mission (**IRLD2021041**).

2.6.3 Fatigue Risk Management System

The IAA-issued AN O.58, '*Flight Time Limitations (FTL) and Rest Requirements for crew members (Helicopters)*' set out the parameters governing an IAA-approved FTL scheme. In July 2010, the IAA agreed to a temporary variation to the Operator's FTL scheme based on the Operator providing, *inter alia*, '*supporting scientific research (sleep study)*'.

A copy of a Sleep Study was provided by the Operator to the IAA. The study concluded that there was no difference in the sleep quality or amount of sleep accrued by SAR Crew members based solely on the location where they slept (i.e. on-base or at home). However, the study found that SAR Crew members in the study accrued less sleep than that recommended by the US National Sleep Foundation and that this may not be enough sleep for optimal operational duty. The study made recommendations that further research be carried out; the Investigation found no evidence that the further research recommended in the study was undertaken.

On 29 June 2012, the IAA issued an approval for the Operator's variation of the requirements of AN O.58; this variation applied to provisions in Section 7 of the then extant OMA (which included SAR, at section 7.22), and the HEMS limitations in the then extant OMG. The IAA approval stated '*This variation shall remain in force so long as* [the Operator] *has in place a Fatigue Risk Management Programme acceptable to the Authority*'. The approval was to be re-assessed at a date not later than 12 months after the implementation of the Fatigue Risk Management Programme; no evidence was provided to the Investigation to demonstrate that such a re-assessment took place.

Fatigue management training was provided for a number of the Operator's personnel in June 2012. On 19 October 2012, the IAA asked the Operator for an overview of the implementation programme for its FRMS to date, and details of the next phase. The Operator provided an FRMS consultancy report, dated August 2012, titled '*Enhancing Fatigue Risk Management at* [Operator's name]*: Gap analysis, FRMS Implementation Plan and Assessment of Sleep accommodation*.' The Operator said that it was meeting with the FRMS consultancy on 28 November 2012 to carry out the next phase which was a risk assessment.

The August 2012 implementation plan which was presented to the IAA incorporated a pivotal role for an FRMS manager. The Investigation notes that neither the Operations Manuals nor the Safety Management and Compliance Monitoring Manual (SMCMM) identified who the FRMS Manager was. Furthermore, the Investigation found no evidence that the Operator had implemented an FRMS.

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In April 2014, in an email thread between some Post-Holders, there was concern that the Operator was not fully adopting FRM policy, and that this may have been an issue with regard to the Operator's HEMS approval. It also appears that some Post-Holders were unsure at that stage who the members of its FRMS Committee were. The thrust of the email thread was focused primarily on the need to ensure that individuals received FRM training, rather than on FRMS implementation.

OMA states '*A crew member shall not perform duties in flight if he knows or suspects that he is suffering from fatigue, or feels unfit to the extent that the flight may be endangered.*' However, the Civil Aviation Safety Authority of Australia (CASA) in its report titled *'Fatigue-The Rules Are Changing',* stated *'People are notoriously poor judges of their own level of fatigue.'* Consequently, the Investigation believes that the OMA instruction to personnel not to perform flight duties if they are fatigued, though well-intentioned, is not consistent with published guidance. Furthermore, the OMA instruction could have the effect of relying on individuals to manage their own fatigue, instead of an Operator implemented system, which would minimise the likelihood of individuals becoming fatigued. Fatigue management requires a combination of an operator implemented FRMS and an effective reporting culture fostered by management support.

FAA and CASA information highlights hours of prior wakefulness are correlated with increased error rates and judgment lapses, in personnel who are awake for longer than 10 hours. Based on the information in the 72-hour activity study, the Commander was likely to have been awake for more than 15 hours at time of tasking, more than 16 hours at time of lift-off and more than 18 hours at the time of the accident. The Co-pilot was likely to have been awake for more than 14 hours at time of tasking, more than 15 hours at time of lift-off and more than 17 hours at the time of the accident. Research indicates that the likely hours of wakefulness for the accident Flight Crew, during the accident flight, meant that they were more prone to making errors, and indeed there is evidence of trapped and un-trapped errors on the CVR. Furthermore, OMF stated that there was a potential for fatigue to set in quicker for the crew of a support SAR helicopter rather than on a SAR helicopter, due to the somewhat monotonous nature of a SAR support mission. Accordingly, the Investigation makes the following Safety Recommendation:

CHCI should ensure that it has in place a Fatigue Risk Management System based on scientific principles, which takes advantage of modern techniques such as bio-mathematical analysis of roster patterns, is known to all its crew members, and that it encourages the reporting of fatigue related issues (**IRLD2021042**).

On 4 September 2017, the IRCG published SAR Ops notice 6/17 titled '*HEMS/Air Ambulance (HEMS/AA)'* which stated that all HEMS/AA flights must be flown under CAT (Commercial Air Transport)/HEMS/AA rules and that crew were obliged to rest on completion of a 12-hour shift. The notice said that the rules as issued by the IAA take cognisance of the 24-hour SAR helicopter shift pattern and impose obligatory rest periods for HEMS/AA missions conducted within the 24-hour shift pattern. From a human performance point of view, if it makes sense to limit HEMS operators, conducting missions primarily under CAT rules, to 12-hour shifts, then the advisability of allowing SAR operators, who are approved to operate outside of many of the standard protections of CAT rules, under more challenging conditions than HEMS missions, to operate a 24-hour shift pattern, must be considered. Accordingly, the Investigation makes the following Safety Recommendation:

The IAA should review the Operator's 24-hour SAR shift pattern to ensure that it adequately accounts for concerns arising from published research on human performance; and that the Operator's FRMS and SAR variation to Aeronautical Notice O.58 provide appropriate levels of safety and protection for crews (**IRLD2021043**).

2.6.4 Automation and Cognitive Biases

The Operator's OMF required that maximum use should be made of automation and SAR approach modes. The Flight Crew followed this dictum and seemed to have relied on the fact that the APBSS route was available in the FMS and readily displayable on cockpit MFDs, rather than conducting a detailed analysis of the route documentation. The Flight Crew's susceptibility to such reliance (an automation bias), was made more likely by the fact they both expressed dissatisfaction with the cockpit lighting (as evidenced on the CVR recording), which may have affected their ability to easily read documentation. Furthermore, their likely hours of wakefulness meant that both Flight Crew members may have been tired, which Kahneman found predisposed individuals to intuitive rather than deliberate decision-making.

The Operator's operations manuals provided guidance regarding primary and secondary sources of navigation, which could be misinterpreted. One example of this was the OMF guidance, which stated that EGPWS (which was listed as a secondary navigation source), may not necessarily be authorised in the OMB for helicopter navigation but may '*augment aircraft situational awareness*'. Another example open to misinterpretation was found in OMA, which stated under flight preparations '*Current maps, charts and associated documents or equivalent data are available to cover the intended operation of the aircraft including any diversion which may reasonably be expected*.' The Investigation asked the Operator if the term '*equivalent data*' could reasonably be taken to refer to Euronav and Memory Map; the Operator said that it would agree that it could reasonably be taken to be the case in the Operator's manuals. It is therefore, not unreasonable that crews might come to consider Euronav and Memory Map as being equivalent to '*Current maps, charts and associated documents',* particularly in light of the greater utility of automated mapping systems over paper-based maps and charts. This is another example of a potential automation bias.

In the parlance of OMF, the Flight Crew was using two primary navigation sources, the FMS, and the radar; and four secondary navigation sources: the Euronav; the EGPWS; the Toughbook; and the FLIR (EO/IR). For night overland operations, OMF said that '[…] *The Euronav alone should not be used for primary navigation* […] *Using only the FMS / Euronav will get the aircraft in the general vicinity of the landing site'.* The Flight Crew was not conducting an overland operation; they were conducting an overland transit with the intention of descending over open water and following a company route that was available in the FMS. R116's cross-country, overland transit was conducted at safe altitudes, initially
321 3,000 ft and climbing to 4,000 ft as it approached high ground while heading west.

The 1:250,000 Aeronautical Chart, Euronav imagery did not extend as far as Black Rock, and hence the BLKMO waypoint marker would have displayed in the white margin of the chart image, as was the case during the Investigation's Review Flight.

It is possible that the Commander, who said that she was going to '*stick on the map*', if presented with a waypoint in the white chart margin, could have succumbed to what Kahneman described as a '*What You See Is All There Is*' (WYSIATI) effect. If presented with a waypoint in the white chart margin, the Flight Crew may have felt confident that the white area of the chart margin, where the BLKMO waypoint appeared, would not contain obstacles. Indeed, it might be considered reasonable that since '*the FMS / Euronav will get the aircraft in the general vicinity of the landing site'*, then the imagery would extend as far as any significant obstacles.

The Euronav and FMS were being used in conjunction with the radar, on which the BLKMO magenta waypoint marker and track line would have overlaid radar returns from the terrain at Black Rock, on the 10 NM range that was being used. The EGPWS did not have the terrain or lighthouse at Black Rock in its databases, but it was being cross-checked, as required by OMF, with the radar. This was a possible source of bias, as the absence of Blackrock from the EGPWS could have adversely affected the likelihood of the Crew detecting Black Rock on the Radar. Furthermore, the fact that the radar was not selected to a shorter range intermittently, suggests that the Flight Crew may have believed that hazards undetected at the 10 NM range, would be detected and alerted by the EGPWS.

The Investigation believes that the Operator's operations manuals should provide specific information on automation and cognitive bias, and that statements such as '*Maximum use should be made of automation and SAR approach modes*' should be qualified with warnings about automation bias. This is a particular concern when system design, by default (e.g. APP1 going down to 200 ft unless interrupted), can place a helicopter into a low level operating regime where safety margins are reduced. The Investigation believes that the Operator's crews should be provided with training specifically aimed at heightening their awareness of, and strategies for combatting, automation and cognitive bias. Accordingly the Investigation makes the following Safety Recommendation:

CHCI should review its training syllabi and operations manuals to increase crew awareness of automation and cognitive bias, and as far as possible to provide strategies for recognising and combatting these threats (**IRLD2021044**).

2.6.5 Summary — Human Factors

The CVR recorded the Flight Crew expressing dissatisfaction with the cockpit lighting, a topic which had been the subject of SQID reporting. The Investigation has recommended that the Operator review a range of issues in relation to cockpit ergonomics. The Investigation has also recommended that EASA, which has an existing rulemaking task to include human factor assessments in future helicopter cockpit designs, should issue guidance regarding cockpit ergonomics to operators of existing helicopter designs.

The Investigation has recommended that the Operator should provide explicit guidance around the transfer of the roles of PF and PM in flight, and that it should review its approach to Fatigue Risk Management. Furthermore, in relation to fatigue, the Investigation has recommended that the IAA should review the Operator's 24-hour shift pattern.

Finally, while the Operator provides guidance to flight crew to make maximum use of automation, the Investigation believes that it would be prudent to review training syllabi to increase awareness of automation and cognitive bias and possible strategies for combatting them.

2.7 Analysis Summary

The Flight Crew descended the Helicopter to 200 ft and used the FMS to manoeuvre '*Direct To*' the first waypoint, BLKMO, on the APBSS route, unaware that BLKMO was adjacent to a 282 ft obstacle comprised of terrain and a lighthouse.

The Flight Crew did not verbalise the obstacles listed for the APBSS route, although it appears that the Commander had read at least some of the hazards/obstacles information, because she mentioned an obstacle to the west of Blacksod when selecting the escape heading. Accordingly, it seems that the Flight Crew believed that the design of APBSS, one of the Operator's '*Low Level*' routes, if faithfully followed using the FMS, would provide adequate lateral terrain separation. Although the Operator had no formal procedure for designing routes, guidance in OMF about selection of an '*offset*' initial point adjacent to high terrain may have nurtured a belief that routes would provide lateral terrain separation, if vertical separation could not be assured.

Furthermore, both Flight Crew members reviewed the APBSS route separately, but neither identified the presence of Black Rock. The cockpit operating environment appears to have been sub-optimal regarding the combination of cockpit lighting and coloured documents, the size of font used in some documents, the tabulation of a large amount of numerically dense information and the combined portrait/landscape presentation of some routes, including APBSS.

The reasons for selecting a 282 ft obstacle as the starting point for what the Operator described as a '*Low Level*' route, with no vertical profile, could not be determined because the origins of the route design itself were unknown to the Operator. It may have been related to previous generation navigation systems, which required in-flight re-calibration by transiting over a known geographic feature such as Black Rock Lighthouse. However, there were a number of other factors which militated against the Flight Crew detecting Black Rock in time to carry out an effective avoidance manoeuvre: Black Rock was not in the EGPWS databases; the BLKMO magenta waypoint symbol and track line likely obscured radar returns from Black Rock (which might have been detected on the 10 NM range); 1:250,000 Aeronautical Chart, Euronav imagery did not extend as far as Black Rock, and the 1:50,000 OSI imagery in the Toughbook did not show Black Rock, but instead showed open water at Black Rock. Furthermore, the Operator did not have formal processes or procedures to approve mapping data/imagery for use in its helicopters.

323 The operating environment on the west coast would have been more challenging than east coast crews were familiar with, particularly regarding the availability of visual cues in the littoral environment. This meant that it would not have been possible for the Flight Crew to accurately assess their horizontal visibility. However, given that Black Rock was only detected on the FLIR camera when the Helicopter was approximately 600 m from it, it seems that the horizontal visibility to the naked eye was probably less than 600 m. Furthermore, the Flight Crew's night vision may have been compromised due to the Helicopter's external lighting.

Research indicates that if the Flight Crew were awake for the length of time suggested by the Investigation's review (18 hours for the Commander and 17 hours for the Co-Pilot), they would have been more prone to errors in judgement and decision-making. The tempo of the mission was different to east coast missions and furthermore, the SAR support nature of the mission was known to be monotonous, increasing the risk of the Crew succumbing to fatigue.

Routes were generally viewed as base-centric, and a level of local knowledge and familiarity may have been assumed, which was an invalid assumption when an east coast crew was utilising a west coast route, a situation compounded by darkness and poor weather. The Operator said that the routes were merely there as a framework on which to build a plan for entry/exit to a number of known sites. However, there was no formal training in the use of routes; there was no formal procedure for how a route was to be designed; there was no formal procedure for how a crew should use a route guide; routes did not include a vertical profile or minimum altitudes generally, for route legs; and routes were not available for use in the simulator.

The Route Guide was prefaced with the statement that it was '*a work in progress and should be used with the necessary caution until all routes/waypoints are proven*'. Therefore, the routes were unproven, and the Operator did not have a defined process for route proving. Consequently, in the absence of formal, standardised training, a design procedure or a procedure for how a crew should use a route guide, it is unclear what beliefs/expectations individual pilots may have had regarding routes and how they could be used operationally. Problems with a number of routes had been identified in the SQID system, however the SQID report was closed after personnel were emailed to resolve the matter, but without checking that the routes had actually been updated correctly.

The closing of SQIDS without checking that effective action had been completed was one of a number of issues identified with the Operator's SMS. The Investigation also found that safety meetings were not being held as often as called for; minutes were not being uploaded onto SQID; SQID closure was not following the protocols set out in the SMCMM; the quality of Risk Assessments could be improved; personnel involved in risk assessments could benefit from targeted training; and events in which safety margins had been significantly reduced were not being captured. Furthermore, the Investigation found that important safety information, which should have been captured in the SQID system and followed up, was instead raised in email but not captured or followed up.

The Operator's reliance on a secondary duty model to discharge safety critical tasks meant that matters could arise and be left in abeyance while personnel were on leave, off-shift or otherwise engaged in their primary SAR duties.

Despite the fact that its published reports and Aeronautical Notice said that the IAA SAR operations were classified as a '*State*' activity and were to be regulated by the National Aviation Authority, the IAA subsequently expressed uncertainty about its mandate to regulate SAR; however, it neither withdrew nor restricted the Operator's National SAR Approval. The Operator, IRCG and DTTAS all believed that the IAA was regulating SAR operations. Audit reports of the Operator's bases that were submitted to the IRCG by its consultant do not appear to have been critically reviewed. Furthermore, DTTAS lacked the technical expertise to oversee the IAA. In addition, the IRCG did not have a safety management system.

Numerous areas, across several agencies, are explored in-depth in this Report. The issues identified demonstrate that the accident was, in effect, what [Professor James] Reason[90] termed '*an organisational accident*'.

The Report highlights the importance of robust processes in relation to the following areas: Route Guide design, way point positioning, and associated training; reporting and correcting of anomalies in EGPWS and charting systems; Fatigue Risk Management Systems; Toughbook usage; en route low altitude operation; and the functionality of emergency equipment. It is particularly important that an operator involved in Search and Rescue has an effective Safety Management System, which has the potential to improve flight safety by reacting appropriately to safety issues reported, and by proactively reducing risk with the aid of a rigorous risk assessment process.

This Report identifies the importance of the levels of expertise within organisations involved in contracting and tasking complex operations such as Search and Rescue, to ensure that associated risks are understood, that effective oversight of contracted services can be maintained and that helicopters only launch when absolutely necessary.

Finally, regulatory authorities have a role to play in assuring the safety of aviation operations, including Search and Rescue activities. Within Ireland, the State Safety Programme aims to achieve this by focussing resources in areas that '*present the greatest risk* […]'. While it was acknowledged by the Authority that the Operator was engaged in '*medium to high risk*' operations, there was no greater oversight at regulatory authority level.

3. CONCLUSIONS

3.1 Findings

The Accident Flight

1. R116 was tasked to provide Top Cover for R118 which was tasked with a MEDEVAC mission, in the Atlantic Ocean, 140 miles from Eagle Island, at night.

2. There were gaps in the way tasking protocols were followed at MRSC Malin.

3. The Flight Crew members' licences and medicals were valid; the Rear Crew members were appropriately qualified.

4. The extent of R116's pre-flight planning could not be fully determined, although it was not unusual for SAR crews to brief for changed plans and destinations whilst airborne.

5. The airworthiness certification for the aircraft was valid.

6. R116's initial intention was to route to Sligo for fuel, but on learning that R118 reported that conditions in Blacksod were good, the decision was made to go to refuel at Blacksod.

7. APBSS was selected in the FMS as the route to be used for the arrival into Blacksod.

8. Both Flight Crew members commented adversely about the quality of cockpit lighting.

9. Neither Flight Crew member had been to Blacksod recently.

10. BLKMO was selected as a '*Direct To*' waypoint in the FMS.

11. The Commander reviewed the route waypoints with the Co-Pilot and took '**overfly**' off one waypoint, which the Investigation believes was BKSDC.

12. The Commander did not verbalise the obstacle information from APBSS when she briefed the route but it appears that she did read at least some of the information because she was aware of an obstacle to the west of Blacksod when the Co-pilot asked about an escape heading.

13. The Co-Pilot self-briefed the route and he did not verbalise the obstacle information.

14. It is probable that each pilot believed, as they flew to join it, that the design of the APBSS (waypoint BLKMO to BLKSD as described in legs 1 to 4 of narrative and on the map in FMS Route Guide in respect of APBSS) route would provide adequate terrain separation if the FMS was used to follow the route, and that obstacles need only be considered if going off the route.

15. The FMS Route Guide was commonly referred to as the '*Low Level Route Guide*' although there was no shared understanding of what the term '*Low Level*' meant.

16. There were a number of anomalies in the APBSS route information including an incorrect leg length which had gone uncorrected since at least 1999.

17. Prior to descent from 4,000 ft, DVE Approach checks were completed and all external lights, except the NIGHTSUN which was armed, were selected to '*On*'.

18. As DVE Approach checks had been completed, Approach checks, which included a check of crossing altitudes, were not completed.

19. When the Flight Crew members were satisfied that the Helicopter was over open water, the Helicopter descended from 4,000 ft using ALT PRE to 2,400 ft, and then APP1 was used to descend to 200 ft before manoeuvring to commence the APBSS route.

20. The FDR data did not indicate any technical issues or exceedances during the flight.

21. The CVR recording did not contain any discussion of horizontal visibility in the Black Rock area although the Commander commented that she could see the sea surface.

22. It appears that APBSS was being used as the basis for a SARA although it had not been designed as an ARA.

23. Radar was operated on the 10 NM range throughout the descent and manoeuvring to commence APBSS.

24. GMAP2 mode on the weather radar uses the colour magenta to represent terrain returns – the same colour as the active track and waypoint on the S-92A navigation display.

25. Black Rock was not identified on radar which was likely due to obscuration caused by the magenta BLKMO waypoint marker and the magenta track line to the waypoint marker.

26. Black Rock was not in the EGPWS databases.

27. The 1:250,000 Aeronautical Chart, Euronav imagery did not extend as far as Black Rock.

28. The 1:50,000 OSI imagery available on the Toughbook did not show Black Rock Lighthouse or terrain, and appeared to show open water in the vicinity of Black Rock.

29. The AIS transponder installed on the Helicopter was capable of receiving AIS Aids-to-Navigation transmissions; however, the AIS add-on application for the Toughbook mapping software could not display AIS Aids-to-Navigation transmissions.

30. The Winchman announced that he had detected an island ahead on the EO/IR camera system when the Helicopter was about 0.3 NM from it, travelling at a groundspeed of 90 kts.

31. The Winchman called for a change of heading and the Flight Crew were in the process of making the change when the urgency of the situation became clear to the Winchman.

32. There is no indication on the CVR that the Flight Crew saw Black Rock, although in the final seconds of flight there was a significant, manual input on the Collective Lever, an associated '*droop*' in main rotor RPM and a roll to the right.

33. The Helicopter collided with terrain at the western end of Black Rock, departed from controlled flight, and impacted with the sea.

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34. At no stage did any member of the Crew comment on seeing, or expecting to see, a light from Black Rock Lighthouse.

Organisational Aspects

35. The IRCG did not have a formal risk assessment process for helicopter missions and SMC personnel were not explicitly trained in risk assessment.

36. The Operator's routes were viewed as base-centric; there was no formal training/testing in the use of route guides, and routes were not available for use in the simulator.

37. The Operator had no formal processes for designing routes, proving routes or selecting waypoints.

38. The Operator's manuals were inconsistent in some areas and did not provide sufficient detail of processes and procedures for the discharge of some safety-critical functions.

39. The Operator relied on a Secondary Duty model for safety-critical support functions, which compromised the reliability and continuity of safety management and oversight.

40. There were anomalies in a number of aspects of the Operator's SMS including safety reporting, risk assessments, the management of meetings and minutes, the apparent non-reporting of serious incidents, and the use of email instead of SQID for safety management.

41. OMF required flight crews to have sufficient visual cues for the task in hand but it did not provide any specific guidance on how crews should carry out such an assessment.

42. There were various terms such as Top Cover, SAR Support, Chase Helicopter and Shadow Helicopter being used without a common understanding, and the efficacy of using a second helicopter of the same type (as the primary SAR helicopter), as a Top Cover asset, given their similar endurance, required further consideration.

43. There were weaknesses in the Operator's document management processes.

44. There was no HFDM programme for the Operator's fleet nor was there a regulatory or contractual requirement for such a system at the time of the accident.

45. There was no published guidance regarding the AFCS SAR Modes SRCH function.

Oversight

46. Neither DTTAS nor the IRCG had aviation expertise available within their own personnel resources, and lacked the capacity to remain an '*intelligent customer*' in relation to contracted helicopter operations or auditing.

47. The IRCG relied on an external contractor to conduct annual audits of the Operator's bases.

48. The IRCG appears not to have appreciated the severity of some of the matters the Auditor raised and it appears that the Auditor's reports and supporting evidence were not scrutinised by the IRCG.

49. The IRCG did not have a Safety Management System, and IRCG management completed their first aviation SMS training in October 2018.

50. From the IAA's Annual Safety Reviews and Aeronautical Notice it appeared that the IAA was responsible for, and carrying out, oversight of SAR helicopter operations in Ireland, but after the accident the IAA questioned whether it had the necessary mandate.

51. The IAA asserted that it was subject to oversight by the State, i.e. DTTAS, but DTTAS informed the Investigation that it did not have specialist aviation expertise within the Department to discharge such oversight.

52. The fact that SAR crews, who could avail of a wide range of exemptions under the National SAR Approval when operating SAR, could also be tasked with HEMS missions, which were operated primarily as CAT flights, was a source of confusion and difficulty for crews.

53. The Investigation is of the opinion that EASA should have a role in the regulation of civil-registered SAR aircraft and AOC operators involved in SAR, but EASA informed the Investigation that it did not have the required legal mandate.

Survivability

54. None of the Crew members survived the accident. Neither the Winch Operator nor the Winchman was recovered, and to date they remain lost at sea.

55. Whilst the Commander did manage to egress the Helicopter and inflate her lifejacket, she was submerged to a depth of at least 10 m, and the cold-water shock, darkness and overall sense of shock militated against her survival.

56. The Co-pilot, who was found secured in his seat within the cockpit wreckage, at approximately 40 m depth, was recovered, and post mortem examination concluded that he had suffered multiple injuries following which death would have ensued rapidly.

57. The SARBE installations in the Flight Crew's Mk44 lifejackets were not in accordance with the SARBE manufacturer's recommendations.

58. The two Flight Crew SARBEs, and one SARBE carried on the Helicopter in a spare lifejacket, had been submerged to at least 10 m depth and rendered unserviceable due to water ingress.

Human Factors

59. Although not all Crew Members had been able to attend a colleague's funeral ceremonies, the Investigation found no evidence that this adversely affected Crew Performance.

60. Both Flight Crew members commented adversely on the quality of the cockpit lighting.

61. EASA has recognised that flight deck systems design can strongly influence crew performance.

62. The Helicopter cockpit lighting had been modified to be compatible with NVIS, although NVGs had not been introduced into service.

63. The CVR recording indicates that there were trapped and un-trapped errors during the accident flight.

64. The roles of PF and PM were swapped after the Commander, as PM, had devised the plan and selected the route for arrival into Blacksod.

65. A sleep study of some of the Operator's SAR Crew members found that they accrued less sleep than that recommended by the US National Sleep Foundation and that this may not be enough sleep for optimal operational duty.

66. The Operator had an FTL scheme variation from the IAA which was predicated on the Operator having an FRMS in place; the Investigation was not provided with evidence that such an FRMS had been implemented.

67. R116 was engaged on a SAR support mission, and the Operator's OMF stated that on SAR support missions there was a potential for fatigue to set in quicker than on primary SAR missions, due to monotony.

68. FAA and CASA information highlights hours of prior wakefulness are correlated with increased error rates and judgment lapses, in personnel who are awake for longer than 10 hours. Based on the information in the 72-hour activity study, at the time of the accident, the Commander had likely been awake for more than 18 hours and the Co-pilot had likely been awake for more than 17 hours.

69. OMA quoted directly from EASA CAT.GEN.MPA.100 c(5) that '*A crew member shall not perform duties in flight if he knows or suspects that he is suffering from fatigue, or feels unfit to the extent that the flight may be endangered.';* however, in the absence of an FRMS as required by EASA ORO.FTL.120, and given the Operator's 24-hour roster pattern, this advice is at odds with the scientific findings that individuals are notoriously poor judges of their own levels of fatigue.

70. OMF required crews to make maximum use of automation but it did not warn crews about the dangers of automation bias.

71. The Flight Crew cross-checked EGPWS with radar as required by OMF, although this had the potential to introduce bias, as the absence of Blackrock from the EGPWS could have adversely affected the likelihood of the Crew detecting Black Rock on the Radar.

3.2 Probable Cause

The Helicopter was manoeuvring at 200 ft, 9 NM from the intended landing point, at night, in poor weather, while the Crew was unaware that a 282 ft obstacle was on the flight path to the initial route waypoint of one of the Operator’s pre-programmed FMS routes.

3.3 Contributory Cause(s)

1. The initial route waypoint, towards which the Helicopter was navigating, was almost coincident with the terrain at Black Rock.

2. The activities of the Operator for the adoption, design and review of its Routes in the FMS Route Guide were capable of improvement in the interests of air safety.

3. The extensive activity undertaken by the Operator in respect of the testing of routes in the FMS Route Guide was not formalised, standardised, controlled or periodic.

4. The Training provided to flight crews on the use of the routes in the (paper) FMS Route Guide, in particular their interface with the electronic flight management systems on multifunction displays in the cockpit, was not formal, standardised and was insufficient to address inherent problems with the FMS Route Guide and the risk of automation bias.

5. The FMS Route Guide did not generally specify minimum altitudes for route legs.

6. The Flight crew probably believed, as they flew to join it, that the APBSS (waypoint BLKMO to BLKSD as described in legs 1 to 4 of narrative and on the map in FMS Route Guide in respect of APBSS) route by design provided adequate terrain separation from obstacles.

7. Neither Flight Crew member had operated recently into Blacksod.

8. EGPWS databases did not indicate the presence of Black Rock, and neither did some Toughbook and Euronav imagery.

9. It was not possible for the Flight Crew to accurately assess horizontal visibility at night, under cloud, at 200 ft, 9 NM from shore, over the Atlantic Ocean.

10. The Flight Crew members’ likely hours of wakefulness at the time of the accident were correlated with increased error rates and judgment lapses.

11. There were serious and important weaknesses with aspects of the Operator’s SMS including in relation to safety reporting, safety meetings, its safety database SQID and the management of FMS Route Guide such that certain risks that could have been mitigated were not.

12. There was confusion at the State level regarding responsibility for oversight of SAR operations in Ireland.

4. SAFETY RECOMMENDATIONS

A safety recommendation made in this Report shall in no case create a presumption of blame or liability.

	It is Recommended that:	Recommendation Ref.
1.	CHCI should review its guidance, operating and training procedures in relation to the use of EGPWS in its operations, ensuring crews are aware of the limitations of the system and that the EGPWS manufacturer's guidance on the use of Low Altitude mode is followed.	IRLD2021003
2.	CHCI should ensure that it has in place processes to ensure that mapping imagery used in its Euronav and Toughbook are suitable, current and sufficiently comprehensive for its intended uses, and that appropriate guidance for the use of such systems is provided in the operations manual.	IRLD2021004
3.	The IAA should require operators who have exemptions from Rules of the Air, to provide a full safety case, including details of the acceptable navigation data sources to be used, as part of the exemption application and review processes.	IRLD2021005
4.	The IAA should require an operator that has exemptions from Standard Rules of the Air to state the minimum height at which each leg of its company routes can be flown.	IRLD2021006
5.	CHCI should develop and promulgate procedures/processes for all aspects of Route Guide management including route design, review, approval, updating, usage, briefing, operational limitations (to include at a minimum, visibility & altitude limits and ARA compatibility), crew training and periodic familiarisation requirements.	IRLD2021007
6.	The Minister for Transport should ensure that the training syllabus for personnel involved in the decisions to launch SAR helicopter missions includes the following: information regarding the protocols used by other agencies with whom they work, so that it is clear where responsibilities lie, and how to make best use of each agency's expertise; recognition of and strategies to address cognitive bias which could affect decision-making/risk assessment regarding the initiation and continuation of SAR missions; the potential for in-flight communications with helicopter crews to adversely affect crew effectiveness; and practical scenario-based exercises.	IRLD2021008

	It is Recommended that:	Recommendation Ref.
7.	CHCI should, with input from its parent company, ensure that OMA assignment and alignment of Nominated Persons' responsibilities is appropriately defined; that limitations regarding assignments are appropriately set out and adhered to; and that appropriate processes, procedures and training enable staff to discharge assigned responsibilities in a transparent and auditable manner.	IRLD2021009
8.	CHCI should, with input from its parent company, review its organisational structure, secondary duty model, staffing levels and personnel training, for its operations and support functions, to ensure that there are sufficient resources available to discharge all necessary responsibilities, safety management oversight, and the drafting, approval and management of documentation.	IRLD2021010
9.	CHCI should consider implementing a LOSA programme within its SAR operation which can routinely review operational standards for flight and technical crew, and provide reports on these reviews to the Accountable Manager for actioning by the relevant function.	IRLD2021011
10.	CHCI should formalise its monitoring of all SAR flights to ensure that use of any exemptions allowed under the National SAR Approval is monitored, that minimum horizontal visibility is always recorded and that missions and decision-making are routinely reviewed with crews to maximise safety margins and standardise launch criteria.	IRLD2021012
11.	The Minister for Transport should implement a procedure for IRCG to engage, at an appropriate level, with its SAR helicopter operator in relation to mission launch concerns in a manner that minimises any impact on duty crews and avoids creating a perception of competition or commercial pressure.	IRLD2021013
12.	CHCI should ensure that appropriate time is provided within the roster to facilitate staff attendance at safety-related meetings and that the minutes of all safety related meetings are stored in a manner that facilitates their incorporation into the knowledge base of safety information within the company.	IRLD2021014

	It is Recommended that:	Recommendation Ref.
13.	CHCI should review its OMF procedures in order to: remove consideration of casualty condition from flight crew dispatch/ continuation criteria for SAR missions; require crews of support SAR helicopters to specifically consider when/whether it is appropriate to dispatch under SAR criteria; and provide specific guidance to crews about the assessment of visibility under conditions of darkness and or poor weather.	IRLD2021015
14.	The Minister for Transport should, in conjunction with the relevant agencies, review processes regarding the requesting/tasking of Top Cover assets, fixed wing or helicopter, and should ensure that terminology is well-defined and consistently used.	IRLD2021016
15.	The Minister for Transport should ensure that proposed changes to IRCG operating procedures are the subject of a risk assessment or safety case, that any mitigations required are in place prior to implementing the changes, and that SOPs are updated in a timely fashion to reflect any such changes.	IRLD2021017
16.	CHCI should review its policies, manuals, training and guidance in relation to the operational use of radar in the SAR role and ensure that manuals and training accurately reflect the limitations of the systems used.	IRLD2021018
17.	CHCI should ensure that rear crew members receive operational EO/IR training and periodic, formal training and rating(s) to operate the Toughbook, with particular emphasis on approaches and construction of routes to target areas, the limitations of the databases and software in use; and that OMF and other documentation for both systems should be reviewed and updated.	IRLD2021019
18.	CHCI should review its document management and updating methodologies and the robustness of its practices to ensure that current documents are readily apparent, that older revisions are appropriately archived and that staff members are provided with a uniform method for confirming the latest revision state of any document.	IRLD2021020

	It is Recommended that:	Recommendation Ref.
19.	CHCI should introduce, and regularly review, a Helicopter Flight Data Monitoring programme, to support its SMS and personnel in identifying and addressing operating issues and trends to optimise safety margins within its operation.	IRLD2021021
20.	The Sikorsky Aircraft Corporation should make the necessary updates/modifications to the S-92A helicopter, when configured for SAR operations, to ensure that the active lateral navigation mode information, including AFCS SAR modes, are recorded on the Flight Data Recorder during all flight regimes and mission profiles.	IRLD2021022
21.	The Sikorsky Aircraft Corporation should make the necessary updates/modifications to the S-92A Helicopter Rotorcraft Flight Manual Supplement No. 4 Part 2, to include a description of the operational usage of the AFCS SAR SRCH mode.	IRLD2021023
22.	The Minister for Transport should ensure that the IRCG's internal processes are sensitive to warnings from its process auditors, and that mechanisms are in place to ensure that appropriate and necessary actions are expeditiously implemented in response to any such warnings.	IRLD2021024
23.	The Minister for Transport should review the provision of aviation expertise to the IRCG to ensure that the IRCG is effective and structured to support appropriate governance arrangements and that IRCG operating procedures are risk assessed and maintained current.	IRLD2021025
24.	The Minister for Transport should ensure that appropriate departmental governance arrangements are in place to oversee the functioning of the IRCG and to ensure that issues identified are addressed so that the systems in place will be sufficiently comprehensive and robust.	IRLD2021026
25.	The Minister for Transport should ensure that the IRCG fully implements a Safety Management System which encompasses all aspects of its air operations and which includes all stake holders in those operations.	IRLD2021027

	It is Recommended that:	Recommendation Ref.
26.	The Minister for Transport should review extant service level agreements involving IRCG air operations to ensure that they are suitably robust and complete, and to ensure the viability of statements of responsibility provided in such service level agreements.	IRLD2021028
27.	The Minister for Transport should periodically review the availability of in-house expertise, to ensure that the Department retains the necessary technical capabilities to intelligently oversee and review all activities associated with SAR aviation operations.	IRLD2021029
28.	The IAA should review its arrangements, guidance and procedures for overseeing civilian operators providing SAR services within the State, to ensure that they are sufficiently robust and transparent so that all parties involved have a full understanding of the scope and limits of their responsibilities and that agency interface arrangements are designed for optimal clarity and shared understanding.	IRLD2021030
29.	The Minister for Transport should ensure that the Department has sufficient specialist aviation expertise to enable it to discharge effective oversight of the full range of IAA activities.	IRLD2021031
30.	The Minister for Transport should institute a detailed review of the IAA's regulatory and oversight mechanisms to ensure that they are sufficiently robust and comprehensive, and that interfaces and delineation of responsibilities are clearly defined and understood by the IAA and the entities it regulates.	IRLD2021032
31.	The European Commission should carry out a review of how SAR is managed in EU member states with a view to identifying best practice/minimum safety standards and, as appropriate, promulgating guidance for SAR operations using civil registered aircraft, which at the moment are excluded from Regulation (EU) No 2018/1139 so that an appropriate and uniform level of basic safety will apply in civil SAR operations throughout Europe.	IRLD2021033
32.	The Minister for Transport, should engage with EASA and the European Commission to ensure that an appropriate SAR regulatory framework, and associated guidance material are in place whether by opt-in to Regulation (EU) No 2018/1139, or otherwise.	IRLD2021034

