SERVICE INQUIRY INTO THE FLOODING OF HMS ENDURANCE 16 DECEMBER 2008

References:

A. Joint Service Publication 832 (Service Inquiries).
B. FLEET/500/4 dated 6 Mar 09 (Convening Order).

INTRODUCTION

1. A Service Inquiry was convened at Whale Island between 13 Mar 09 and 1 May 09 to investigate the flooding which occurred in HMS ENDURANCE on 16 Dec 08 while the ship was transiting the Straits of Magellan. The aim of the Inquiry was to ascertain the facts surrounding the incident, identifying factors contributing to it and making recommendations to prevent recurrence of a similar incident.

2. At the commencement of the Inquiry, six persons were identified as potentially affected persons in accordance with Reference A Chapter 4 Annex A and were duly informed of their entitlements. Relevant signed proforma are at Enclosure 16.

EXECUTIVE SUMMARY

3. Whilst operating in the South Atlantic, as part of an 18 month deployment, HMS ENDURANCE suffered a major flood in her Engine Room, resulting in the near loss of the ship. At the time of the incident ship's staff were cleaning a high level sea water inlet strainer, in an attempt to improve the ship's production of fresh water. During this operation a remotely operated hull valve opened unexpectedly, allowing water into the ship through the disassembled strainer, causing the flood. A very satisfactory damage control response by the Ship's Company, in very challenging conditions, together with the fortunate proximity of a suitable anchorage led to the successful stabilisation of the situation and saved the ship. External support, from both UK and Chilean agencies, allowed the recovery of the platform.

4. The opening of the hull valve was caused by the incorrect re-connection of the air control lines during the reassembly of the strainer, and a failure to fully isolate the compressed air supply to those lines. There were a number of contributory factors: poor system knowledge among those attempting the maintenance work; the absence of the appropriately trained system maintainer due to the manpower constraints of an extended deployment; management failure to implement a safe system of work including adequate risk assessment and mitigation measures; a failure to apply satisfactory engineering practice and design shortfalls in the valve control system. Externally, the provision of engineering and management assurance for a unit

conducting an unusually lengthy deployment in a remote and challenging environment was insufficient, and the significance of previous incidents suggesting poor engineering management were not recognised.

NARRATIVE

PRE-INCIDENT

5. Early in 2007 the Fleet Command directed a study of the feasibility of deploying HMS ENDURANCE for an extended period of 18 months. A paper[1] was produced by the ship, drawing upon a recent 9 month deployment, and a Multi Disciplinary Team (MDT) was established in the Headquarters. The MDT reported to Commander Maritime Operations (COMOPS)[2] and recommended that ENDURANCE deploy for 18 months. The recommendation was approved, and the newly formed IPV FCIG[3] was directed to plan for the deployment.

6. A key issue identified by the feasibility work was the challenge of meeting the mandated harmony requirements[4] for a ship deployed for such a length of time. The engineer officer post was recognised as one with particular challenges and so her Ship's Company was increased by an additional Engineer Officer, known as EO2 (along with other personnel not relevant to this Inquiry) prior to her deploying. To satisfy the mandated harmony requirements the ship established a manning regime, centred somewhere between 'managed gapping'[5] and a formal three watch system[6], dependent upon the person's role onboard. Key personnel returned to the UK, when the programme permitted, whilst others whose tasking was less programme dependent simply rotated leave on a 1 in 3 basis. **Panel Comment**: The total manning to achieve a formal 3 watch system is greater (by approximately a third) than that necessary to achieve managed gapping, hence it is the panel's opinion that 'managed gapping' carries greater operational risk than a formal 3 watch system. The ship subsequently identified the need for an additional POET(ME)[7], which was authorised but never met, due to Fleet wide shortages of this rate and specialisation.

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[1] ENDURANCE 230/1 dated 11 Jan 07 – Increased Utilisation of ENDR.

[2] Fleet/230/1 dated 26 Mar 07 – Enclosure 11

[3] Ice Patrol Vessel Fleet Capability Integration Group.

[4] Annual Leave requirements and Separated Service

[5] In managed gapping personnel take leave as the ship's tasking allows for their particular responsibilities to be delegated or re-distributed.

[6] In three watch manning each function can be achieved by having 2 out of 3 individuals embarked. One third of the Ship's Company will be absent from the ship at any one time.

[7] Petty Officer Engineering Technician (Marine Engineer).

7. In Oct 07, just prior to commencing her deployment, ENDURANCE completed a 4 week period of Operational Sea Training. Overall, in accordance with Flag Officer Sea Training's (FOST) final report, she performed well, although she had not adopted the manning posture for her deployment. The 18 month deployment comprised three phases, two periods in Antarctica separated by a period of Wider Regional Engagement (WRE) off West Africa. Prior to the WRE phase the ship conducted a visit to Simonstown, South Africa, (7 Jun 08 – 7 Aug 08) during which they undertook a Fleet Time Support Period (FTSP) (11 Jun 08 – 22 Jul 08), and a further period of training alongside (4-6 Aug 08) focusing solely on Aviation and Force Protection, to prepare her for West Africa Tasking.

8. In October (13 - 24 Oct 08) she completed a period of Directed Continuation Training (DCT) which was focused upon Damage Control and Fire Fighting, preparing the Executive Officer (XO) to assume temporary command, and develop strength in depth of the Ship's Company. On 21 Oct a flood occurred in the Engine Room. This was caused by the inadvertent dumping of fresh hot water into the bilges[8], and was effectively handled by the Ship's Company. This earlier flood had no bearing on the flooding incident of the 16 Dec – but as a result of the requirement to repair the damage caused, much of the DCT period was spent training alongside rather than at sea. Overall the response to training conducted under the DCT was assessed as satisfactory.

9. A roulement on 21 Nov saw the Executive Officer (XO) (Lt Cdr **A**) assume temporary command, the Engineer Officer (EO) (Lt **B** RN)[9] rejoin and assume the role as Head of Department (HOD) and a new EO2, Lt **C** RN join. The Deputy Engineer Officer (DEO) proceeded on leave, with his role being covered by the Propulsion Chief (CPOET(ME)[10] **D**). The Services Group Head (CPOET(ME) **E**) and Services Domestic Head (CPOET(ME) **F**) also departed, on leave, with their roles being covered by the Services Outside Section Head (CPOET(ME) **G**).

10. There were 38 passengers onboard for most of this passage; these were from British Schools' Explorer Society, British Antarctic Survey, the BBC, Spiderlight film crew and contractors.

11. On the 14 Dec there was a flood within the Engine Room, a ship's investigation was initiated but not concluded although the likely cause was assessed as one of the ship's double bottom ballast tank lids, to tank number 5, not being fitted correctly and fluid spilling over when the tank was overfilled[11].

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[8] See Enclosure 8.

[9] Lt **B** RN had been EO2 for the 10 months prior to rejoining from leave on 21 Nov 08.

[10] Chief Petty Officer Engineering Technician (Marine Engineering).

[11] This flood had no direct bearing on the flooding incident of 16 Dec.

12. Prior to the 16 Dec, fresh water production had been lower than normal, whilst consumption with a significant number of passengers embarked had been higher. In ENDURANCE fresh water is produced using two independent fresh water generators. These generators use an evaporation system where sea water is passed into a chamber, heated to boiling temperature and separated into brine and steam. The brine is discharged back to the sea, whilst the steam is condensed into fresh water and passed to the ship's tanks for subsequent use. The sea water supply to the generators is provided through pumps taking suction from a dedicated sea water inlet. To increase the efficiency of the fresh water generators the incoming sea water is warmed by the waste heat from the main engine coolant system. Steam is also used within the fresh water generators to provide the heat to boil the sea water; this steam is provided from a combined oil fired and exhaust gas boiler (Parat boiler), located in the Engine Room.

13. Under normal circumstances the fresh water generators are designed to produce around 25 cubic metres (25 m^3) of water over a 24 hour period. Fresh water is used throughout the ship for all domestic supplies; cooking, laundry, showers and also for the toilets and bathrooms. Under normal circumstances, daily usage is less than production, although in some circumstances, such as proximity of glacial water or in estuarine waters, production may be reduced.

14. **G**, temporarily covering the Services Domestic Section, had spent the previous two days improving the fresh water generators' performance. He had conducted maintenance on the systems associated with fresh water production (high temperature water supply valves and the Parat boiler) which had resulted in both fresh water generators being inoperative for about five hours each day. By 16 Dec, the EO had become sufficiently concerned about fresh water holdings to have put some restrictions of usage in place. He called a departmental management meeting that morning with all Group and Section Heads present during which he emphasized the importance of improving the rate of production. Without improvements he commented that a return to the Falkland Islands, where support would be more readily available, may have to be made.