	It is Recommended that:	Recommendation Ref.
33.	The Minister for Transport should review the SAR/HEMS Decision Tree and all arrangements regarding the tasking of SAR helicopters to ensure that there is maximum clarity in the tasking process and that HEMS missions are not conducted under provisions which should only apply to SAR missions.	IRLD2021035
34.	The IAA should ensure that its review procedures, for operators that carry out multiple mission types, particularly where different regulatory regimes are in place, consider and address all aspects of mission differentiation, to ensure that operators are applying full, appropriate regulatory rigour to all flights.	IRLD2021036
35.	CHCI should review and update its offshore survival training procedures to ensure that all helicopter crews carry out their mandatory training wearing the safety clothing and types of equipment that would be worn during day-to-day operations, and to ensure that the correct functioning and compatibility of all safety clothing/equipment is verified during this training.	IRLD2021037
36.	CHCI should review and update its procedures relating to the introduction into service of non-mandatory equipment generally, and safety equipment in particular, to ensure that the procedures are sufficiently robust to identify and resolve integration issues before equipment is introduced into operational service.	IRLD2021038
37.	CHCI should engage with all relevant parties to conduct an in-depth study and review of the cockpit environment of its S-92A helicopter to ensure that safe operations can be achieved under all ambient lighting conditions and that all aspects of information presentation (colour schemes, typography, size, font, surface reflectivity, etc.) used in the presentation of Route Guides, Landing Site Directories and other information provided for use by flight crew, are optimised for use in the cockpit environment.	IRLD2021039

	It is Recommended that:	Recommendation Ref.
38.	EASA should carry out a safety promotion exercise, in parallel with the development of certification specifications for human factors in the design of rotorcraft cockpits, to provide operators of in-service helicopters with a best practice guide to mitigate the risks associated with human factors and pilot workload issues.	IRLD2021040
39.	CHCI should provide explicit guidance in its Operations Manual on the protocols and briefing requirements for transfer of PF and PM roles during a mission.	IRLD2021041
40.	CHCI should ensure that it has in place a Fatigue Risk Management System based on scientific principles, which takes advantage of modern techniques such as bio-mathematical analysis of roster patterns, is known to all its crew members, and that it encourages the reporting of fatigue related issues.	IRLD2021042
41.	The IAA should review the Operator's 24-hour SAR shift pattern to ensure that it adequately accounts for concerns arising from published research on human performance; and that the Operator's FRMS and SAR variation to Aeronautical Notice O.58 provide appropriate levels of safety and protection for crews.	IRLD2021043
42.	CHCI should review its training syllabi and operations manuals to increase crew awareness of automation and cognitive bias, and as far as possible to provide strategies for recognising and combatting these threats.	IRLD2021044
	View Safety Recommendations for Report 2021-008	

LIST OF ACRONYMS AND TERMS

AAIB	Air Accidents Investigation Branch – UK
AAIU	Air Accident Investigation Unit – Ireland
ACC	Area Control Centre
AD	Airworthiness Directive
ADC	Air Data Computer
ADELT	Automatically Deployable Emergency Locator Transmitter
AFCS	Automatic Flight Control System
AGL	Above Ground Level
AHRS	Attitude and heading reference system
AIC	Aeronautical Information Circular
AIP	Aeronautical Information Publication
AIS	Automatic Identification System
ALT	Altitude e.g. 2,400 ft
AMC	Acceptable Means of Compliance
AMS	Avionics Management System
AMSL	Above Mean Sea Level
AN	Aeronautical Notice
AOC	Air Operator Certificate
APBSN	A navigation route from the Operator's Route Guide, for use at Blacksod
APBSS	A navigation route from BLKMO to BLKSD, via BKSDA, BKSDB and BKSDC
APMB	Accident Protected Memory Board
APP	Approach
APP1	Approach One, a SAR AFCS descent mode
APU	Auxiliary Power Unit
AQE	Consultants contracted by DTTAS
ARA	Airborne Radar Approach
ARC	Airworthiness Review Certificate
ARCC	Aeronautical Rescue Co-ordination Centre
ARM	A state whereby a system has been configured for a mode capture but the mode has not yet been captured
ARSC	Aviation Rescue Sub-Centre
ASD	Aviation Services Division (of the Irish National Meteorological Service)
ASL	Above Sea Level
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
AtoN	Aids to Navigation
ATPL	Airline Transport Pilot Licence
ATS	Air Traffic Services
AVAD	Automatic Voice Alert Device
AVC	Active Vibration Cancelling
AWL	Above Water Level
AWP	Aerial Works Permission

AWSAR	All-weather Search and Rescue
BFSM	Base Flight Safety Meeting
BFSO	Base Flight Safety Officer
Bingo	Minimum off-scene fuel
BKSDA	A navigation waypoint on the APBSS route
BKSDB	A navigation waypoint on the APBSS route
BKSDC	A navigation waypoint on the APBSS route
BLKMO	A navigation waypoint at the start of the APBSS route; it was located in the water at the eastern end of Black Rock
BLKSD	A navigation waypoint for the Blacksod helicopter-pad and refuelling facility
BLMO	A reference by the Commander to a 'little island'
BSF	The three-letter designator which was used to refer to the Blacksod refuelling facility in the S-61N Route Guide
C	Celsius
CAA	Civil Aviation Authority – UK
CAM	Cockpit Area Microphone
CAP	Civil Aviation Publication
CASA	Civil Aviation Safety Authority – Australia
CAT	Commercial Air Transport Category also Clear Air Turbulence
CCS	Chief Crewman Standards
CDS	Chip Detection System
CDU	Control Display Unit(s)
CET	Civil Evening Twilight
CFD	Coupled Flight Director
CFIT	Controlled Flight Into Terrain
CG	Coast Guard
CHC	The Operator's parent company
CHCI	CHC Ireland DAC
CHOV	Crew Hover
cm	Centimetre
CMS	Central Monitoring System
COCISS	Clear of cloud, in sight of the surface
COSPAS	Cosmicheskaya Sistyema Poiska Avariynich Sudov (search and rescue satellite-aided tracking)
CPA	Corrective and Preventive Action
CPL	Commercial Pilot Licence
CRM	Crew Resource Management
CSMM	Crash Survivable Memory Module
CSMU	Crash Survivable Memory Unit
CT	Computer Tomography
CV	Cockpit Voice
CVC	Cockpit Voice Channel
CV2	Co-pilot Channel on the CVR
CVR	Cockpit Voice Recorder

DCP	Display Control Panel(s)
DCU	Data Control Unit(s)
DF	Direction Finder
DGRD	Degraded
DME	Distance Measuring Equipment
DOA	Design Organisation Approval
DOC	Disk-on-Chip
Doc	Document
DoT	Department of Transportation
DPT	Departure Mode
DTED	Digital Terrain Elevation Data
DTMU	Data Transfer Memory Unit
DTO	Direct To (a navigation waypoint)
DTTAS	Department of Transport, Tourism and Sport
DTU	Data Transfer Unit
DVE	Degraded Visual Environment, defined by the Operator as visibility less than 4,000 metres or no distinct natural horizon.
DVR	Digital Video Recorder
EASA	European Union Aviation Safety Agency
EC	European Commission
EFB	Electronic Flight Bag
EFS	Emergency Flotation System
EGPWS	Enhanced Ground Proximity Warning System
EIBT	ICAO code for Belmullet Airfield
EICAS	Engine Indicating and Crew Alerting System
EIDW	ICAO code for Dublin Airport
EIKN	ICAO code for Ireland West Airport – Knock
ELT	Emergency Locator Transmitter
EMER	Abbreviation for emergency
EMS	Emergency Medical Service
ENR	En Route
EPIRB	Emergency Position Indicating Radio Beacon(s)
ETA	Estimated Time Of Arrival
ETSO	European Technical Standards Order
ETSOH	ETSO Holder
EU	European Union
F	Fahrenheit
FAA	Federal Aviation Administration – USA
FADEC	Full Authority Digital Engine Control
FAF	Final Approach Fix
FAT	Final Approach Track
FD	Flight Director
FDM	Flight Data Monitoring – used to monitor flight operations
FDP	Flight Duty Period

FDR	Flight Data Recorder
FIR	Flight Information Region
FLIR	Forward Looking InfraRed
FM	Flight Management and also Frequency Modulation
FMA	Flight Mode Annunciator
FMGC	Flight Management Guidance Computer
FMS	Flight Management System
FO	First Officer
FOV	Field of View
FPM	Feet Per Minute
FRM	Fatigue Risk Management
FRMS	Fatigue Risk Management System
FS	Flight Safety
FSI	Flying Staff Instruction
FSTD	Flight Simulation Training Device
FTL	Flight Time Limitations
FV	Fishing Vessel
FY	Fiscal Year
GA	General Aviation
GAIN	A sensitivity adjustment for a Radar system
GB	United Kingdom
GEAR	The landing gear
GEN1	First Generation
GEN2	Second Generation
GEN3	Third Generation
GMAP2	A radar mode with colour thresholds and pulse width set for terrain-mapping operation
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
HD	High Definition
HDG	Heading
HEED	Helicopter Emergency Egress Device
HEELS	Helicopter Emergency Egress Lighting System
HEMS	Helicopter Emergency Medical Services
HESS	Health, Environment, Safety & Security
HF	High Frequency
HFDM	Helicopter Flight Data Monitoring
HID	Hazard IDentification, a type of SQID report
HLTH	Health
hPa	hectoPascals
HQC	A High-Quality CVR audio channel
HSE	Health Service Executive
HUET	Helicopter Underwater Escape Training
HUMS	Health and Usage Monitoring System
IAA	Irish Aviation Authority

IAC	Irish Air Corps
IAF	Initial Approach Fix
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IAMSAR	International Aeronautical and Maritime Search and Rescue
IAS	Indicated Air Speed
IAW	In Accordance With
IC	Integrated Circuit
ICAO	International Civil Aviation Organisation
ICRS	InterComRadio System
ICS	InterCom System
IFR	Instrument Flight Rules
IGB	Intermediate Gear Box
IIC	Investigator-In-Charge
ILS	Instrument Landing System
ILV	Irish Lights Vessel
IMC	Instrument Meteorological Conditions
IMO	International Maritime Organisation
IR	Instrument Rating and also Implementing Rule
IRCG	Irish Coast Guard
IRE	Ireland
JAR	Joint Aviation Requirement
KIAS	Knots Indicated Airspeed
KPI	Key Performance Indicator
KSI	Key Safety Indicator
LAF	Local Area Forecast
LDP	Landing Decision Point
LED	Light Emitting Diode
LEO	Low Earth Orbit
LH	Left hand
LL	Low Level
LNAV	Lateral Navigation
LPC	Licence Proficiency Check
LQC	A Low-Quality CVR audio channel
LSD	Landing Site Directory
LZ	Landing Zone
m	Metres
M	Mach Number
MAIB	Marine Accident Investigation Branch UK
MAP	Missed Approach Point
MAYDAY	Distress R/T transmission
Mb	Millibars
MCA	Minimum Crossing Altitude and also UK Maritime and Coastguard Agency
MCIB	Marine Casualty Investigation Board Ireland

MDA	Minimum Descent Altitude
MDC	Maintenance Data Computer
MDH	Minimum Descent Height
ME	Multi-Engine
MEDICO	An international term meaning the passing of medical information by radio
MET	Meteorology
MFD	Multi-Function Display
MFO	Manager of Flight Operations
MHWS	Mean High Water Spring
MI	Marine Institute of Ireland
MINS	Minimums
MLG	Main Landing Gear
mls	Millilitres
MMMS	Multi-Mission Management System
MMSI	A nine digit number used by maritime digital selective calling (DSC), AIS and certain other equipment to uniquely identify a ship or a coastal radio station
MOC	Maritime Operations Centre
MOCA	Minimum Obstruction Clearance Altitude
MODE	A helicopter system selection
MORA	Minimum Off-Route Altitude
MOT	Mark On Top
MPFR	Multi-Purpose Flight Recorder
MPU	Main Processor Unit
MRCC	Maritime Rescue Co-ordination Centre
MRSC	Marine Rescue Sub-Centre
MSA	Minimum Safe Altitude
MSL	Mean Sea Level
MSP	Mode Select Panel
NACC	National Aero-medical Coordination Centre
NAS	Naval Air Station
NASA	National Aeronautics and Space Administration - USA
NAV	FMGC Navigation mode
NIMROD	A maritime patrol aircraft developed and operated by the UK's RAF
NM	Nautical Miles
NMCI	National Maritime College of Ireland
NOTAM	Notice to Airmen
NTSB	National Transportation Safety Board - USA
NVG	Night Vision Goggles
NVIS	Night Vision Imaging System
OAT	Outside Air Temperature
OCC	Operator Conversion Course
OEM	Original Equipment Manufacturer
OIP	Offset Initial Point
OM	Operations Manual
OM	Outer Marker

OMA	Operator's Operations Manual, Volume A
OMB	Operator's Operations Manual, Volume B
OMC	Operator's Operations Manual, Volume C
OMD	Operator's Operations Manual, Volume D
OMF	Operator's Operations Manual, Volume F
OMG	Operator's Operations Manual, Volume G
OPC	Operator Proficiency Check
ORB	Occurrence Review Board
OS	On Scene
OSC	On Scene Commander
OSI	Ordnance Survey Ireland
OWTA	Organisation of Working Time Act
PAS	Public Appointments Service
PC	Performance Class
PCMCIA	Personal Computer Memory Card International Association - a data card
PF	Pilot Flying
PFD	Primary Flight Display
PHECC	Pre-Hospital Emergency Care Council
PIC	Pilot In Command
PLB	Personnel Locator Beacon(s)
PM	Post Meridiem Pilot Monitoring or PNF
PNF	Pilot Non-Flying
PPE	Personal Protective Equipment
PPL	Private Pilot Licence
PR	Preliminary Risk
PRR	Preliminary Risk Rating
QC	Queen's Counsel
QMS	Quality Management System, Qualifications Management System
QNH	An altimeter barometric setting that displays altitude above mean sea level
R116	Rescue One One Six, the call sign of the Dublin-based SAR helicopter
R118	Rescue One One Eight, the call sign of the Sligo-based SAR helicopter
RA	Resolution Advisory
RADALT	Radar/Radio Altimeter
RADAR	Radio Detection and Ranging
RAF	Royal Air Force - UK
RALT	Radar Altitude Hold Mode
RAM	Risk Assessment Matrix
RCC	Rescue Coordination Centre
RCSMM	Replacement Crash Survivable Memory Module
RDC	Request for Document Change
REF	Reference
Rev	Revision
RFM	Rotorcraft Flight Manual

RIPS	Rotor Ice Protection System
RNAV	Area Navigation, navigation capability that allows the aircraft to navigate accurately outside the airways system
RNLI	Royal National Lifeboat Institution
ROV	Remotely Operated Vehicle
RPM	Revolutions Per Minute
RRRF	Rotors Running Refuelling
RSVR	Reservoir
RVR	Runway Visual Range
RWY	Runway
s, sec	Second(s)
SAG	Safety Action Group
SAR	Search and Rescue
SARA	SAR Airborne Radar Approach
SARBE	A Personal Locator Beacon
SAS	Stability Augmentation System
SAT	Abbreviation for Satellite
SATCOM	Satellite Communications
SB	Service Bulletin
SBD	Short Burst Data
SE	Safety Equipment
SEO	Safety Equipment Operative
SERA	Standardised European Rules of the Air
SHEQ	Safety, Health, Environment, Quality
SI	Statutory Instrument
SIB	Safety Information Bulletin
SITREP	Situation Report
SLA	Service Level Agreement(s)
SMC	SAR Mission Coordinator
SMCMM	Safety Management and Compliance Monitoring Manual
SMCP	Standard Marine Communications Phrases
SMM	Safety Management Manual, ICAO Doc 9859
SMS	Safety Management System
SO	Second Officer
SOLAS	Safety Of Life At Sea
SOP	Standard Operating Procedure(s)
SQID	Safety and Quality Integrated Database
SR	Safety Recommendation
SRB	Safety Review Board
SRCH	A SAR AFCS navigation mode
SRR	Shannon Recue Region
SRU	Search and Rescue Unit
SSP	State Safety Programme
SSp	State Safety Plan
STASS	Short Term Air Supply System

SVFR	Special Visual Flight Rules
SYS	System
TAF	Terminal Area Forecast
TBA	To be advised
TC	Technical Crew
TEMPO	Temporarily, a term used in meteorological reports
TETRA	Terrestrial Trunked Radio. A European standard for a trunked radio system and two-way transceiver specification
TILT	The tilt angle of a radar antenna beam in relation to the horizon
TIS	Time-In-Service
TMAS	Tele-Medical Assistance Service
TR	VFR Low Altitude Training Routes and also Tail Rotor(s)
TRIR	Total Recordable Incident Rate
TRPCS	Tail Rotor Pitch Change Shaft
TX	Transmission
UCD	University College Dublin
UK	United Kingdom
ULB	Underwater Locator Beacon
URL	Universal Resource Locator
US	United States
USA	United States of America
USBL	Ultra-Short Base Line
UTC	Universal Coordinated Time, formerly known as GMT or Z
UTIL	Utility
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
VOR	VHF Omni-Directional Radio Range
V_{TOSS}	Take-off Safety Speed – Category A rotorcraft take-off safety speed
WNS	Western North Sea
WRT	With Respect To
WX	Weather
WxR	Weather Radar

LIST OF APPENDICES

All appendices are contained in a separate volume to this Report.

- END -

Produced by the Air Accident Investigation Unit

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FORMAL REPORT
APPENDICES

ACCIDENT
Sikorsky S-92A, EI-ICR
Black Rock, Co. Mayo, Ireland
14 March 2017

An Roinn Iompair
Department of Transport

Foreword

This safety investigation is exclusively of a technical nature and the Final Report reflects the determination of the AAIU regarding the circumstances of this occurrence and its probable causes.

In accordance with the provisions of Annex 13[1] to the Convention on International Civil Aviation, Regulation (EU) No 996/2010[2] and Statutory Instrument No. 460 of 2009[3], safety investigations are in no case concerned with apportioning blame or liability. They are independent of, separate from and without prejudice to any judicial or administrative proceedings to apportion blame or liability. The sole objective of this safety investigation and Final Report is the prevention of accidents and incidents.

Accordingly, it is inappropriate that AAIU Reports should be used to assign fault or blame or determine liability, since neither the safety investigation nor the reporting process has been undertaken for that purpose.

Extracts from this Report may be published providing that the source is acknowledged, the material is accurately reproduced and that it is not used in a derogatory or misleading context.

[1] **Annex 13**: International Civil Aviation Organization (ICAO), Annex 13, Aircraft Accident and Incident Investigation.
[2] **Regulation (EU) No 996/2010** of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation.
[3] **Statutory Instrument (SI) No. 460 of 2009**: Air Navigation (Notification and Investigation of Accidents, Serious Incidents and Incidents) Regulations 2009.

CONTENTS

Appendix A — S-92A Dimensions

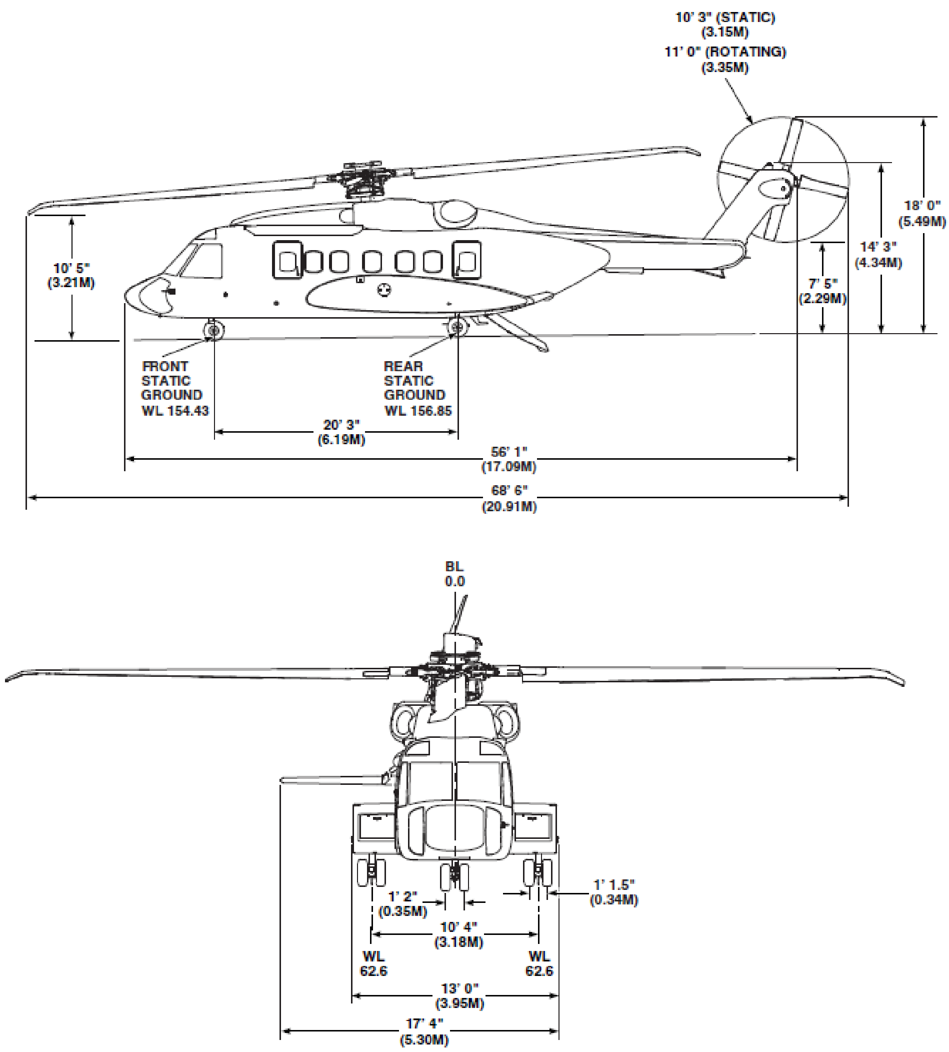

Figure No. A1: The principal dimensions of the S-92A helicopter

Appendix B — Automatically Deployable Emergency Locator Transmitter (ADELT)

The IRCG S-92A helicopters are equipped with a Model 503 ADELT, manufactured by HR Smith. It is compatible with the search and rescue systems, including the COSPAS/SARSAT satellite-based locator system. The Helicopter Manufacturer's RFM describes the ADELT as an emergency locator transmitter, mounted on the aircraft, which generates two radio beacons to aid in locating downed aircraft. When the beacon is activated, the 406 MHz transmitter transmits a digital signal to the satellites every 50 seconds. The satellites receive the signal and relay it to a ground station that decodes the data providing the aircraft tail number, country of origin, and beacon type. This allows the beacon position to be located to within 3 miles (4.8 Km) directing SAR resources to the general search area.

Once within 50 miles (80 Km) of the search area, the 121.5 MHz beacon, which transmits every three seconds, will be received to allow SAR resources to home-in on the ADELT and the crash site. The technical specification for the ADELT states that it will transmit a tone of 520ms (±1%) duration every 50 secs (±5%) for the 406 MHz transmitter, and a tone of 520ms (±1%) duration every 3 secs for the 121.5 MHz transmitter. The main components of the ADELT System are shown in **Figure No. B1**.

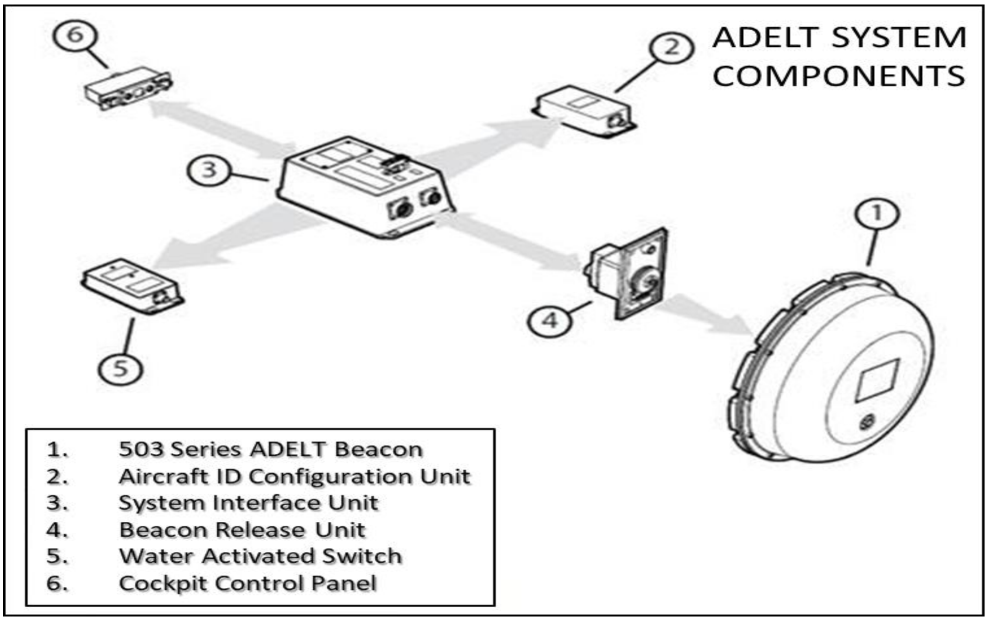

Figure No. B1: The main components of the ADELT System

The ADELT System consists of an ADELT beacon, Aircraft ID Configuration Unit, System Interface Unit, Beacon Release Unit, Water Activated Switch, Cockpit Control Panel, and three crash sensors. The DEB is mounted on the left side of the tail boom and is activated either manually or automatically in response to airframe deformation and/or water submersion. When ejected in flight, aerodynamic forces will carry the ADELT safely away from the aircraft. If ejected on the ground or in the water, the ADELT will fall close to the aircraft to aid in recovery. The system includes three crash sensors, two of which are frangible switches; one below the floor at the aft end of the cockpit and the other amidships.

The third is a hydrostatic switch that is located in the tail-cone near the Beacon Release Unit (BRU). The frangible switches are normally open switches enclosed in glass envelopes that close when crushed. The hydrostatic switch detects water pressure at a depth between three and 10 feet (0.91 to three meters). Upon impact, the crushing of the frangible switch envelope or water pressure will trigger a deploy signal to the BRU.

The Manufacturer informed the Investigation that based on the damage to the ADELT baseplate shown in AAIU Preliminary Report 2017-006, '*The beacon itself would most certainly not continue to function in this condition*.'

-END-

Appendix C — Automatic Identification System (AIS)

1. General

AIS was developed by the International Maritime Organization (IMO) technical committees as a technology to avoid collisions among large vessels at sea that are not within range of shore-based systems. AIS is intended, primarily, to allow ships to view marine traffic in their area and to be seen by that traffic. It enables vessels and Coast Guard shore stations to transmit and receive information regarding identity, position, course and speed of vessels. The AIS standards include a variety of automatic calculations based on these position reports, such as Closest Point of Approach (CPA) and collision alarms. As AIS is not used by all vessels, AIS is usually used in conjunction with radar.

The system requires a dedicated VHF AIS transceiver that allows local traffic to be viewed on an AIS enabled chart-plotter or computer monitor, while transmitting information about the ship itself to other AIS receivers. Port authorities or other shore-based facilities may be equipped with receivers only, so that they can view the local traffic without the need to transmit their own location. All AIS transceiver-equipped traffic can be viewed this way very reliably, but it is limited to the VHF range – about 10-20 nautical miles.

In Ireland, AIS transmissions and information is broadcast over VHF radio by IRCG Operations, via one of sixteen AIS base stations located around the coast and is freely available to those with AIS equipment. Recent regulations have mandated the installation of AIS systems on all Safety Of Life At Sea (SOLAS) vessels and vessels over 300 metric tons, but AIS can be used by small craft as an additional safety feature. The AIS standard also envisioned the possible use on SAR aircraft, and included a message (AIS Message 9) for aircraft to report their position. To aid SAR vessels and aircraft in locating people in distress, the specification (IEC[4] 61097-14 Ed 1.0) for an AIS-based SAR transmitter (AIS-SART) was developed by the IEC's TC80 AIS work group. AIS-SART was added to Global Maritime Distress Safety System regulations effective January 1, 2010. AIS-SARTs have been available on the market since at least 2009.

All IRCG SAR helicopters are equipped with AIS and utilise an R4 AIS Class A Transponder System through the Toughbook.

The AIS aids to navigation (AtoN) product standard was developed with the ability to broadcast the positions and names of objects other than vessels, such as navigational aid and marker positions and dynamic data reflecting the marker's environment (e.g. currents and climatic conditions). These aids can be located on shore, such as in a lighthouse, or on water, platforms, or buoys. AtoNs enable authorities to remotely monitor the status of a buoy, such as the status of the lantern, as well as transmit live data from sensors (such as weather and sea-state) located on the buoy back to vessels fitted with AIS transceivers or local authorities.

[4]**IEC**: International Electrotechnical Commission

An AtoN will broadcast its position and Identity along with all the other information. The AtoN standard also permits the transmit of '*Virtual AtoN*' positions whereby a single device may transmit messages with a '*false*' position such that an AtoN marker appears on electronic charts, although a physical AtoN may not be present at that location.

2. Public Access

AIS data can be viewed publicly on the internet without the need for an AIS receiver. Global AIS transceiver data collected from both satellite and internet-connected shore-based stations are aggregated and made available on the internet through a number of service providers. Data aggregated this way can be viewed on any internet-capable device to provide near global, real-time position data from anywhere in the world. Typical data includes vessel name, details, location, speed and heading on a map, is searchable, has potentially unlimited global range, and the history is archived. Most of this data is free of charge, but satellite data and special services such as searching the archives are usually supplied at a cost. The data is a read-only view and the users will not be seen on the AIS network itself. AIS mobile apps are also readily available for use with Android, Windows and iOS devices.

-END-

7

Appendix D — ToughBook Functionality

In addition to the Helicopter's avionics suite, a stand-alone ruggedized Toughbook computer, loaded with specific application software and map data, was located at the SAR operator's console. The following description was extracted from the Operator's User Guide.

It is loaded with several applications:

1) Memory-Map: This is the main mapping application for rear crew and is suitable for use on all missions, whether inland, coastal or offshore. AIS data is available to Memory-Map via an add-on application.

2) K-Nav: This is an *Excel* spreadsheet application, which is designed to assist with time-distance-fuel calculations.

3) PHECC CPG Book and Field Guide – This is provided for reference.

The Operator's Memory-Map User Guide states:

> '*The Toughbook provides the main electronic mapping and GPS navigation capability for the rear crew. Its main purpose is twofold, namely to assist with mission planning and to provide a back-up and cross-check to the cockpit navigation systems*.'

OMF states '*Secondary navigation equipment: i. Independent GPS position (Memory map, cockpit moving map, GPS)*'.

Memory-Map System Description

The helicopter AIS transponder feed contains a combination of GPS position information and encrypted AIS vessel data. On its own, Memory-Map can utilise the GPS element of the feed to establish the current position of the helicopter; however, it cannot decrypt the AIS element of the feed – to do this it needs to work together with '*Memory-Map AIS'*, which is a separate add-on app, that integrates closely with Memory-Map. Its function is to decrypt the helicopter AIS feed and supply the GPS position and decrypted AIS data to Memory-Map itself in a format that Memory-Map recognises. The AIS feed can only be utilised by a single software application at any given time – if one app is already using the AIS feed it becomes unavailable to any other app on the Toughbook.

There are three main aspects to Memory-Map: the **Map Display**, the **Overlay display,** and the **Navigation display**:

The **Map Display** allows for the viewing of a variety of different map types and scales (Ordnance Survey, Marine and Aeronautical, from 1:2,500 through to 1:1,500,000). The user can select the required map and zoom in/out as necessary.

The **Overlay Display** comprises a wide range of additional data, which forms a layer on top of the chosen map. Individual overlay items can be displayed or hidden as required. Overlay items include current GPS position, pre-planned routes, FMS and temporary waypoints, helicopter '*snail trail*', and AIS items etc.

The **Navigation Display** is used when the GPS signal is live and comprises a separate small window (the '*position window*'), which usually sits on top of the main map window and shows information such as current location, speed, direction of travel, altitude, etc. If a destination has been set, two further windows will also display: one showing destination information (e.g. distance, bearing and ETA to the next waypoint and the final destination) and the other showing an arrow, which indicates the approximate direction to the next and subsequent waypoints relative to the current direction of travel. In order to ensure speed of operation, maps in Memory-Map always display in '*north-up*' format - it is not possible to display maps in a '*track-up*' orientation.

The Toughbook is pre-loaded with the following maps:

- 1:50,000 ordnance survey maps (Island of Ireland) (elevations in m)
- All marine charts (Ireland and UK) (elevations in m)
- IAA 1:250,000 and 1:500,000 aeronautical charts (elevations in feet)
- CAA 1:250,000 and 1:500,000 aeronautical charts (UK) (elevations in feet)
- Road atlas and regional maps (Ireland and UK)

9 **Viewing Map Scale**

Memory-Map doesn't have a scale-bar; however, there are a few alternative ways of providing visual cues:

- When the GPS feed is active and the position icon is visible, an adjustable range ring can be displayed around your current position.

- You can use the route feature to create a single-leg '*route*'. This will display as a line on the map giving a visual indication of the map scale. This can either be an accurate measurement of the distance between two landscape features or can be a convenient distance (e.g. 1 mile, 10 miles etc.) to be used as a scale reference line on a blank area of the map.

Working with Routes

A route is a selection of single points, which are linked together. In Memory-Map, a mark, which is incorporated into a route, is known as a waypoint. Distance and bearing of each leg of the route can be displayed, and if height data is available for the underlying map (OS maps) a surface profile of the route can be viewed, which can be useful to determine areas of high ground.

When GPS is active, a '*Follow Route*' option is available. When activated, Memory-Map will display the direction and estimated time to the next waypoint and to the final destination.

Operator pre-planned FMS routes have been created and saved as an .mmo (memory-map overlay) file and can be imported and displayed as required. This database is updated periodically.

If height data is available for the displayed map (OS maps), right clicking the route and selecting '*Profile*' will display the surface profile along the selected route (with an exaggerated vertical scale). The elevation profile gives an indication of the high ground to be aware of. Moving the cursor along the profile will display a red marker point and the surface elevation at that particular point, along with a corresponding red marker on the map.

The Position Marker

The helicopter position marker will display as a red circle with crosshairs as soon as GPS data is received. In addition, the centre spot of the crosshairs will continually pulse as confirmation that the GPS data stream is live. In the absence of GPS data, the position marker will display in grey at the last known position. The position marker can be displayed with a radius ring, and when the AIS stream is live, a velocity vector line can also be displayed. You can choose to have the position marker stationary on-screen with the map scrolling beneath it (GPS lock on), or the map stationary on-screen with the position marker travelling over it (GPS lock off).

When the AIS stream is live, a '*velocity vector*' can be displayed based on AIS data for the helicopter course and speed. This feature indicates the current direction of travel and the projected future position of the helicopter after a specified time (represented by the head of the arrow). Moving AIS vessels can also be configured to display a velocity vector.

AIS vessel markers

When AIS data is being received, vessels will display as a triangular icon on screen (usually green for moving vessels). The overlay properties box for an AIS vessel is identical to the properties box for the aircraft [helicopter] position marker, i.e. you can display a velocity vector and radius ring for the vessel in the same way as you can for the helicopter.

-END-

Appendix E — Significant Weather Chart

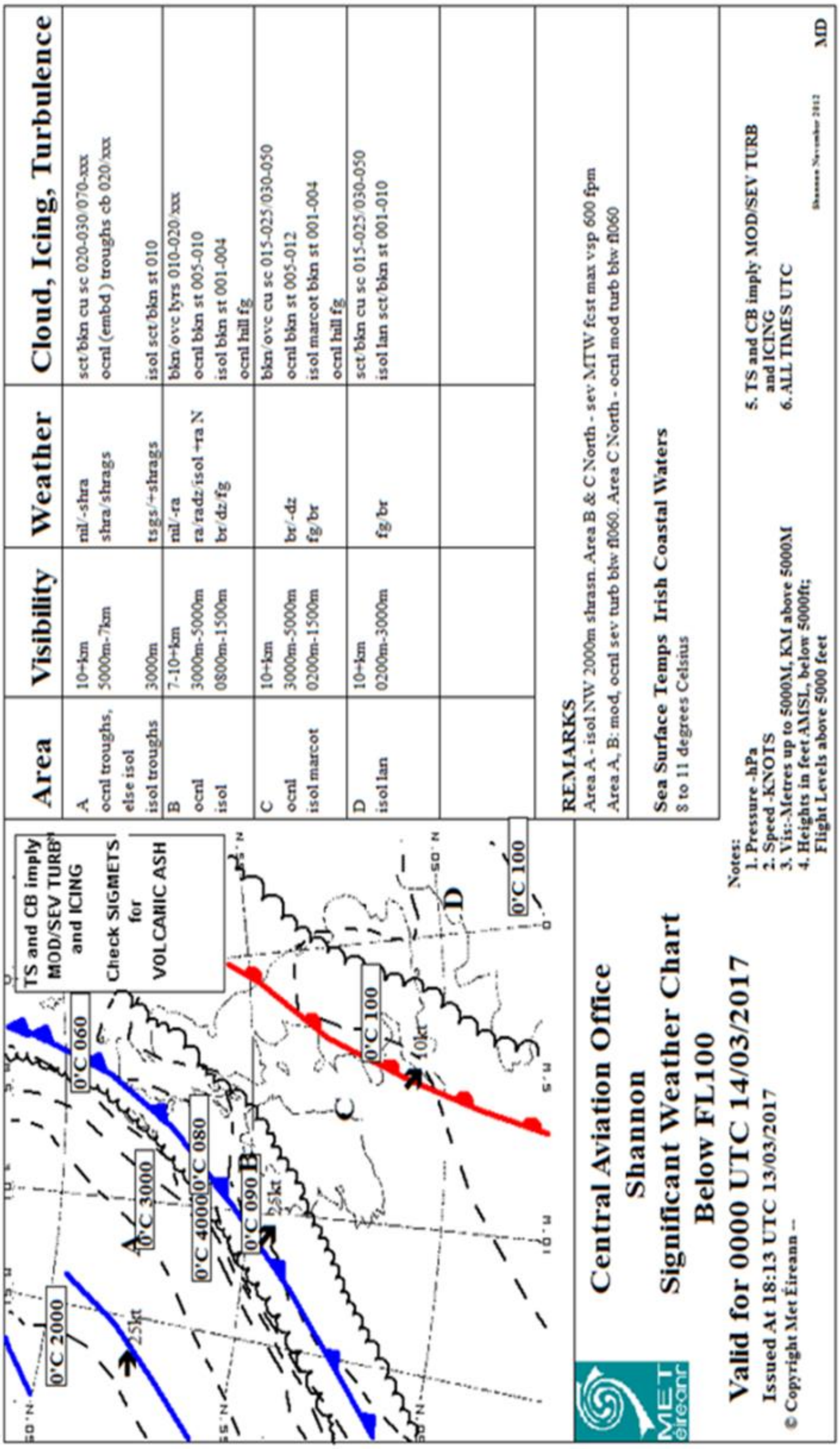

Figure No. E1: Significant weather chart valid for 00.00 hrs UTC 14 March 2017

Appendix F — Meteorological Information

1. Hourly Weather Conditions

Summary of the hourly weather conditions experienced in the occurrence area (18 km west of Blacksod) for the period 23.00 hrs on 13 March 2017 until 04.00 hrs on the 14 March 2017 **(Table No. F1)**.

Date/Time	Wind	Visibility	Cloud Ceiling	Weather
13 March 23.00 hrs	230° 25 kt gusting 35 - 40 kt	3000 m - 6 km with a risk of 2000 m	BKN 1000 - 1500 ft TEMPO 600 - 800 ft	RADAR echoes clear - only risk of very light precipitation. Misty
14 March 00.00 hrs	240° 25 kt gusting 35 - 40 kt	3000 m - 6 km with a risk of 2000 m	BKN 1000 - 1500 ft TEMPO 600 - 800 ft	RADAR echoes clear - only risk of very light precipitation. Misty
14 March 01.00 hrs	240° 25 kt gusting 35 - 40 kt	3000 m - 6 km with a risk of 2000 m	BKN 1000 - 1500 ft TEMPO 600 - 800 ft	RADAR echoes clear - only risk of very light precipitation. Misty
14 March 02.00 hrs	250° 27 kt gusting 35 - 40 kt	5 - 8 km with a risk of 3000 m	BKN 2000 - 2500 ft PROB30 TEMPO BKN 1000 ft	RADAR echoes clear - only risk of very light precipitation. Misty
14 March 03.00 hrs	250° 25 kt gusting 35 kt	5 - 8 km with a risk of 3000 m	BKN 2000 - 2500 ft PROB30 TEMPO BKN 1000 ft	RADAR echoes clear - only risk of very light precipitation. Misty
14 March 04.00 hrs	240° 25 kt gusting 35 kt	10+ km with risk 5 km	BKN 2000 - 2500 ft PROB30 TEMPO BKN 1000 ft	RADAR echoes clear - only risk of very light precipitation.

Table No. F1: Hourly weather conditions for the occurrence area 23.00 - 04.00 hrs

2. Sea Area Forecast

Sea Area Forecast for Irish Coastal Waters issued at 18.00 hrs on 13 March 2017 (**Table No. F2**).

Forecast for Irish coastal waters	From Valentia to Erris Head to Malin Head
Wind:	Southwest force 5 to 7 and gusty, veering southwest to west force 4 to 6 for a time overnight
Weather for all Irish coastal waters and the Irish Sea	Occasional light rain or drizzle. Patchy mist and fog
Visibility for all Irish coastal waters and the Irish Sea	Moderate to poor in precipitation, mist and fog. Otherwise good
Warning of heavy swell	Developing overnight and Tuesday on west and north coasts

Table No. F2: Sea Area Forecast Irish Coastal Waters

3. Belmullet Automatic

A graphical representation of the recorded weather conditions at Belmullet automatic synoptic weather station between 00.00 hrs and 01.00 hrs on the 14 March 2017 **(Figure No. F1)**.

13

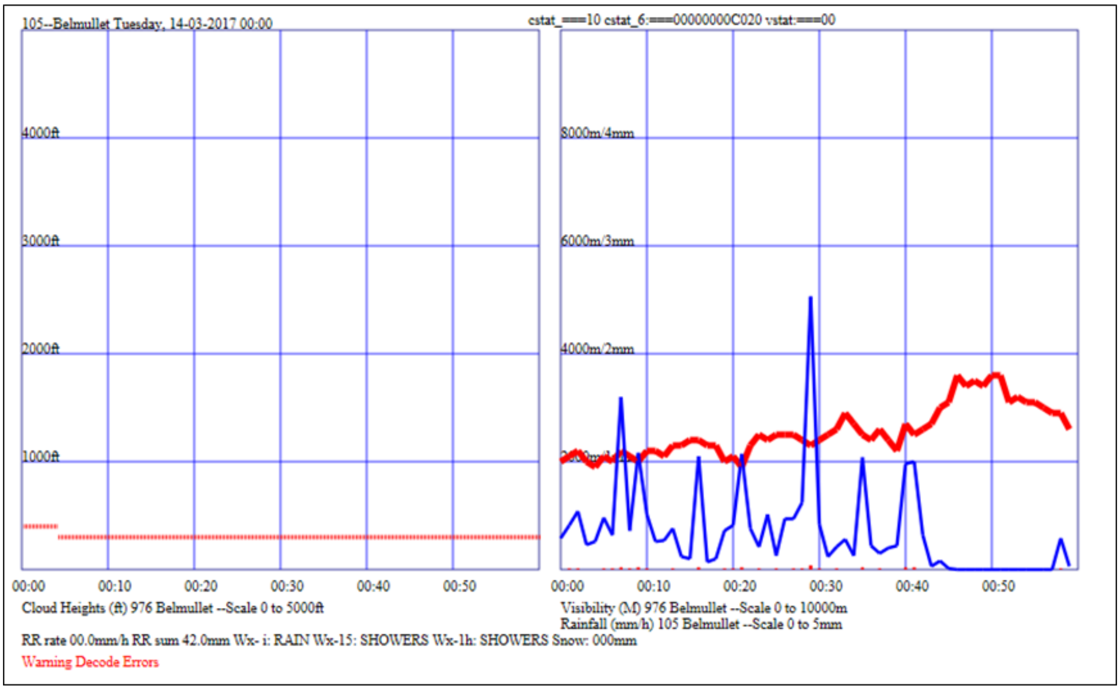

Figure No. F1: Graphical representation of weather conditions Belmullet automatic

4. Forecast for R118 mission and Blacksod Bay

A forecast for a position west of the intended mission location for R118 on the evening of the 13 March 2017, was issued by Met Éireann at 22.34 hrs and is presented as **Table No. F3** (Forecast No. 1).

A second forecast was issued by Met Éireann at 02.28 hrs on 14 March 2017) for the Blacksod Bay area and is presented as **Table No. F3** (Forecast No. 2).

Report Type	Forecast No. 1	Forecast No. 2
Location:	5417N 1406W (263 km west of Blacksod)	Blacksod Bay
Date and Time:	13 March 2017, 22.30 - 04.30 hrs	14 March 2017, 02.30 - 08.30 hrs
Wind (surface):	250° 25 - 30 kt with a 40% probability of a temporary change to 25 kt gusting 40 kt in the same direction	240° 20 kt gusting 30 kt
Wind (1000 ft):	35 kt at 250°	32 kt at 250°
Visibility:	Temporary change between 22.00 and 24.00 hrs of 4 km (30% probability)	In excess of 10 km with a 30% probability that this will temporarily reduce to 5 km
Weather:	Temporary change to rain and drizzle	30% probability of temporary light rain and mist
Cloud coverage and height above mean sea level (MSL):	Temporary change to broken cloud at 1200 ft, 30% probability of a temporary shift to broken cloud at 700 ft between 22.00 and 24.00 hrs	Scattered at 300 ft with broken cloud at 1500 ft, becoming broken cloud at 3000 ft between 03.00 - 06.00 hrs
Air Temperature:	10/11°C	10°C
Sea Temperature:	10°C	9°C
State of Sea:	Very rough becoming high	Rough
MSL Pressure:	1034 hPa	1026 hPa
Freezing Level:	8000 ft becoming 5000 ft	8000 ft
Additional information:	Cold front moving eastwards through area	Cold front clearing eastwards

Table No. F3: Forecast for R118 mission and Blacksod Bay

-END-

Appendix G — Preliminary Report/Interim Statement Safety Recommendation Responses

Preliminary Report

A Preliminary Report into the accident to Sikorsky S-92A, EI-ICR at Black Rock, Co. Mayo, Ireland on 14 March 2017 was published on the 13 April 2017 and contained two Safety Recommendations. The first (IRLD2017005) related to Route Guides and the second (IRLD2017006) related to PLB Installation in Mk44 Lifejackets. Both Safety Recommendations from the Preliminary Report and the associated responses to date are set out below.

Safety Recommendation IRLD2017005

CHC Ireland should review/re-evaluate all route guides in use by its SAR helicopters in Ireland, with a view to enhancing the information provided on obstacle heights and positions, terrain clearance, vertical profile, the positions of waypoints in relation to obstacles and EGPWS database terrain and obstacle limitations.

Response:

On 10 October 2017, the Operator advised the AAIU by letter that:

‘1. CHCI Manager of Flight Operations (MFO) issued Flight Staff Instruction (FSI) – 030 CHCI Route Guide on 14th April 2017 (see attached). This FSI put immediate additional weather controls on the use of all routes within the current route guide, pending the full review in accordance with the Safety Recommendation, and is still in force today.

2. A review of all routes in the CHCI route guide was conducted between April and June 2017 culminating in a general communication sent to all staff by email on the 4th July 2017:

a. Email sent to all CHCI flight and technical crew which provided an update to all personnel on the progress and methodology being used to review the route guide.

b. Plates_Preamble_and_Guides_2017-Jun-30 which provides a detailed explanation of the process for ‘proving’ the routes as well as introducing the new format and content of each route.

c. Proving flight check list_v2 which is the actual checklist to be completed by the crews allocated to conduct each of the proving flights.

3. The first review of ‘proving flight check lists’ provided by crew having flown the revised routes was conducted on 5th September 2017. The review takes into consideration obstacle heights and positions, terrain clearance, vertical profile, positions of waypoints in relation to obstacles and EGPWS database terrain and obstacle limitations. Any revisions required are currently being input and this process is due for completion by 30th October 2017’.

The Operator further advised by email on 12th March 2018 that:

'The Route Guide has been reviewed and re-evaluated in line with the Safety Recommendation contained within the Preliminary Report dated 13 April 2017. Following an extended period of 'proving' the revised routes (a process undertaken by a number of crews from across the bases), pre-publication of the revised FMS Route Guide details had been circulated to crews via a company Ops Memo. The new FMS Route Guide will be formally encapsulated in the relevant Operations Manual (OMC) as part of the next scheduled revision to be submitted to the IAA at the end of March 2018'.

On 12 March 2019, the Operator informed the AAIU that:

'The Route Guide has been reviewed and re-evaluated in line with the Safety Recommendation contained within the Preliminary Report dated 14 April 2017. Following an extended period of 'proving' the revised routes (a process undertaken by a number of crews from across the bases), pre-publication of the revised FMS Route Guide details had been circulated to crews via a company Ops Memo. The new FMS Route Guide will be formally encapsulated in the relevant Operations Manual (OMC) as part of the next scheduled revision to be submitted to the IAA at the end of March 2018'.

1. CHCI Ops Memo No 06/2018 was issued on the 12th March 2018 to inform flight and technical crew of how to access the newly formatted 'FMS Route Guide' in order to review changes prior to its operational introduction.

2. OPS Memo No 07/2018 was issued on the 27th March 2018 delaying the introduction of the new 'FMS Route Guide' until the next FMS cycle update due at end April 2018 and also to permit the routes to be overlaid on the new IRE Aeronautical Charts.

3. The 'go live' date for the new FMS Route Guide was anticipated to be in April 2018. The assumption was that the new IRE Aeronautical charts would be available to CHCI by then. The optimal solution in introducing the new FMS route guide for operational use, would be to have the same revision of IRE Aeronautical charts on the Euronav display, Toughbook, Hard Copy (paper charts) and on the 'cockpit/cabin FMS Route Guide'. As the introduction of the new IRE Aeronautical charts was delayed, OPS Memo No: 09/2018(27 Apr '18) was issued to advise all flight and technical crew that the issue of the new FMS Route Guide would be deferred until the publication of the new aeronautical charts.

4. The following updates to the FMS Route guide were made on completion of the review process. The roll out date for the new FMS Route Guide was scheduled for the end of September 2018:

- *Coastal Routes and Onshore Routes are overlaid on the 2018 Aeronautical charts (except 2 x Heathrow rotes)*

- *New presentation of 'Route description' information*
- *Introduction of 'joining arc' for each route and location of 'initial' waypoint over sea on each Coastal Route.*
- *'Significant obstacle' information displayed on 'Route Description' page and corresponding reference on the respective 'Route Map' page.*
- *Redesign of routes following crew feedback after proving flights*
- *Amalgamation of routes:*
    - *Inisboffin – reduction from 3 to 2 Coastal routes*
    - *Dublin – reduction from 2 to 1 Coastal routes*
    - *Sligo – reduction from 2 to 1 Coastal routes*
    - *Blacksod – reduction from 3 to 1 Coastal Routes*
- *Removal of routes following proving flight feedback*
    - *Cork – 2 Coastal Routes*
    - *Carlingford – removal of Coastal route*
- *Operations Manual text changes in OMC and OMF providing to be used when using the FMS Route Guide.*
- *Introduction of a '90 day' currency item in OMF for the use of the FMS Route Guide for flight and technical crew*
- *Control and Management of FMS Route Guide comes under the direct control of the MFO*

5. The introduction of the new FMS Route guide was delayed from September 2018, due to the ongoing process of configuring the new IRE Aeronautical charts onto the cockpit 'Euronav display'. This was completed with the various 3rd party agencies in October 2018. The revised FMS Master Waypoint database (19 Sept 2018) list was sent for configuration to Euroavionics and a delivery date for this update was given as 21 November 2018. As a result, a 'go live' target date was set for 30th November 2018. The following Ops memos were issued to inform flight and technical crew of the ongoing process:

a) 18/2018 (10 July '18) – IRE Aeronautical charts
b) 19/2018 (1 Aug '18) – Clarification of weather minima for flying the CHCI Route Guide
c) 25/2018 (16 Oct '18) – Euronav system chart revisions
d) 26/2018 (1 Nov '18) – Toughbook update
e) 27/2018 (17 Nov '18) – FMS Route Guide
f) 28/2018 (26 Nov 2018) – FMS Route Guide

6. In addition the following FSI's were issued in advance of the 'go live' date for both OMC and OMF:

a) FSI – 2018 -064 FMS Route Guide information in OMC
b) FSI - 2018 – 417 Changes to OMF

7. The new FMS Route Guide went 'live' on the 30th November 2018 while FSI 2017 – 030 'CHCI Route Guide' issued on the 13th April 2017 (reissued as FSI 2018 – 027 CHCI Route Guide dated 26th April 2018) remained in force until the 14th December 2018 when it was withdrawn.

8. OMC Rev 02 and associated FMS Route Guide were accepted by the IAA on the 4th December 2018.

9. The unrestricted ‘FMS Route Guide’ came into use with CHCI on the 14th December 2018.’

AAIU Comment:

The AAIU notes the Operator's responses and awaits further updates in relation to this Safety Recommendation. While references are made in the Operator's response to files which were provided to the AAIU as supporting material, these files will not be made available by the AAIU to any third party. The Operator provided the Investigation with a copy of the revised Route Guide referred to in its response of 12 March 2019 and the Investigation provided the Operator with some observations. The Investigation considers that this Interim Safety Recommendation remains ‘*Open*’.

Safety Recommendation IRLD2017006

RFD Beaufort Ltd should review the viability of the installation provisions and instructions for locator beacons on Mk 44 lifejackets and if necessary amend or update these provisions and instructions taking into consideration the beacon manufacturer’s recommendations for effective operation.

Response:

On 7 July 2017 RFD Beaufort informed the AAIU by email that:

‘Following our review with CHC Ireland concerning the Mk44 lifejacket and integration of the SARBE 6 406 beacon, we have performed a number of modifications to the lifejacket to optimize the performance of the beacon unit. These changes have also been validated through a trial with CHC and MRCC last month, as the report attached refers.

Our next action is to formalize the service bulletin advising of the change and have one of our Part 145 organizations preform the necessary revision to the CHC lifejackets. An advance draft of the service bulletin is included within the report and we will provide you with a copy of the final version when it is released. We will also advise when all the CHC lifejackets have been updated and returned to them’.

On 8 March 2018 RFD Beaufort further informed the AAIU by email of the following:

‘In May 2017, we (RFD Beaufort), in conjunction with the Operator, carried out a review of the Mk44 lifejacket and the integration of the SARBE 6 406 beacon. Following this review we performed a number of modifications to the lifejacket and validated the changes through a trial with the Operator and MRCC held in June 2017.

In August 2017, we formalised the modification by issuing Service Bulletin 25-147, Version 1. This service bulletin describes the components, tools and method required to install the SARBE 6 406 Beacon in the Mk 44 lifejacket such that the signals from the beacon antennas meet requirements.

In February 2018, we issued Service Bulletin 25-147, Version 2, to provide the maintenance and service personnel more detailed instructions on the installation of the beacon, the routing of cables and positioning of the antennas. A copy of this service bulletin has been provided to EASA.'

On 6 June 2019 RFD Beaufort informed the Investigation by e-mail that:

- SB 25-147 V2 had been issued to all registered holders of the Mk 44 lifejacket Component Maintenance Manual (CMM) and RFD Beaufort believed that all affected units in service had been updated to the latest standard.
- A full review of all RFD Beaufort lifejacket installations and the beacons fitted to them had been completed.

RFD Beaufort also informed the Investigation of changes to its internal procedures:

- All enquiries for commercial lifejackets requiring beacons to be fitted are reviewed. If it is an assembly that has been supplied within the last 2 years, the order can proceed. If not, a full review is carried out to assess the feasibility
- A Design Failure Mode Effects Analysis is carried out on all work.
- The CMM is updated, or created as appropriate, for all new assemblies entering production. The CMM is then checked as part of the initial production phase.

On 6 November 2019, in response to the Investigation's Draft Final report RFD Beaufort informed the Investigation that:

"[...] *communication continued with EASA between February and June 2018. The Manufacturer* [RFD Beaufort] *has provided EASA with copies of all trial documentation, service bulletins, etc. related to this safety recommendation, however, there have been no comments received from EASA."*

EASA informed the Investigation that they had received and reviewed the documentation from RFD Beaufort relating to this Safety Recommendation and that as the modification that was described in SB 25-147 V2 did not affect the primary function of the lifejacket, EASA considered the change acceptable at equipment approval level.

AAIU Comment:

The AAIU notes these responses and considers the status of this Safety Recommendation as "Closed".

First Interim Statement

An Interim Statement into the accident to Sikorsky S-92A, EI-ICR at Black Rock, Co. Mayo, Ireland on 14 March 2017 was published on the 16 March 2018 and contained a further three Safety Recommendations. The first relates to the Flight Data Recording System, the second to the Operator's Safety Management System (SMS) and the third to the Oversight of SAR Helicopter Operations in Ireland. All three Safety Recommendations from the first Interim Statement and the associated responses to date are set out below.

Safety Recommendation IRLD2018001

> The Sikorsky Aircraft Corporation should make the necessary updates/modifications to the S-92A helicopter to ensure that the latitude and longitude information recorded on the Flight Data Recorder reflects the most accurate position information available during all flight regimes and mission profiles.

Response:

In a letter dated 17 July 2018, the Sikorsky Aircraft Corporation advised the Investigation that:

> *'Following the issue of the AAIU's Interim Report dated 16 Mar 2018, Sikorsky's engineering safety leadership team convened to specifically address the AAIU's recommendation. Our S-92 program Platform System Integration lead presented information detailing the findings of the investigation.*
>
> *Sikorsky recognizes that while this is not a safety critical deficiency, incorporating the recommendations of the AAIU would provide a benefit to recipients of the FDR data. It is Sikorsky's intent to incorporate the recommendations of the AAIU in the next update to the S-92A AMS software. Sikorsky is currently wrapping up a three-year certification effort of S-92A AMS software which began in 2015.*

The window for changes to that software closed in 2016, after which all the testing and certification efforts have been accomplished. Sikorsky is currently awaiting foreign validation of the completed update.

The next update to S-92A AMS Software has been funded for planning and requirements analysis. The recommendations of the AAIU have been considered by the analysis team and are on the list for incorporation in the next update. However, because Sikorsky is in the early stages of defining this AMS update, the schedule for completion has not been determined. Once the analysis team completes their recommendations, the list of changes will be sent to the supplier and a proposal requested. Once the suppliers cost and schedule proposal is received, negotiations will begin. Because Sikorsky has executed a project of this type many times in the past, we can confirm that this next AMS update will likely take about three years to complete. That would position the update completion at the end of 2021, with field deployment available to customers starting the next year, 2022'.

AAIU Comment:

The AAIU notes the response of the Sikorsky Aircraft Corporation. The status of the recommendation will remain '*P*' (In process of implementation) until the Sikorsky Aircraft Corporation formally advises the AAIU that the appropriate software update has been distributed.

Safety Recommendation IRLD2018002

CHCI, with external input, should conduct a review of its SMS and ensure that the design of its processes and procedural adherence are sufficiently robust to maximize the safety dividend; this review should consider extant risk assessments and a thematic examination of the corpus of all safety information available to the Operator, both internally and externally.

Response:

On 24 July 2018 CHCI informed the Investigation that:

'As part of continued internal safety oversight of CHCI, we have engaged with two independent aviation SMS specialists to carry out compliance audits as per EASA ORO.GEN.200 requirements. To complement this we will continue to carry out corporate SMS oversight audits.

In addition all SMS processes are currently being subjected to a rigorous review in order to ensure that their design and subsequent procedural adherence are sufficiently robust to maximize the safety dividend. This review will consider extant risk assessments and a thematic examination of the corpus of all safety information available to CHC Ireland, both internally and externally.

The results and output of the review will be the subject of analysis by an experienced independent aviation safety expert.

These various activities will ensure CHCI's SMS continues to meet all regulatory, contractual and internal safety requirements'.

AAIU Comment:

The AAIU notes the response of CHCI and awaits further updates on this ongoing work.

Safety Recommendation IRLD2018003

The Minister for Transport, Tourism and Sport, as the issuing authority for the Irish National Maritime Search and Rescue Framework, should carry out a thorough review of SAR aviation operations in Ireland to ensure that there are appropriate processes, resources and personnel in place to provide effective, continuous, comprehensive and independent oversight of all aspects of these operations.

Response:

On 13 June 2018, the Secretary General of the Department of Transport, Tourism and Sport, writing on behalf of the Minister, informed the Investigation by letter that:

'The review is underway and is being conducted by a three-member independent consultancy team whose members have extensive range of experience in the areas of aviation regulation, Search and Rescue requirements, safety oversight, auditing and Search and Rescue operations. It is expected that the review should conclude within two months and a report with recommendations will be published.

The terms of reference for the consultancy team require them to focus in particular on:

- *The specific reports, audits and frameworks highlighted in the AAIU's interim statement in relation to oversight arrangements for Search and Rescue (SAR) aviation operations, including any follow-up actions arising from these.*
- *The practices and procedures in place for oversight of SAR aviation operations within the IAA, as the national aviation regulator and the Irish Coast Guard, as the tasking authority for SAR aviation operations, and any other entities deemed relevant, and benchmark them in terms of their effectiveness, continuity, comprehensiveness and independence against models of best practice internationally (ideally using analogous models of SAR provision).*
- *The legal basis underpinning the oversight roles related to SAR aviation operations.*
- *The resourcing of these roles and processes within each organisation.*

Based on a thorough review of these and any other issues determined by the Reviewer as relevant to the AAIU recommendation, the review should:

- *Identify any gaps or lack of clarity in terms of roles, legal vires, processes, training, resources and/or personnel within these organisations to carry out their oversight of SAR aviation operations.*

- *Make recommendations on practical measures to address these to ensure oversight arrangements for SAR aviation operations in Ireland measure up to international best practice in terms of effectiveness, continuity, comprehensiveness and independence.*

In order to meet the requirements of the recommendation in the AAIU's interim statement, the review will need to be completed as a matter of urgency'.

On 20 September 2018 the Secretary General of the Department of Transport, Tourism and Sport provided the Investigation with a copy of a consultants' report, which was subsequently published on the DTTAS website on 21 September 2018.

The Investigation notes that the consultants' report contains 12 recommendations.

On the 3 July 2019 the Secretary General of the Department of Transport, Tourism and Sport provided a further response to the AAIU in relation to AAIU Safety Recommendation No IRLD2018003:

23

In its interim report (No.2018-004), the AAIU called on the Minister for Transport Tourism and Sport to carry out a thorough review of SAR aviation operations in Ireland to ensure that there are appropriate processes, resources and personnel in place to provide effective, continuous, comprehensive and independent oversight of all aspects of these operations.

As notified to you on 24 August 2018, this review was completed and the report was published on 21 September 2018. As you know, the Minister accepted the 12 recommendations and set out a series of actions to follow-up on the report. He also undertook to keep the AAIU updated on developments on a periodic basis.

Please find attached, (see link below) herewith the latest update in the form of a report from the SAR Framework Review Group, including various appendices, notably a new National SAR Plan (to replace the existing National Maritime SAR Framework document).

Apart from those AQE recommendations specific to the terms of reference for the Review of the SAR Framework itself, the report also provides progress updates on the other recommendations arising from the AQE Report.

The Minister has approved the report and the National SAR Plan. He is bringing the report to Cabinet for their information next week.

On the 19 July 2019, the Minister issued a Press Release relating to the National SAR Plan and other matters relating to ongoing response to AAIU Safety Recommendations No. IRLD2018003:

Http://www.dttas.ie/press-releases/2019/minister-ross-publishes-new-national-search-and-rescue-plan-ireland

AAIU Comment:

The AAIU notes the responses from the Department of Transport, Tourism and Sport and awaits further updates.

Note: Further Safety Recommendation responses received post-publication of the Final Report can be viewed on each Safety Recommendation link contained within the Report itself.

-END-

Appendix H — Extracts from OMA and OMD (Route Familiarisation)

OMD Vol 1-1 states:

'2.1.10 Route and aerodrome competence qualification
[…] The Company shall only designate a flight crew member to act as commander if they have:
[…]
b. Adequate knowledge of the route or area to be flown and of the aerodromes, including alternate aerodromes, facilities and procedures to be used

2.1.10.2 Required training

Aerodrome and area of operation training is required for pilots to qualify them for areas of operation to which they are assigned. Before being assigned, the pilot shall undergo initial familiarisation training to ensure they have obtained adequate knowledge of the route to be flown and of the heliports (including alternates), facilities, and procedures to be used. Training ensures safe operations and is detailed as follows:
[…]
c. Required for each geographic area of operation
d. Route and aerodrome competence flights flown under supervision of a training pilot may be required with the amount of flights determined on a case-by-case basis
e. Sub-bases (an additional base with the same scope of work within the same country) do not require an additional route and aerodrome check, however the local base area examination or detailed briefing shall cover any differences to mitigate risk. An orientation should also be provided upon arrival at a sub-base, with documentation to record that the pilot has been thoroughly prepared. Course details are provided in OMD Vol 3, and training is recorded in the QMS or other approved tracking program.'

OMD Vol 3 states:

'2.1.10 Route and aerodrome competence
[...] *For commercial air transport (CAT) operations, the experience of the route or area to be flown and of the aerodrome facilities and procedures to be used shall include the following:*

a. Area and route knowledge
i. Area and route training should include knowledge of:
A. Terrain and minimum safe altitudes
[...]
ii. Depending on the complexity of the area or route, as assessed by the Company, the following methods of familiarisation should be used:
A. For the less complex areas or routes, familiarisation by self-briefing with route documentation, or by means of programmed instruction;
and

B. In addition, for the more complex areas or routes, in-flight familiarisation as a PIC / commander or co-pilot under supervision, observer, or familiarisation in a flight simulation training device[5] *(FSTD) using a database appropriate to the route concerned*
b. Aerodrome knowledge
i. Aerodrome training should include knowledge of obstructions, physical layout, lighting, approach aids and arrival, departure, holding and instrument approach procedures, applicable operating minima and ground movement considerations
ii. Knowledge of the method of categorisation of aerodromes and, in the case of CAT operations, where a list of those aerodromes categorised as B or C is documented (usually OMC)
iii. All aerodromes to which the Company operates should be categorised in one of these three categories:
A. Category A: an aerodrome that meets all of the following requirements:
I. An approved instrument approach procedure
II. At least one runway with no performance limited procedure for takeoff and / or landing
III. Published circling minima not higher than 1000 feet above aerodrome level; and
IV. Night operations capability
B. Category B: an aerodrome that does not meet the category A requirements or which requires extra considerations such as:
I. Non-standard approach aids and / or approach patterns
II. Unusual local weather conditions
III. Unusual characteristics or performance limitations; or
IV. Any other relevant considerations including obstructions, physical layout, lighting etc
C. Category C: an aerodrome that requires additional considerations to a category B aerodrome […]'

The Operator informed the Investigation that it '*would regard our 4 bases as category A aerodromes.'*

OMA Chapter 8 '*Operations procedures*' states:

8.1.1 Minimum flight altitudes
CAT.OP.MPA.145, CAT.OP.MPA.270, SERA.3105, SERA.5005(f)
The minimum altitude or flight level except for the purpose of takeoff and landing shall be the highest of national regulations, ATC requirements, published procedures and minimum altitudes for specified routes.

a. IFR flights onshore:

IFR flights shall be conducted at an altitude / flight level ensuring:
i. *1000 feet terrain or obstacle clearance for elevations up to 5000 feet*
ii. *2000 feet terrain or obstacle clearance for elevations exceeding 5000 feet*

[5] The Investigation was informed that routes from the Route Guide were not available for use in the FSTD that the Operator used.

These minimum altitudes shall be sufficient for navigation signal reception and for communication with flight following. These minimum altitudes shall be corrected if necessary for the effects of wind, temperature and pressure.

b. IFR flights offshore:

The minimum cruising altitude shall be 1000 feet MSL providing radar does not identify any obstacles within 5 nm of aircraft track. If any obstacles are identified within 5 nm of track, the minimum cruising altitude shall be 1500 feet, or higher if a known obstacle exceeds 500 feet.

c. VFR flights:

Except by permission from the competent Authority, a VFR flight shall not be flown:
i. *Over the congested areas of cities, towns or settlements or over an open air assembly of persons at a height less than 1000 feet above the highest obstacle within a radius of 600 m from the aircraft*
ii. *Elsewhere than as specified in* ***i.*** *above, at a height less than 500 feet above the ground or water, or 500 feet above the highest obstacle within a radius of 150 m from the aircraft*

Commanders shall ensure that flight does not take place below the minimum altitude or flight level for the route except when necessary for takeoff and landing.

8.1.1.1 Altitude selection

Cruise altitude shall be selected in accordance with tables of cruising levels as described in the AIP ENR. Commanders are to give due regard to weather, wind, icing, turbulence, etc., when selecting altitudes. For offshore operations in strong winds, the lower altitudes should be avoided due to salt laden atmosphere, which reduces the efficiency of rotors and engines.

[…]*When operating within 20 nm of terrain with a maximum elevation above 2000 feet AMSL, the effect of wind may create pressure variations. Commanders are to increase the minimum flight altitude according to the table below.*

[…]
8.1.1.6 Minimum IFR flight altitudes

Commanders are responsible for ensuring that flight does not take place below the minimum altitude or flight level for the route except when necessary for takeoff and landing or in accordance with section 8.1 Flight preparation instructions.

There are various definitions for and methods of calculating minimum flight altitudes. The common terms are MEA [Minimum En route Altitude]*, MOCA and MORA, all of which equate to a correctly calculated minimum safe altitude appropriate to the flight. Those terms used within CHC are described below. For convenience, the term MSA is normally used in the OMB and associated checklists.*

8.1.1.7 Minimum obstacle clearance altitude (MOCA)

The MOCA represents the minimum safe altitude on a defined route. On published routes defined by navaids or waypoints, for example airways, MOCA for that route will be shown or may be calculated. Chart MOCA for an airway between VORs, for example, will be valid for a maximum assumed width of airway of 20 nm out to 140 nm from the VOR. Note also that the minimum usable flight level may be above the MOCA for the route. Within the Company, MOCA is defined as:

a. *The elevation of the highest obstacle within 5 nm of a route extending a maximum of 100 nm from navigation aid to navigation aid or between defined waypoints in the area navigation equipment, including a circle radius 5 nm round the fix or waypoint, rounded up to the next 100 feet, plus*

b. *An appropriate altitude increment from the table below*

Calculation of MOCA:

Elevation of obstacle	***Altitude increment***
Below 5000 feet	*1000 feet*
5001 feet or above	*2000 feet*

8.1.1.8 Minimum off-route altitude (MORA)

The MORA represents the minimum safe altitude when not on a defined route. When operating off published routes (for example, when on a direct routing) it is essential that pilots calculate an appropriate MORA by referring to the relevant chart. Depending on the chart convention, it will either show the appropriate grid safety altitudes, or the MEFs, from which the basic MORA may be calculated. MORA is calculated on a similar basis to MOCA as follows:

a. *The elevation of the highest point in the applicable grid square through which the track runs, rounded up to the next 100 feet, plus*

b. *An appropriate altitude increment from the 'Calculation of MOCA' table above.'*

-END-

Appendix I — Communications Equipment

Introduction

The S-92A helicopter is equipped with a wide array of communications equipment, with voice and data capabilities, for use during SAR missions. This Appendix focuses on the voice communications between the Crew Members within the Helicopter, and the external communications with the supporting organisations, such as Air Traffic Control, other aircraft, other helicopters, IRCG radio stations or bases.

Communication Controls

The heart of the helicopter's communication system, both internal and external, is the *dB Systems* (now *Cobham*) *Model DB380 Audio Controller Panel* (**Figure No. I1**). There are five of these panels located throughout the helicopter. Their purpose is to link the various radio and communication systems to the microphone and headset/speakers in the cockpit and cabin in order to enable the selection of the required source by each person on board the helicopter. The panel consists of three rows of controls, which are labelled '*Radio Transmit', 'Radio Receive'/'Vol',* and '*NAV receive*'. There are additional buttons on each row that have specific features not directly associated with the three main categories.

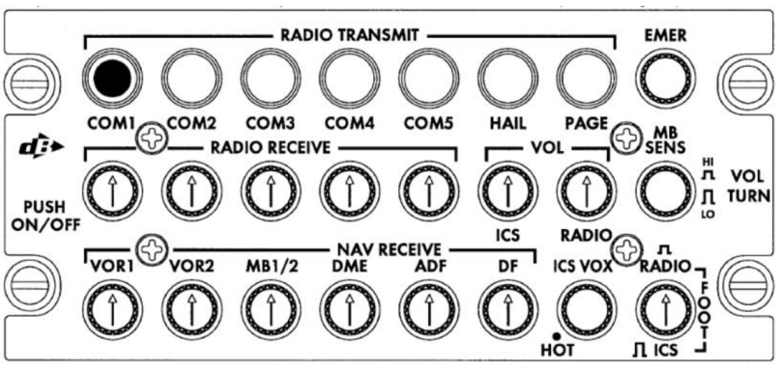

Figure No. I1: DB380 Audio Controller Panel designed for IRCG S-92A Helicopters

The '*RADIO TRANSMIT*' buttons (top row) are used to select the radio that is to be used by the crew member for transmitting. Each button is a single use pushbutton. In the example shown in **Figure No. I1**, COM1 is selected for transmission and receipt of audio on the COM1 selected frequency. Pressing any of the other COM buttons on the same row would select that source for transmit and receive, while simultaneously causing COM1 to deselect by popping the associated button up again. This ensures that only one source is in use for transmission at any time. The HAIL function is disabled on the ICRS S-92A. The PAGE button is used for making internal cabin announcements. The EMER button links the pilot's headset and microphone directly to the respective on-side's COM1 or COM2 box in order to maintain communications with ATC in the event of a failure of the DB380 box.

The centre row of the Audio Controller Panel consists of RADIO RECEIVE knobs, which are used to select the source that the user can hear in their headset or on the speaker system. Each control is a push/pull rheostat type control.