15. Following the departmental meeting **G** continued to investigate ways to improve fresh water production; this included consultation with the EO2. Shortly after lunch, **D** and **G** discussed the issue and **G** sent an e-mail to the absent Group Head (**E**) and Section Head (**F**), stating recent work carried out and seeking their advice. Before sighting any response, **D** and **G** decided that reduced water flow into the evaporators may affect overall performance and hence considered that cleaning all the strainers at the sea water inlet points of the sea water system would be beneficial. The strainer associated with the high level sea water inlet was suspected by **D**, of being blocked since at least 6 Dec, prior to the visit to King Edward Point and so it was decided by **D** and **G** to start there.

16. The main sea water system provides cooling for the closed circuit fresh water system which cools the main engines, main generators and other auxiliaries. Sea water is circulated around the system by a series of pumps which can take their suction from

any of three sea water inlets: a high level, a low level and an emergency. Under normal operating conditions either the high or low level sea water inlet are used; if one of these becomes blocked the emergency routine is to connect to a dedicated sea water tank before transferring to the other sea water inlet or the emergency sea water inlet. The sea water supply to the fresh water generators is designed to be independent of the main sea water system, but can be cross connected if required to maintain suction if its own dedicated sea water inlet is blocked.

17. To prevent marine life or ice build up within sea water systems the high level, low level, emergency sea water and dedicated fresh water generator inlets all have strainers fitted. These strainers are designed to collect any foreign items before they can block, damage or contaminate the system. It is necessary when they become blocked to clean them. The strainer comprises of a casing with a removable basket within; dependent upon the nature of the ingress both may need cleaning. Each strainer can be isolated from the sea water inlet and the system which it supplies to facilitate removal and cleaning. The cleaning of strainers is a fleet wide routine which is accepted as a normal procedure to maintain the effectiveness of sea water cooling systems.

18. Prior to undertaking strainer cleaning **D** and **G** discussed their analysis with the EO and the requirement to increase sea water flow rate into the evaporators. The EO assumed that the team intended to clean the strainers for the dedicated fresh water production supply whilst **D** and **G** assumed that this discussion provided the authorisation for them to go ahead with cleaning all the strainers.

THE INCIDENT

19. The high level sea water inlet strainer, located in the Engine Room has an outboard isolation valve (referred to as Vv 1113) and an inboard isolation valve (referred to as Vv 1114). Similar to many other valves onboard ENDURANCE, the high level hull valve (Vv 1113) can be remotely operated pneumatically via an electronic control system from the Engine Control Room. The control system, Damatics, is a multi functional digital system which monitors and controls a variety of the main and auxiliary machinery in ENDURANCE. Vv 1113 can be isolated, to prevent remote operation during maintenance, by a 'no operation' signal key board injection to the control panel. **D** informed CPOET(ME) **H**, the Engineer Officer of the Watch (EOOW) in the Engine Control Room that he was about to conduct maintenance and **D** disabled the remote operation of Vv 1113 accordingly. **Panel Comment**: There is no evidence that the Damatics system had any faults which impacted on the incident or the post incident actions.

20. In the Engine Room, **D** and **G** isolated the sea water system from the strainer by manually closing Vv 1114 inboard of the high level strainer. Vv 1113 was then visually sighted, confirmed closed and the nuts securing the strainer lid were slackened. When it was clear that there was no water ingress from either the outboard side or the inboard system the strainer lid was removed exposing the strainer.

21. Each pneumatically controlled valve has two control air lines connected to it, one to open the valve and one to close it. Unique to Vv 1113 the control air lines interfere with the removal of the strainer basket, they must be disconnected and moved aside to enable the basket to be removed. **Panel Comment**: Vv 1113 is dissimilar to all other sea valves on the main sea water system in design. The spindle to which the actuator connects is 50mm shorter than that of the other valves which results in the interference between the strainer basket and the control air lines. There is no obvious reason why this discrepancy exists.

22. In order to isolate the control air supply to Vv 1113 prior to removing the air lines, it is necessary to shut the air supply to the Local Control Panel (LCP); the valve used to isolate the LCP is identified as Vv 6[12]. **D** informed the EOOW, **H**, of his intent to close the Vv 6, which he subsequently did. **G** then proceeded to disconnect the two air lines from Vv 1113, moving the control air line attached to the left hand terminal of the actuator to the left and the right hand control air line to the right. **D** and **G** then removed the strainer basket for cleaning. **D** then replaced the air lines (correctly) and reopened Vv 6 informing the EOOW that he had done so. **D** returned control of the LCP to the EOOW as soon as possible as **D's** imperative was to limit the time that the ballast system was unavailable. The ballast system enables the addition or removal of sea water, or its movement between tanks, to change the weight distribution of the ship. This has the effect of being able to change the trim or heel which may be required by command for operational purposes.

23. LET(ME)[13] **I**, who had recently arrived in the Engine Room to assist, commenced cleaning the strainer basket, whilst **D** and **G** left the Engine Room for a break. On route to the Senior Ratings' Mess, **D** and **G** met CPOMEM **J** who volunteered his assistance. **J** went to the Engine Room with LET(ME) **K** and commenced cleaning the strainer housing.

24. After about 30 minutes **D** and **G** returned to the Engine Room during the EOOW handover between **H** and CPOET(ME) **L** at approximately 1545[14]. **G** commenced checking the line up of the sea water system valves planning the next strainer cleaning operation, whilst **D** resumed supervision of the current strainer clean. When the strainer and housing were clean and the strainer lid seal had been greased, **D** informed **L** that he was about to close Vv 6 again prior to removing the air lines. Once Vv 6 was isolated **J** removed the air lines, pushing them aside. The strainer was then replaced in its housing and **J** then reconnected the air lines.

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[12] This has the effect of preventing any of the 24 valves served by the LCP from being operated, including some of the valves on the main sea water system and all the remote valves associated with the ballast system.

[13] Leading Engineering Technician (Marine Engineer).

[14] All times local.

25. Once the air lines had been replaced, **D** directed **K** to open Vv 6 with the intention of restoring the air supply to the LCP as quickly as possible (and before the lid was re-secured), in order to minimise the time lost to command for availability of the ballast system. Before **K** could carry out this task Vv 1113 opened suddenly, without warning, causing the major flooding incident.

26. As water entered the Engine Room, **J** was struck on the forehead, either by the strainer lid or through contact with the deck head[15], and was escorted out of the Engine Room whilst simultaneously a verbal flood alarm was raised. **D** rushed to the LCP, opened Vv 6 and operated the normal close side of the solenoid anticipating that a regular “close” demand would be successful. Finding that this had no effect **D** then cycled between the open and close solenoids over at best a maximum of ten seconds awaiting the response of a reduction in the rate of flooding. He was unable to make any reduction to the inflow using this method. His last action was to push the close button before proceeding to the Engine Control Room and supporting the efforts to safeguard machinery.

POST INCIDENT

27. Within the Engine Room personnel involved in the strainer clean then attempted to find and replace the strainer lid. They were unsuccessful as the force of the incoming water was too great. On the alarm being raised further within the ship, the Standing Sea Emergency Party (SSEP)[16], mustered to address the incident; within three minutes of the initial pipe, two members of the SSEP were entering the Engine Room in multi-fab suits. **J**, who was the first casualty, and should have been in charge of the Forward Control Point (FCP)[17] was replaced by PO(LOGS)(Pers)[18] **M**, who was an NBCDQ[19]. **Panel Comment**: This was a seamless transfer of responsibility which had no effect upon the post incident activity and demonstrated ability in depth. Initial reactions from the SSEP are assessed as good and well within standard response times.

28. As part of the initial reaction the ship’s command team consisting of the XO and the Operations Officer closed up on the bridge. The EO and the Damage Control

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[15] The strainer is located under the Engine Control Room mezzanine deck and the deckhead is only 5 feet above the deck plates.

[16] A nominated and trained team of personnel ready to address any fire or flood.

[17] The Forward Control Point is the controlling position for the SSEP.

[18] Petty Officer (Logistics)(Personnel).

[19] An individual who has undergone a dedicated long training course (4 weeks) covering Nuclear, Biological, Chemical Defence and Damage Control enabling him to fill a key training billet onboard. These individuals are colloquially known by the title NBCDQ.

Officer (DCO) (Logistics Officer nominated DCO) closed up in HQ1[20], which is located on the bridge. The XO observed the flooding using the remote camera in the Engine Room and immediately assessed the flood as severe and ordered the ship to Emergency Stations.. Conscious of the ship's proximity to navigational danger and anticipating loss of propulsion, he took an immediate decision to head away from land, which was approximately 5 miles to leeward of their present position. **Panel Comment**: This decision undoubtedly gave the ship more time to deal with the incident.