The rheostat is turned to control the volume of the respective individual source, and pulling the button up enables the audio source to be heard by the user. Unlike the TRANSMIT function, the RECEIVE function can be enabled for multiple radios at the same time. The VOL knobs to the right of the centre row control the volume for the Interphone Communication System (ICS), and a combined master volume control for the RADIO RECEIVE sources. The MB SENS knob controls the sensitivity and volume of marker beacons that are used during an ILS approach.

The bottom row of the Audio Controller Panel consists of NAV RECEIVE knobs, which are also of the push/pull rheostat type control knobs. These are used to listen and control the audio volume of the various radio navigation sources available to the crew. The purpose of these volume controls is to permit identification by the crew of navigation beacons that transmit a discreet Morse code signal. Some airports or ATC organisations transmit important navigation and weather information on the navigation beacon frequency. The ICS VOX knob controls the quality of the interphone signal (known as '*squelch*') and the RADIO/ICS FOOT button at the lower right corner of the box controls the functioning of the foot transmission switches which are located on the cockpit floor at the pilot and co-pilot stations. The locations of the Audio Panels are shown in **Figure No. I2**. The rear passenger cabin has been omitted for clarity.

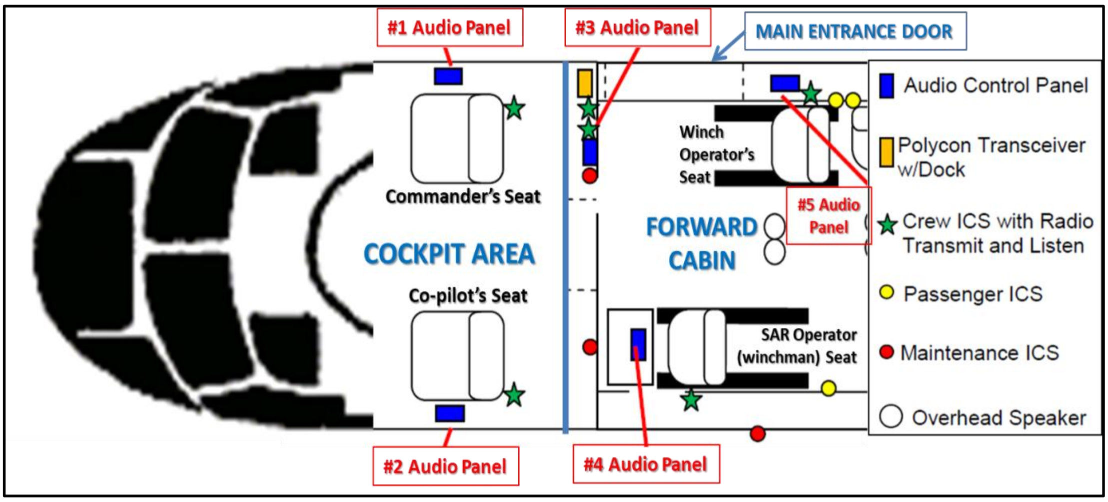

Figure No. I2: Audio Panel Locations

The radio communications systems available to the crew are as follows;

- COM1 enables VHF1 (Collins VHF -422D radio) audio, transmit/receive.
- COM2 enables VHF2 (Collins VHF -422D radio) audio, transmit/receive.
- COM3 enables FLEXCOMM II (Global Wulfsberg RT-5000) audio, transmit/receive.
- COM4 enables SATCOM (Skytrac ISAT-100) audio, transmit/receive.
- COM5 enables TETRA (Chelton 7-450) *or* Honeywell HF1050 audio, transmit/receive.

The TETRA radio and HF radio share the COM5 channel on the Audio Controller Panel. The active radio is selected by use of a separate COM5 toggle switch located beside each of the five Audio Controller Panels. The HF control head which permits the selection of the required radio frequency is located on the main cockpit instrument panel just below MFD5. A change to the desired HF frequency would require the rear crew member to request a member of the cockpit crew member to manually tune the HF control head. The TETRA control panel is located at the SAR Operator's Station.

The crew ICS enables effective communication between the flight crew, those in the cabin, and maintenance crew as required. There are a total of 19 ICS jack-sockets. These are located in the cockpit area, at the main entrance door, and in the main cabin. The jack-sockets are installed in the cabin ceiling to allow a user to easily plug in a headset and microphone. The S-92A ICS system is separated into distinct zones (**Figure No. I3**[6]) and is designed so that both crew and passengers may communicate independently.

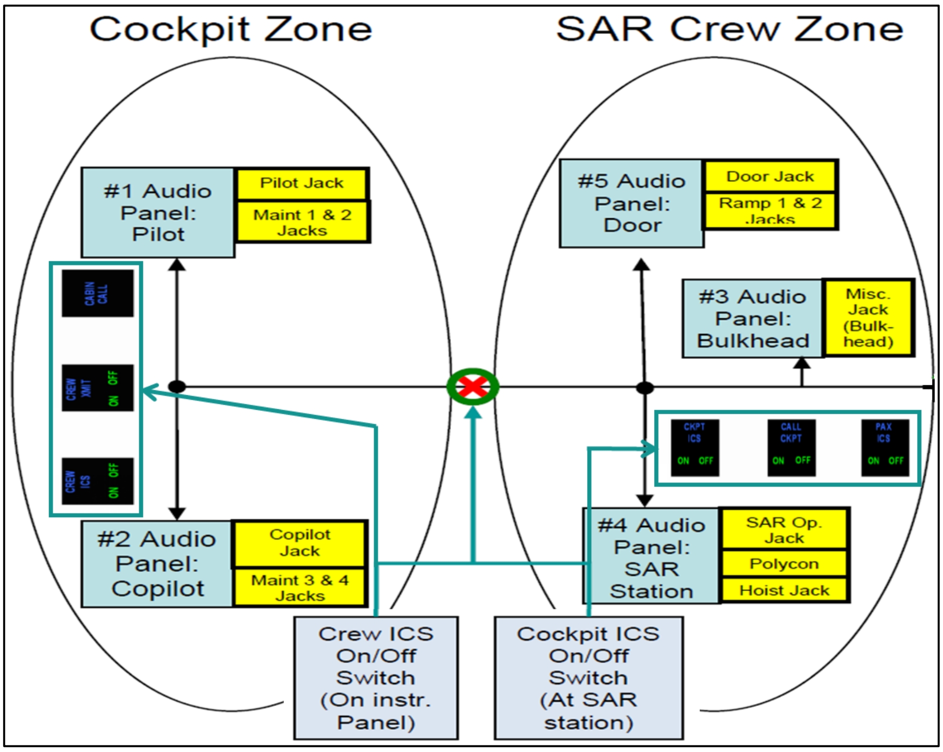

Figure No. I3: S-92A ICS Zones

The '*SAR Crew Zone*' ICS is controlled from annunciator switches at the SAR operator's station, although the cockpit crew has the ability to override the selection if required. The '*Cockpit Zone*' ICS is controlled from annunciator switches in the centre of the cockpit instrument panel. This allows the flight crew to isolate the cockpit zone from all other ICS zones when a sterile cockpit environment is necessary. The configuration of the ICS annunciator switches are not recorded on the FDR or HUMS.

-END-

[6] There is a third *'Passenger Zone'* which has been omitted from **Figure 999** for clarity.

Appendix J — R116 Radio Communications

All communications between the Helicopter and ATC during the flight were conducted by either the Pilot, or the Co-pilot. The first communication from the Helicopter was to Dublin Ground Control by the Co-pilot at 22.53 hrs, and consisted of a verbal flight plan request, and confirmed that there were four persons on board. The Co-pilot stated at that time that they were unsure whether the destination would be Sligo or Blacksod, and that they might need to use RWY 28 for departure. Dublin Ground acknowledged the transmission and asked if R116 was ready to start engines. The Co-pilot confirmed that they were ready, and ATC granted start clearance. Dublin Ground asked R116 to confirm if RWY 28 was essential as the active runway was about to change and might result in a delayed departure. The Commander replied that R116 was happy to use RWY 16 for departure. At 23.01 hrs the Co-pilot advised that R116 was ready for departure and that they could depart from RWY 16. Dublin Ground Control handed R116 over to the Tower frequency. The Tower subsequently cleared R116 for take-off and the Helicopter departed Dublin at 23.02 hrs. The Co-pilot confirmed that R116 would be departing from RWY 16 as they were '*quite heavy here with fuel*'.

After departure, the Tower cleared R116 to route on a westerly heading and climb to an altitude of 3,000 ft, which was read-back to ATC by the Co-pilot. At 23.07 hrs the Tower handed R116 over to Dublin Centre frequency 132.575 MHz for onward clearance. The Co-pilot acknowledged the handover and immediately contacted Dublin Centre. The Co-pilot requested a right turn onto a heading of 310 degrees. Dublin Centre advised the Helicopter to turn initially onto 290 degrees. The Co-pilot acknowledged and confirmed that 3,000 ft would be acceptable as the Helicopter's cruising altitude. At 23.12 hrs, the Co-pilot contacted Dublin Centre and asked if it was ok for R116 to route direct to Sligo. Dublin confirmed that R116 was cleared for '*own navigation and terrain separation*'. At 23.14 hrs, the Co-Pilot advised Dublin that R116 would require 4,000 ft altitude at some stage in the flight. Dublin approved climb to 4,000 ft and the Co-pilot acknowledged the clearance.

Following a crew discussion about destination planning, the Commander called Dublin Centre at 23.21 hrs to change the Helicopter's destination from Sligo to Blacksod, near Belmullet, Co. Mayo and that this would entail a left turn of approximately 20 degrees. Dublin Centre confirmed the re-routing and that R116 would be handed over to Shannon Centre in about 12 miles. At 23.26 hrs, Dublin centre advised R116 to contact Shannon Centre on 119.075 MHz.

At 23.27 hrs, the Commander called Shannon ATC and advised that R116 was seven miles south of Kells at 3,000 ft on a QNH of 1029 hPas and confirmed that they were routing to Blacksod and not Sligo. Shannon ATC advised that R118 was passing the west coast at that time but was not in radio contact. Shannon requested R116 to contact R118 to request them to call Shannon ATC. The Winchman noted at this time that R118 was on the AIS display at 12 miles west of Blacksod. At 23.34 hrs, following a call on TETRA by R116, R118 called Shannon ATC and provided an estimate arrival time at the casualty vessel of 00.47 hrs.

At 23.51 hrs, the Commander requested, and received confirmation from Shannon that Connaught Airport was closed and had no traffic as they would be routing over the top of the airport.

At 00.01 hrs, the Winch Operator requested the Commander to try and call R118 on the Aero-VHF frequency. The Commander called first on the Operator's Company frequency of 131.875 Mhz and then responded '*nope*'. The Co-pilot suggested that they could ring them on the Sat Phone, to which the Winch Operator replied '*yeh, if we got desperate*'. The Commander then tried to call R118 on 123.1 Mhz and again said '*nope*' soon after. The Commander also remarked to the other crew that they were at 4,000 ft and directly overhead Connaught Airport. At 00.07 hrs, the Commander tried again on the Operator's company frequency to call R118. No reply was received. The Commander then called Shannon ATC to ask if they have two-way communications with R118. Shannon did not, but offered to conduct a radio relay through another commercial aircraft to establish contact with R118. At 00.09 hrs, Shannon called the Lufthansa Cargo 8231 and requested them to call R118. This aircraft was high level and in the vicinity of the casualty vessel. The aircraft called R118 requesting a position and ETA for the fishing vessel. There was no reply.

At 00.15 hrs, the Co-pilot called Shannon Centre and requested the latest weather for Sligo. Shannon replied that they would need to call the controller for the current weather. The Shannon controller then provided the Sligo TAF which the Co-pilot acknowledged. At 00.17 hrs, Shannon provided R116 with the METAR for Sligo which the Co-pilot acknowledged. At 00.18 hrs, Shannon provided R116 with the TAF for Dublin Airport, which the Co-pilot acknowledged.

At 00.19 hrs, Shannon asked R116 how far west they intended to go, and whether they would go all the way to the vessel. The Co-pilot replied that it was not their intention, but that it was a possibility. He also advised Shannon that they were having problems establishing two-way communications with R118. He said that they would '*land-on Blacksod refuel and eh we'll, we'll figure it out from there Rescue one one six*'.

At 00.34 hrs, the Co-pilot called Shannon and advised that R116 was leaving 4,000 ft and making their way into Blacksod for refuelling. Shannon requested R116 to call again when airborne. The Co-pilot acknowledged this request. This was the last transmission received from R116. At 01.11 hrs Shannon attempted to call R116 but received no reply.

Other Radio Communications

There was no indication from the CVR that either pilot or the Winchman transmitted on any of the non-ATC radios. Other radio communications were conducted by the Winch Operator for the duration of the flight.

The first transmission by the Winch Operator that was recorded on the CVR was at 22.58 hrs. It was on the TETRA radio and it was an advisory call to MRCC Dublin that R116 was starting engines on the ramp at EIDW. MRCC Dublin acknowledged the transmission.

While TETRA was being used for communications with MRCC Dublin, at 23.02 hrs during the take-off sequence, the CVR recorded the sound of a transmission advising all stations of the marine weather forecast for the east coast, including Carlingford, Dublin, Wicklow Head and Rosslare areas. This indicated that the Winch Operator was maintaining a listening watch on Marine Channel 16.

At 23.03 hrs, just after the Helicopter was airborne, the Winch Operator called MRCC Dublin to advise that they were airborne and enroute to Sligo initially with four people on board and a fuel endurance of three and a half hours. He advised that the next call would be on Marine Channel 83. MRCC Dublin acknowledged the transmission. At 23.06 hrs, R116 called R118 on the TETRA radio. R118 replied that they were receiving R116 strength 5 and requested R116 to standby as R118 was landing at Blacksod, and that they would call R116 when on the ground. R116 replied to R118 that he just wanted them to know that R116 was airborne from EIDW.

At 23.11 hrs, R118 is heard on the CVR calling Malin Head Coastguard advising that they are on the ground at Blacksod and receiving fuel. R116 then called R118 to request the weather conditions at Blacksod. R118 advised that conditions at the pad were fine, that there was some low cloud approximately five hundred feet up to the north while they were inbound through Broadhaven Bay. The Winch Operator acknowledged this transmission and advised the Commander that the conditions at Blacksod were good. The Winch Operator then responded to what he believed was a call from MRCC Dublin. MRCC Dublin advised that they did not call, but that Malin Head Radio now had flight watch on R116. At 23.13 hrs, R116 called Malin Head Radio and advised that their destination was Sligo, and that they would advise if this changed. Malin Head Radio acknowledged this transmission. R116 then called MRCC Dublin on Marine Channel 83 to advise that they had established communications with Malin Head Radio, but that they would stay with MRCC Dublin for the moment. The Winch Operator then advised the Commander that R116 had established 2-way communications with Dublin on Marine Channel, and with R118 on TETRA.

At 23.20 hrs, the Winch Operator contacted Malin Head Radio and advised them that R116 was now proceeding direct to Blacksod with an estimate of one hour and twelve minutes for arrival, and that they were listening on Marine Channel 16. Malin Head Radio acknowledged the transmission and advised that they would notify the staff at Blacksod of their arrival details. At 23.21 hrs, R118 called R116 on TETRA and advised that they had departed Blacksod routing out to the west, that they had heard R116's communication with Malin Head Radio in relation to R116 heading to Blacksod. R116 replied that they would be operating on Marine Channel 16 and probably a HF frequency as well.

R118 did not reply to this transmission, but Malin Head Radio interjected that R118 had received the transmission from R116 and that they were transmitting on marine radio at the time. R116 requested a HF frequency and Malin Head Radio advised 3023 kHz. Malin Head Radio advised that they were getting the casualty vessel very well, that they were transmitting on 1677 kHz and receiving on 2102 kHz. Malin Head Radio offered to conduct a radio check with R116 on HF, but the Winch Operator suggested that they wait for around 30 minutes. Malin Head Radio acknowledged this transmission. The Winch Operator requested the Flight Crew to tune 3023 kHz on the HF radio in the cockpit.

At 23.33 hrs, the Winch Operator called R118 on TETRA and advised that Shannon ATC were looking to talk to them. R118 acknowledged the transmission. R118 was subsequently heard on the R116 CVR calling Shannon ATC on the aero-VHF frequency. At 23.37 hrs, R116 called MRCC Dublin on Marine Channel 83, advised that they were '*Ops Normal*', passing Longford, and were going to hand over helicopter watch to Malin. MRCC Dublin acknowledged the transmission.

R116 then called Malin Head Radio to advise the transfer of flight watch, that R116 was listening on Marine Channel 16, TETRA and HF. The Winch Operator then requested the non-handling pilot to tune channel 16 on the marine radio. There then followed a sequence of communications on HF and TETRA that continued regularly for the remainder of the flight as R116 tried unsuccessfully to establish communications on HF with Malin Head Radio or R118. During this period, the various crew members commented on the quality of the on-board communications. At 23.41 hrs, the Winch Operator noted '*Good ol' HF…it's terrible, eh bad, nearly unworkable'* following a sequence of test calls that Malin Head Radio could not receive.

At 23.46 hrs, Malin Head Radio called R116 on TETRA and advised that they were trying to establish two-way communications with R118, and asked R116 to do a radio check on the HF frequency of 2182 kHz. The Winch Operator asked the Co-pilot to tune the frequency on the HF radio in the cockpit. The Co-pilot asked the Winch Operator in response '*do you have to key the, the mike for this to do the, the way it used to do the old way, for tuning it*.' The Commander interjected '*don't know*'. The Winch Operator did not answer the Co-pilot's question directly, but began calling Malin Head Radio on the HF radio. The CVR recorded a garbled response on the HF frequency. The Winch Operator called Malin Head Radio on the TETRA and described the HF as '*Strength two, a lot of background noise, unworkable really*'. Malin Head Radio requested R116 to maintain communications with R118 on Marine Channel 16. R116 then began to call R118 on channel 16 without success. The Co-pilot then suggested trying HF again as he had just made some changes to the 'squelch' settings on the radio.

The Winch Operator continued to attempt contact with R118. He noted that Malin Head Radio was unreadable on HF, and strength one on Marine Channel 16. R118 was unreadable on any frequency. At 23.51 hrs, the Winch Operator stated that '*yeh no point in us not having comms with one one eight. That's what we're here for.*'

The Commander asked '*were you chatting with them on it before?*' to which the Winch Operator replied that '*yeh I was but now they've gone out of reach of TETRA once they go off shore by twenty miles they're out of reach of TETRA so I'm trying to get them now on sixteen and HF…anything at all just to make contact would be..*'. At 23.54 hrs, Malin Head Radio advised R116 that they wanted to try an optional piece of equipment and asked R116 to do another HF test call. During this transmission, Malin Head Radio also advised that '*I just wanted to let you know as well actually while I've got you that the visibility at eh Blacksod is now down to three nautical miles that's three miles Over*'.

Over the following period, R116 continued unsuccessfully to contact Malin Head Radio on HF and R118 on HF or marine radio. At 23.59 hrs, the Winch Operator asked Malin Head Radio if they had contact with R118. Malin Head Radio responded that '*I'm going to try them again there now on sixteen briefly but he's moving further out now so that's obviously just a bit concerning that we might not be able to establish contact with them there via HF so I'll just try them once more on sixteen*'. During this period there was an internal discussion about the communications in general. The Winch Operator said that '*this all happened last week as well it's an almighty* [mess] *with the radio*'. The Co-pilot asked if the HF worked the previous week, to which the Winch Operator replied '*no it didn't we drop kicked it we got fed up with it after about ten minutes and we went onto sixteen, never known it to work yeh we were high enough then to keep in contact on sixteen with the eh one one eight ah it never works*'.

In the background on the CVR, Malin Head Radio can be heard calling R118. The Winch Operator observed that '*he can't get them on sixteen it's not good if there's no one talking to them… it would surely be listening out wouldn't it on sixteen em eh the one one eight ah they would yeh*'. The Commander then attempted to call R118 on both the company aero-VHF frequency and an aero-VHF chat frequency without response from R118. Malin Head Radio told R116 that '*yeh just to advise there is some sort of problem with one one eight at the moment on sixteen*' and that they would try to contact R118 via the casualty vessel, and that R118 was still visible to them on AIS. The Winch Operator continued to try to contact R118 by all available on-board means. At 00.02 hrs, the Co-pilot suggested that they '*could always ring them on the Sat Phone I suppose*', to which the Winch Operator replied '*yeh if we got desperate*'.

At 00.08 hrs, the Winch Operator called Blacksod Helipad on Marine Channel 16 and received a response. The Winch Operator requested details of the wind, cloudbase and visibility at Blacksod. This was provided as 'three four five hundred feet…it's good enough to come in over'. Blacksod advised that the wind was west south west at 25 to 33 knots, and that the sea-level visibility was two miles. The Winch Operator acknowledged the information and said that he would talk to them again when landing. During this sequence of communications, the Flight Crew were transmitting to Shannon ATC and asked the Winch Operator to standby. Ten seconds after this, the Commander told the Winch Operator that she had copied him and repeated the transmission as '*three hundred feet and whatever*'. The Winch Operator said that he would '*carry on trying to get them on all the different channels until we reach them on something*'.

At 00.27 hrs, Malin Head Radio, using the callsign '*Belmullet Coastguard Radio*' called R116 on Marine Channel 16 and advised that they had two-way communication with R118 via the casualty vessel. R116 replied that they would be shortly landing at Blacksod and would call again when airborne. At 00.31 hrs, the Winch Operator called Blacksod Helipad and said that they could probably hear the helicopter, and that they were working their way into the pad. This was acknowledged by the staff at Blacksod.

At 00.44 hrs, the Winch Operator called Belmullet Coast Guard Radio to advise that '*we should be landing very shortly now at Blacksod and we'll call again when airborne, over*'. Malin Head Radio acknowledged the transmission. This was the final radio transmission received from the helicopter.

Appendix K — MPFR Corrosion Report (AAIB UK)

Flight Recorders

Introduction

EI-ICR was equipped with a Penny & Giles[7] manufactured Multi-Purpose Flight Recorder (MPFR), part number D51615-102, which records the most recent 120 minutes of cockpit audio and 25 hours of flight data into a solid state, non-volatile memory that is protected within a Crash Survivable Memory Module (CSMM).

The MPFR was installed in the left-hand avionics rack located behind the co-pilots seat and is stopped automatically if the helicopter lands on water by the activation of an immersion switch, or if an acceleration of 10 g or greater is sensed by an inertia switch.

MPFR Certification

The MPFR was certified in 2001 under the manufacturer's design and production authority[8], which was granted by the UK CAA. The MPFR was certified as meeting the requirements of European Organization for Civil Aviation Equipment (EUROCAE) ED-55 'Minimum Operational Performance Specification For Flight Data Recorder Systems' Category A1[9], ED-56A[10] 'Minimum Operational Performance Specification For Cockpit Voice Recorder System' Amendment 1, (J)TSO-C123a and (J)TSO-C124a.

ED-55 and ED-56A specify the crash survivability requirements for the FDR and CVR respectively, which include impact shock, penetration resistance, static crush, fire, fluid, deep sea pressure and sea water immersion. Of note, there is no requirement that a hermetic seal is in place to prevent fluids entering the CSMM and coming into contact with the recording medium. Therefore, the design should ensure that the recording medium is not damaged through mechanisms such as corrosion.

The ED-55 and ED-56A crash survivability fluid, deep sea pressure and sea water tests specify that the recorder is immersed in:

1. Sea water at a pressure equivalent to a depth of 6,000 m (20,000 ft) for 30 days[11].

2. Sea water at a depth of 3 m (9 ft) and nominal temperature of 25°C for a period of 30 days.

3. Aviation fuel, oil, fire extinguishing agents, hydraulic and toilet flushing fluids for 48 hours.

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[7] Part of the Curtiss Wright group of companies http://www.curtisswright.com
[8] DAI/5817/59, Issue 1996 and Joint Aviation Authorities, Production Organisation Approval Ref CAA.G.0214 respectively.
[9] Class A1 is equivalent to ICAO Type 1, which is a recorder that has sufficient memory capacity to meet the parameter recording requirements specified for '*large aeroplanes'.*
[10] Both ED-55 and ED-56A are applicable to the MPFR as it is a combined CVR and FDR.
[11] This may be reduced to 24 hours if the materials used to protect the recording medium have been shown to be unaffected by sea water.

The crash survivability tests are combined into three test sequences[12]. Following each sequence the recorder is readout to ensure that the data is '*readily recoverable',* which ED-55 and ED-56A defines as meaning '*only minor repairs can be permitted for a damaged storage medium….e.g renewal of the interface connection of a solid state memory module'* and that the '*repair of individual memory devices is not permitted'*.

MPFR Design

There are several different models of the MPFR, however, the same basic design layout of CSMM is used across the model range. Since the MPFR was introduced in 2001, the manufacturer has made two design changes to the internal construction of the CSMM; this is discussed later in this report. **Image No. K1** is a photograph of an MPFR and the CSMM that is installed within its chassis. MPFR's are fitted to a range of commercial and military operated helicopters and aircraft, and is standard equipment on the Sikorsky manufactured S-92 helicopter.

The MPFR records audio and flight data to non-volatile memory devices that are installed on a circuit board that is protected within the CSMM. This circuit board is referred in this report as the Accident Protected Memory Board (APMB) (**Image No. K2 and No. K3** show the same type of APMB fitted to the MPFR from EI-ICR). The APMB provides the interconnection between the MPFR's electronics that are external to the CSMM that process the incoming flight data and cockpit audio, and the non-volatile memory devices fitted to the APMB that store the data.

The non-volatile memory devices on the APMB are modular in design and use disk-on-chip (DOC) technology[13] **(Image No. K4 and No. K5)**. There are four DOC modules fitted[14] to the APMB, with each DOC module consisting of a controller and three flash memory devices. One in-line flash memory device[15] per DOC module are also installed on the APMB (image 3). The four DOC modules are defined by the manufacturer as 'FDR1', 'FDR2', 'CVR1' and 'CVR2'. The CVR1 module stores audio from the Cockpit Area Microphone (CAM), CVR2 stores audio from the crew microphone channels and FDR1 and FDR2 store flight data; the two FDR modules record the same data with the dual design intended to provide redundancy if one module fails.

[12] The test sequences consist of a combination of impact shock, penetration resistance, static crush, fire, fluid immersion and deep sea pressure and sea water immersion. More than one recorder may be used to complete the test sequences.
[13] https://en.wikipedia.org/wiki/M-Systems
[14] Each module is attached by being soldered to the APMB.
[15] The in-line flash is used to store data before it is written to the three flash memory devices on the DOC.

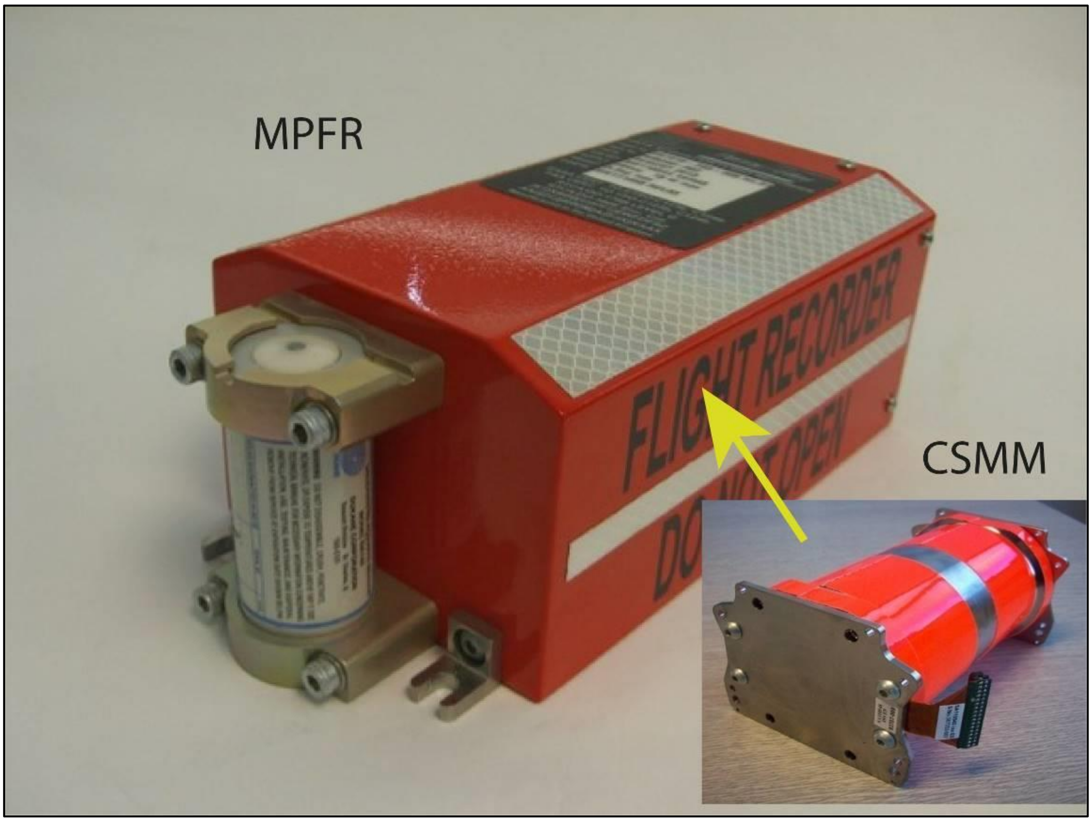


Image No. K1: MPFR and internal CSMM

39

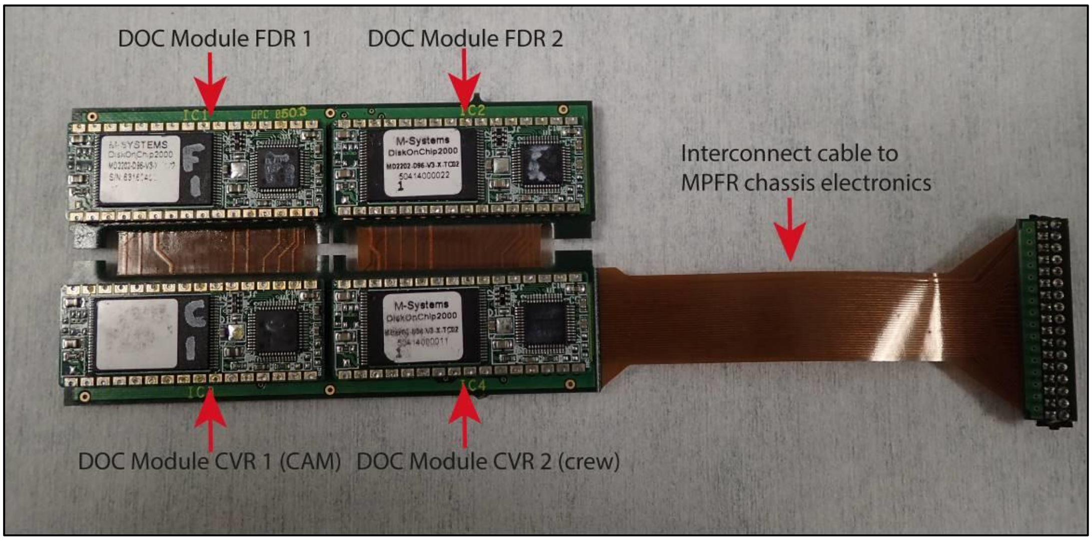


Image No. K2: Top of an APMB showing four DOC modules

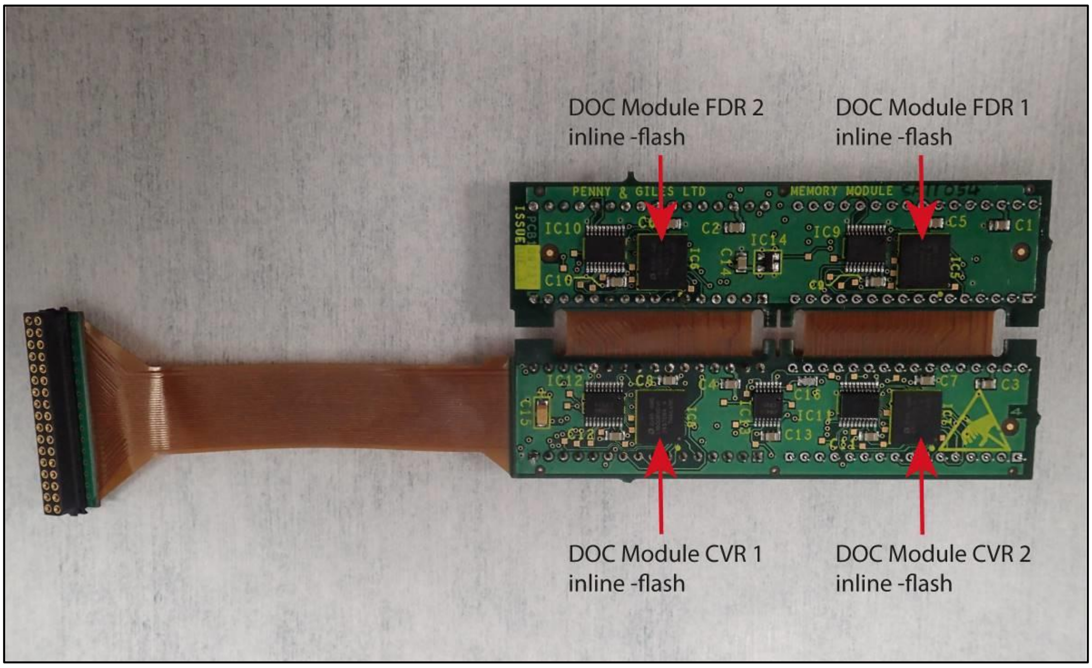


Image No. K3: Underside of an APMB showing in-line flash memory

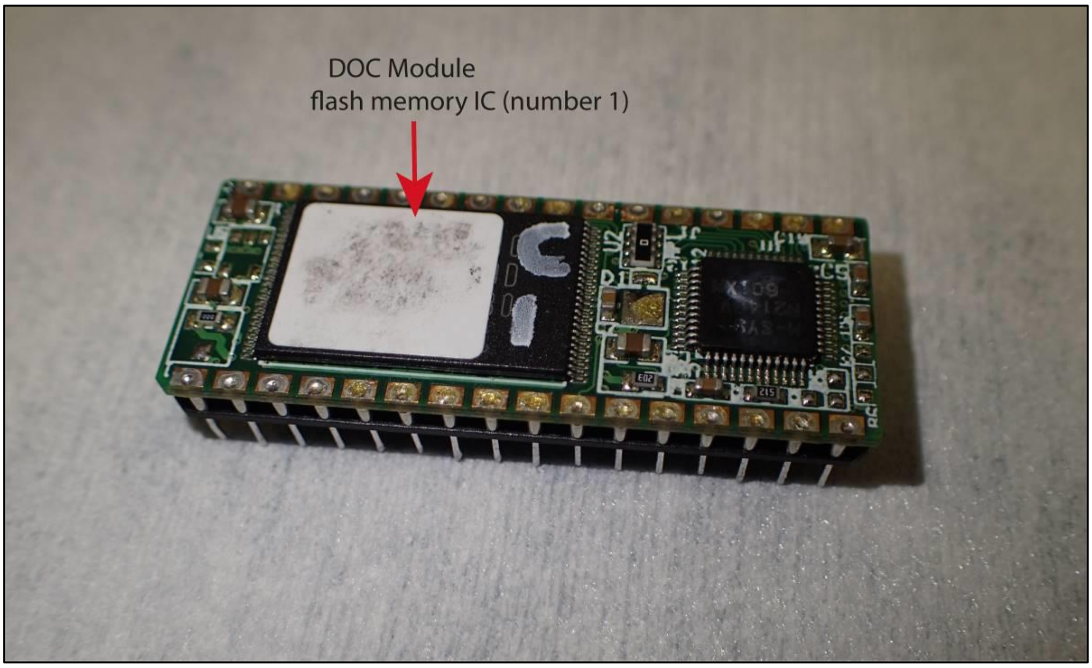


Image No. K4: Top of a DOC module (removed from APMB)

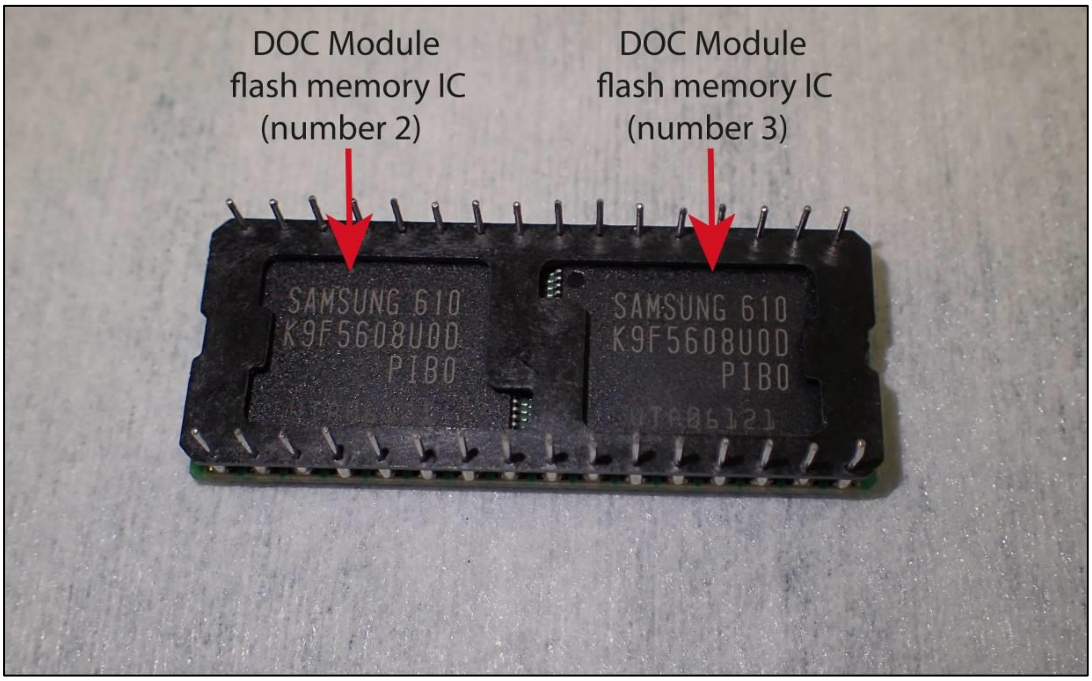


Image No. K5: Underside of a DOC module (removed from APMB)

The APMB and DOC modules are coated with a conformal coating. This is a layer of synthetic material that is intended to provide protection against mechanical hazards that may damage the board and electronic components. These hazards include corrosion.

41 The CSMM fitted to the MPFR is of a cylindrical design **(Figure No. K1 and Image No. K6)**. The APMB is installed in the centre of the CSMM within a metal cylinder. This cylinder is filled with 'glass spheres' and is enclosed at both ends by metal caps. This inner cylinder is surrounded by a 'ring' of thermal insulation material (referred to as 'insulation material A'), which is contained within a second metal cylinder that is capped at both ends with insulation material. Installed between the second cylinder, and inner wall of the outer case, is a second layer of thermal insulation material (referred to as insulation material B). Different materials are used for insulation A and B.

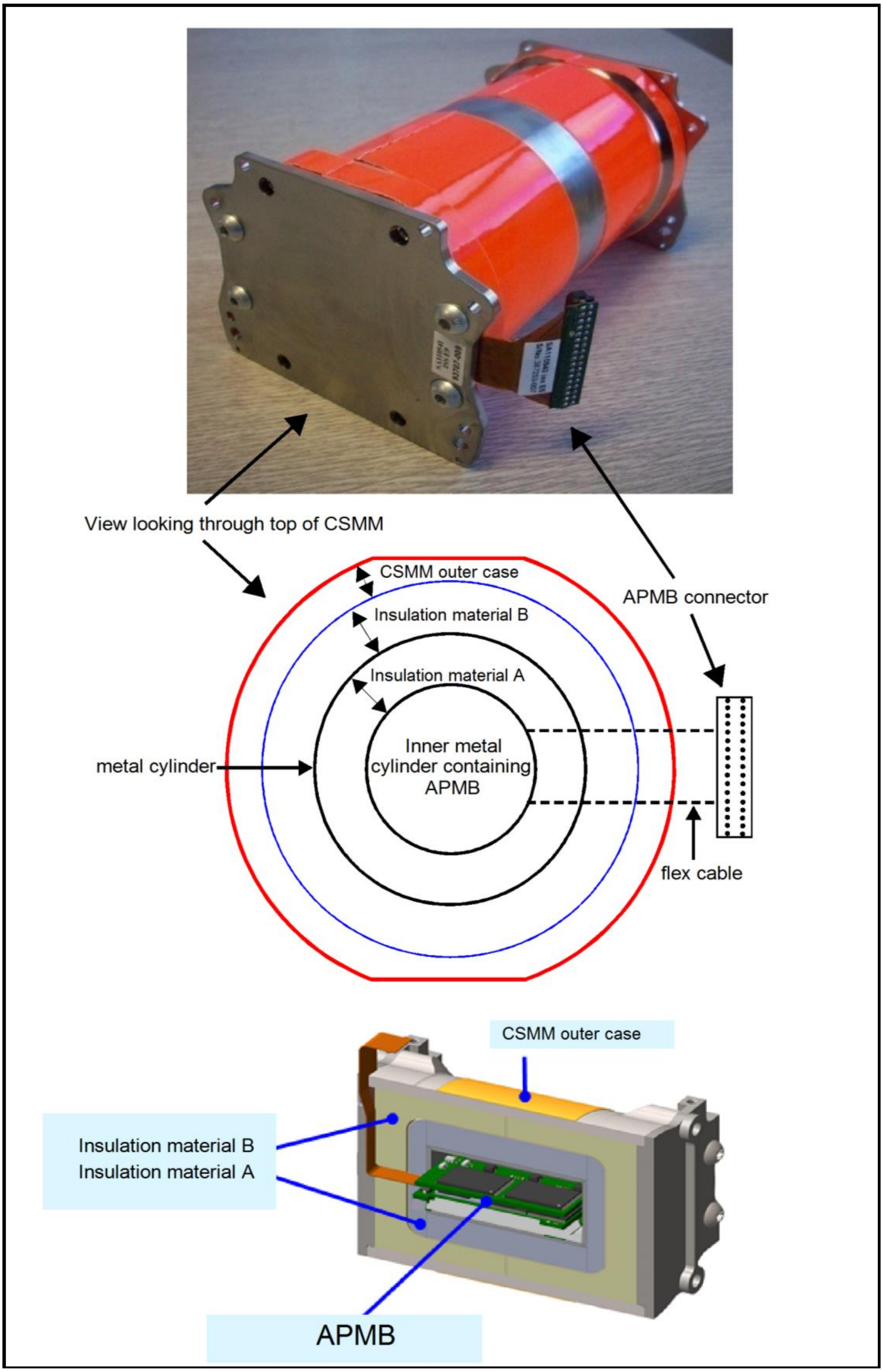


Figure No. K1: CSMM internal design

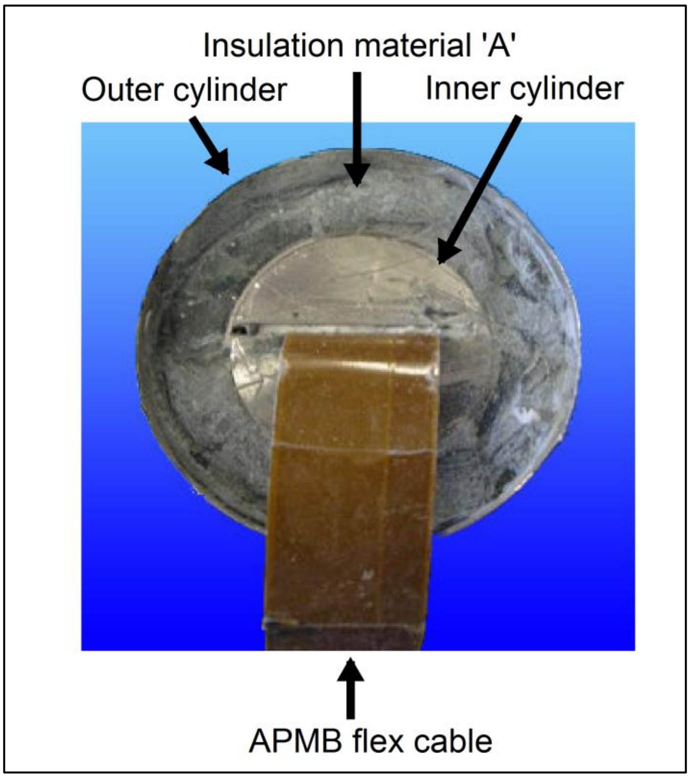


Image No. K6: Inner and outer cylinders and position of insulation material 'A'.

When the MPFR entered service in 2001, insulation material A was constructed from boric acid, and a Polyurethane based conformal coating was applied to the APMB.

In 2006, the manufacturer reviewed the CSMM design and identified that a change in the composition of insulation material A from boric acid to a copper based product would improve the performance of the CSMM in a fire; insulation material B remained unchanged. The change to the CSMM insulation material A was classified by the manufacturer as 'minor' and approved under its design authorisation[16]. As the change was classified as 'minor', it was not necessary to consult with the EASA. The manufacturer retested the modified CSMM against the ED-55 and ED-56A crash survivability requirements for impact shock, penetration resistance, static crush, and high temperature fire. However, the manufacturer concluded that it was not necessary to repeat the low temperature fire, fluid, deep sea pressure or sea water immersion tests. The AAIB was made aware of this by the MPFR manufacturer after the accident to EI-ICR.

In accordance with the manufacturer's procedures, 'engineering change notices' were issued as a record of the design change. No written record was available as to how the manufacturer satisfied itself that the low temperature fire, fluid, deep sea pressure or sea water immersion tests did not need to be repeated. The modified CSMM passed the impact shock, penetration resistance, static crush, and high temperature fire tests and entered service towards the end of 2006.

[16] After 28th September 2005, design changes needed to be compliant with the requirements of the EASA. Design changes to equipment, parts and appliances, which included the MPFR, originally certified prior to 28 September 2003 were provided with 'grandfather provisions', meaning that minor changes to grandfathered equipment could be undertaken by the design holder.

In 2013, an alternative design[17] of the APMB was introduced. The CSMM insulation materials remained the same, using the copper based product for insulation material A, but the conformal coating applied to the APMB was changed to ‘Parylene’[18]. The manufacturer advised that this type of conformal coating had been demonstrated as providing improved protection compared to the Polyurethane used in the first and second generation CSMM. The CSMM with alternative design of APMB was retested against all of the crash survivability requirements of ED-55 and ED-56A, which it passed.

The manufacturer stated that the change to the conformal coating applied to the APMB had not been instigated by a ‘specific design review’, although it had taken into consideration two previous occasions[19] when it had assisted the AAIB in the recovery of data from accidents where MPFR’s had been submerged in the sea. On both occasions the DOC modules had suffered from corrosion resulting in damage to the memory devices storing the FDR and CVR data.

MPFR’s Manufacturing History

Approximately 2,400 MPFR’s have been manufactured since 2001. Of these, about 1,950 units are fitted with second generation CSMM’s that use a combination of the copper based insulation and Polyurethane conformal coating on the APMB. Of this batch, 781 units are certified for fitment to civil aircraft with the remainder certified for military aircraft.

Of the remaining units, about 320 are of the first generation CSMM design fitted with boric acid insulation and 130 units are of the third generation CSMM design fitted with the alternate design of APMB that is coated in Parylene.

MPFR Accident Readouts

The AAIB contacted the manufacturer and other international accident investigation laboratories to ascertain how many MPFR’s had suffered from corrosion of the APMB following submersion in sea water. The following table (**Table No. K1**) provides these results; those units that suffered from corrosion of the APMB are highlighted in yellow:

[17] Referred to by the manufacturer as the Replacement Crash Survivable Memory Module (RCSMM).
[18] Parylene is the trade name for a variety of chemical vapor deposited poly(p-xylylene) polymers used as moisture and dielectric barriers.
[19] Helicopter registrations EC-KYR and B516.

No	Date of accident	Reg	Lead SIA[20] for readout	Insulation material A	Type of conformal coating	Duration submerged / approximate depth	Corrosion on AMPB	Repairs required to APMB to recover data
1	12/03/09	C-GZCH	TSB Canada	Boric Acid	Polyurethane	5 days / 169 m	NO	NO
2	04/01/09	N748P	NTSB USA	Boric Acid	Polyurethane	~14 days / <1m shallow water	NO	NO
3	23/08/13	G-WNSB	AAIB UK	Boric Acid	Polyurethane	7 days / ~3 m	NO	NO
4	Not provided[21]	Not provided	US Military	Copper based product	Parylene	<3 days / 30 m	NO	NO
5	Not provided	Not provided	US Military	Copper based product	Parylene	<3 days / 2 m	NO	NO
6	03/07/12	ZD743	QinetiQ Boscombe Down	Copper based product	Parylene	7 days / 50 m	NO	NO
7	03/07/12	ZD812	QinetiQ Boscombe Down	Copper based product	Parylene	15 days / 50 m	NO	NO
8	03/07/12	ZG792	QinetiQ Boscombe Down	Copper based product	Parylene	23 days / not reported	NO	NO
9	15/02/16	5N-BQJ	AAIB UK	Copper based product	Polyurethane	<2 days / <1 m helicopter rolled inverted on sea	NO[22]	NO
10	19/08/11	PR-SEK	NTSB USA	Copper based	Polyurethane	~14 days / 100 m	NO	NO
11	03/02/10	EC-KYR	AAIB UK	Copper based product	Polyurethane	9 days / 85 m	YES	YES
12	17/03/11	B516	AAIB UK	Copper based product	Polyurethane	16 days / shallow water	YES	YES
13	25/03/17	EI-ICR	AAIB UK	Copper Based product	Polyurethane	10 days / 40 m	YES	YES
14	Not provided	Not provided	US Military	Copper Based product	Polyurethane	<3 days/ 50 m	YES	YES
15	Not provided	Not provided	US Military	Copper Based product	Polyurethane	<3 days/ 50 m	YES[23]	NO

Table No. K1: MPFR's readouts following submersion in sea water (Units highlighted in yellow had suffered from corrosion of the APMB)

[20] Safety Investigation Authority (SIA).
[21] This information was not provided due to confidentiality.
[22] Fluid had not entered the CSMM inner cylinder containing the APMB.
[23] Did not result in the need for repairs over and above that specified by the ED-55/ED-56A crash survivability requirements.

A common feature during disassembly of units fitted with the copper based insulation and where water had entered the inner cylinder of the CSMM, was discolouration of the glass spheres surrounding the APMB, which were stained 'blue' by the copper based insulation. **Image No. K7** is of the APMB from EI-ICR taken shortly after removal from its CSMM. It was also noted by the AAIB that the Polyurethane conformal coating did not appear to have been applied 'evenly' to all surfaces of the APMB and it had not penetrated behind all pins of the memory devices. This has also been observed on other APMB's by the AAIB.

Image No. K7: APMB from EI-ICR showing copper based insulation staining of glass beads

From the 15 reported cases of MPFRs that have been submerged in sea water, five had suffered from corrosion of the APMB. All five of these units were fitted with the second generation CSMM fitted with a combination of copper based insulation and APMB's coated in Polyurethane. Four out of five of these units suffered from the loss of electrical pins on the memory devices due to corrosion.

In 2010, the AAIB worked on its first MPFR that had been submerged in sea water. This unit was from helicopter registration EC-KYR. Following disassembly, corrosion was found on the APMB and the unit was taken to the MPFR manufacturer. Several pins on the memory devices had corroded away, but these were subsequently identified as not being critical to the operation of the memory devices. Following repairs to remove corrosion, the data was successfully recovered.

In 2011, the AAIB assisted with the download of the MPFR fitted to helicopter registration B516. This unit required the most extensive repairs to date. All of the memory devices were 'de-soldered' and removed from their DOC modules so they could be readout individually. Four of the memory devices required new lead-wires to be attached to the internal die structure due to the extent of the corrosion damage (**Image No. K8**).

This process required '*acid-etching*'[24] of the memory devices to expose the lead-wire pads. The '*raw binary*' images from each memory device were then combined using specialist software to recover the CVR and FDR data. The process took over a month and required specialist support to repair the memory devices.

The recorder from helicopter registration B516 was transported to the AAIB '*dry*'[25], which may have exacerbated the level of damage by some degree, but did not account fully for the extensive damage.

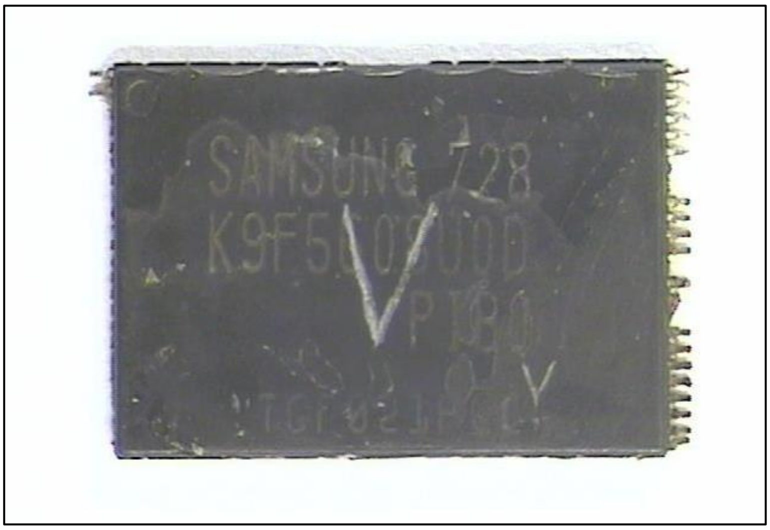


Image No. K8: Helicopter registration B516 missing pins from MPFR non-volatile memory device due to corrosion

The corrosion of the MPFR fitted to EI-ICR had effected two DOC modules (FDR1 and CVR1), causing electrical 'short circuits' that prevented the normal recovery of data.

Both FDR1 and CVR1 modules were de-soldered and removed from the APMB for repair. The most significant area of corrosion was on the underside of the DOC modules (image 10), which cannot be readily accessed whilst installed on the APMB. A number of pins were missing on four of the memory devices due to corrosion.

Among the missing pins were two on each device that provided electrical power to the memory device. At the opposite end of the memory device are pins that also provide electrical power. Although corroded, these pins were still intact and the memory devices were able to operate following the removal of short circuits **(Image No. K9)**. The other pins that were missing were not used by the memory devices. Using a combination of specialist hardware and software, the CVR and FDR data from all DOC modules was eventually recovered. The corrosion delayed the data recovery by several days.

[24] The packaging material surrounding the pins was removed using a chemical erosion process.

[25] It is recommended that flight recorders that have been submerged, remain stored and transported in water until they can be disassembled at a specialist laboratory. This is to reduce the unit's exposure to air which accelerates the effects of corrosion.

The US Military has also worked with the MPFR manufacturer to recover data from a corroded memory device. Specific details of the work carried out are not available due to confidentiality restrictions, but the AAIB is aware that repairs were required to a memory device that were similar to those applied to the MPFR fitted to helicopter registration B516.

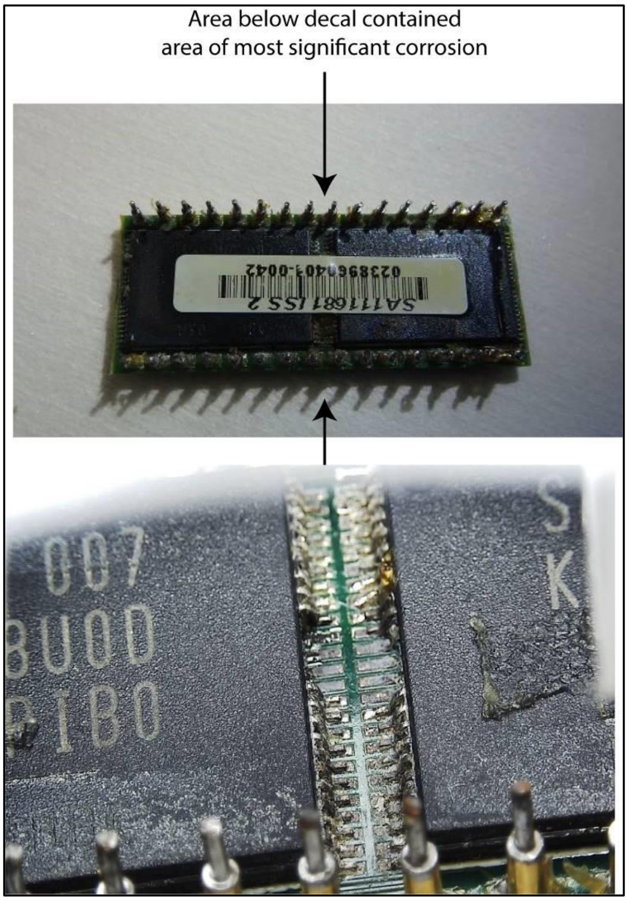


Image No. K9: Underside of FDR1 DOC module from EI-ICR showing missing pins due to corrosion

Other Cases of FDR and CVR Corrosion

The AAIB has experience of replaying accident damaged flight recorders manufactured by several other manufacturers. Of those flight recorders using non-volatile solid state memory, the AAIB has not experienced any other recorder model that has suffered from the same effects of corrosion of the APMB memory devices as the MPFR. The AAIB is also not aware of any other international safety investigation laboratory that has experienced data recovery issues from flight recorders using non-volatile solid state memory due to corrosion, except the MPFR.

MPFR Corrosion Analysis

The AAIB asked the manufacturer for its opinion on the cause of the corrosion of APMB's fitted to second generation CSMM's. The manufacturer stated *'We now know that the combination of sea water and the copper compound* [insulation material A] *can cause corrosion on memory modules.........This problem was resolved in early 2013 when the change from varnish* [Polyurethane] *to Parylene as a conformal coating was made'.* The manufacturer subsequently carried out research to understand the mechanism by which second generation CSMM's 'corroded'.

It was identified that two different types of material were used to construct the pins of the memory devices fitted to the APMB used in the second generation CSMM. One batch of memory devices was fitted with pins constructed of a base material manufactured from Alloy 42, which consists of 58% iron and 42% nickel, plated in either tin-lead or tin, and the other batch were manufactured with pins that used a copper base material plated in tin. The external appearance, form, fit and function of the two batches of memory devices are identical.

The manufacturer advised that during construction of the second generation CSMM's, the two batches of memory devices were not mixed. However, it was not possible to identify from manufacturing data which CSMM's had been installed with memory devices constructed using Alloy 42 or the copper base material. In addition, the manufacturer carried out a test on an APMB fitted with memory devices manufactured with pins constructed of Alloy 42 base material. The APMB was submerged in a solution of water and copper for three weeks before being removed, cleaned and inspected. The results of this test showed that the water / copper solution was able to permeate the polyurethane conformal coating and come into contact with the pins of the memory devices. Thereafter, a chemical 'single substitution reaction' took place, whereby the iron in the Alloy 42 was depleted to the extent that the pins structural integrity were lost and electrical connections broken.

The manufacturer confirmed that memory devices with pins constructed of the copper base material are not similarly affected and will not suffer from a loss of structural integrity leading to the loss of pins.

Safety Action Taken

- As of December 2017, the MPFR manufacturer started to replace second generation CSMM's fitted to commercial aircraft with third generation CSMM's.
- In February 2018 the MPFR manufacturer issued Service Bulletin (SB) D51615-31-22. This lists the part and serial number of MPFR's that require modification from second to third generation CSMM. The modification is free of charge to operators.
- The EASA has issued Safety Information Bulletin (SIB) 2018-05 to raise awareness of SB D51615-31-22.
- The EASA has stated that the MPFR modification program is to be completed by September 2023.

Further Safety Action

- The manufacturer of the MPFR has stated that it is developing specialist techniques to recover data from memory devices fitted to second generation CSMM if they suffer from the loss of pins due to water immersion.

Analysis

The MPFR recovered from EI-ICR was fitted with a ‘second generation’ design of CSMM, which was introduced in 2006 when the manufacturer changed one of the two thermal insulation materials within the CSMM from boric acid to a copper based product. Approximately 1,950 MPFR’s fitted with this type of CSMM have been manufactured.

During the course of the investigation, the AAIB was advised by the manufacturer that the second generation design of CSMM had not been tested against the effects of low temperature fire, fluid, deep sea pressure or sea water immersion as specified in ED-55 and ED-56A. The manufacturer stated that it had repeated the tests for impact shock, penetration resistance, static crush, and high temperature fire, but had concluded at the time that the remaining tests were not necessary.

The data show that only those CSMM’s fitted with the copper based insulation material and APMB’s coated in a Polyurethane conformal coating have suffered from corrosion of the memory devices. The corrosion of the memory devices is understood to be caused by a solution of water and the copper based insulation material entering the inner cylinder of the CSMM and coming into contact with the APMB. Testing by the manufacturer has shown that a change in conformal coating to Parylene has resolved the problem of corrosion. Therefore, it can be concluded that the Polyurethane conformal coating has not provided adequate protection against the combined corrosive effect of water and copper solution. This finding is also supported by that of the manufacturer.

Of the six[26] CSMM’s fitted with copper based insulation material and APMB’s coated in a Polyurethane conformal coating that have been submerged in sea water that has come into contact with the APMB, five units suffered from the effects of corrosion. Of these five, four required repairs to remove damaged pins, three required repairs that necessitated the need to de-solder devices, and two required specialist repairs to the memory devices themselves. None of the units that had corroded had been submerged in sea water for a period, or at a depth, in excess of the 30 day sea water immersion test specified by ED-55 and ED-56A.

The reason why the unit fitted to helicopter PR-SEK did not corrode is not fully known. However, one explanation is that the CSMM was fitted with memory devices, whose pins were constructed from a copper base material, which the manufacturer stated would not be susceptible to corrosion compared to those constructed from Alloy 42.

[26] The MPFR fitted to helicopter registration 5N-BQJ is not included as fluids had not entered the CSMM inner cylinder containing the APMB.

ED-55 and ED-56A state that the CVR and FDR data *'shall be readily recoverable'* which means that '*only minor repairs can be permitted for a damaged storage medium….e.g renewal of the interface connection of a solid state memory module',* and that '*repair of individual memory devices is not permitted'.* Had the manufacturer carried out the sea water immersion test on the CSMM fitted with the copper based insulation and APMB coated in Polyurethane conformal coating, the evidence indicates that it is likely that the CSMM would have failed this test.

To date, the CVR and FDR data has been successfully recovered from all MPFR's that have suffered from corrosion of the APMB following sea water immersion. However, in all cases, there has been a delay in the recovery of data due to the technical challenges faced when dealing with damaged electronic components. Further, the facilities capable of making repairs at 'chip-level' are very limited, the process is slow, there is a risk of further damaging the devices, and success is not guaranteed. In the case of EI-ICR, it was fortunate that the corrosion had not extended to other pins on the memory devices, as had it done so, it may have been several months before all of the CVR data was available to the investigation.

It is important that flight recorders survive accidents so that the CVR and FDR information can be quickly recovered and made available, enabling accident investigators to understand the cause of an accident, and make timely safety recommendations where required to prevent future occurrence. MPFR's fitted with CSMM's using a copper based insulation in combination with APMB's coated in Polyurethane pose a significant risk that they will corrode when submerged in sea water following an accident. The corrosion will, at best delay the availability of the CVR and FDR data, and at worst, could result in the data not being recoverable. Further, those MPFR's fitted with CSMM's using copper based insulation in combination with APMB's coated in Polyurethane have not been tested for fluid and sea water immersion. Therefore they may be considered to not be fully compliant with their certification basis of ED-55 and ED-56A.

In the UK, and across Europe, several helicopter types used in the support of the offshore oil and gas industry, and for Search and Rescue (SAR) activities, are fitted with MPFR's. These helicopters frequently operate over the sea, and therefore the risk of submersion of an MPFR is increased in the event of an accident or ditching where the helicopter does not remain upright.

In light of the identified safety action being taken by the MPFR manufacturer and EASA, the Investigation did not consider that a Safety Recommendation was necessary

16 February 2018

-END-

Appendix L — EASA MPFR SIB

EASA SIB No.: 2018-05

Safety Information Bulletin

Airworthiness – Operations

SIB No.: 2018-05

Issued: 08 February 2018

Subject: **Multi-Purpose Flight Recorders**

Ref. Publications:
Penny & Giles Aerospace Limited Service Bulletin (SB) No. D51615-31-22, dated Feb 2018.

Applicability:
Penny & Giles multi-purpose flight recorders (MPFRs), as listed in the effectivity of SB No. D51615-31-22, a copy of which is attached to the record of this SIB on the EASA SP Tool.

Description:
During data recovery from crash-damaged MPFRs, previously installed on five helicopters involved in accidents where the aircraft was submerged in water, corrosion was detected on the pins of memory devices inside the recorder. To recover the data, these units required the use of special techniques, not permitted according to the Minimum Operational Performance Specifications of the relevant ETSO, which delayed the availability of data to accident investigation boards.

This type of corrosion is due to a chemical reaction between the fire insulation material, when partially dissolved in water, and the iron content within the pins of the memory device. Under certain circumstances, the conformal coating on the memory module can be insufficient to protect the device pins from the corrosive solution.

This issue potentially affects certain second generation "GEN2" memory modules installed on MPFRs manufactured between 06 April 2006 and 02 January 2013. The subsequent GEN3 memory modules use a different conformal coating process and are protected from corrosion.

At this time, the safety concern described in this SIB is not considered to be an unsafe condition that would warrant Airworthiness Directive (AD) action under Regulation (EU) 748/2012, Part 21.A.3B, nor the issuance of an operational directive under Regulation (EU) 965/2012, Annex II, ARO.GEN.135(c).

Recommendation(s):
EASA recommends owners and operators to accomplish the actions as specified in Penny & Gilles Aerospace Limited SB No. D51615-31-22 dated Feb 2018.

This is information only. Recommendations are not mandatory.

Page 1 of 2

Extract from EASA SIB No.2018-05 - Multi-Purpose Flight Recorders

Appendix M — CVR Transcript from Preliminary Report (updated)

Note: One minute and forty seconds approximately of relevant CVR data from the period immediately prior to the accident

Elapsed time	Commander	Co-pilot (PM)	Rear Crew Channel	Other Source	Comment
2.01:27.694 2.01:31.544			Belmullet Coast Guard Radio from Rescue one one six, sixteen		
2.01:33.789. 2.01:37.332				Rescue one one six This is Belmullet Coastguard Radio sixteen go ahead	Received transmission on Marine VHF Radio
2.01:38.964 2.01:39.032 2.01:41.622 2.01:41.847 2.01:46.998	[unintelligible] coming left yep slowly coming left	Roger	Roger Belmullet Coast Guard Radio from one one six eh yes we should be landing very shortly now at Blacksod and we'll call again when airborne, over		
2.01:47.291 2.01:48.650	Groundspeed's gonna start increasing				
2.01:49.834 2.01:53.085				That's all copied, we'll standby, thanks very much, standing by on sixteen	Received transmission on Marine VHF Radio

Elapsed time	Commander	Co-pilot (PM)	Rear Crew Channel	Other Source	Comment
2.01:55.479 2.01:57.746	Eh the baro's a little bit off but we're on radalt only				
2.01:57.935 2.01:58.301		Roger			
2.02:13.597		One point three err miles to run to eh blackmo… and after that its bravo kilo sierra delta alpha			
2.02:16.632 2.02:16.857	Roger				
2.02:19.575					
2.02:19.589 2.02:22.981	Copied and with you have eh indicated airspeed search and radalt confirmed				
2.02:22.990		Roger			

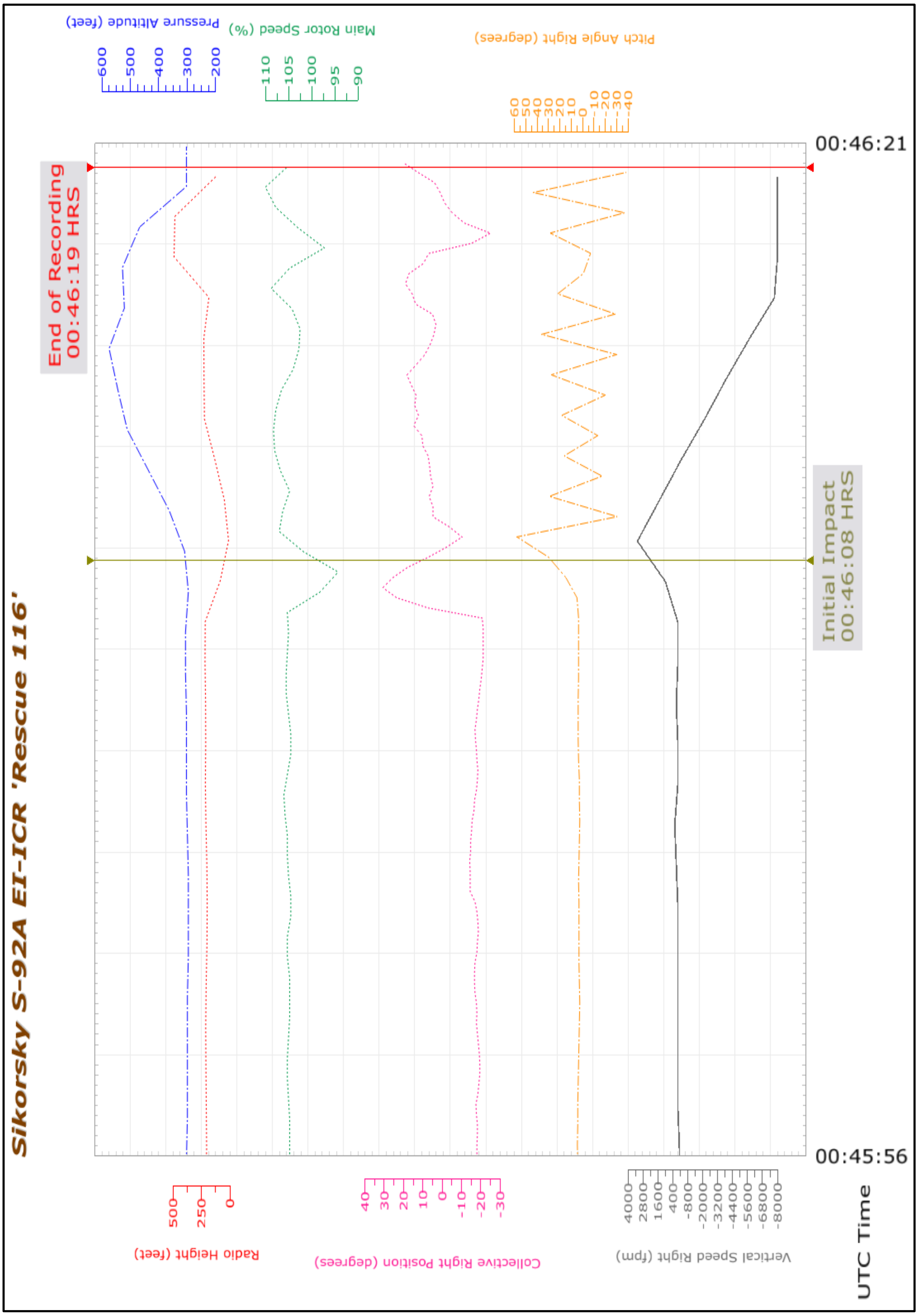
Elapsed time	Commander	Co-pilot (PM)	Rear Crew Channel	Other Source	Comment
2.02:28.261 2.02:31.234 2.02:31.533 2.02:32.411 2.02:33.561 2.02:33.580 2.02:33.624 2.02:36.184	 Roger There's just a small little island that's B L M O itself	OK so small targets at six miles eleven o'clock Large out to the right there ehm		 ALTITUDE ALTITUDE	 Radalt Automated callout
2.02:46.767 2.02:50.417			K…looking at an island just in, directly ahead of us now guys, you want to come right [Commander's Name]		
2.02:50.862 2.02:51.810	OK, come right just confirm?		 About…		
2.02:52.035 2.02:52.888			twenty degrees right yeah		
2.02:53.404 2.02:54.416	OK Come Right…select heading				

Elapsed time	Commander	Co-pilot (PM)	Rear Crew Channel	Other Source	Comment
2.02:55.231 2.02:55.384 2.02:55.691 2.02:56.164 2.02:57.231	Select heading	 Roger… Heading selected			
2.02:57.691 2.02:59.005			Come right now come right COME RIGHT		
2.02:59.097 2.02:59.893 2.03:00.730 2.03:01.198		 [Expletive] OOOHHHH [Expletive]		ALTITUDE ALTITUDE	Automated callout Loud noise Automated callout
2.03:01.734				SMOKE IN BAGGAGE	Automated callout
2.03:02.557		We’re gone			
2.03:03.647				SMOKE IN BAGGAGE	Automated callout
2.03:04.305 2.03:05.377				2 Pings	Sound of ELT transmission
2.03:05.565				DECOUPLE	Automated callout
2.03:06.605 2.03:06.707					Engine note variance
2.03:06.601 2.06:06.959					Unknown sound
2.03:07.109				TOO LOW GEAR	Automated callout
2.03:08.526 2.03:08.990		[Short muffled sound]			

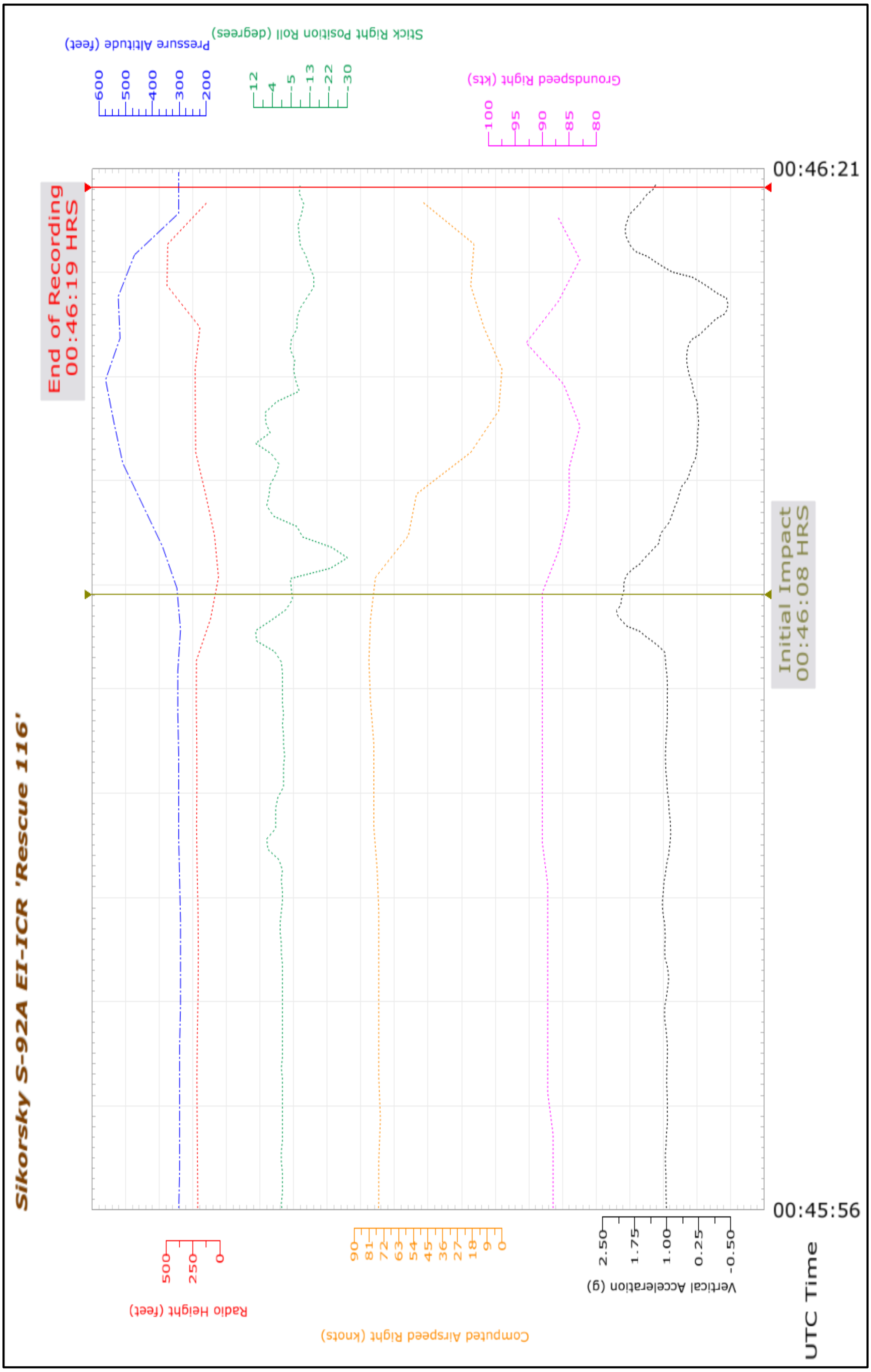
Elapsed time	Commander	Co-pilot (PM)	Rear Crew Channel	Other Source	Comment
2.03:09.026 2.03:09.676				TOO LOW GE..	Automated callout cut-off by static noise
2.03:09.676 2.03:09.868					Loud static noise
2.03:09.868 2.03:09.963					Silence
2.03:09.963					Sound similar to that of audio disconnection
2.03:10.168					End of Recording

-END-

Appendix N — FDR Parameters



Graphic No. N1: Flight Data Recorder Parameters



Graphic No.N2: Flight Data Recorder Parameters

A number of additional binary parameters were recorded on the FDR between 00.46:09 hrs and the end of the recording at 00.46:19 hrs. These parameters indicated the functional state of particular systems. The term ‘binary’ refers to a system that was recorded as either ON or OFF, ACTIVATED or DEACTIVATED, FUNCTIONAL or FAILED. They were, in chronological order;

- CHIP SYS FAULT ... activated
- LOW ROTOR RPM WARNING ... deactivated
- #1 AIRSPEED MODE FAIL caution ... activated
- #1 AIRSPEED MODE ON ... deactivated
- #1 Heading Select Fail ... activated
- #1 Heading Select ON ... deactivated
- Co-pilot Pitch IAS Captured ... deactivated
- Co-pilot Roll Heading Captured ... deactivated
- Landing Gear Up Warning ... deactivated
- MGB Low Press SW DCU2 ... activated
- EGPWS – Gear ... deactivated
- MGB Low Press SW DCU1 ... activated
- #1 Weight on Wheels ... deactivated
- #2 Weight on Wheels ... deactivated
- HYD 3 RSVR LOW ... activated
- Temp Ch6 IGB ... deactivated
- #1 NAV Vertical Mode ON ... activated
- #2 NAV Vertical Mode ON ... activated
- Co-pilot Coll Alt Captured ... deactivated
- MGB OIL PRESS warning ... activated
- ENG 2 OIL PRESS warning ... activated
- ‘SMOKE IN BAGGAGE’ caution ... deactivated
- Temp Ch6 IGB ... activated
- #1 Baro Altitude Mode ON ... deactivated
- Co-pilot FD Valid ... deactivated
- EGPWS – Gear ... activated
- HYD 3 PUMP FAIL caution ... activated
- ENG 1 OIL PRESS warning ... activated
- EGPWS – Gear ... deactivated
- MGB Low Press SW DCU2 ... deactivated
- MGB Oil Bypass ... activated
- #1 Tail Stage Hyd System Select OFF ... deactivated
- #2 Heading Hold ON ... activated
- #2 Tail Stage Hyd System Select OFF ... deactivated
- APU Bleed Valve Position ... deactivated
- MGB OIL BYPASS caution ... activated
- EGPWS – Gear ... activated
- Landing Gear Up Warning ... activated
- MGB Low Press SW DCU1 ... deactivated
- MTOP Bypass IBIT Complete ... deactivated
- MTOP Bypass IBIT Pass ... deactivated
- Pilot FD1 Selected ... deactivated

-END-

Appendix O — Warning and Caution Annunciations

Note: RFM Part 2, Section I: Avionics Management System

EICAS CAUTIONS	EXPLANATION
TRN PIT HEAT ON	Turn pitot heat on. In flight only. Set when OAT is less than 41°F and any of the three pitot heat switches are off.
TURN RIPS ON	Turn rotor ice protection system on. Set by RIPS controller when the aircraft is in the air, ice is detected, and RIPS is off.