29. As part of Emergency Stations personnel allocated to the Fire and Repair Party Post (FRPP[21]) closed up. In the ship's reduced manning state, she had established a standard routine of only manning a single FRPP. In accordance with this routine, for an Engine Room incident the personnel mustered at the forward of the two FRPPs, located in the forward hold. Shortly afterwards the FRPP 5-man team[22] arrived at the incident, complete with mattresses from C-deck with the aim of stemming the flow from the strainer, but the force of the water prevented any attempt to stop the flow. There was an attempt to mechanically close the valve and to replace the lid, but access was again prevented. Initial actions by the EOOW were to start the bilge pumps to remove water from the Engine Room; soon after, he commenced shutting down both primary and auxiliary machinery to prevent damage to equipment, resulting in the eventual loss of the main propulsion. Shutting down both the auxiliary generators caused the automatic starting of the emergency generator, located four decks above the Engine Room adjacent to the hangar, which provided partial lighting and power to essential equipment. **Panel Comment**: The correct actions were taken by the EOOW.

30. On the Bridge the command team were building a picture of the incidents and establishing command priorities. A VHF Mayday call was authorised by the XO and issued by the Operations Officer. Further emergency calls via the Global Maritime Distress and Safety System (GMDSS), were delayed due to the need to repair a pre-existing defect on the aerial. The Operations Officer contacted the Duty Fleet Controller at the Fleet Headquarters at Northwood, reporting the flooding incident, and that the ship was now in very significant danger.

31. Communications between the Bridge, the FRPP and the FCP were at times difficult to establish and maintain hindering command and control. To improve communications between his manpower groups, the officer in charge of the FRPP

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[20] A designated area on board where the command and control organisation muster to manage the ship's response to an incident. It is supported by additional communications and specific information boards to aid the team in information management and compilation of the incident picture.

[21] A set of individuals, which includes leadership and communications personnel, assigned to muster in a predetermined location and respond to an incident under the overall direction of the Damage Control Officer.

[22] The 5-man team are predetermined personnel who obtain equipment and clothing from the FRPP locker appropriate to the type of incident to which they are responding. They are the individuals who provide the first line of support to the SSEP personnel.

relocated with his spare hands to the Senior Ratings' Dining Hall. **Panel Comment**: establishing a common picture particularly with the limited internal communication systems that ENDURANCE has fitted and the scale of the incident that they were confronted with is inevitably difficult and they used all their resources to overcome the 'fog of war'. In the circumstances the amended FRPP organisation worked well, however it is not reflected in current NCHQ policy.

32. A continuous and aggressive attack on the flood now ensued with every fixed and portable pumping system being operated or deployed in an attempt to control the flooding. A WEDA pump, a portable submersible pump with a pumping capacity of up to 150m^3 of water per hour, was deployed to the Engine Room from the Engineers Workshop; ENDURANCE only has one of these pumps and there is only one electrical socket, powered from the main switchboard but not the emergency switchboard, and one discharge overboard. Portable eductors with a capacity of 15m^3 per hour were also used. **Panel Comment**: All portable pumping equipment carried onboard was deployed successfully but, with the volume of the flood (estimated 1000m^3 per hour), there was no prospect of bringing it under control by pumping alone.

33. Fifteen minutes into the incident there was the first report of secondary flooding, in the shaft tunnel[23] space. By this stage all watertight doors were closed except for the starboard forward hydraulic door to the aft hold which remained open, with the Command's approval, in order to maintain access from the aft hold to the Engineers Workshop from where the incident was being attacked. Thirty six minutes into the incident, when the water had entered the Engine Control Room and the decision had been made to contain the flood, rather than to attempt to remove water, this final watertight door was closed. **Panel Comment**: This logic to leave the door open as long as possible and only close once containment was the priority is fully supported.

34. An early priority for the EO was to assess the ship's damaged stability state. This was achieved through consultation with naval architect advisors ashore but was hampered by the ship's stability computer (NAPA) losing electrical power. The ship sat beam to sea and was rolling in excess of 25 degrees either side of upright and an early decision was taken to empty the roll reduction tank. (This tank is located high up in the ship, just aft of the bridge and is designed to reduce the roll of the ship in normal circumstances when in adverse weather.) **Panel Comment**: Due to the nature of the damage and the significant increase of flood water in the ship, emptying the roll reduction tank improved the stability situation.

35. Additional secondary floods were reported both forward and aft outside the primary flooding boundary. A slow flood in the forward hold resulting from a burst pipe[24]

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[23] The compartment aft of the engine room through which the shaft passes before it exits the hull of the ship.

[24] The DESMI fire pump is used to supply the high pressure sea water system fire main in the event of a total electrical failure . It had been working correctly prior to the incident on the 16 Dec.

on the DESMI diesel driven fire pump was quickly and effectively repaired with a 'Stopit' leak bandage. Secondary flooding was also reported from the backflow of grey water through pipes to basins in the bathrooms. Damage Control teams attacked these minor floods with wedges and soft furnishings to reduce flow and break up free surface[25]. As all portable pumping methods had been used in the Engine Room, and remained there following evacuation, Ship's Company and civilian passengers were assigned to bailing out the secondary floods; this task was fruitless as far as the main incident was concerned but had a positive effect on secondary floods and in reducing free surfaces.

36. Secondary flooding within the gymnasium, due to leakage through the cable glands in the forward Engine Room bulkhead (No 58), was being controlled by bailing. It was assessed locally as having only limited success and so it was decided to attempt secondary leak stopping on the bulkhead gland and to seal it with a cement box. To facilitate this there was a need to cut a number of cables passing through the gland. The EO was aware of this task, as was the EO2 from a visit he conducted to the gymnasium in his roving capacity. Both the EO and EO2 assumed that the cables were dead, as the switchboard was now under water, so no attempt was made to isolate or electrically test the cables. The EO had issued a directive through the FRPP communications to ensure rubber gloves were worn; this instruction never reached the damage control team. Subsequently CPO SR[26] **N** undertook to sever the cables, using wire snips and bolt croppers, standing on a chair whilst supported by ET (ME) **O** who was standing in the water. Both **N** and **O** received an electric shock, which fortunately they both recovered from.

37. On three occasions attempts to dive in the Engine Room were made. As part of the initial attack on the flood, LS(D)[27] **P** was summoned to the Engine Control Room where he was briefed by **D** to attempt to replace the strainer lid; the depth of water at this time was about waist deep but the pressure of the incoming water in the vicinity of the strainer housing was such that **P** was beaten back. A second attempt was made by **P** supported by his two AB(D)[28]; this was foiled due to significant ship movement, increased water levels and loss of lighting within the compartment. **P** considered it too risky to continue with the dive, and the diving team exited through the workshop door. Following evacuation from the Engine Room a third attempt was made to dive. **D**, who has only dived a few times whilst on holiday, proposed that he accompany **P** into the compartment as **D** was more familiar with the engine room space and was more likely to

[25] Liquid within a compartment which is free to surge around as the ship moves. The larger the surface area of the water the more impact this free surface has on the ship's stability and movement. Any flooded compartment that is not pressed full with have some free surface effect.

[26] Chief Petty Officer Survey Recorder.

[27] Leading Seaman (Diver)

[28] Able Seaman (Diver)

be able to locate the strainer lid. It was assessed by the command team that by this time, the ship would have settled to her damaged water line and the flow of the incoming water would have reduced such that the strainer lid could be replaced. Command approval was sought and obtained for this third dive. Shortly after **P** and **D** entered the water, **P** terminated the activity again, due to the hazards and the assessed risk. **Panel Comment**: The panel is uncomfortable with the decisions to dive at all, although the initial reaction to attempt to replace the strainer lid is understood and accepted. However, on the third occasion despite the dire situation the panel considers that diving should not have been attempted.

38. Whilst the initial command priority was to attack the flood, the ship's drift rate towards land soon became a key concern, indicating that the ship was likely to be set aground. The ship made radio contact with the nearby Felix Lighthouse[29] who then requested the cruise liner NORWEGIAN SUN to close ENDURANCE's position to render assistance. However, it was apparent that the NORWEGIAN SUN would not be on the scene before ENDURANCE's predicted grounding. Discussions on options for evacuating the ship were commenced.

39. On the advice of the Salvage & Marine Operations Integrated Project Team (S&MO IPT), 9 shackles[30] of the starboard anchor were lowered whilst the ship was still drifting and in a depth of 300m of water; the logic was that the anchor could act as a drogue and slow the ship's drift rate. It remains uncertain whether this was the case or not, however, a significant change in the direction of drift was observed. This had the effect of setting ENDURANCE down onto the 'Bas Magellanas Bank' and over the next few hours, analysis of the drift indicated that there was a prospect of anchoring and not being set ashore. Eventually the starboard anchor took hold, albeit dragging before the port anchor was also let go to enable the ship to hold her position, coming round into wind, significantly reducing the roll and making conditions below decks for the damage control effort more tenable. Planning for any potential evacuation of the ship was now put in abeyance.