The warning and aural alert table lists all possible red warnings, yellow alerts, and aural alerts in order of precedence. If two aural alerts are initiated simultaneously, the higher priority alert will be heard first. The following information is provided for each warning and aural alert:

The warning/alert as it is shown on the affected display

The aural alert as it is heard over the intercom system

Title of the warning/alert

Brief explanation of the warning/alert

The conditions that will cause the warning/alert to illuminate or sound

Where the warning/alert will be shown

How often an aural alert will be heard

The conditions that will cause an aural alert to be silenced or suppressed

WARNING "AURAL ALERT"	EXPLANATION
LOW ROTOR "LOW ROTOR"	Low rotor speed. Set when N_r <95% and aircraft is in flight. Red warning light on master warning panel. Aural alert will sound continuously until N_r increases above 95%, the aircraft is landed, or the VOICE CNCL button is pressed.
FIRE "FIRE ENGINE 1" "FIRE ENGINE 2" "FIRE APU"	Engine/APU fire. Set when fire is detected by either of two fire detectors located in the affected main engine bay or the single fire detector located in the APU compartment. Red warning light on master warning panel. Red warning on affected fire control panel. Aural alert will sound twice.
#1 ENG OUT "ENGINE 1 FAILURE" #2 ENG OUT "ENGINE 2 FAILURE"	Engine failure. Set by the FADEC of the non-affected engine when either of the following occurs: 1. Affected engine N_g is 4% below idle. (67%-4% = 63% at sea level on a standard day). 2. N_g decelerates faster than commanded by the FADEC. Red warning light on master warning panel. Red X over affected engine on EICAS. Aural alert will sound twice. Aural alert suppressed on the ground.
LNDG GEAR "TOO LOW GEAR"	Gear is not down prior to landing. Set by EGPWS when airspeed is below 60 KIAS and radar altitude is below 150 feet. Red warning light on master warning panel. Aural alert will sound twice and will sound twice again each time altitude is decreased 20% with the gear still up. Aural alert is silenced when the conditions no longer exist or the VOICE CNCL button is pushed.

WARNING "AURAL ALERT"	EXPLANATION
MASTER CAUTION S/P TEMP LIMIT "SWASHPLATE TEMPERATURE"	Swashplate temperature limit. Swashplate temperature above 300°F. Set by the BMU with inputs from two temperature sensors located on the stationary swashplate. Red warning on EICAS. Aural alert will sound twice.
MASTER CAUTION MGB OIL PRES "GEARBOX OIL PRESSURE"	Main gearbox oil pressure. Set when both conditions below occur: 1. Oil pressure less than 35 psi as measured by the pressure transducer located on the input manifold. 2. Oil pressure less than 24 psi set by a switch located at the "last jet" in the left accessory module. Red warning on EICAS. Aural alert will sound twice. Caution and aural alert suppressed when the aircraft is on the ground and $N_r < 40\%$.
MASTER CAUTION SMOKE IN BAGGAGE "SMOKE IN BAGGAGE"	Smoke in baggage. Smoke detected in the rear baggage compartment. Set by the smoke detector located in the rear compartment overhead. Red warning on EICAS. Aural alert will sound twice.
TERRAIN "WARNING TERRAIN"	Terrain is obstructing the aircraft flight path. Set by EGPWS when the aircraft is approximately 20 seconds from hitting terrain. Based on inputs from GPS position, geometric altitude, aircraft flight path, and the Digital Terrain Elevation Database (DTED). Red warning on PFD. Aural alert will sound continuously until the conditions no longer exist or the VOICE CNCL button is pushed. Aural alert suppressed by selecting AUD INHB.
OBSTACLE "WARNING OBSTACLE"	An obstacle is obstructing the aircraft flight path. Set by EGPWS when the aircraft is approximately 20 seconds from hitting an obstacle. Based on inputs from GPS position, geometric altitude, aircraft flight path, and the obstacle database. Red warning on PFD. Aural alert will sound continuously until the conditions no longer exist, the VOICE CNCL button is pushed, or AUD INHB is selected.
DON'T SINK "DON'T SINK"	Inadvertent descent after takeoff. Set by EGPWS based on radar altitude and time since takeoff. The aircraft must be above 40 KIAS and gear up. Yellow caution on PFD. Aural alert will initially sound twice and will sound twice again each time the radar altitude decreases by 20%. Aural alert is silenced when a climb rate is established or the VOICE CNCL button is pushed. Aural alert suppressed by selecting AUD INHB.
PULL UP "TERRAIN TERRAIN PULL UP PULL UP"	Excessive terrain closure rate. Set by EGPWS based on radar altitude closure rate. The "TERRAIN TERRAIN" call is a caution which will be closely followed by a continuous "PULL UP" warning. Red warning on PFD.

WARNING "AURAL ALERT"	EXPLANATION
	Aural alert (PULL UP) will sound continuously until the conditions no longer exist or the VOICE CNCL button is pushed. Aural alert suppressed by selecting AUD INHB. This mode is inhibited when the enhanced portion of the EGPWS has sufficient integrity, when the Low Altitude Mode is selected, or during autorotation.
TERRAIN "CAUTION TERRAIN"	Terrain is obstructing the aircraft flight path. Set by EGPWS when the aircraft is approximately 30 seconds from hitting terrain. Based on inputs from GPS position, geometric altitude, aircraft flight path, and the DTED. If the aircraft flight path is not changed, this caution will be replaced with the "WARNING TERRAIN" alert. Yellow caution on PFD. Aural alert will sound every seven seconds until the conditions no longer exist or the VOICE CNCL button is pushed. Aural alert suppressed by selecting AUD INHB.
OBSTACLE "CAUTION OBSTACLE"	An obstacle is obstructing the aircraft flight path. Set by EGPWS when the aircraft is approximately 30 seconds from hitting an obstacle. Based on inputs from GPS position, geometric altitude, aircraft flight path, and the obstacle database. If the aircraft flight path is not changed, this caution will be replaced with the "WARNING OBSTACLE" alert. Yellow caution on PFD. Aural alert will sound every seven seconds until the conditions no longer exist or the VOICE CNCL button is pushed. Aural alert suppressed by selecting AUD INHB.
TERRAIN "TOO LOW TERRAIN"	Low terrain clearance. Set by EGPWS in accordance with two schedules: 1. Gear up: Airspeed is above 60 KIAS and radar altitude is below 150 feet. 2. Gear down: At 120 KIAS, alert will sound at 100 feet. As airspeed decreases, the alert altitude also decreases down to 80 KIAS and 10 feet. See diagram in EGPWS manual. Yellow caution on PFD. Aural alert will initially sound twice and will sound twice again each time the radar altitude decreases by 20%. Aural alert is silenced when the conditions no longer exist or the VOICE CNCL button is pushed. Aural alert suppressed by selecting AUD INHB.
TRAFFIC "TRAFFIC"	TCAS traffic alert. Set by TCAS when separation from another transponder equipped aircraft is cause for concern. There are two sensitivity levels. Below 2000 feet AGL a traffic alert will be displayed when: If current closure rate is maintained, separation of less than 600 feet in altitude will occur in 20 seconds. Current separation is less than 600 feet and 0.2 nautical miles in range.

WARNING "AURAL ALERT"	EXPLANATION
	A non-altitude reporting intruder is within 15 seconds or 0.2 nautical miles. Above 2000 feet AGL a traffic alert will be displayed when: If current closure rate is maintained, separation of less than 800 feet in altitude will occur in 30 seconds. Current separation is less than 800 feet and 0.55 nautical miles in range. A non-altitude reporting intruder is within 20 seconds or 0.55 nautical miles. Yellow caution on PFD. Aural alert will sound twice. Aural alert is inhibited when below 400 feet AGL.
"ONE HUNDRED FEET" or other selectable altitudes.	Hardwired altitude alert. Set when radar altitude first goes below the set radar altitude. These alerts are selected by the customer prior to delivery and cannot be adjusted by the customer. It is possible to have none, one, or several of these alerts. Aural alert will sound once and will not sound again until reset by climbing 50 feet above the selected altitude and then descending through it again.
"TAIL TOO LOW"	Tail strike warning. Set by the EGPWS based on pitch attitude, radar altitude, pitch rate, and barometric rate of descent. See EGPWS manual for diagram. Aural alert will sound continuously until the conditions no longer exist or the VOICE CNCL button is pressed. Aural alert suppressed by selecting AUD INHB.
"HOVER ALTITUDE"	Hover altitude too low. Set when both of the following occur: 1. Coupled hover or approach to hover mode engaged. 2. Radar altitude descends below 30 feet. Aural alert will sound continuously until radar altitude increases above 30 feet, the aircraft is decoupled, or the VOICE CNCL button is pressed.
"AIRSPEED"	Velocity never exceed. Set when airspeed is 3 knots greater than computed V_{ne}. Portions of airspeed gauge turn red. Aural alert will sound continuously until airspeed is decreased below V_{ne} or the VOICE CNCL button is pressed.
CHECK POWER **"CHECK POWER"**	Coupled flight director collective limiting. Set when altitude or vertical speed is coupled to the collective channel and continuous power limits will not maintain the selected altitude or airspeed. Yellow caution on PFD. Aural alert will sound once.
"MINIMUMS"	Set when barometric altitude first goes below the selected minimum barometric altitude.

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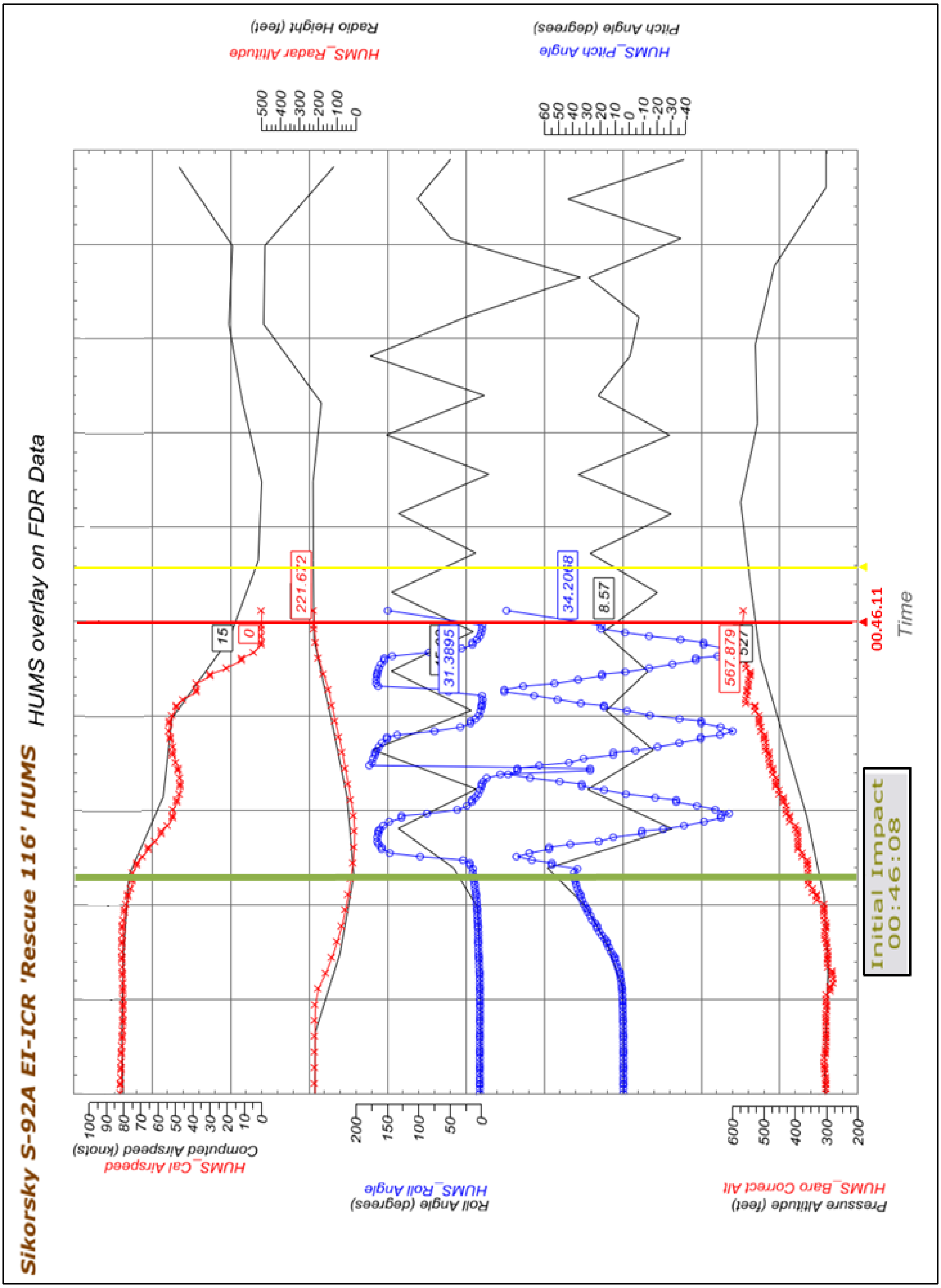
WARNING "AURAL ALERT"	EXPLANATION
	Aural alert will sound once and will not sound again until reset by climbing 50 feet above the selected altitude and then descending through it again.
"ALTITUDE"	Set when radar altitude first goes below the selected radar altitude. Aural alert will sound once and will not sound again until reset by climbing 50 feet above the selected altitude and then descending through it again.
"GLIDE SLOPE"	Deviation below glideslope. Two levels of alert set by EGPWS. Both alerts require the gear down and the aircraft established on a front course ILS. The "soft" alert is set when more than 1.3 dots below the glideslope. The "hard" alert is set when more than 2 dots below glideslope and below 300 feet AGL. The hard alert is louder than the soft alert and takes precedence. The soft aural alert will initially sound twice and will sound twice again each time the aircraft descends an additional 20% below glideslope. The soft alert is cancelled when the conditions no longer exist, the hard alert takes over, or the VOICE CNCL button is pressed. The hard aural alert will sound continuously until the conditions no longer exist or the VOICE CNCL button is pressed. Yellow caution on PFD. Both aural alerts are suppressed by selecting AUD INHB or G/S CNCL.
"BANK ANGLE"	Excessive bank angle at low altitude. Set by EGPWS based on bank angle and radar altitude. See EGPWS manual for diagram. Aural alert will initially sound twice and will sound twice again each time the bank angle increases by an additional 20%. Aural alert is silenced by the VOICE CNCL button. Aural alert suppressed by selecting AUD INHB.
"LEVEL OFF"	Level off. Set when both of the below occur: 1. Altitude preselect is engaged. 2. Aircraft altitude is 300 feet from the selected altitude. Aural alert will sound once and will not sound again until reset by deviating 330 feet from the selected altitude and then climbing/descending to 300 feet from the selected altitude.
"CHECK ALTITUDE"	Check altitude. Set when altitude hold is engaged (either coupled or uncoupled) and actual aircraft altitude deviates more than 200 feet from the selected altitude. Aural alert will sound once and will not sound again until reset by climbing/descending to within 20 feet of the selected altitude and then deviating by 200 feet again.
"DECOUPLE"	Flight director decouple. Set when the flight director is decoupled either intentionally by the pilot or unintentionally due to a malfunction. Aural alert will sound once.
"BE ALERT TERRAIN INOP"	EGPWS look ahead function not available. Set by EGPWS when GPS reception is degraded.

-END-

Appendix P — HUMS Parameters



Graphic No. P1: HUMS Data Recorder Parameters

-END-

Appendix Q — Inspection of Recovered Lifejackets

General

The first three lifejackets recovered were two RFD Beaufort Mk44 Lifejackets worn by the two Pilots and one RFD Beaufort Mk15 Lifejacket carried as a spare on the aircraft. The fourth and fifth lifejackets to be recovered were identified as Mk15 Lifejackets worn by the two Rear Crewmen of the Helicopter.

The initial inspections of the occurrence lifejackets found that:

i. Mk44 Lifejacket worn by the Commander

Recovered with the Commander, 14th March 2017

The Commander's lifejacket was found to have been manually inflated. The stole inflation bottle was pierced and the stole deployed. A SARBE 6-406G was found in the PLB pocket of the lifejacket with the GPS antenna installed in the same pocket. The strobe light fitted to the lifejacket was found selected to 'ON'. The lifejacket was found without a HEED bottle. The Operator's maintenance records show that a HEED bottle was installed to the lifejacket.

ii. Mk44 Lifejacket worn by the Co-pilot

Recovered with the Co-pilot, 26th March 2017

The Co-pilot's lifejacket was found with the stole packed and not deployed. On examination, the stole inflation bottle was found not to be discharged. A SARBE 6-406G was found in the PLB pocket of the lifejacket with the GPS antenna installed in the same pocket. This lifejacket was also found without a HEED bottle.

iii. Helicopter Spare Mk15 Lifejacket

Recovered by ROV, 23rd March 2017

This lifejacket was found with the stole packed and not deployed. On examination, the stole inflation bottle was found not to be discharged. A SARBE 6-406G was found in the PLB pocket of the lifejacket with the GPS antenna installed around the stole of the lifejacket. There was no STASS bottle in the lifejacket and the HEED bottle retaining cord was found sheared.

iv. Mk15 Lifejacket worn by the Winchman

Recovered from shallow water at Elly Bay, Clogher, Ballina, Co Mayo, 30th September 2017.

This lifejacket was found with the stole deployed and some of the fabric mesh of the jacket torn. The stole inflation bottle was discharged and the manual activation handle was missing from the jacket.

A SARBE 6-406G was found in the PLB pocket of the lifejacket. The PLB pocket itself was damaged with approximately ¼ of the stitches missing. The strobe light and HEED bottle were missing. The flares box was found intact with all flares inside.

v. Mk15 Lifejacket worn by Winch Operator

Recovered in a fishing vessel's nets, 12th July 2018, 1 NM northwest of Achill Head.

This lifejacket was found badly damaged, with large tears to pockets, and with significant corrosion on the inflation bottle. The inflatable stole was unpacked but the inflation bottle was not pierced indicating that the lifejacket had not been inflated. A light was found still attached to the lifejacket, but other accessories such as the SARBE 6-406G and the HEED bottle were missing.

-END-

Appendix R — SARBE Inspections

General

The four SARBE 6-406G units underwent an external visual examination, a battery test, self-test[27] and a test of the TX/RX antenna. In all cases, the self-test was carried out with a known 'good' battery as the batteries fitted to the units were not serviceable. The internal seals and circuits of the first three units were not examined as this would compromise further planned testing by the SARBE 6-406G manufacturer.

SARBE 6-406G installed in Commander's Lifejacket

Inspection

The Commander's SARBE 6-406G was recovered from the Commander's lifejacket at the sea surface on the day of the accident, installed in the Commander's Mk44 Lifejacket. The SARBE 6-406G was found armed but the activation pin was not pulled. The activation lanyard was wrapped around a D-ring in the SARBE pouch. The saltwater activation switch was set to 'ON'. Both the GPS and the TX/RX antennas were in good condition, but the connectors on both antennas were loose with salt deposits around them.

The body of the SARBE 6-406G was in good condition with some signs of wear on the buttons. Black marks were noted on the base of the SARBE 6-406G next to the battery terminal. This may have been from an electrical short but it was not possible to confirm. The battery expiry date was marked on the battery as November 2018.

Initial testing

The conclusion of the initial testing of this unit was:

- SARBE 6-406G was unserviceable.
- The battery was marginally unserviceable i.e. it had a small amount of power remaining.
- The TX/RX antenna was serviceable.

SARBE 6-406G installed in Co-pilot's Lifejacket

Inspection

This SARBE 6-406G was recovered from a water depth of 40 m, 12 days after the accident. The SARBE 6-406G was armed but the activation pin was not pulled. The saltwater activation switch was set to 'ON'.

[27] The self-test or BIT (Built-in Test) is initiated by pushing a button on the outside of the unit. If successful, two LEDs on the body of the unit begin to flash and the unit emits an audible siren. In order to preserve battery life, the manufacturer recommends carrying out a self-test twice, and no more than four times per year.

Both the GPS and the TX/RX antennas were in good condition, but the connector on the GPS antenna was loose. There were salt deposits around both antenna connectors.

The body of the SARBE 6-406G was in good condition with some signs of wear on the buttons. Salt deposits were noted around the gasket seals of the main body of the unit. The battery of this unit had an expiry date of January 2017 indicating that the battery had expired at the time of the accident.

Initial testing

The conclusion of the initial testing of this unit was:

- SARBE 6-406G was unserviceable.
- The battery was marginally unserviceable i.e. it had a small amount of power remaining despite being beyond its expiry date.
- Both antennas appeared to be physically sound.

SARBE 6-406G found in Helicopter Spare Mk15 Lifejacket

Inspection

This SARBE 6-406G was recovered from a water depth of 40m, several days after the accident. The SARBE 6-406G was armed and the switch was seized in the 'ON' position. The saltwater activation switch was set to 'ON'. The TX/RX antenna was broken but the GPS antenna looked physically sound. Both antennas were loose on their mountings. The battery was intact and had an expiry date of August 2018.

Initial testing

The conclusion of the initial testing of this unit was:

- SARBE 6-406G was unserviceable.
- The battery was unserviceable.
- The TX/RX antenna was broken.

SARBE 6-406G installed in the Winchman's Lifejacket

Inspection

This SARBE 6-406G was recovered from the shoreline of the Mullet peninsula, County Mayo six months after the accident. It was found with the GPS antenna broken off.

The activation pin was out of its housing on the SARBE 6-406G but the manual activation toggle was not pulled from the lifejacket.

Initial Testing

The conclusion of the initial testing of this unit was:

- SARBE 6-406G was unserviceable.
- The battery was unserviceable.
- The GPS antenna was found broken.

Inspection and Test by SARBE 6-406G Manufacturer

Following the initial testing of the SARBE 6-406G units described above, the first three units to be recovered were taken to the original manufacturer for a detailed examination and test. A detailed examination and test was not carried out on the fourth unit to be recovered. This was because the significant level of damage observed at the initial examination indicated that nothing further could be learned by a more detailed examination. In addition, as the unit had been in the sea for several months, it would not be possible to ascertain when the damage occurred.

Description of Inspection and Testing Carried out By Manufacturer

The SARBE 6-406G manufacturer carried out the following tests on each SARBE 6-406G:

1. General external inspection
2. Self-test
3. Battery test
4. Pressure test to determine if the seals of the units were intact. In this test the manufacturer replicated the pressure conditions at 10m water depth by introducing air at 15 psi into the unit via a pressure test screw located on the base of the unit.
5. General inspection of the internal circuits and the main seal.
6. Antenna test to determine if the units were capable of radiating the correct frequencies and at the correct power. In this test the antennas were connected to a slave PLB, activated and placed inside a screened enclosure. The frequency and power of the output was then measured.

Results of Examination and Testing

Table No. R1 below shows the results of the SARBE 6-406G Testing. In summary:

1. The exterior of all three units showed signs of saltwater immersion.
2. The batteries of all three units had been discharged or were inoperative.
3. Two of the units passed the manufacturer's standard production pressure test.
4. The antennas for all three units passed a live activation test using a known good PLB and battery.
5. There was no damage to the main seal on any of the units.
6. All three units showed evidence of internal flooding (**Photo No. R1**).

		SARBE 6-406G		
		Commander	Co-pilot	Spare
Initial External Survey	Body Work	Pass	Pass	Fail
	Antenna TNC Connectors	Fail	Fail	Fail
	Arming Switch	Pass	Fail	Fail
	Keypad	Fail	Pass	Pass
	Labels	Pass	Pass	Fail
Battery Test	Visual Condition	Fail	Fail	Fail
	Voltage Test	Fail	Fail	Fail
	Operational Test	Fail	Fail	Fail
Test Regime	Program Read	Fail	Fail	Fail
	Self-Test	Fail	Fail	Fail
	Pressure Test	Pass	Fail[28]	Pass
	Tx Antenna Live Test	Pass	Pass	Pass
	GPS Antenna Live Test	Pass	Pass	Pass
	Antenna Extension Test	Pass	Pass	Pass
Internal Survey	Heel Plate Removed	Pass	Pass	Fail
	Front & Rear Case Separated	Pass	Pass	Pass
	Internal Inspection	Fail	Fail	Fail

Table No. R1: Results of SARBE 6-406G Testing

[28] When tested, this unit exhibited a leak on the right-hand side of the unit's self-test button

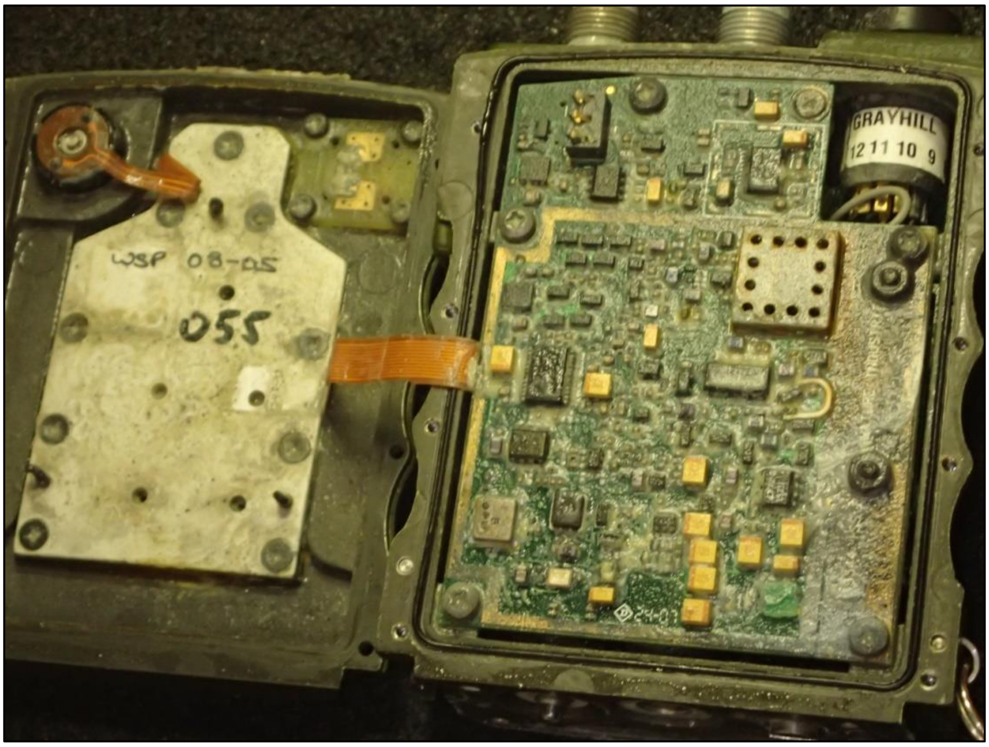


Photo No. R1: Internal Water Damage to Commander's SARBE 6-406G

Conclusions of Examination and Testing

73 Following the examination and testing the PLB Manufacturer produced a test report which concluded that:

> *'All the PLBs investigated appear to have suffered a similar significant ingress of water. This water ingress could short circuit internal componentry and cause damage to the batteries, sufficient to cause the PLB to fail to operate.*
>
> *During the survey and test, it was noted that despite the extent of water ingress the case seals appeared to be in good condition. The results of the described pressure tests indicated that the seals continued to perform as designed, and therefore were likely to have been in good condition prior to the accident event.*
>
> [The PLB manufacturer] *were advised that at least two of the PLBs* [the Co-pilot's and the spare] *had been immersed to a depth of about 40m for an extended period. The immersion depth of the third [*the Commander's*] was unknown. The results found are consistent with this information.*
>
> *The SARBE 6-406G PLB has not been tested for immersion in depths greater than 10 metres, and the results of immersion to greater depths are therefore unknown. However, it is considered likely that during the period that the PLBs exceeded this depth the PLB sealing was breached, causing the PLBs to fail. There is no evidence to suggest that the PLBs were not fully serviceable at the time of the accident event, although it appears that at least one of the tested PLBs was fitted with a life expired battery.*

Presuming that the PLBs functioned as designed through activation of the salt water switch, and were therefore transmitting, the PLBs may have been underwater at this point. The antennas are not designed to transmit underwater, but must rather have a clear view to the sky. This would have prevented any signals being radiated by the PLB, or received by the satellite. The subsequent dive beyond the specified immersion depth and ingress of water would probably have caused the PLBs to fail; this would result in any transmission stopping. The ingress of water would have prevented any further operations of the PLBs even following a return to the surface and visibility of the sky for the antennas.

NOTE: *Life jacket integration is outside the scope of this* [the PLB] *investigation. However, it was noted that the configuration of two of the life-vests did not provide the recommended separation of the two antennas (TX and GPS) and did not provide a clear view of the sky without manual intervention. The operation of the GPS antenna, especially in this configuration, may be compromised.'*

-END-

Appendix S — PLB Installed Performance - Mk44 and Mk15 Lifejackets

General

In response to Safety Recommendation IRLD2017006 the Lifejacket Manufacturer with assistance from the PLB Manufacturer and the Operator carried out a two phase investigation into the installation and performance of the SARBE 6-406G PLB as installed in both the Mk44 and Mk15 Lifejacket. Phase 1 was a table-top examination of both types of lifejacket with PLB and antennas installed.

Phase 2 assessed the performance of the SARBE 6-406G in the sea when installed in both Mk44 and Mk15 Lifejackets. In each performance test the test subject entered the water whilst wearing an industry standard immersion suit and one of the two lifejackets. The test subject adopted a floating position. Observers noted the position of the beacon pocket, antenna and GPS antenna relative to the waterline. The Marine Rescue Coordination Centre (MRCC) of the Irish Coastguard monitored the signal emitted/collected from the PLB. A handheld device capable of receiving the transmitted signal was also located on the shoreline. The test was repeated with each lifejacket in the un-inflated and inflated configurations.

PHASE 1

The table-top review of the two lifejacket types concluded that:

Mk44 Lifejacket:

- The beacon pocket is located on the right-hand side of the jacket, as worn and is orientated in a vertical position.
- The SARBE 6 406G locator beacon is stored in the pocket but without a fixed tether point.
- The SARBE 6 406G beacon fitted includes a fixed antenna and GPS antenna. The antenna is directly attached to the base unit and the GPS antenna is stowed within the beacon pocket alongside the beacon.
- The fixed antenna and GPS antenna are therefore immediately adjacent to the subject's torso when the lifejacket is worn.
- The PLB manufacturer noted the standard antenna being used was of an older revision that is now obsolete. A new '*blade*' type antenna was introduced in May 2013 as an improvement. The GPS antenna was of the current standard.

Mk15 Lifejacket:

- The beacon pocket is located on the left-hand side of the jacket, as worn and is orientated in a horizontal position.

- The SARBE 6 406G locator beacon is stored in the pocket, but without a fixed tether point.

- The SARBE 6 406G fitted includes a standard type antenna and GPS antenna. The standard type antenna is remotely attached to the base unit via an extension cable. The antenna is mounted on the inflatable lifejacket stole. The GPS antenna cable is routed along the periphery of the lifejacket stole and is attached to a patch on the stole.

- The standard type antenna and GPS antenna are therefore positioned away from the subject's torso when the lifejacket is worn and would be positioned prominently on the stole above the water line.

- The connector from the GPS antenna to the base unit was loose and was hand tightened prior to the in-water assessment. If the connection points are loose, connectivity could be compromised and the risk for water ingress is increased.

- The PLB Manufacturer noted that the standard type antenna, extension cable and GPS antenna were of the current standard.