40. Overnight, at anchor, efforts continued onboard to contain flooding, increase pumping capacity and land non-essential personnel to shore. The Chilean Naval Vessel CASMA arrived on the scene to assist and two Chilean tugs, BEAGLE and AGUILLA had departed Punta Arenas. A Chilean liaison officer from CASMA had also been transferred across to ENDURANCE.

41. Both ship's helicopters were utilised to transfer pumps, drinking water and salvage equipment to the ship. A Chilean Search and Rescue helicopter was also in attendance throughout the evening of 16 Dec and the morning of 17 Dec and was used to transport 15 civilian personnel off the ship.

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[29] Initial language barriers with the lighthouse staff were overcome by employing a spanish speaking member of staff from the embarked British Schools Exploring Society (BSES).

[30] Approximately 250 metres

42. At 1115 the following day, 17 Dec, the tug BEAGLE arrived on the scene. Preparations were made by both the ship and the tug to commence a tow. S&MO IPT advice was to await the arrival of the second tug before departing from the anchorage and, initially this advice was accepted by the XO. However, it was apparent by forecast and observation that the weather was significantly deteriorating and the command assessment was that BEAGLE was a most capable and well handled tug. Given the risk of the conditions further deteriorating and potentially becoming out of limits for towing, the command decision was taken to connect and proceed with the single tow. The tow was connected with BEAGLE, satisfactorily strength tested with the ship still at anchor, then both anchor cables were cut, as ENDURANCE did not have the electrical power to recover them. The tow got underway safely although the initial turn across the sea caused some shoring to break loose. Problems were encountered with directional stability, with the ship yawing up to 90 degrees off the tug's heading. When the second tug arrived, approximately an hour and a half later, it was connected on ENDURANCE's starboard side for steerage. **Panel Comment**: In the circumstances, it is judged that the XO's decision was sound and minimised the risk of further hazarding the ship.

43. The remainder of the tow to Punta Arenas continued without further significant incident. The Commanding Officer returned onboard, accompanied by the head of the S&MO IPT team (Mr **Q** MBE), approximately an hour before the ship berthed. Once alongside in Punta Arenas, the main salvage effort commenced, primarily to restore watertight integrity and to prepare the ship for onward tow.

DISCUSSION

MAIN INCIDENT – CAUSAL FACTORS

44. There is no doubt, from both this inquiry and the Technical Investigation that the flood was caused as a consequence of the air lines attached to Vv 1113 actuator being incorrectly re-installed during the cleaning of the high level sea water inlet strainer. These air lines were removed twice. On the first occasion they were removed by **G** and correctly replaced by **D** . On the second occasion they were removed and replaced by **J**. It is evident from the work of the Technical Investigation[31] that on this second occasion the air lines were reinstalled incorrectly with the air line that would cause the valve to stay shut, connected to the "open" side of the actuator and vice-versa. (**J** does not recall any mistake or confusion on his part but concedes that the evidence indicates that this must have happened).

45. Additionally control air must have been passing through the close line to the actuator of Vv 1113 at the time when **J** incorrectly replaced the lines. It was sufficient to open Vv 1113 after a period of approximately 90 seconds.

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[31] Enclosure 2.

46. The air supply to the LCP through Vv 6 was required to be isolated in order to safely remove the control air lines for Vv 1113. **D** operated Vv 6 three times during the task; firstly to close it to facilitate removal of the strainer basket, secondly to open it and return control air pressure to the LCP and finally to close it to allow the replacement of the strainer basket. On the replacement of the strainer, **D** instructed **K** to open Vv 6, this he did not achieve due to the start of the incident when Vv 1113 opened flooding the Engine Room.

47. There are three options for the state of Vv 6 which would have resulted in the inadvertent opening of Vv 1113:-

a. Vv 6 was passing air despite being closed. The Technical Investigation determined that with the valve closed, air was passing but at an insufficient rate to operate Vv 1113.

b. **K** or a third person had opened Vv 6. **K** asserts that he did not reach Vv 6 and was in sight of the valve when the flooding commenced, and that no other person was near Vv 6[32].

c. **D** had not closed Vv 6 fully. **D** asserts that he fully closed Vv 6, however the Technical Investigation determined that with the valve open by only 1/8th of a full turn, it passed sufficient air to operate Vv 1113.

Panel Comment: It is judged that full isolation of Vv 6 was not achieved by **D** when he closed it prior to **J** replacing the control air lines to Vv 1113.

48. In investigating why Vv 1113 did not close when **D** 'cycled' the LCP solenoid, **F**, the Services Domestic Section Head responsible for the sea water System, stated that the Vv 1113 was slow and variable in its response time, possibly up to 20 to 30 seconds from open to shut and vice-versa. Given that there is no evidence that Vv 1113 could not close from an open signal with its air lines transposed, it is likely that **D** did not wait long enough between operating the close and open solenoids to close Vv 1113 or to notice a reduction in water flow. A small movement of the valve butterfly flap would not make a noticeable reduction in the rate of flow which was bouncing back from the deck head[33], thus preventing any judgement of the height of the column of water.

49. Whilst **G**, as the temporary head of the Services Domestic section, was responsible for the overall task of improving fresh water production, **D** as the DEO and the individual with previous experience of cleaning the high level sea water inlet strainer had effectively assumed responsibility for the task; **D** unambiguously accepted this in interview.

MAIN INCIDENT – CONTRIBUTORY FACTORS

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[32] **Panel Comment**: Following the interviews and noting the position of Vv 6 following a visit to the ship it is the panel's view that no other person operated Vv 6.

[33] The height of the deck of the Engine Room above the strainer is approximately 5 feet.

50. It is the Panel's view that analysis of the fresh water system and the perceived low fresh water production was incomplete. **G**, who though not experienced with this particular fresh water generator, has had extensive training as a Marine Engineering Artificer and should be expected to analyse such systems effectively. Pressures and temperatures for both evaporators identified that they were operating within normal parameters, and indication of low performance was ascertained only from low output levels, which were different for each fresh water generator. No other system associated with the main sea water supply system was underperforming, which would have been expected if a strainer was blocked.

51. The Parat boiler was defective and subject to investigation and maintenance in the two days prior to the incident, which necessitated it being shut down. This would have had an immediate effect on fresh water production. Defects on the high temperature valves for the steam booster system had also required systems to be taken down for maintenance, again impacting on overall fresh water production. Furthermore, ship's staff stated, but did not take into account, that it takes time for any fresh water generator to settle, once new settings are made, before adjustments are reflected in a noticeable change in output. In sum the maintenance on systems associated with fresh water production had resulted in considerable down time on each generator, directly impacting upon overall daily production.

52. **F** stated that the onboard documentation supporting the fresh water generators is of a good quality and comprehensive, yet other personnel showed scant awareness of it and in light of the predicament they were in, not to have referred to it was an error. Wisely **G** contacted **F** and **E**, who were on leave, by e-mail; however before a response could be received a course of action was initiated which at best could be described as premature.

53. In 2004 the ship was fitted with a Hi-Fog system, a fire suppressant system for the Engine Room. It draws upon the ship's fresh water holdings, although it can be connected to the sea water system. Ship's staff understanding is that this has effectively reduced the ship's available domestic fresh water by 50 m^3, however in discussion with the Platform Team this is not correct and is not a requirement of class[34].

54. With water usage exceeding water production, one of the ship's laundries had been closed down, and the Ship's Company were routinely being advised to minimise water usage. Tighter restrictions upon water usage, which had been utilised earlier in the deployment, had not been discussed or implemented. A cursory analysis indicates that left to produce water steadily there would not have been a critical shortage threatening a return to the Falkland Islands. Production rate had improved to $17m^3$ per

[34] The ship is classed by Det Norske Veritas who specify requirements and acceptable standards of ship design, build and maintenance.

day, leaving a shortfall of 7 m^3 per day and with $60m^3$ of usable water held, the ship had 9 days endurance, even without strict water rationing being applied.

55. It is judged by the Panel that:

a. The defect analysis on the fresh water generator system was not comprehensive enough.

b. That there was not sufficient imperative to undertake the strainer clean at that time and external advice should have been awaited[35].

c. The lack of fresh water was not a valid reason to clean the high level sea water inlet strainer at this time.