PHASE 2

The table below describes the results of the Phase 2 testing of the PLBs installed in Mk44 and Mk15 Lifejackets:

Lifejacket	Mk44 Un-inflated	Mk44 Inflated	Mk15 Un-inflated	Mk15 Inflated
Position of PLB	Below waterline	Below waterline	Below waterline	Below waterline
Position of Antenna	Below waterline	Below waterline	Above waterline	Above waterline
Position of GPS Antenna	Below waterline	Below waterline	Above waterline	Above waterline
Hand-held device	No signal detected	No signal detected	Signal detected	Signal detected
MRCC	No signal detected	No signal detected	Signal detected	Signal detected
Standing at water's edge	Test not carried out	Signal detected – no positional information	Test not carried out	Test not carried out

Conclusions and Recommendations

The investigation of PLB performance carried out by the lifejacket manufacturer concluded that:

- The installation of the SARBE 6 406G PLB in the Mk44 Lifejacket was unsatisfactory because although the beacon would be activated by the water activation switch, the full range of signals were not detected from the locator beacon when the test subject adopted a floating attitude, regardless of whether the lifejacket was inflated or un-inflated.

- The installation of the SARBE 6 406G in the Mk15 Lifejacket was satisfactory because the beacon was activated by the water activation switch and the full range of signals was detected when the test subject adopted a floating attitude and regardless of whether the lifejacket was inflated or un-inflated.

In light of these conclusions the lifejacket manufacturer decided that:

a) The Mk44 Lifejacket would be modified to adopt the same standard antenna and GPS antenna mounting methods and positioning as the SARBE 6 406G installation on the Mk15 Lifejacket.

b) The Lifejacket manufacturer would carry out initial assessments of a modified Mk44 prototype to demonstrate functionality. These initial assessments would be carried out in a swimming pool and would ensure that the stole deployed correctly and that the antennas were correctly positioned.

c) Formalised trials would then be carried out with MRCC and the Operator to validate the modification and to provide user confidence.

d) Once the trials were completed successfully a service bulletin would be raised to introduce the modification.

e) A review of all SARBE 6 406G beacons installed in the lifejacket manufacturers product portfolio would be carried out to ensure correct installation, function and operation. Acceptance of each installation would be sought from the PLB manufacturer.

f) A wider review of all lifejackets with integrated beacons in the portfolio would be carried out to ensure the correct function and operation of the equipment. Acceptance from the relevant PLB manufacturer would be sought.

-END-

Appendix T — Differentiation SAR vs HEMS

The definitions and regulations relating to HEMS missions are covered in OMG.

SAR flight:

All taskings to incidents at sea, cliffs, inland waterways, mountainous areas or locations where access to, and extraction of, the casualty is not safe by an ambulance crew shall be classified as SAR and remain so until the mission has been completed. This shall be based on the best available information as provided by the SAR mission controller (SMC) at the time of tasking.

If, upon arriving on-scene, the casualty is in, or has been moved, to a location where an ambulance crew can safely access and extract the casualty, the following restrictions shall apply:

a. *For day operations:*
i. *Landing: Site shall have a minimum dimension of 2D x 2D*
ii. *Hoisting: Only permitted if a suitable 2D x 2D site is not available and significant delays would result in positioning to such a site.*

b. *For night operations:*
i. *Landing: Only permitted at CHC approved surveyed sites, on beaches or licensed airfields*
ii. *Hoisting: Only permitted where the aircraft can safely approach over the water, and remain on the shoreline. An unobstructed flyaway shall be maintained at all times.*

Note:

For the purposes of night off-airport operations on both SAR and HEMS missions, night shall be deemed to begin 15 minutes prior to CET and end 15 minutes after CMT.

c. *Offshore islands:*

i. *Missions to offshore islands, where in the opinion of the paramedic or other suitably qualified medical personnel that the casualty's condition is life threatening, or where the casualty needs to be winched into the helicopter, will be operated as a SAR flight.*
ii. *If the best available information at the time of tasking indicates that the casualty does not need to be winched and the condition of the casualty is not life threatening, then it will be conducted in accordance with OMG.*

In certain circumstances, missions to incidents which are not at sea, cliffs, inland waterways, mountainous areas or areas which are inaccessible to ambulance crews may also be designated SAR. However, the following criteria must be applied:

- ***a.*** *In the opinion of the paramedic, or other suitably qualified medical personnel, the condition of the casualty is life threatening.*
- ***b.*** *Where it is obvious that a casualty is likely to expire if not facilitated by immediate air transport, even when a road ambulance is available.*
- ***c.*** *Weather minima and performance shall be in accordance with OMG limits.*
- ***d.*** *For day operations, the operating site shall have a minimum dimension of 4D x 2D. (In certain circumstances this may be reduced to 2D x 2D.) See section 'Site dimensions' in OMG chapter 2 for site dimensions.*
- ***e.*** *Hoisting is not permitted.*
- ***f.*** *For night operations, land at CHC approved surveyed sites only.*

Note:

- ***a.*** *The above conditions are not mutually exclusive.*
- ***b.*** *CHC shall record and report to the IAA all such situations where this discretion has been exercised.*
- ***c.*** *CCS shall continuously review (through a follow-up process) all post-flight medical case, based on the medical information available to the paramedic (or suitably qualified medical personnel) at the time of the airlift.*
- ***d.*** *This discretion may be used for inter facility transports where the condition of the casualty is life threatening.*
- ***e.*** *This discretion may be used for the transport of organ patients or organs, when the organs could potentially become unusable if not facilitated by immediate air transport*'.

OMG defines a HEMS flight as:

'A flight by a helicopter operating under a HEMS approval, the purpose of which is to facilitate emergency medical assistance, where immediate and rapid transportation is essential, by carrying:

- *a. Medical personnel, or*
- *b. Medical supplies (equipment, blood, organs, drugs), or*
- *c. Ill or injured persons and other persons directly involved'.*

OMG defines an Air Ambulance flight as '*A flight, usually planned in advance, the purpose of which is to facilitate medical assistance, where immediate and rapid transportation is not essential, by carrying:*

- *a. Medical personnel, or*
- *b. Medical supplies (equipment, blood, organs, drugs), or*
- c. *Ill or injured persons and other persons directly involved'.*

-END-

Appendix U — Measures outlined by the Minister for Transport, Toursim and Sport following the accident and in response to the Investigation's Draft Final Report

Following the accident and in response to the Investigation's Draft Investigation Report, the Minister advised the following on 12 November 2019 (de-identified where appropriate):
[…]

[In summary: Several measures were undertaken which were grouped under six headings and that much of these measures anticipated findings and safety recommendations contained in the draft report]:

1. Development of a new National SAR Plan following extensive review
2. Enhancing safety and oversight across the SAR system
3. Addressing SAR aviation oversight – nationally and internationally
4. Review and revision of all relevant Standard Operating Procedures (SOPs) and training for the IRCG personnel, particularly SAR Mission Coordinator (SMC) training with a focus on aviation tasking
5. Development of an externally accredited safety management system in the IRCG
6. Review of governance arrangements in relation to [the Operator], enhancing aviation expertise in critical areas and legislative reform of the IAA

[…]

1. **Development of a new National SAR Plan following extensive Review**

[Cross-reference Table removed]

On foot of a recommendation in the AAIU's interim report (March 2018), I commissioned an independent review of oversight arrangements for SAR aviation operations in Ireland. Following publication of the [independent consultant's] Report in September 2018 (hyperlink here), I committed to implement in full and without delay the 12 recommendations contained in that report. A key element to this was a review of the National SAR Framework (referenced at various points in the AAIU draft report) to take account of the [independent consultant's] report's findings. This review was led independently by [the former] CEO of the UK's Maritime Coastguard Agency, commenced work in November 2018 and completed its report to me in June 2019. It was published along with the new National SAR Plan in July having been noted by Government.

The first output from this review was a new National SAR Plan (NSP). This new NSP provides for a re-balancing of the previous maritime-centric SAR Framework to encompass both aeronautical and land SAR more comprehensively; it provides for more explicit governance, assurance and oversight roles across the SAR system; it reconfigures and re-names the previous Irish Aeronautical and Maritime Emergency Advisory Committee as a more strategic National SAR Committee with a leaner, more coherent set of sub-committees. It also provides for a clearer description of the National SAR system including roles, inter-relationships and responsibilities from strategic through tactical to operational levels; and it sets out guidance to develop a common approach to managing SAR incidents across all three domains.

The NSP is being delivered on a phased basis over 18 months to enable a managed and integrated approach to the revised SAR structures and to the development of the necessary MoUs and SLAs between SAR stakeholders, both horizontally and vertically, within the system.

The second output was an implementation plan for the recommended model for a Joint Rescue Coordination Centre (JRCC). This '*virtual*' JRCC will capitalise on the strengths of the current ARCC/ARSC and MRCC/MRSC model, while minimising disruption and exploiting the potential of enhanced technology, closer cooperation and revised operating procedures. It will also address vulnerabilities identified in the existing model, and provide for stronger oversight arrangements.

The SAR report also sets out revised arrangements for overseeing the international SAR agreement between the IRCG and UK's MCA [Maritime and Coastguard Agency]. It also addresses aspects of SAR relevant to the 2018 MCIB report into the tragic Kilkee accident in September 2016.

The SAR review was assisted by […] Consultants, who provided independent expertise and supporting analysis. Their submissions underpin the findings of this report and the direction taken in developing the new NSP and selecting the most appropriate JRCC model for Ireland.

Following the conclusion of the SAR Review Report in June, [independent consultancy] were asked to review the follow-up actions taken since their report was published on SAR Aviation Oversight the previous September. [The independent consultancy] completed this review which was broadly positive and concluded that 8 of its 12 recommendations have been fully addressed with the remaining 4 either '*partly*' or '*initially*' addressed with some further work required to complete. A copy of this report has been provided to the AAIU.

A major theme covered by the SAR Review which is addressed in the NSP relates to roles and responsibilities within the SAR system, particularly the governance and oversight roles. This issue is also mentioned in the draft AAIU report. A new chapter in the National SAR Plan captures how SAR policy is set, responsibilities are assigned, performance is monitored and managed and how the primary SAR stakeholders are overseen, including from a regulatory perspective where relevant. This includes a definition of 'oversight' itself. This goes very directly to the issues raised in the AAIU's draft report in relation to bringing clarity to state oversight, not just in the aviation area, but across the entire SAR system, at strategic, tactical and operational levels. Furthermore, the new NSP identifies SAR regulatory roles more explicitly – including those of the IAA, the Marine Survey Office and the Road Safety Authority.

2. **Enhancing safety and oversight across the SAR system**

[Cross-reference Table removed]

Also of clear relevance to the AAIU's draft report, the new National SAR Plan introduces a new element to provide assurance in relation to the performance and safety of the SAR system. This is described under the '*Assurance, Risk Management and Safety Culture*' section of the NSP.

This approach is adapted from the New Zealand SAR model of '*system assurance*' and places an onus on all participants to provide annual assurances across key areas. While this does not obviate or supplant any statutory or other formal requirements, it provides a mechanism for routinely assuring a minimum set of requirements are in place in relation to safety management and oversight across the SAR system. Essentially, it requires all SAR stakeholders to implement a range of measures along the principles of risk assessment, safety management and continuous system improvement. Collectively, these measures represent an improved level of assurance in relation to the overall system. A key principle embedded in this assurance mechanism is that it should be proportionate to the scale and complexity of the organisations involved – so that smaller voluntary SAR units are not subject to the same degree of administrative scrutiny as a larger, professional SAR stakeholder.

As a support mechanism to the new SAR assurance system, the NSP establishes a new SAR Regulators' Forum and a new Health and Safety Forum. The Regulators' Forum is intended to sit along-side the National SAR Committee and act in an advisory capacity. It will review the SAR system assurance reports, share regulatory best practice and inform further enhancements of this system. It will report to me as necessary in relation to regulatory compliance matters arising and offer advice when requested. This Forum is now up and running, with membership drawn from the IAA, the Marine Survey Office and the Road Safety Authority with the Chair of the National SAR Committee in attendance.

The new Health and Safety Forum aims to encourage a collaborative and cooperative approach among the primary SAR stakeholders and service providers to health and safety issues in the SAR sector. Its membership has been agreed by the National SAR Committee to include experts in health and safety management within the main SAR service providers. This model exists and works well in other jurisdictions but is new to the Irish system.

Finally, the National SAR Committee has also been assigned a role to monitor and review the adequacy of this enhanced mechanism for assurance. In that context, it will ensure the following activities are carried out:

- Regular reviews and updates of SAR agreements internationally;
- Regular reviews of MoUs / SLAs between SAR system participants;
- Provision of submissions (as appropriate) to the ICAO / IMO Joint Working Group on SAR to share lessons learned and experiences with other States for the continuous improvement of the worldwide SAR system;
- Regular analysis of SAR operational data to identify trends and areas of improvement and a commitment to make this information available to the wider SAR system through the National SAR Committee;
- Annual review of the SAR system to identify any specific gaps in capability and /or areas for improvement against minimum requirements of relevant international conventions and guidelines (including Annex H of IAMSAR manual) (IAMSAR);
- Other initiatives to promote system assurance through consultation with the Regulatory Forum and/or the Health and Safety Working Group.

This new SAR assurance mechanism places an onus on the IRCG to conduct an annual Annex H assessment. This voluntary self-assessment tool is specifically mentioned in the AAIU draft report. The first of these assessments was conducted in the context of the SAR Review process in June 2019. This identified a number of minor areas for improvement in what was found to be a fundamentally compliant and soundly administered SAR regime. This self-assessment will now be undertaken annually under the auspices of the National SAR Committee. For clarity, this a system-wide review rather than aviation specific. It is designed to assess the entire system and its components, and is not confined to SAR aeronautical operations nor indeed, considers the presence/absence of an SMS.

As regards external assessments, the NSP provides greater clarity in relation to regulation, involving external audits, of the SAR system. For example, oversight of the ARCC, MRCCs and the new Virtual JRCC is set out clearly, as follows. The ARCC continues to be overseen by the IAA's Safety Regulation Division as the national aviation safety regulator. MRCC/MRSC operator training in relation to tasking SAR aviation assets is being conducted by an aviation Approved Training Organisation (ATO) which is subject to certification and oversight by the IAA. MRCC/MRSC operations generally will be overseen by the IRCG enhanced internal audit regime (in support of its new Safety Management Systems) and reinforced by periodic external audit by an independent and suitably experienced entity.

All of these elements are designed to bring clarity in terms of oversight at all levels in the SAR system, make roles and responsibilities more explicit than previously and ultimately, provide adequate reassurance in relation to how the SAR system operates and builds in a stronger and systematic commitment to continuous improvement and developing a '*just culture*' across the entire system.

3. **Addressing SAR aviation oversight – nationally and internationally**

[Cross-reference Table removed]

As outlined above, the new National SAR Plan sets out more clearly the roles and responsibilities in relation of oversight. The SAR Review Report (published July 2019) also describes the measures undertaken by the IAA as the national aviation regulator to address recommendations arising from the [independent consultant's] review of SAR aviation oversight which are clearly relevant to those aspects of the AAIU's draft Report. The implementation of these specific recommendations is also addressed in the [independent consultant's] 2019 Report on implementation. I expect the IAA's response to [the AAIU's] draft report will provide the latest state of play in this regard.

One of the recommendations from the [independent consultant's] SAR oversight review report, which is picked up in the draft report [recommendation No. removed], relates to engagement with European bodies concerning on an EU-wide framework for SAR regulation and the '*opt-in*' provision for SAR under the European Aviation Safety Regulation EC 2018/1139. The Department has, on 4 November 2019, engaged in discussion with relevant counterparts in European Commission and the European Aviation Safety Agency (EASA) in this regard.

With regard to a possible future EU-wide SAR regulation framework, the European Commission and EASA have confirmed that EASA does not have competence under the European Aviation Safety Regulation to develop such a framework, rather this is a European Commission responsibility in consultation with the Member States. The European Commission will respond directly to the AAIU in this regard as named parties of the draft Report. However, my Department understands that the development of an EU-wide SAR regulation framework by the European Commission would involve a long-term assessment of surveys and trend data over time, as well as political will by Member States.

It is also noted that the SAR opt-in under the European Aviation Safety Regulation was proposed by the EU and agreed by the member states, with flexibility to select some and not all of the specific regulatory requirements to opt in to. This indicates perhaps that a number of Member States may not support an EU-wide aviation safety oversight framework for SAR. Within this context there are limits to which Ireland can ensure the bringing about of such an EU-wide SAR framework.

Notwithstanding, taking account of the recommendation of the [independent consultant's] SAR oversight review report and the AAIU recommendation, my Department has sought and received legal advice that primary legislation is required for Ireland to exercise the EASA opt-in under Article 2(6) of the European Regulation 2018/1139. The Department is seeking further Counsel advice concerning a possible draft Heads of Bill for this purpose. Subject to Government agreement this could be considered within the Air Navigation and Transport Bill 2019. EASA has, in the recent discussion, advised my Department officials that an analysis should be undertaken of the requirements of the European Regulation which apply to the SAR opt-in against the National requirements for SAR oversight, in order to assess any potential gaps which may need to also be provided for under National legislation.

4. **Review and revision of all relevant SOPs and training for the IRCG personnel, particularly SMC training with a focus on aviation tasking**

[Cross-reference Table removed]

The Coast Guard, in its role as a helicopter tasking authority, has identified and addressed a series of measures that provide for more robust and clear cut decision making by IRCG Rescue Coordination Centre (RCC) staff, and more explicitly incorporate risk assessment procedures to be followed.

A key document in this context is the IRCG's Heli OPs SOP (Standard Operating Procedure). This document captures the operating criteria under which CG helicopters can be tasked by IRCG RCCs, for different mission types and the associated constraints and limitations that apply. The key audience for this document are RCC staff. [The Operator's] primary engagement with this document is to ensure that it complies with the applicable, IAA-overseen [Operator's] Operations Manual (OM-G). This engagement with [the Operator] is critical in ensuring that the IRCG as the tasking authority and [the Operator] as the recipient of such requests have a shared understanding of the IRCG's operating criteria as it impacts on them. The SOP was re-issued in 2018 following an extensive review between IRCG and [the Operator]. Technical advice on IRCG input into the document was provided by the retained IRCG Aviation consultant.

This document is kept under constant review. Future iterations of the document will also include IAA input in accordance with arrangements prescribed in the recently agreed Advance Arrangement (referred to elsewhere in this letter). Any internal operational notices issued by IRCG must conform with the Heli Ops SOP.

Internal IRCG procedures referred to as Coast Guard Operations Notices are kept under ongoing review and are managed under a document control procedure. These documents are driven by a lessons identified and lessons learned process with input from key stakeholders and address some important matters identified in the AAIU [draft] report – three in particular:

i) IRCG reviewed and updated the internal operational notice on the procedure to be followed when considering a request for a MEDEVAC and sourcing medical advice. MEDICO Cork as a key stakeholder participated in the drafting of this document. The latest version contains very specific guidance to assist IRCG watch officers determine more explicitly the views of MEDICO personnel on the medical necessity and options, in responding to a particular incident.

ii) Similarly revised procedures for determining the requirements for, and coordination of, air support for long range SAR operations, including Fixed Wing or Helicopter options, have been issued. [The Operator] participated in the drafting of this document – again to ensure compliance with their regulatory and / operational parameters.

iii) Revised arrangements governing operational criteria for the conduct of HEMS operations were also published in 2018 following consultation involving IAA, [the Operator], IRCG and Dept of Health / HSE. This Operations Notice reflects a clear delineation of HEMS as a Commercial Air Transport activity as opposed to SAR.

The establishment of a Safety, Quality and Compliance Section within the Coast Guard at a structural level provides for significant improvement in its internal oversight and risk assessment procedures. All Coast Guard RCC and Operations staff undergo a SAR Mission Coordinator course at the NMCI [National Maritime College of Ireland]. This syllabus reflects IMO Model Course for SMC training and the Coast Guard has completed a review and update of its syllabus. The course attracts international students and the Coast Guard in conjunction with NMCI/CIT [Cork Institute of Technology] is working towards securing formal third level recognition for this training.

In October 2019 the Coast Guard rolled out a new course entitled SAR Aviation Tasking and Coordination (SATaC). This course, delivered by an IAA Approved Training Organisation (ATO) provides in-depth theoretical knowledge on Aviation coordination to Coast Guard operational personnel. Risk assessment procedures are an integral element of this course.

The Coast Guard has reviewed the provision of aviation expertise by identifying technical capabilities to oversee and review all activities associated with SAR aviation operators. The Coast Guard has received sanction to recruit a new aviation manager who will improve technical capabilities in relation to activities associated with the SAR aviation operator.

Following a review of the IRCG's SOPs for Boat Launching and Search and Recovery as part of the SAR Review completed in June last, the IRCG is undertaking a programme of review of all its extant SOPs. This will aim at greater clarity and uniformity in the style and presentation of such SOPs, taking account of the intended audience and how such documentation is used in practice. The deadline for completion of this review as part of the implementation of the NSP is March 2020. In addition, improved document control will form part of the IRCG's roadmap to an accredited Safety Management System based on rigorous quality management.

The Coast Guard has an established '*lessons learned /lessons identified*' process which is embedded in its Operations logging system (SILAS). The IRCG has enhanced its in-house resourcing to conduct regular analysis across SILAS and other data sources available to the IRCG to better interrogate how incidents have been carried out.

The advent of a new Volunteer Information Management IT System will ease the promulgation of new SOPS and associated guidance material across the IRCG volunteer population. Together with the existing Incident Logging System (SILAS), this will provide for more consistent and comprehensive approaches to dynamic decision-making and risk assessment.

5. **Development of an externally accredited safety management system in the IRCG**

[Cross-reference Table removed]

87 In support of Continuous Improvement of the SAR system, Coast Guard has established a Safety and Quality Compliance (SQC) Section, and within which includes a dedicated Health and Safety Officer to provide oversight of the SMS, and work in conjunction with the Department's safety officer(s) in pursuit of Health and Safety Policy, Procedures, Goals and Objectives.

IRCG has also committed to the development and implementation of an effective and functioning Safety Management System, applicable to the specific needs of the IRCG and in adherence with the requirements of ISO 45001:2018 - Occupational Health and Safety Management Systems.

Per the recommendations of [the independent consultant's] Review, and specifically concerning the necessity to implement a Total System Approach (TSA) regarding safety management, Coast Guard and [the Operator], have drafted an interface agreement to link their respective Safety Management Systems. Doing so provides a structure in which to facilitate more open communication on identified safety issues, aids joint hazard identification and mitigation activities, defines safety responsibilities and supports the continuous improvement of safety performance.

The administrative integrity and operational performance of the MRCC/MRSCs are also now overseen and assured by the IRCG's internal compliance and audit regime, led again by the recently established SQC section and to be reinforced by periodic external audit by an independent and suitably experienced entity, in accordance with the new NSP.

In the context of delivering its part of the SAR assurance mechanism as prescribed in the new National SAR Plan, the IRCG has commenced a review of all its Memoranda of Understanding / Service Level Agreements to ensure respective roles and responsibilities are articulated clearly and understood by the respective parties. Such MoUs and SLAs are particularly important in determining where the risk lies when organisations are being requested to respond to an incident. This review will include the existing SLA with the Department of Defence / Air Corps in relation to issues such as top cover to ensure a common understanding of the terms used and operational implications. This review will be completed by March 2020 as part of the implementation of the new NSP.

6. **Review of governance arrangements in relation to [the Operator], enhancing aviation expertise in critical areas and legislative reform of the IAA**

[Cross-reference Table removed]

Contacts between the IRCG and [the Operator] happen at various levels and follow the contractual arrangements set out in the 2012 contract with [the Operator]. As such, day to day operational matters – including tasking, incident management etc - are handled through the Rescue Coordination Centres directly with their [Operator] base contacts. These are governed by the IRCG SOPs – primarily the Heli –Ops SOP – which is kept under constant review by both IRCG and the external aviation consultant when requested. As noted already, Coast Guard has reviewed its Heli SOPs in particular the SAR/HEMS decision tree in close consultation with the operator and the aviation consultant. Future updating of SOPs will incorporate enhanced risk assessment processes. As mentioned already, specific aviation training is underway for RCC staff complete with explicit risk assessment training for tasking of aviation assets i.e. rotary and fixed wing.

SAR Operation management issues, including more strategic issues such as availability issues, Hospital Landing sites, etc - are managed by the CG Operations Manager with his counterpart in [the Operator], Manager of Flight Operations (MFO). Safety related matters are managed between the Health and Safety personnel of both – under the terms of the aforementioned SMS bridging document with input from the external aviation consultant contracted by the IRCG.

Broader governance issues – in terms of contract performance issues, contract changes, high level safety matters and any financial issues - are managed through regular Contract Liaison meetings between IRCG and [Operator] management personnel. These meetings cover a broad range of issues and are facilitated by the IRCG's aviation consultant who prepares the paperwork, agenda, identifies and monitors appropriate follow-up actions, etc.

Through these structures, there is a very clear delineation in the day to day operational engagement and the more strategic governance arrangements with [the Operator], which are inter alia, intended to avoid any perception that IRCG may be exerting undue pressure – commercial or otherwise - on day to day decision-making of [the Operator's] crews. These arrangements would have pertained at the time of the accident.

In order to further strengthen the IRCG as an '*intelligent customer*', a recruitment of a full time Aviation Manager position is underway. This individual will have, inter alia: technical aviation qualifications and aviation safety management background particularly ICAO Annex 19 Safety Management and European Aviation Safety Agency Requirements for Air Operations. Gen 200 Management System. It is expected that the post will be filled by end 2019.

The Department itself conducted a review of governance in relation to roles and procedures in relation the [the Operator] contract changes in February 2018. This was intended mainly as a hygiene check in relation to how contract changes were managed and to ensure that language within the contract was consistent with practice as it had evolved over the initial term of the contract itself. Subsequent to this, some changes were made to the manner in which IRCG – [Operator] contract meetings were held, adding greater focus to safety related matters and encouraging a more robust engagement on issues around contract compliance.

The use of the external aviation consultant (currently [named auditing company] Ltd) has also been enhanced – within the existing parameters of the contract – to enable a more robust engagement with [the Operator] in terms of the performance of its contractual obligations. The audit approach applied by the external contractor is rigorous in terms of safety compliance. [named auditing company] reports are narrative accounts of the audit and the evidence examined (rather than simply being checklists) and accompanied by typically half a dozen relevant photographs. They are a written record of the major pieces of evidence reviewed (such as taskings, Technical Log pages, documents etc). They are typically 2000+ words. The emphasis varies between audits. While each looks at the SAR capability of that base, deeper audits are conducted on specific areas during individual audits, which are spread out over the year, with all 4 bases examined. For example the safety function and flight ops / flight training is examined more deeply in Dublin and the CAMO (continuous airworthiness management) and base maintenance in Shannon. The 2018 and 2019 audits at Dublin have featured two auditors, with different backgrounds, as a team. Two auditors have examined Sligo during the period and one auditor Waterford and Shannon so far. This gives a useful mix of diversity and consistency.

The Flight Safety Foundation BARS [Basic Aviation Risk Standard] Offshore Helicopter Operations standard, which included high level reference to regulations and a framework of operational, technical and equipment requirements for offshore, SAR and MEDEVAC, is used to code findings which may be against regulations, the contract, [the Operator's] own policies and procedures and industry good practices that deserve consideration.

The contractor holds a debrief after each audit with [the Operator] who typically send the Safety and Compliance Manager or another manager to provide some liaison. The reports are supplied to IRCG for comment before being issued to [the Operator]. Audit feedback is given jointly to [the Operator] and IRCG at Contract Ops Meetings. A spreadsheet of all findings and responses is maintained by [the named auditing company] and is now on a secure SharePoint site accessible between Contract Ops Meetings by IRCG and [the Operator].

A mid-term review of the overall contract was commissioned through [the named auditing company]. They were tasked to identify lessons learned, any areas of non-compliance and areas for future improvement. The report was finalised in May 2019 and made a series of 10 recommendations – all of which are being followed up as appropriate. The review forms an important input into on-going deliberations in relation to the next SAR aviation contract.

On the regulatory aspects of the contract, the [independent consultant's] Report made a specific recommendation in relation to how IRCG and IAA interact in this context. Throughout the recent SAR review process, the IAA and IRCG engaged very constructively in relation to the wider regulatory aspects of SAR aviation. It was agreed that a formal mechanism should be found to ensure this engagement continue in a way that facilitates constructive interaction and avoids encroaching on IAA-SRD's regulatory responsibilities in relation to [the Operator]. It was agreed that the mechanism will take the form of an Advance Arrangement between IAA and IRCG. The text for this arrangement has been agreed. [The independent consultant organisation], in its review of the follow-up to its report, found that this arrangement met the requirements of that particular recommendation.

IAA Oversight of SAR

As regards oversight of the IAA's role in regulating SAR, the Department does not retain specialist aviation expertise (pilot or engineering) but contracts expertise for the purposes of the discharge of the Minister's statutory function pursuant to section 32 of the IAA Act, 1993. Section 32(3)(a) of the Irish Aviation Authority Act 1993 requires me as the Minister for Transport, at least every three years, to appoint a person to carry out an examination of the performance by the company of its functions in so far as they relate to the application and enforcement of technical and safety standards in relation to aircraft and air navigation.

The current Section 32 examination is being carried out by the Independent Consultants [another consultant organisation]. The Department is engaging with [the other consultant organisation] about the possibility of including in its examination a review of the IAA regulatory oversight, i.e. that it is sufficiently robust, and that there is a clear understanding of responsibility with regard to functions of the IAA, both which fall within or outside of the International and European regulatory competence (but with a particular focus on operations under IAA national competence such as aerial firefighting) (Recommendation 30 refers).

The previous Section 32 examination noted that while functional separation existed between the IAA safety regulation functions and air navigation service functions, that this needed to be kept under review by the Department. This was addressed through work under the action (2.5.1) of the National Aviation Policy 2015, to ensure that the organizational arrangements and structures for economic and safety regulation of the Irish aviation sector are effective and appropriate.

Finally, the AAIU should be aware that I have been given Government approval for wholesale reform of aviation regulation in Ireland, which will separate out the regulatory and commercial functions of the Irish Aviation Authority. The rationale behind the initiative is to provide much clearer lines of responsibility and accountability in relation to aviation regulatory oversight and, at the same time, to invest in strengthening regulatory capacity. A general scheme of a Bill to give effect to this regulatory overhaul has been considered and approved by the Joint Oireachtas Committee under its pre-legislative scrutiny process, and in September the Government included this legislation in its priority list. The Department has prioritised this legislation and is working with the Office of the Attorney General on drafting a Bill or publication. In the meantime, all of the necessary administrative arrangements are being made in preparation for the new arrangements.

-END-

Appendix V — Extracts from the National SAR Framework

National SAR Framework

The IRISH NATIONAL MARITIME SEARCH AND RESCUE (SAR) FRAMEWORK, published by the Department of Transport on 2 March 2010 states, inter alia:

> *'Search and Rescue (SAR) comprises the search for and provision of aid to persons who are, or are believed to be, in imminent danger of loss of life.*
>
> *…*
>
> *This National Maritime Search and Rescue Framework is the standard reference document for use by all Irish Search and Rescue authorities working in the maritime domain and promulgates the agreed methods of coordination through which search and rescue operations are conducted within Ireland's SAR Region.*
>
> *…*
>
> *In providing a search and rescue response, nothing in the content of the Framework precludes properly qualified officers from using their initiative in providing a SAR response in circumstances where these procedures are judged to be inappropriate. In so doing, however, officers' actions should conform as closely as possible to those instructions contained in the Framework most closely pertinent to the circumstances and they should keep all other parties involved informed.*
>
> *…*
>
> *1.1.3 Where applicable this Framework encompasses the national aviation SAR Framework where the aircraft frame lands into the sea or a major inland lake.*
>
> *…*
>
> *1.6.1 The Department of Transport (DoT) exercises overarching responsibility for maritime and aviation SAR services and for maritime and aviation safety through its Divisions, agencies, the IAA, airport, port and harbour authorities.*
>
> *1.6.2 The Irish Coast Guard, as a Division of DoT, has responsibility for the 24/7/365 coordination of maritime SAR emergency response at sea and along the coasts and cliffs of Ireland, and on major inland lakes. It maintains its Coast Guard national Maritime Operations Centre (MOC) incorporating Irelands Marine Rescue Co-ordination Centre (MRCC) at Dublin and Marine Rescue Sub-Centres (MRSC) at Malin Head in Co. Donegal and Valentia Island in County Kerry. It has a comprehensive Marine Communications Network covering Irish offshore and inland waters. It maintains a network of strategically located Coastal Units equipped to deal with local marine emergencies.*
>
> *1.6.3 The Irish Aviation Authority (IAA) is a semi-state agency responsible to the DoT for the provision of Air Traffic Services including Air Traffic Control and the coordination of Aeronautical SAR emergency response. The IAA maintains an Aviation Rescue Co-ordination Centre (ARCC) at Shannon Airport and an Aviation Rescue Sub-Centre (ARSC) at Dublin Airport. The Safety Regulation Division of the IAA is the body responsible for the regulation and oversight of aircraft operations, including aeronautical Search and Rescue, within the State.…*

1.6.8 The HSE through Medico Cork in Cork University Hospital provides Irelands 24/7 Radio Medical Advice Service to seafarers through the Coast Guard radio network to sick or injured seafarers on a 24-hour basis.

The HSE also provide a Marine Ambulance Response Team for major emergencies. If medical advice requires the casualty to be taken off the vessel then the MRCC/MRSC providing the link will arrange for the casualty to be transported from the vessel to a hospital.
…
1.8.1 Maritime SAR
Within the Department of Transport (DoT), which has overall responsibility as Lead Government Department for maritime and aviation SAR. Primary responsibility has been delegated for Marine Emergency Management within Irelands various responsibility Regions to the Irish Coast Guard. The Coast Guard co-ordinates maritime SAR services within the Irish SRR and will lead and co-ordinate national participation in the SAR and safety related initiatives of the International Maritime Organisation (IMO).
...
1.8.3 Aviation SAR
The Department of Transport (DoT) while retaining overall responsibility for Aviation SAR has determined that the Irish Aviation Authority shall operate the ARCC requirements of ICAO Annex 12. The Safety Regulation Division of the IAA is the body responsible for the regulation and oversight of aircraft operations, including aeronautical Search and Rescue, within the State.
…
1.12 FUNCTIONS COVERED BY THIS FRAMEWORK

1.12.1 The efficient operation of the Maritime components of the co-ordinated SAR system.

1.12.2 The provision of SAR services for aircraft at the request of the IAA or An Garda Síochána.

1.12.3 The establishment, maintenance and operation of a maritime operations centre and maritime rescue co-ordination centres capable of adequately discharging the responsibilities for the efficient detection, co-ordination and rescue of persons in distress or potentially in distress and that have adequate and resilient means of communications, equipment and properly trained and resourced staff.

1.12.4 The provision of assistance to the relevant authorities in the event of natural disasters.

1.13 FUNCTIONS NOT COVERED BY THIS FRAMEWORK

1.13.1 Air Ambulance service not resulting from maritime or aeronautical SAR operations. National Maritime SAR Framework version final 2010 Publish date: 2nd March 2010 Pg 17 of 61.

1.13.2 Helicopter Emergency Medical Services (HEMS).

1.13.3 Civil Disturbance, insurrection, terrorist or other emergencies, which endanger citizens or property.

1.13.4 Salvage and aircraft recovery operations.

1.13.5 Pollution operations.

1.13.6 Ship Casualty incidents where live [life] *is not at risk.*
…
1.16.5 No provision of this Framework is to be construed as an obstruction to prompt and efficient action to relieve distress whenever and wherever found.

1.16.6 SAR Co-ordinators shall arrange for the receipt of distress alerts originating within the Irish SRR, and ensure that the MRCC/MRSC can communicate with the persons in distress, and with the SAR facilities.
…
1.17.2 The Marine Rescue Sub Centre (MRSC) Valentia is the contact point for routine operational matters in the area between Ballycotton and Clifden. MRSC Malin Head is the contact point for routine operational matters in the area between Clifden and Lough Foyle. MRCC Dublin is the contact point for routine operational matters in the area between Carlingford Lough and Ballycotton.
…
1.18.3 SAR Authority

1.18.3.1 A SAR Authority is the authority within a national Administration with overall responsibility for establishing and providing SAR services and ensuring that planning for those services is properly coordinated. The national SAR authority in Ireland is the Irish Coast Guard in respect of maritime SAR and the IAA in respect of aviation SAR. The SAR Authority takes on the roles of the SAR Coordinator as described in the IAMSAR Manual.

1.18.3.2 A SAR Authority shall ensure that a SAR operation can be promptly initiated and prosecuted with the efficient use of available SAR resources, until rescue has been completed or until chance of success is no longer a reasonable possibility. An operation may thereafter continue if appropriate to effect recovery of deceased persons.

1.18.3.3 The Coast Guard on behalf of the Department of Transport has the overall responsibility for establishing, staffing, equipping and managing the SAR system, including providing appropriate legal and funding support, establishing RCC's, providing or arranging for SAR assets, coordinating SAR training and developing SAR policies. The SAR authority, where applicable, shall:

- *establish a Rescue Coordination Centre (RCC) to coordinate all participating search and rescue assets and facilities;*
- *ensure that the RCC conforms to the SAR procedures contained in this manual or local SOPs and manuals;*
- *establish close liaison and formulate agreements with other authorities and organisations having SAR potential;*

- *establish liaison with SAR authorities of adjacent areas to ensure mutual cooperation and coordination in combined operations;*

- *ensure that a comprehensive and current SAR Framework is prepared and distributed;*

- *establish and supervise communication facilities and assign SAR frequencies from those authorised to assets designated for SAR tasks;*

- *establish communications with adjoining RCC's and appropriate organisations to ensure two-way alerting and dissemination of SAR information;*

- *ensure immediate action is taken to provide assistance, advising the appropriate SAR authorities and passing all information received concerning the distress incident and any action taken;*

- *ensure that the operating authority or agency of any craft, aviation asset or land party in need of assistance has been advised of initial actions taken, and they are kept informed of all pertinent developments;*

- *designate an SMC for a specific SAR incident;*

- *ensure that each incident is prosecuted until assistance is no longer necessary, rescue has been completed or chance of success is no longer a reasonable possibility;*

- *ensure that if the scope of the operation exceeds the authority's capacity to plan and execute the operation, it shall seek advice and assistance from, or by mutual agreement, hand over coordination, to an appropriate authority;*

- *maintain and preserve adequate records; and*

- *develop new and improved techniques and procedures.*

1.19.1 The staff of a RCC performs duties in the conduct of search and rescue events and in addition they have responsibility for maintaining the RCC in a continuous state of preparedness. The RCC staff consists of personnel who are experienced and/or trained in SAR operations. When a period of heavy activity is anticipated or during major SAR incidents, the regular staff may be supplemented as required or workload may be shared between Coordination Centres. Each centre will be able to link landline or marine communications in and out of the Tetra network.