56. System knowledge of all those involved in the analysis of the fresh water production system is assessed by the Panel as inadequate: in particular the configuration of the sea water system. At the time of the incident it is believed that the fresh water plant was drawing off its own dedicated sea water inlet, with the cross connection made from the main sea water system. At the time of the incident the main sea water system was taking its suction from both the lower sea water inlet and the emergency sea water inlet, this was not a normal configuration[36].

57. On **D's** and **G's** logic that sea water flow was restricted, the obvious strainer to clean was the dedicated fresh water generator sea water inlet strainer, which has manual isolation valves and is inherently safer to clean. Their understanding of the sea water system during interview was incomplete and they were unaware of the fresh water generators' dedicated sea water inlet at the time of the flooding incident.

58. In the Panel's opinion the EO clearly was not aware of the system's configuration at the time of the incident and for several days beforehand, despite conducting regular rounds of the machinery spaces and claiming to be driving an improvement in engineering standards. He was unaware that the high level sea water inlet strainer had been blocked for a significant period, and that the ship was operating with the low level, dedicated fresh water and emergency sea water inlets all open and cross connected. His limited involvement in the defect analysis of fresh water production, which was his highest priority issue, is surprising and his cursory acceptance of an extremely shallow brief by **G** and **D** indicates a limited understanding of the system. This consequently prevented him from engaging them in an informed debate before making a decision to progress any task.

59. The importance to the ship of returning control of the ballast system to the Engine Control Room was overestimated by **D**. On average this system was only used once per day to adjust trim, and although the ship was conducting flying operations,

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[35] **E** responded to the request for advice that afternoon, and **F** the following morning.

[36] Only one sea inlet is normally required on the propulsion system, and the fresh water inlet is normally isolated from the main sea water system.

albeit that this was not considered throughout the maintenance task, it was highly unlikely that the ballast system would be required to be used for the short period required to clean the strainer. This misplaced focus was at the expense of increased time with the strainer lid off and hence an increased risk of flooding.

60. It is a requirement of all watch keeping personnel to become familiar with the equipment that they are operating[37]; this is achieved through double banking, a period of machinery breakdown drills and a local examination which culminates with the award of a platform endorsement. The main sea water system, which is integral to the main propulsion plant and features in a key machinery breakdown drill (Drill Number 8), is a system that all qualified EOOWs should have a good understanding of. The configuration of the main sea water system at the time of the incident, was not recognised by each of the EOOWs and also by **D** and **G**, who are both qualified as EOOWs. The lack of awareness that the main sea water system was not in its normal configuration, for some time prior to the incident (since at least 6 Dec 08), indicates that the quality of the induction and endorsement process for new joiners, and subsequent continuation training is inadequate.

61. Due to regular machinery failures during breakdown drill training periods there was an onboard decision, endorsed by Portsmouth Flotilla (PORFLOT), to undertake touch drills in place of normal operation of valves and systems[38]. In making the decision to undertake touch drills in place of full machinery breakdown drills ship's staff had balanced the risk of machinery failure during formal drill periods against the benefit of developing an individual's system knowledge, most effectively achieved through normal operation of systems. This decision may have contributed to the poor system knowledge of those maintainers present during the incident.

62. The Panel assesses that the Engineering Department Standing Orders are somewhat sparse and lack the detail necessary for new joiners to ENDURANCE to be become conversant with her unique equipment and routines; this compounds the general lack of system knowledge.

63. The Services Domestic Section was effectively gapped with both the Group (**E**) and Section (**F**) heads absent, with **G** providing temporary cover. Whilst **D** had some experience of the sea water system, **G** had very little and was reliant upon handover notes provided by **F**. Whilst these handover notes were extensive they relied on a level of basic system knowledge by the recipient (**G**). For example, despite the main sea water system being commented on in the handover notes **G** was not aware of his responsibility in this area until the strainer clean was being undertaken at which point he took the opportunity to trace the system.

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[37] BR 3000, Flotilla Engineering Orders and Engineering Departments Standing Orders.

[38] ENDURANCEs 503/1 dated 25 Nov 08. Enclosure 19.

64. **D** had been aware of the need to undertake the high level sea water inlet strainer clean before arriving at King Edward Point, but as the head of the propulsion section he had prioritised the maintenance to the main engines (injector changes). Arguably, if the DEO had been present, there would have been clearer lines of responsibility between the role of DEO and that of propulsion head. In this situation the EO would more than likely have been made aware of this blocked strainer and may have directed that the task be completed in the more benign environment alongside.

65. In the Panel's opinion poor engineering standards were applied to the maintenance task of cleaning the high level sea water inlet strainer. There was no plan developed to undertake the task, subsequent preparation was lacking and the contribution made by a number of individuals was uncoordinated. There was no continuity of oversight, and the involvement of Senior Ratings in basic tasks such as cleaning, removing the strainer lid denied them the opportunity to supervise effectively. In essence there was no effective supervision exercised over the system isolation, strainer clean and setting to work on completion.

66. Given the requirement to dis-connect the air lines, it is surprising that on this occasion no-one appreciated the impact of failing to connect the lines in the correct orientation. It is the Panel's opinion that the labelling of the control air lines for Vv 1113 might have aided **J** in re-securing them in the same orientation as he removed them, if he had noticed the position of the labels and had then recalled them[39].

67. Interviews have identified that engineering standards were known to be poor, having contributed to a number of previous engineering incidents. The recently joined CO had expressed his concerns to the EO on joining. The previous EO had been similarly aware, and management effort had focussed on making improvements. The Ship's Investigation into the Plummer Block failure[40] in Jul 08 identified lack of SAFER[41] cards and poor roundsmanship as key contributing factors; and the investigation into the Shaft Generator damage[42] in Oct 08 again identified poor roundsmanship as well as an acceptance of alarms. Both suggest to the Panel that a more rigorous plan was required to change the attitude of a department firmly set in its ways, despite being able to rise to the challenge during assurance visits. This attitude, founded on over confidence from senior maintainers, many who had been long in post, undoubtedly contributed to this incident.

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[39] The left hand air control line is labelled X, and the right hand line labelled Y. There is no corresponding marking on the valve actuator hence replacement would have to be done by memory.

[40] Enclosure 7.

[41] Sequential Action Flow Routine – A system of checks and instructions to ensure that equipment is safely brought on line from a state of lower readiness. The procedures are detailed in a set of cards which are passed to an appropriately trained person to complete the required actions.

[42] Enclosure 8.

68. It is the Panel's opinion that it was highly likely that someone would at some time make the critical error of transposing the air lines given that their interference with the sea inlet strainer had gone unreported. The extremely poor installation of the lines of Vv 1113 control air lines makes re-connection ambiguous and falls below the generally accepted standard for pipe installation.

69. It is considered that the state and position of the control air lines for Vv 1113 have been the same since Vv 1113 was changed and the actuator lowered by 50mm to connect to the shorter valve spindle. In addition to Vv 1113 having a shorter spindle, it operates in a counter intuitive manner[43]. The fitting of this valve in this way may have resulted in the need to re-route the control air lines. It is believed that the latest this modification could have been made was in the 2004 refit. The Platform Team have confirmed that they were unaware of the situation and have never received any notification from Ship's Staff.

70. With the exception of the poor installation of the control air lines attached to Vv 1113 no other element of the system design directly contributed to the incident. For a ship that is not expected to survive battle damage the design is considered fit for purpose. The system does not, however, lend itself to normal accepted TAGOUT[44] procedures which would help make the risk of a strainer cleaning task as low as reasonably practical. In ENDURANCE, for this particular valve the fact that there is a need to remove the control air lines places greater emphasis on the need to mechanically isolate Vv 1113 and provide clear, unambiguous indication of its position, as either open or closed. Additionally the Damatics 'no operation' signal can be lifted easily, without knowledge of the reason for it being applied, and there is no means of preventing individual operation of valves at the LCP. It is the panel's belief that if a risk assessment of the strainer clean had been undertaken it would more than likely have identified an improved TAGOUT such as lashing of Vv 1113 in the closed position prior to removal of the control air lines.

71. Cleaning of the high level sea water system strainer introduces greater risk in ENDURANCE than for any other strainer as more components have to be dismantled. The actual sequence of events improvised by **D** and **G** failed to consider whether it was imperative to do the job at that time and also did not then optimise the sequence to minimise the risk of flooding.

72. The requirement to disconnect the control air pipes and hence remove the positive closing pressure on the actuator of Vv1113 coupled with the consequences of the valve opening, should have been identified by a risk assessment. For a period of

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[43] Under normal convention a valve is turned clockwise to close.

[44] The TAGOUT[44] procedure provides a common method for the isolation of mechanical, pneumatic, hydraulic and electrical systems. It provides the minimum level of protection and additional safe guards may be employed. For equipment to be properly isolated all power and/or fluid pressure must be removed.Reference: BR 2000(20), 2000(52) and FPN 167.

approximately 30 minutes the strainer lid was removed, held on a single valve with those nominally in charge and best placed to understand the task, absent; whilst individuals who had never completed the task beforehand progressed with it; this was further compounded by a watch change. This lack of consistent supervision, both at the task itself and within the Engine Control Room, is indicative of the lack of appreciation of the risk at this time.

73. Events showed that the greater risk lay with the potential for flooding rather than the loss of availability of the ballast system. Simple analysis of the sequence of events [Annex B] shows that the time at risk to flooding (about 66 minutes) could have been halved to about 34 minutes, by biasing the order of events to minimise the time that the strainer lid was off. This would have increased the time that air was denied to the LCP from 21 to 53 minutes, however it would have eliminated the consequence of the crossed air lines as the strainer lid would have been replaced before the airlines were transposed. This improvement to the sequence of events would have prevented the incident even if the air lines had been transposed and Vv 6 had been passing air.

74. Similar to other filters and strainers within equipment fitted in the Fleet, time at risk with open strainer lids would be further reduced if duplicate strainers are procured to facilitate a swifter exchange. The time at risk of flooding could be halved again to about 18 minutes, whilst the time the air supply was denied to command could be reduced to almost the same time as currently achieved (about 22 minutes). A further improvement could be achieved if the strainer lid was hinged with quick release wing nuts fitted. This might reduce both times at risk by about another five minutes, although it is not a counter to a flooding situation.

75. Risk management within the Marine Engineering Department onboard ENDURANCE is not instinctive, and is seen as a non dynamic activity, conducted by the one departmental Risk Assessor. It is evident from the responses given during interview that the hazards associated with the opening of a large hole in the salt water system, protected by a valve which could not be locked shut, were not identified and therefore not effectively mitigated. Despite a number of personnel with many years of engineering knowledge being involved, the possibility of valve failure or unintentional or incorrect operation of the valve was not identified as a significant risk. Likewise the inability to arrest a flood of this magnitude was not considered prior to the start of work. These failures to identify the hazards associated with the strainer clean and the subsequent risk of flooding would appear to have gone undetected or unreported for many years.

76. The cleaning of strainers in ENDURANCE was considered as a routine task although it was not undertaken regularly. The Unit Maintenance Management Systems(UMMS) for ENDURANCE does not specify any procedure for undertaking any strainer clean. UMMS onboard ENDURANCE is recognised by the Platform Team as

inadequately populated and is subject to defect reporting[45]. UMMS is a software package to support the management of onboard maintenance. It is a generic system whose data specifically reflects the equipment for the ship in which it is loaded. The initial format of the data relies heavily on the information which has been transposed from the previous maintenance system. For ENDURANCE this previous system was also lacking in detail, and hence the UMMS database when installed in 2007 was short of the specific information to be effective onboard. Support had been provided during the recent Falkland Island period, with effort concentrating on the development of the long term maintenance requirement. There were outstanding concerns onboard, of which the Platform Team was aware, that a significant number (approx 800 of 1100) of maintenance tasks, including the strainer clean, were still lacking in detail. Prior to the incident the Platform Team had identified funds (£45k) to remedy these shortfalls and has the action in hand.

77. The deployment was founded upon a period of operational sea training conducted without representative manning and the routines and procedures for routine changeover of personnel had not been ratified by the CO. It is the Panel's opinion that if all of the above had been considered, analysis of their inter-relationships would have been identified. This would have been key to understanding what might go wrong and the likelihood and consequence of occurrence.

MAIN INCIDENT - ROOT CAUSES

78. One of the most significant deficiencies at all levels was the failure to identify the effect of cumulative risk. As with most other incidents, this incident was not the result of one failing but a collection of contributory factors. At the tactical level, many interviewees were of the opinion that risk management can only be a formal process which focuses on the protection of personnel rather than equipment or the platform. It was also evident that personnel were of the opinion that application of risk management is limited to those who have attended the course. At the higher level, there does not appear to be a mature process to address cumulative risk.

79. The feasibility study[46] into deploying ENDURANCE for 18 months identified only one caveat; that of financial risk associated with the undertaking, despite there being a number of significant risks against capability, within each of the Manpower, Equipment, Training and Sustainability (METS) pillars. Whilst actions/mitigation to resolve the individual risks had been identified a number remained outstanding at the final FCIG Sub Group Meeting[47] held in Nov 07. In interviewing key FCIG members, it was clear

[45] OPDEF 05/08 Cat C2

[46] Enclosure 11

[47] HMS ENDURANCE 18 month deployment Final FCIG Sub Group Meeting 22 Nov 07 – Enclosure 12

to the Panel that the cumulative effect of the individual risks within the METS pillars had not been identified; more disturbingly, outside of the ship, there appeared to be no clear owner of the cumulative risk. Whilst a key strength of the FCIG is unity of purpose, clarity of command has been lost, with no one person within NCHQ holding responsibility for the success of the deployment and being in a position to report robustly go/no-go items up the command chain.

80. Since ENDURANCE's force generation in the summer of 2007, the FCIG Concept of Operations (CONOPS) has been published and reviewed and there is greater clarity in the role of the FCIG. The CONOPS define FCIGs as teams that integrate capability across the Defence Lines of Development into coherent components of capability that generally require further aggregation into broader strands of platform or force capability. These teams are multi-disciplinary with the core of the FCIG sitting within the Capability Area of the NCHQ. Through a Readiness Management Group, all Force Generation stakeholders are required to look at units being generated, or currently on operations, to identify any potential risks in generation, or operational performance and to highlight these to the FCIG leader. In interviews it was evident that Force Generation Stakeholders do not appreciate fully the importance of continual monitoring of risk to generation and in particular to assets on current operations. Whilst the CONOPS specifically state that the FCIG leader is responsible to Chief of Staff Capability (COS(Cap)) for overseeing the generation of a Force Element for future employment, it does not give him/her any specific authority, or responsibility for managing cumulative risk. It is the Panel's opinion that a tauter organisation would be achieved by giving greater authority and responsibility to the FCIG leader, particularly for managing cumulative risk, whilst retaining the benefit of the collaborative/cooperative forum existing to date and ensuring clearer lines of accountability.

81. The status of the 18 month period is unclear; several references refer to it being a trial, though there is no trial order and no data collection. The outgoing CO, on his supersession, captured some very pertinent points in a report.[48] In particular the need to adopt 'a more formal three watch manning system rather than leave the risk with the CO.' Also the importance of high quality maintenance periods in order to 'limit the burden on the ship's company and preserve the sustainability of the ship, in manpower and equipment terms, in the long run' is highlighted.

82. That assurance does not appear within the earlier feasibility studies or final FCIG minutes speaks for itself. The implications of conducting a longer deployment and the routine turnover of personnel were not allowed to affect the standard assurance battle rhythm. PORFLOT Staff conducted an assurance visit whilst the ship was alongside in Simonstown (Jul 08) which included a Ship Administration Check (Engineering) (SAC(E)); based on the view of PORFLOT[49] that the SAC(E) is not only an

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[48] ENDR/500/1 dated 27 Oct 08

[49] Interview with Cdr **U** – at Enclosure 4.

administration check, but also looks at wider engineering standards, the value of this visit when alongside and with key personnel absent on leave has to be questioned. A further visit was scheduled in Oct, prior to the ship's DCT, but at the last moment the staff were 'bounced' off the flight to the Falklands. No attempt was made to engage NCHQ (through the FCIG), by PORFLOT, to raise their priority, or flag up this major shortfall in assurance.

83. A more robust scrutiny of the assurance processes adopted may have resulted in some of the contributory risks being identified prior to the incident. The ship had two engine room floods in the preceding 8 weeks, both of which damaged shaft generators, one impacting upon her programme. Her SAC(E)[50] had identified on at least the second occasion that the safe system of working was neglected. It is the Panel's view that there is a lack of a 'trip wire' ashore, that initiates a reaction, whether that be increased assurance or some other mitigating action.

84. Lack of specific courses has been a perennial problem for ENDURANCE, as a commercially procured platform. Several interviewees state that their Pre-Joining Training (PJT) was not completed, either due to non-availability of courses, or following requests from the ship to NCHQ for dispensation to be given to allow individuals to advance their joining date. The shortfall in PJTs was recognised sometime ago by FOST. ENDURANCE's latest report on shortfalls is at Enclosure 13. It is the Panel's view that for a ship that is routinely operating in an isolated and hostile location that all PJTs should be completed and that closer scrutiny should be afforded to dispensations.