1.19.2 Each SAR operation is carried out under the coordination of a SAR Mission Coordinator (SMC) designated for the purpose by the Coast Guard. The SMC is responsible for efficiently prosecuting a SAR incident using the assets available. The SMC is responsible for all stages of the SAR system. Their responsibilities include the prompt dispatch of appropriate and adequate SAR assets and the prosecution of SAR operations until rescue has been completed, or chance of success is no longer a reasonable possibility.

The SMC is responsible for ensuring that the following duties are carried out depending on the SAR incident and local circumstances:

- *Obtaining and evaluating all information pertaining to the incident, including emergency equipment carried by the person or craft in distress.*
- *Classifying the SAR incident into the appropriate emergency phase (Uncertainty, Alert/Urgency, or Distress).*
- *Alerting appropriate SAR assets and SAR organisations that may be of assistance during the incident.*
- *Conducting a risk assessment.*
- *Dispatching initial SAR Units if situation warrants.*
- *Conducting initial communications checks. If unsuccessful, making an extended communications search to obtain additional information on the incident, personnel involved and equipment carried by the vessel, aircraft or party in distress.*
- *Calculating the search area. Preparing optimum plans and promulgating attainable plans.*
- *Obtaining past/present/forecast weather, drift information and oceanographic conditions if applicable.*
- *Providing for SAR crew briefing, dispatching of appropriate SRU's, or other assets.*
- *Organising logistical support for all SAR assets including fuel, food and accommodation, through to the completion of the incident.*
- *Making arrangements for appropriate communications.*
- *Maintaining a continuous, chronological plot showing sighting and hearing reports, DF bearings, air plot, radar plot, fixes, reports of debris, areas searched or not searched and other intelligence.*
- *Maintaining a continuous, chronological record or log of the search effort, including actions taken in relation to intelligence, SRU's employed, sorties, hours flown/underway, sightings, leads, results obtained, message traffic, briefing notes, telephone calls, daily evaluation of progress and probability of detection.*
- *Initiating marine distress broadcasts or marine information broadcasts and initiating the alerting of enroute aircraft.*
- *Arranging communication schedules when and if needed.*
- *Requesting additional SAR assets, as required.*
- *Exercising overall coordination of SAR assets.*
- *Maintaining liaison with the next of kin, owner, agent or management of the missing craft or persons.*
- *Liaise, and brief as appropriate, the Minister for Transport and the Government Information Service.*
- *Keeping all authorities involved fully advised of SAR incident progress with timely and regular situation reports (SITREPs).*
- *Making recommendations and decisions in relation to the continuation or suspension of searches.*
- *Issuing news media releases on the progress of incidents in accordance with the procedures and policies.*
- *Providing debriefs of SRU's, cancel alerts, release SAR assets and organisations involved, and issuing the final SITREP to all concerned.*

- *Acting as required coping with any unique, unusual or changing circumstances of the emergency.*

1.19.3 Where a maritime incident requires an aviation response, the Coast Guard shall liaise directly with agencies that may supply such resources. IRCG's MRCC/SC shall be responsible for the provision of such services as fuelling, accommodation, security and any such additional services. Where aviation resources are required in response to an aviation incident, the IAA's RCC shall be responsible for the provision of resources and any such support services as are required. Where airport facilities for marine related incidents are required outside the normal hours of availability of such facilities, MRCC/SC shall be responsible for the call-out of such services as required.

1.23.2 The Department of Transport while retaining overall responsibility for Aviation Search and Rescue Operations (ICAO Annex 12) has determined that the Irish Aviation Authority (IAA) will operate the ARCC requirements of ICAO Annex 12 as an agent of the Department of Transport (Ref. ICAO Annex 12; S.I. No. 171 of 1995; S.I. No. 172 of 1995). The Aviation Search and Rescue Region covers an area coincident with the Shannon FIR/UIR

1.23.3 In the event of an aviation emergency over a maritime or littoral area, ARCC/ARSC will co-ordinate the incident in close liaison with MRCC/MRSC. Should an aircraft force land in a maritime area, ARCC/ARSC will be responsible for determining the initial search area, but co-ordination will then transfer to MRCC/MRSC with continued close co-operation and back-up services from ARCC/ARSC.

1.23.4 In the event of an emergency meeting at the Marine Emergency Room, requiring an aviation input, the Head of ARCC Shannon will decide on the appropriate representation. The AAIU may also consider a need for representation at this meeting where appropriate or where requested by the IRCG.

1.23.5 Routine communication shall take place by means of documentary, electronic or verbal transfer. ARCC/ARSC will be included as information addressee in routine Sitreps issued by MRCC/MRSC where the incident may require or include an aviation response. The AAIU will be included as information addressee in routine Sitreps issued by MRCC/MRSC where the incident may require a response and investigation by the AAIU.

1.23.6 Where a maritime incident requires an aviation response, it is the MRCC/MRSC who will liaise directly with agencies, which may supply such resources. MRCC/MRSC are responsible for the provision of refuelling, accommodation, security and any additional related services.
…
2.1.2 IRCG provide medical link calls from ships at sea to the vessel's national medical centre and evacuation of the casualty from the vessel by helicopter or lifeboat if required. If medical advice requires the casualty to be taken off the vessel then the MRCC/MRSC providing the link will arrange for the casualty to be transported from the vessel to a hospital. IRCG Responders or aircrew dealing with patients in remote locations can be linked live through a Coordination centre on marine communications to Medico Cork or any foreign Medico Centre.

2.2.4 Helicopter tasks include:

- *The location of marine and aviation incident survivors by homing onto aviation and marine radio distress transmissions, by guidance from other agencies, and by visual, electronic and electro-optical search.*
- *The evacuation of survivors from the sea, and medical evacuees from all manner of vessels including high-sided passenger and cargo vessels and from the islands.*
- *The evacuation of personnel from ships facing potential disaster.*
- *Search and/or rescue in mountainous areas, caves, rivers, lakes and waterways.*
- *The transport of offshore fire fighters or marine ambulance teams and their equipment following a request for assistance.*
- *The provision of safety cover for other SAR units including other Marine Emergency Service helicopters.*
- *Inter-agency training in all relevant aspects of the primary role.*
- *Onshore emergency medical service, including evacuation and aero-medical tasks carried out with specific Approvals issued in accordance with Joint Aviation Requirements JAR OPS 3.005(d).*
- *Relief of the islands and of areas suffering from flooding or deep snow.*

The secondary roles of the helicopter include:

- *The exercise of the primary search, rescue and evacuation roles in adjacent Search and Rescue regions. • Assistance to onshore emergency services in accordance with IAA approvals.*

…

2.3.1 The IAA is a semi-state agency responsible to the Department of Transport for the provision of Air Traffic Services (ATS) including Air Traffic Control (ATC). This includes the provision of an Aeronautical Rescue Coordination Centre (ARCC) at Shannon Airport and an Aeronautical Rescue Sub Centre (ARSC) at Dublin airport. The Aviation Search and Rescue Region covers an area coincident with the Shannon FIR/UIR.

2.3.2 ARCC/ARSC shall be the co-ordinating agency for establishment of Temporary Restricted Areas when so required for SAR purposes. Clearance to enter, operate in or leave any of the above mentioned areas should be obtained from the appropriate ATS units.

2.3.3 Where aviation resources are required in response to an aviation incident, ARCC will request resources and any support services as are required.

2.3.4 The Safety Regulation Division of the Irish Aviation Authority has the function with regard to aviation legislation and regulatory oversight of all civilian aircraft operations, including in this case Search and Rescue.

IRCG Standard Operating Procedures For Helicopter Operations, IRCG Helicopter SOPs, Issue 4 dated 25 April 2016 state, inter alia:

7.1. SAR flight:
All taskings to incidents at sea, cliffs, inland waterways, mountainous areas, or locations where access to, and/or extraction of the casualty is not safe by land ambulance or its crew, shall be classified as SAR and remain so until the mission has been completed. This shall be based on the best available information at the time of tasking.
…
10.1. Call-Out Authority.
The authority to call-out the aircraft is delegated by the Director IRCG to the Divisional Controller at the local RCC. To avoid the pitfalls of dual control and possible conflict of priorities, the aircraft shall in no circumstances respond to any call-out other than from its RCC, the Designated Officer or the Director IRCG.
…
10.4. Additional Night Callout Procedures.
When the state of readiness changes to 45 minutes each night, each base is to notify its local RCC of the names and telephone numbers of the Duty Aircraft Commander and Duty Winch Operator. In the event of a call-out the following standard actions will be taken unless different procedures are agreed for a specific base and promulgated in CHCI Local Staff Instructions and an Operational Notice to the relevant RCC.
…
11. Briefing Information.
Prior to launching, the RCC Controller should provide the crew with as much of the information listed at ANNEX H - MISSION BRIEFING as possible, and equivalent information for overland rescues.
…
12.1. A doctor at Medico Cork is constantly available to both IRCG and CHCI duty personnel to assess the urgency of the medical condition of injured survivors, to contribute to decisions on whether and when to launch, and to provide advice on the treatment of patients. CHCI crews can obtain the advice before launch or when airborne by requesting a link-call to Medico Cork through the co-ordinating or local RCC.
…
15.1. If the scene is more than 80 miles from shore, the Duty Controller should attempt to arrange Top-Cover by an IAC Casa or French Coastguard fixed-wing. The Top-Cover's greater height improves communications with the RCC, reduces the workload on the helicopter crew, and reduces search time by directing the rescue helicopter to the scene. The Top-Cover should be designated as OSC; […] see para 14.4 above.

15.2. If a fixed-wing aircraft will not be available in time, the rescue helicopter commander may request the RCC to launch a second S92 helicopter to shadow the rescue helicopter.

15.2.1. The decision to request the Shadow Helicopter will be based on the urgency of the operation, current and forecast conditions (daylight, cloud base, visibility, temperature and sea-state) and mitigations including waiting for the target vessel to steam closer, back-up by UK or French fixed wing and ships in the area.

15.2.2. The Shadow Helicopter will be positioned by the Rescue Helicopter in the optimum location to provide a communications link and to assist in the event that the rescue helicopter is ditched.

15.2.3. The Shadow Helicopter will be launched from the most appropriate base – probably Shannon for Waterford and Sligo rescues, Waterford for Shannon rescues south of N52, and Sligo for Shannon rescues north of N52.30. The Shadow Helicopter will launch with maximum fuel and fly for maximum endurance.

…

16.3. CHCI helicopters are to report their positions, status and endurance (to dry tanks) every 15 minutes to the Co-ordinating RCC which will maintain a continuous safety watch on aircraft movements. Position reports are to be by magnetic bearing and range from a significant point out to a range of 30 miles from the coast; at greater distances position is to be reported by latitude and longitude.

…

16.5. RCCs will track the helicopters on AIS and SkyTrac when it does not interfere with other RCC duties. Helicopters' 15-minute ops normal checks (as para 16.3) are the primary means of RCC monitoring.

ANNEX H - MISSION BRIEFING

MISSION BRIEFING		
1	Name/type of vessel and/or incident outline:	
2	Location/position: or grid reference: or bearing and distance from:	Lat: Long: at time: Carrickfin: Sligo: Blacksod: Shannon: Kerry: Castletownbere: Cork: Waterford: Dublin: Belfast International:
3a	Ship's course and speed:	
3b	Ship description/winching area:	
3c	Visual markings / description of LS:	
4a	Details of casualty(s) and injuries:	
4b	Medico Cork advice:	
5	Top cover/cooperating units:	
6	Radio frequency/call sign:	
7a	English speaking?	
7b	Deck crew briefed or experienced with hi-line:	
8a	Weather en-route:	
8b	Weather on scene:	

-END-

Appendix W — Technical Details Black Rock Light

Black Rock Mayo Marine Aid to Navigation Light: A Technical Review

The present marine aid to navigation light at Black Rock Mayo is a Tideland TRB-220 revolving beacon, shown here. The light character is created by an always ON (at night) 35W lamp within a rotating carousel containing 6 lens panels. The carousel rotates once every 72 seconds which creates a 0.3 second flash every 12 seconds.

Each of the 6 lens panel focuses the light coming from the lamp into a 'pencil beam' such that there are 6 'pencil beams' rotating at night. The passing of the 'pencil beam' across the observer creates the flash of light. The red flash (in the red sector) is created by the beam passing through red filter material installed at the lantern room glazing. This is illustrated below in **Figure No. V1**.

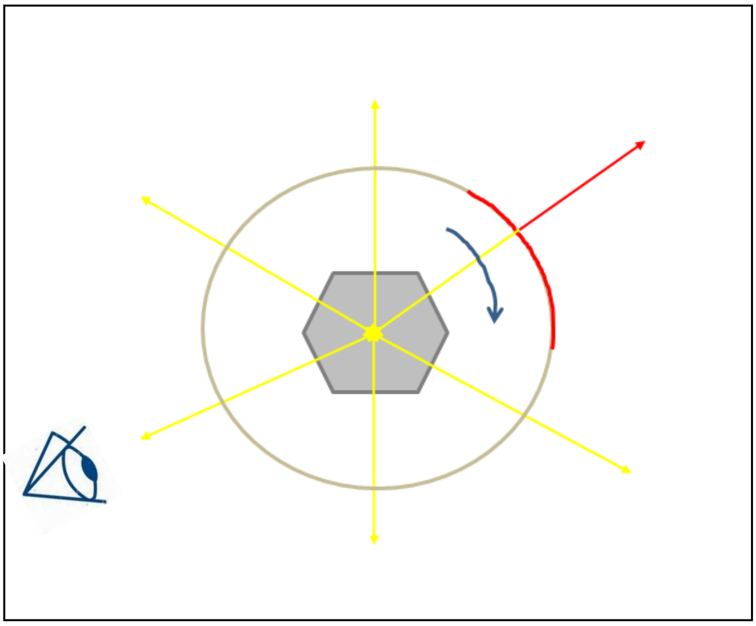


Figure No. V1: Illustration of white and red 'pencil beam' rotating through observer position (not to scale)

Peak Intensity and Effective Intensity

When an observer sees a flashing light, the intensity that is perceived is not the actual intensity of the light (the peak or stationary intensity), but a lower intensity based on the shape and length of the flash. This lower intensity is known as the '*Effective Intensity*' and is used to calculate the nominal range of a light.

There are a number of mathematical formulas to calculate the 'Effective Intensity' when the Peak Intensity and flash length are known. IALA recommends the Modified simple Schmidt-Clausen formula is a very close approximation:

$$Ie = \frac{Io \times t}{(0.2+t)}$$

where Ie = Effective Intensity
Io = Peak Intensity
t = flash length

Tests on the Vertical Beam Profile of a 35W lamp in the TRB-220 is shown in **Figure No. V2** below. The peak intensity of 92,000cd (candelas) calculates to an 'Effective Intensity' of 55,200cd at a flash length of 0.3 seconds, which is an 18 NM light according to IALA figures (49,000cd – 73,000cd = 18 NM range).

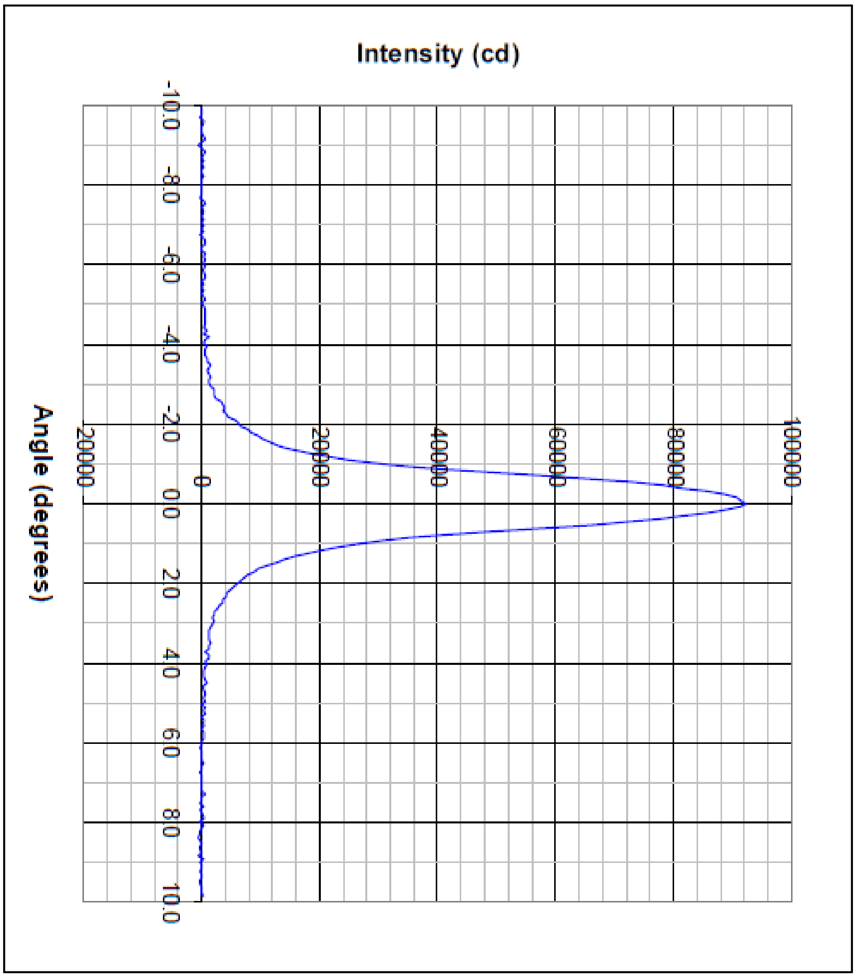


Figure No. V2: Vertical Beam Profile

Divergence

As already noted, the beam of light is referred to as a 'pencil beam'. This is a highly focused beam of light which the manufacturer states as having a horizontal divergence of 1.9^{o} (+/- 0.95^{o}) to 10%. The Vertical Beam Profile tests noted above show that the Tideland TRB-220 lantern has a vertical divergence of about 3.5^{o} (+/- 1.75^{o}) to 10%. This means that the intensity of the beam reduces to 10% of its maximum intensity at 1.75^{o} above and below the beam centre.

This means that if the observer is 1.75° below or above the beam centre, they will only see a light 10% as intense or as bright as if they were in the beam centre. At angles greater than 1.75°, the intensity of the light further reduces and, in effect, the observer can be said to be either above or below the beam.

Data shows that Rescue 116 was flying towards Black Rock over the last 1.5 NM (2,778m) on a steady heading at 200 ft ASL or approximately 100 ft (30 m) below the level of the light. Calculations show (**Table No. V1**) that if an observer were 30 m below the level of the light, the angle between the observer and the light is greater than 1.75° when closer than 1,000 m from the light. Effectively the observer is below the beam of light when closer than 1,000 m. At a distance greater than 1,000 m, the angle between the observer and the light will be less than 1.75° but will still be in the reduced intensity portion of the beam. It is not until approximately 2,000 m from the light that a reasonable intensity of light (44% of peak) would be expected. However, at this point, the distance from the light, especially in poor visibility, has a greater influence on whether the light can be seen or not than the divergence.

Metres below light	**30 m (100 feet)**									
Distance from light (metres)	100	200	300	400	500	600	700	800	900	1000
Angle to light (degrees)	16.7	8.5	5.7	4.3	3.4	2.9	2.5	2.1	1.9	1.7
Intensity percentage (estimated from Beam Profile graph)	0	0	0	0	1.5%	2.5%	4.4%	6.3%	7.5%	9%
Distance from light (metres)	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
Angle to light (degrees)	1.6	1.4	1.3	1.2	1.1	1.1	1.0	1.0	0.9	0.9
Intensity percentage (estimated from Beam Profile graph)	9.4%	10%	15%	20%	25%	28%	31%	31%	44%	44%

Table No. V1: Intensity of light at various ranges and angle to light

Nominal Range and Luminous Range

The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) has the following definition:

'The nominal range of a light used as an aid to marine navigation is its luminous range in a homogeneous atmosphere in which the meteorological visibility is 10 sea-miles (nautical miles)'.

In the case of Black Rock Mayo, the nominal range published at 18 NM (white) and 14 NM (red) is valid only when the meteorological visibility is 10 NM i.e. in clear weather.

IALA publishes a Luminous Range Diagram (**Figure No. V3**), which shows how the Luminous Range of a light varies in different meteorological visibility. This shows for example that for a nominal range of 18 NM, in meteorological visibility of 1,000 m, the luminous range of the light is 3,000 m.

The local visibility on 14 March 2017 @ 00.45 UTC is noted as being 2-3 km (1 – 1.6 NM) with mist and drizzle. **Figure No. V3:** shows that a light of 18 NM ***nominal range*** will only have ***luminous range*** of approximately 3 NM when the meteorological visibility is 1 NM (poor visibility).

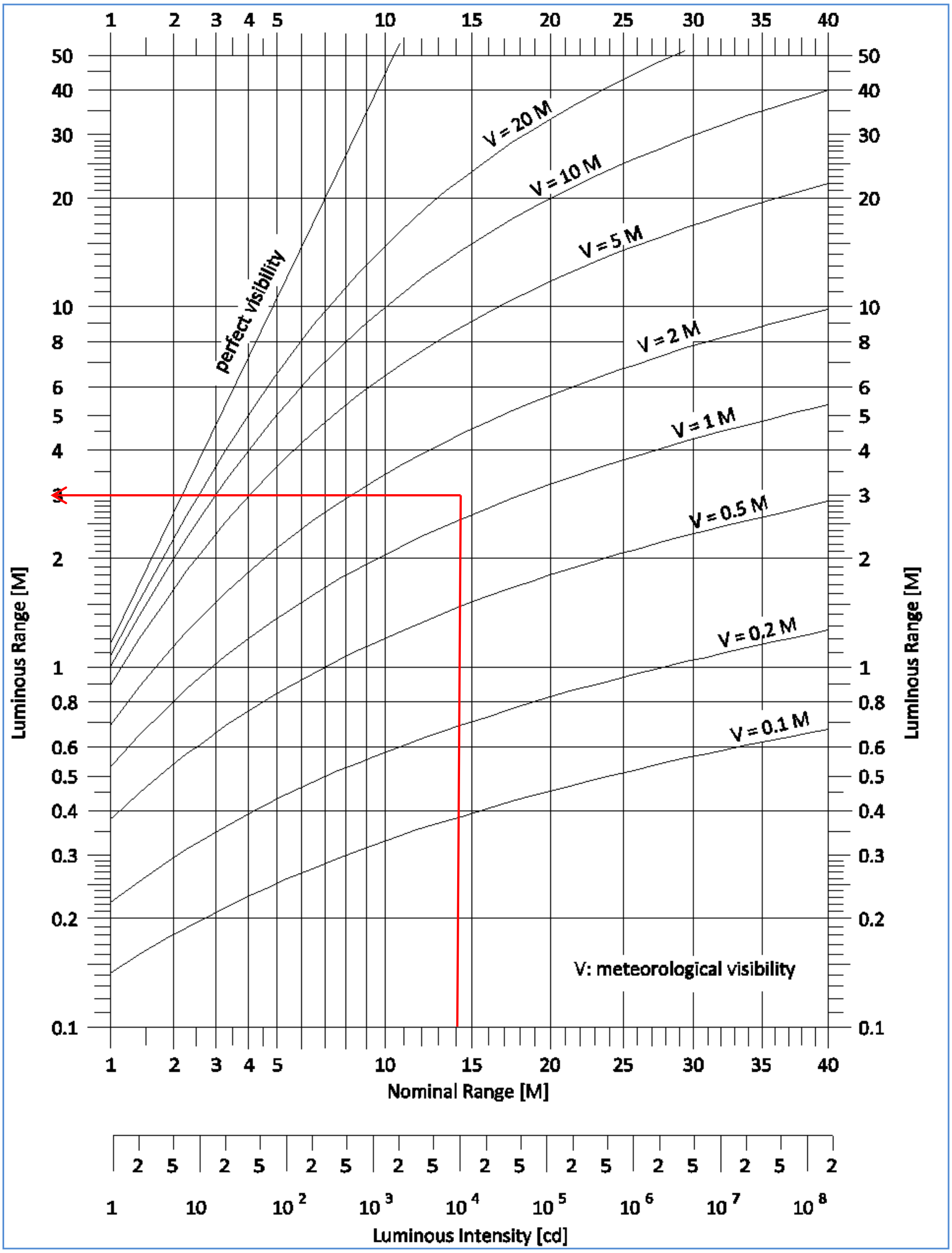


Figure No. V3: Luminous Range Diagram

Character of Light

The character of the light at Black Rock Mayo is published as Fl WR 12s (0.3 + 11.7). This translates to a 0.3 second White or Red flash every 12 seconds, i.e. a very short flash of light with a relatively long eclipse or dark period between the flashes.

Rescue 116 was travelling at a speed of 85 kts (160 km/hr) after turning and when heading eastwards towards Black Rock. At this speed, the Helicopter will travel 433 m in 12 seconds, i.e. will have travelled 433 m between each flash from the lighthouse. Over the last 1.5 NM (2,778 m), while heading towards Black Rock at that speed, only 6 of the short flashes would have been potentially visible, notwithstanding the beam divergence and visibility limitations.

Geographical Range

The Geographical range is defined by IALA as the maximum distance at which light from a light or other aid to navigation can reach an observer, as limited only by the curvature of the earth and refraction in the atmosphere and by the heights of the observer and of the light or aid. For Black Rock Mayo, the light is published as being at an elevation of 86m above water. The horizon (0 m above water) is calculated as being 18.8 NM distant. The beam of light from Black Rock was directed towards the horizon.

Red Sector

The red sector alerts mariners to the dangers of the Inishkea and Duvillaun More Islands to the east and north-east of Black Rock Island. The characteristics of the red flash are identical to the white flash as described above in terms of divergence, flash length etc. but the nominal range of the red flash is less than the white flash. The reduction in luminous range due to poor visibility would be more pronounced in the red sector.

Rescue 116 passed just to the north of Black Rock when travelling from East to West, at an altitude of 1,300 ft. At this altitude, the Helicopter would be well above the beam of light. Furthermore, the cloud base was estimated to be 300 - 400 ft, therefore, it is likely that the Helicopter and light were in cloud and thus they would not have seen the light as it manoeuvred in proximity to the red sector.

-END-

Appendix X — Extracts from OMB and OMF (Visibility and Weather Limits)

OMB says:

'***2.12.9 Night and DVE visual approaches offshore***

DVE is defined as visibility less than 4000 metres or no distinct natural horizon. Circuits shall be flown at 500 feet with reference to the RADALT with speed at least V_Y[29]. Once established on the final approach track inside 2 nm at 500 feet, couple or remain coupled to RALT, HDG and IAS and beep down to 300 feet (or deck elevation plus 50 feet, whichever is the higher), to be level by around 1 nm to run. Aim for gate positions on final approach at 1 nm from the destination with a groundspeed of no more than around 60 knots, and at 0.5 nm from the destination with a groundspeed of no more than 50 knots. Confirm the approach is stabilised at 0.5 nm to run. As the aircraft approaches the descent point, or as IAS is reduced to 55 knots, if sooner, request PM to deselect airspeed, then set a nose up attitude to decelerate the aircraft further. When at the descent point, decouple and descend to the helideck.'

OMF provides the following definitions:

'Airborne radar approach
A radar approach flown using a combination of aircraft radar, AFCS and FMS for horizontal / vertical course guidance and lateral separation from obstacles'

'SAR distress / SAR immediate
An imminent threat to life exists, or may exist under slightly different circumstances.'

'SAR operational flight
This is a flight to retrieve persons in distress from a hostile environment and deliver them to a place of safety. Initial medical care may be provided if specified by the contracting agency. In some jurisdictions, the flight may use a rescue call sign.'

OMF says:

'Commanders are reminded that the application of weather minima should be based on the urgency of each particular mission. At the commander's discretion, higher weather minima may be applied to any particular mission with the decision passed, if required, to the contracting agency. The aim of the weather limitations as set out below is to allow maximum flexibility to aircraft commanders while also providing an appropriate degree of safety.

The intent is to focus the decision to launch on whether or not the meteorological conditions are suitable for the particular task in hand. Secondary tasking limitations are specified in EASA OPS for normal CAT flights.

[29] ***V_Y***: Best rate of climb speed; equivalent to V_{BROC}.

SAR distress / medevac immediate and medevac urgent limits are defined in this section. SAR training limitations are defined in the next section (see section 2.9 Weather limits – SAR training flight).

2.8.1 Departure

2.8.1.1 SAR distress / medevac immediate

Commander's discretion: Cloud base and visibility / RVR should normally be for the class of profile flown.

2.8.1.2 Medevac urgent

Minimum cloud ceiling 100 feet and minimum RVR is 200 m.

2.8.2 En route VMC

2.8.2.1 SAR distress / medevac immediate

a) *Clear of cloud and in sight of the surface. Aircraft is to be operated at an appropriate speed for the prevailing conditions and airspace.*
b) *Certain alleviations and exemptions are contained within the CHC Ireland National SAR approval.*
c) *Night overland: Minimum operational height of 500 feet AGL (reduced to 200 feet offshore if autopilot coupled to RALT).*

2.8.2.2 Medevac urgent

Day:

a) *COCISS (250 feet and 800 m) or visibility 5 km and clear of cloud (1000 feet vertically and 1500 m horizontally)*

b) *Clear of cloud (1500 m horizontally and 1000 feet vertically).*

Night:

a) *Minimum visibility 5 km.*

b) *Aircraft to remain clear of cloud.*

c) *Night overland: Minimum operational height of 500 feet AGL (reduced to 200 feet offshore if autopilot coupled to RALT).*

2.8.3 En route IMC

Comply with the IFR requirements in OMA.

2.8.4 Low-level offshore night or IMC.

AWSAR: Minimum height 200 feet with collective axis coupled to RALT and absolute minimum of 50 feet aircraft hover with collective coupled to an AFCS SAR mode height hold. If the SAR mode auto-hover system is unserviceable, the RADALT limit of 200 feet applies. If the RALT hold is additionally unserviceable, the aircraft may only descend to 300 feet AMSL on the ALT hold provided it is serviceable. If no height hold is serviceable, the aircraft should remain at 500 feet AMSL or above. If the RALT itself is unserviceable, the aircraft may only descend below 500 feet in accordance with any restrictions placed in the type-specific MEL.

Visibility sufficient for the requirements of the task and to satisfy any OMB requirements for system modes being used.

Minimum lateral clearance: An absolute minimum of minimum radar range using permitted navigational radar modes[30] *should applied to all obstacles not visually identified / correlated by eye and / or by FLIR if available.*

Consideration should also be given to the following factors:

a) Increasing the absolute minimum stated above to allow sufficient margin for escape headings and contingency procedures such as OEI.
b) Selection of appropriate airspeeds and / or groundspeeds given the prevailing environmental conditions to provide maximum reaction times and options.
c) If the radar is unserviceable, then descent may be allowed to 500 feet AMSL provided that the let-down is conducted at a minimum of 5 nm from any known obstruction (such as coastlines or an oil and gas platform) into a clear area, confirmed by latitude and longitude from a current chart or by appropriate radio navigation aids. Continued operation at 500 feet AMSL over water may be conducted provided the aircraft can be kept 2 nm clear of contacts / obstructions by FLIR or by FMS correlated with one other system. If at 500 feet AMSL, VMC can be maintained, then further closure or lower operation may continue under these rules.

As a general working guideline, separation from unidentified radar contacts should be at least 0.5 nm by radar unless the mission requirement / profile mandates closer proximity.

2.8.8.3 Offshore or coastal approach AWSAR

SAR distress / medevac immediate:

[30] **Permitted Navigational Radar Modes**: The Investigation asked the Operator what is/are the permitted navigational radar mode(s) and where is this permission laid down? The Operator informed the Investigation that it was not aware of any permissions as such and that it was not sure that such a permission existed. OMF also speaks about '*Radar, serviceable in approved navigation modes*'.

Let down using autopilot SAR modes is permitted to a minimum auto-hover height of 50 feet. Under no circumstances should the aircraft approach within ¼ nm of any target unless the PM is visual with the surface, clear of cloud, and travelling at a height and speed commensurate with being able to stop (if appropriate), initiate a climb, or execute the pre-briefed go-around procedure within the limits of the visibility at that time.

Without the SAR modes of the autopilot available, the missed approach point is 200 feet and ½ nm (radar). Visibility is to be assessed by the aircraft commander as sufficient for the task. Radar must be serviceable in the permitted navigational mode.

Medevac urgent:

Using SAR modes of the autopilot, the missed approach point is 100 feet and ½ nm (radar). Without SAR modes, the missed approach point is 200 feet and ¾ nm (radar).

[…]
3.3 Guidance for operations without AFCS SAR modes

While both LIMSAR and AWSAR helicopters can successfully reach a point in space 200 feet AMSL and ¾ nm at minimum safety speed from an offshore target, a successful winch rescue depends on the ability of the crew to manoeuvre the helicopter from this relatively safe position to a stabilised hover over the target.

Such a manoeuvre can be safely accomplished with minimal visual reference in an auto-hover equipped helicopter. With an AFCS LIMSAR helicopter, the deceleration and transition down to a circa 50-foot hover height requires adequate visual references. Such visual references cannot be easily quantified and a commander's assessment of what may be achievable prior to launch will be based on many variables such as:

a. Forecast or reported ambient light. Such light may be natural or artificial, for example, moon light, light from coastal towns, light from adjacent vessels / installations or indeed flares deployed by top cover aircraft.

b. Restricted vision from the cockpit caused by rain and / or salt spray

c. The nature of the target floating on the water. This includes size, configuration and stability in the prevailing sea state.

d. The likely winching position in relation to potential visual cues, such as a large stable ship under power and able to provide the optimum relative wind over its stern winching area, with full deck lighting, is much more likely to provide adequate visual references than a small fishing vessel which is unable to manoeuvre and which has little or no deck lighting.

While it is impossible to give precise guidance as to what is achievable by a an AFCS LIMSAR helicopter at night owing to the vast number of inter-related variables, some of which are indicated above, commanders are to give full consideration to the safety aspects of the operations particularly the likelihood of a loss of visual references (for example, boats less than 60 feet).

If tasked with a mission while AFCS LIMSAR, in which the lack of adequate visual cues are likely to be a factor, it may be opportune to suggest the tasking of the nearest AWSAR-capable aircraft.

[…]

3.19.1 SARA procedure

[…]

At the conclusion of the approach, the aircraft can continue to close the target until visual under FLIR or radar con or the decision point or appropriate SAR approach limits (whichever comes first), are reached.

3.19.3.1 Decision point

It is imperative that no doubt exists on whether collision avoidance is being provided visually, or by radar. Under no circumstances should the aircraft approach within 0.25 nm of any target unless the PM is visual with the surface, clear of cloud and travelling at a height and speed commensurate with being able to stop (if appropriate), initiate a climb, or execute the pre-briefed go-around procedure within the limits of the visibility at that time.

The decision point is nominated by the commander based on the following considerations:

a) Minimum effective radar range and actual visibility.
b) Radar picture quality and contact density.
c) Sea surface in visual contact (but possibly not with target)
d) Medical category of casualty.
e) Location of obstacles / hazards and high terrain in landing zone area.

Although it may be appropriate for the PF to remain on instruments if adequate visual cues are available when reaching the decision point or SAR approach limits, it must be clearly understood that collision avoidance responsibility remains with the PM throughout, and continues once he takes control and becomes the PF. The aircraft can be positioned for landing or visual hover as required.

*If adequate visual cues are available when reaching the decision point or SAR approach limits, the PM must clearly state, **"Visual, I have control"**. The aircraft can then be positioned for landing or visual hover as required, although it may be appropriate for the PF to remain on instruments and continue to be conned into the target by either the PM or winch operator using RADAR or FLIR as applicable. In this case the PM will call **"Visual, continue"**. It must be clearly understood that collision avoidance responsibility remains with the PM throughout, and continues once he takes control and becomes the PF.*

*If visual cues are not available, then the PM will call **"Go-around"** and the pre-briefed go-around shall be flown.*

After a go-around, repeat approaches may be flown as fuel endurance allows'

-END-

In accordance with Annex 13 to the Convention on International Civil Aviation, Regulation (EU) No 996/2010, and Statutory Instrument No. 460 of 2009, Air Navigation (Notification and Investigation of Accidents, Serious Incidents and Incidents) Regulation, 2009, the sole purpose of this investigation is to prevent aviation accidents and serious incidents. It is not the purpose of any such investigation and the associated investigation report to apportion blame or liability.

A safety recommendation shall in no case create a presumption of blame or liability for an occurrence.

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