85. Undoubtedly had **G** undertaken some training on the fresh water generators, his fault analysis could have been better. If **E** or **F**, who had received some training on the fresh water production system, had been embarked it is unlikely that the incident would have happened due to fresh water shortages. In the circumstances, the ship had endeavoured to ensure the optimal level of suitably qualified and experienced personnel onboard whilst meeting harmony requirements; in hindsight the level of experience on specific equipment and systems was, in the Panel's opinion, extremely low.

86. The Collective Training provided throughout the deployment was not inclusive of all the Ship's Company, did not take heed of the unique manning routine in place and could not possibly exercise the infinite permutations of a flexible managed gapping routine. Programme pressures limited Flag Officer Sea Training[51] (FOST's) ability to support out of area training with an SO1[52] and whilst the syllabus during the training provided in Oct was completed it was not conducted in the optimal environment i.e. underway. And therefore, the opportunity to reveal some of the individual training shortfalls was missed.

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[50] Enclosure 18.

[51] FOST are responsible for all training provision across the RN.

[52] Staff Officer 1; Commander RN rank.

87. Unsurprisingly for a unit that has historically operated in isolation, populated by many individuals who have either served several times in the ship or have extended their assignments undergoing a lengthy deployment, the Panel believes the potential for complacency to establish itself was high. Outside of the assurance visits and high tempo operations there is evidence that individuals were unable to apply standards consistently. Routine procedures were not always followed, unique working practices adopted and accepted as the ENDURANCE way. Clearly there is a benefit in terms of experience, and a saving in training effort by lengthy or repeat assignments; the negative aspect though is the lack of a regular injection of fresh ideas and broader Fleet experience. Whilst it is outside of the Panel's ability to assess the optimal length of an assignment in ENDURANCE, it is the view of both the Panel, and ENDURANCE's command chain, that currently a significant proportion of ENDURANCE's Ship's Company have served too long onboard.

88. The uplift of an additional Engineer Lieutenant was identified, and agreed, in the early stages of the 18 month deployment feasibility work, allowing harmony to be met with two of the three charge qualified engineers (EO, EO2 and the DEO) being onboard at any one time. No use has been made of the available accepted procedures within the Devonport Flotilla (DEVFLOT) (sic) organisation for the effective roulement of these key personnel as applied to survey vessels. In addition the utilisation of **D** as the stand in DEO generated confusion over the employment of the EO2. Once endorsed[53] and when the EO is absent the EO2 deputises for the HOD; however, when the EO is embarked, whether the DEO is aboard or not, the EO2's remit is limited to understudying the EO. This clumsy and inefficient arrangement undoubtedly muddled the command and control hierarchy, particularly when the EO2 was involved in some discussions about fresh water production with **G**. It is evident from earlier in the deployment that a platform endorsed CPO had stood in for the DEO when the EO2 had been absent on leave[54]. Furthermore, it is judged that **B**, who had only just assumed the role of EO, in his own right some three weeks before the event, had yet to establish his full authority over an entrenched set of Senior Ratings, who were among themselves slightly dismissive of him.

89. The ME Department onboard ENDURANCE was clearly struggling to meet the operational tasking and the harmony requirements imposed by the 18 month deployment. Although personnel were reportedly buoyant, a department of 26 personnel was routinely operating with less than 18 personnel, without the correct Suitably Qualified and Experienced Personnel and therefore were more reactive than proactive,

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[53] Whilst the EO2 is professionally qualified to take on the role of EO there is a short period where specific knowledge of ENDURANCE's routines and systems is developed. Once this knowledge has been attained the EO2 is classed as platform endorsed.

[54] EO issue brief to the CO dated 26 Mar 08 – Enclosure 20.

in their maintenance routines[55]. **D**, acting as DEO during this period and retaining the position as head of the Propulsion Section had a challenging deployment so far, and had recently completed major work on the main engines. The uplift of a POET(ME), identified and agreed prior to the commencement of the deployment had not been satisfied and a C2 OPDEF[56] remained outstanding; this additional person would undoubtedly have provided some flexibility within the total department strength of 26 persons.

90. In line with other Fleet units ENDURANCE adopted the structure within its engineering department in accordance with the requirements of the Personnel Change Programme. This programme amalgamated the two streams of engineer training (mechanic and artificer) into one stream (technician) with onboard organisations reflecting the new branch titles much earlier than individuals were available through the training pipeline. This inevitably resulted in Chief Petty Officers (mechanics and artificers) being in billets which had been de-enriched to Petty Officer Technicians posts. Within ENDURANCE there are no PO(ET)s embarked and their 5 designated posts are all filled by CPOs. This top heavy departmental structure brings additional management challenges and clouds the supervisory level of the Chief Petty Officer; with individuals of the same rank, with similar training and equivalent experience operating at different levels.

91. In order to support the delivery of harmony the ship had insisted, at the early stages of the planning for the 18 month deployment, that landed manpower was to be managed by the ship and not the PORFLOT WMO[57]; it was believed that by ring fencing their manpower they would ensure their effective return. Rightly in order to meet separated service requirements, the ship had identified a requirement to land personnel for up to 33% of the deployed time (i.e. 175 days) and during this time leave was to be taken. Employment outside of leave seems to be scarce, and whilst the availability of training for ENDURANCE's unique equipment is limited, the opportunity to return the landed squad back to their ship refreshed and better trained, qualified or experienced was missed.

92. This unique method of coordinating manpower that was ashore also left the Waterfront Manning Office (WMO) out of the planning and decision process,and as a

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[55] Reported separately by both FOST and PORFLOT.

[56] Operational Defect. The letter 'C' relates to the repair category of the defect, where C is the lowest level which indicates that the defect does not have an impact on a major capability. The number '2' is the repair indicator which indicates that repair is required as soon as possible to meet future commitments and can be pursued within the current programme. Only a '1' is higher which would indicate immediate rectification is required which may impact on the existing programme.

[57] The WMO is responsible for the management of those Junior Ratings who are retained ashore from a deployed unit. For example those individuals on a training course, proceeding to or returning from leave and those sick on shore.

consequence the significance of shortages within ENDURANCE's Marine Engineering Department, as well as other key pinch points and singleton billets (PO Medical Assistant, Regulator PO, etc) were never recognised fully by external authorities.

OTHER ISSUES

93. In general the Ship's Staff were very positive at the support provided by NCHQ and other support authorities and particularly welcomed a single point of contact. The liaison between the ship and external agencies was necessarily flexible given the scale and changing nature of the incident, some minor friction was reported from the ship; however this can probably be attributed to the effects of distance, personalities and the overriding pressure that the command team was under.

94. The difficulty of maintaining the flood boundary should not be under-estimated particularly in a ship rolling constantly in excess of 25 degrees either side. The interface between the Engine Room and the deck above (C Deck) was not watertight by design; the Engine Room door into the workshop and the Engine Control Room door onto the deck above were not watertight, again by design; Bulkheads 30 and 58[58] are designed to be watertight however bulkhead penetrations resulted in water leakage, both through design (grey water) and defects (bulkhead glands).

95. The ship was designed to survive the flooding of any one compartment and she did survive the flooding of her largest compartment as expected. The importance given by Ship's Staff to limit free surfaces on C deck, and to limit flooding through bulkheads and decks was soundly judged. Efforts to remove water from the forward hold (DESMI fire pump leaking) and prevent ingress of water into the after hold from the quarter deck (through the McGreggor hatch) prevented a more serious incident that could have lost the ship. The flooding of C deck forward of bulkhead 58 was caused from an open system extending from the aft grey water tank within the initial flooded zone to the bathrooms of the forward cabins. The possibility of such secondary flooding had been identified in the general case for all ships and promulgated within Abbey Wood as a design standard[59]. This requirement to isolate open systems at watertight bulkheads had not been implemented in ENDURANCE.

96. Once the bilge pumps within the flooded engine room had stopped there was a lack of generic pumping capacity to support the removal of water from this space. Additionally the WEDA portable pump was unable to be operated once normal electrical supplies were lost; whilst this would not have overcome the flooding it may have delayed the time for water to egress onto C deck. There was also a lack of portable

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[58] Bulkheads 30 and 58 are the main bulkheads coincident with the aft and forward end of the engine room respectively. All the main bulkheads are designed to be watertight up to A deck.

[59] Naval Architecture Note NAN NSSC 03/2007, now incorporated into MAP 01-024 issue 3.

pumping capacity to support the removal of secondary flooding water, which was being addressed by spare hands, with buckets, who were on the verge of being overwhelmed.

97. As a consequence of rising flood water, the ship soon lost all electrical generation with the exception of that which was able to be provided from the emergency generator via the emergency switchboard. The stability computer (NAPA) was not connected to supplies from the emergency switchboard and therefore was lost to the ship. Whilst the ship does have a laptop also supporting stability software it was defective and awaiting return. Since both the main NAPA stability computer and the back up lap top were unavailable, ship's staff sought guidance from the Platform Team in Abbey Wood. Initially there was a need to provide reassurance that the damaged situation was sustainable and survivable, that the ship was statically stable whilst damaged and that heel could be controlled. These aspects were broadly achieved. There was inevitably a lack of agreement between actual heel experienced and the predicted static heel, due to wind and sea state and the additional consequences of flooding. There was also an instance of incorrect information being forwarded to the ship during the recovery phase due to a poor watch handover at Abbey Wood but this error was spotted and corrected.

98. Although damage control efforts were commendable and ultimately resulted in the saving of the ship some of the actions taken highlight a lack of risk awareness and could easily have resulted in one or more fatalities. The cutting of power cables without assurance that power was isolated, without appropriate tools and whilst standing in water, all indicate a failure to balance the urgency of the job against the likely risks. Likewise the efforts to replace the strainer lid by divers, although commendable in the first two attempts, fails to show a realistic understanding of risk management with the decision to allow a non military trained diver to enter into the water filled engine room with very limited chances of success.

99. ENDURANCE had previously been required to report departure conditions to the Platform Team. This routine had fallen into disuse and not been pursued by the Platform Team. Given that ballasting had occurred since her latest departure such information would in this event have not been up to date but may have been a more accurate position than the closest standard condition assumed by the Platform Team.

100. The SAT C aerial for GMDSS was known to be defective prior to the incident starting, which delayed provision of full GMDSS functionality until a temporary aerial had been rigged. Poor weather and the difficulty of weather deck access had precluded earlier attention to this defect. Despite previous suggestions (Immediate Ship's Investigation) there were no issues with the power supply to GMDSS.

101. Analysis and learning of lessons identified from previous incidents across the Fleet appears to be ineffective. There have been several incidents of flooding resulting from strainer cleans which have been correctly reported but not promulgated to allow a suitable and sufficient risk assessment to be made. This deficiency applies to other incidents and is unlike the approach of the Marine Accident Investigation Panel which

routinely promulgates lessons identified from incidents on merchant ships for the appreciation of all.

CONCLUSIONS

102. The Inquiry concludes that:

a. The flooding which occurred in HMS ENDURANCE on 16 Dec 08 was as a result of hull valve Vv 1113 inadvertently opening during the cleaning of the high level sea water inlet strainer while its lid was off. Valve actuation was due to its control air lines being incorrectly re-installed during the event.

b. It was not necessary to clean any sea inlet strainers in order to improve the fresh water production.

c. It was not necessary to clean the high level sea inlet strainer at this time.

d. The control air lines to Vv 1113 were disconnected-and-then-reconnected on two occasions. On the first occasion this was undertaken correctly by two different persons. On the second occasion it was under taken incorrectly by a third person.

e. The request and subsequent approval to undertake the high level strainer clean were both ambiguous.

103. Key contributory factors were;

a. The absence of the responsible trained maintainer.

b. The inability to maintain consistent and satisfactory engineering standards.

c. A lack of a maintenance procedure to support strainer cleaning.

d. A failure to effectively identify and hence mitigate the risks involved in undertaking the high level strainer clean.

e. The recognition of ENDURANCE's isolated deployment location had not been factored into the construct of her manning organisation. The cumulative risk of up to 33% gapping, insufficient training (both individual and collective) and assurance meant that an incident of some kind was likely to happen during her 18 month deployment.

f. The design and installation of the control air lines to Vv 1113 fall far below the accepted standard for pipe installation.

g. That the design shortfalls of the control air lines to Vv 1113 had existed since 2004 or earlier and had not been reported to the Platform Team who were unaware of the shortcoming.

h. That onboard documentation to support maintenance of the fresh water generators and main sea water system are adequate, but the incorporation of routines and maintenance within UMMS is inadequate.

104. Had the ship's anchor not taken hold over the only shallow patch that ENDURANCE happened to drift over, there was a very real possibility that she would have been lost either by running ashore or by succumbing to the flood and the motion that she was experiencing.

105. Overall the actions of ENDURANCE's Ship's Company to recover themselves from their precarious situation were commendable; however, the reality was that once the hull valve could not be closed there was no hope of pumping out the Engine Room, the only option was to attempt to contain the flood within it.

RECOMMENDATIONS

106. It is recommended that CO ENDURANCE:

a. Re-establishes a safe system of working onboard in accordance with BR 2000(2)), BR 2000(15), BR 9147 and FPN 167.

b. Ensures Engineering Department Standing Orders specifies the normal operating routines for the main sea water system and details the risks associated with its maintenance.

c. Rre-invigorates the ship's reporting of material shortcomings utilising the S2022 facility within UMMS.

107. It is recommended that FOST develops a programme to ensure risk management is more instinctive, inclusive at all levels and includes a better understanding of cumulative risk.

108. It is recommended that COS(CAP):

a. Establishes an effective means of identifying and managing cumulative risk across the METS pillars that also identifies triggers for any action required

b. In consultation with Platform Team ensures that the appropriate level of training is provided to individual's assigned to ENDURANCE.

c. In consultation with Platform Team investigates the provision of increased portable pumping capacity to remove flood water.

d. In consultation with Platform Team, reviews the equipment, for which emergency electrical supplies are required

e. Re-emphasises the importance to all force generation stakeholders of identifying any potential risks, directing the FCIG leader to assume authority and responsibility for identifying, managing and having reported to him cumulative risk in units being generated or on operations.

109. It is recommended that Chief of Staff (Personnel):

a. Reviews the process of granting dispensation for not completing Pre-Joining Training.

b. Identifies and enforces the optimal/maximum length of assignment in ENDURANCE

c. Prioritises the full implementation of the Personnel Change Programme in ENDURANCE.

110. It is recommended that both NCHQ and Defence Equipment & Support ensure that they utilise data and lessons identified from previous incidents across the fleet ensuring that mitigation and preventative measures are implemented and promulgated widely, ensuring Fleet units are fully aware of inherent risks.

111. It is recommended that the Platform Team Leader:

a. Reviews the position of the control air lines on the actuator for Vv 1113 with the view to redesign to prevent the need for them to be removed for a strainer clean.

b. Investigates the provision of spare strainers to reduce the time at risk of flooding.

c. Clarifies the requirement and formally promulgates the need or otherwise to retain $50m^3$ of fresh water within the tanks for use with the Hi-Fog system.

d. Ensures that all bulkhead open system penetrations are isolated

e. Reviews the benefits of re-instating the requirement for ENDURANCE to report departure conditions

112. It is recommended that the Commodore of PORFLOT, as operational duty holder representative:

a. Takes the lead on reviewing all the standard operating procedures and supporting documentation for ENDURANCE ensuring that it is fit for task, reflects the unique nature of equipment, operating pattern and operational environment whilst drawing on the available best practice and NCHQ directives.

b. Reconsiders the acceptability of SAC(E) when conducted alongside and ensure a satisfactory follow up of issues identified.

113. It is recommended that the findings of this inquiry are forwarded to DG Ships to inform future work of the INVEST initiative which aims to promote the better achievement of engineering standards.

Annexes:

A. List of Personnel Interviewed

B. Risk Analysis of Strainer Clean Task

Enclosures:

1. Ship's Investigation

2. Technical Investigation

3. S&MO IPT IPT Report

4. Interview Transcripts:

5. ENDURANCE ME Department Structure

6. E-Mail Exchange **G**/**E**/**F**

7. Plummer Block Ship's Investigation.

8. Flood Oct 08 Ship's Investigation.

9. FOST DCT FINSIG and Report 24 Oct 08

10. SULTAN's e-mail dated 3 Apr 09 – 3018 responses. Covering SULTAN's unreferenced letter dated 2 Apr 09 - MPH PJT shortcomings.

11. FLEET 230/1 dated 26 Mar 07 – 18 Month Deployment Proposal

12. ENDURANCE Final FCIG Meeting 22 Nov 07

13. CO ENDURANCE Feasibility Proposal 11 Jan 07

14. CO ENDURANCE Supersession Letter dated 27 Oct 08

15. ENDURANCE LOTEM 18/08 dated 26 Mar 08

16. SOB Ship's Investigation

17. AFFECTED PERSONNEL PROFORMA x 6

18. SAC(E) Report dated 25 Jun 08.

19. HMS ENDURANCE 503/1 dated 25 Nov 08 – draft Engineer Officer's Supersession Report.

20. EO ENDURANCE Issue brief: Management of Engineering Support to Command dated 26 Mar 08.

ANNEX A
TO FLEET Legal 520/1/50
DATED 1 MAY 09

PERSONNEL INTERVIEWED

Cdre	DFOST
Cdre	Ex CO HMS ENDURANCE
Capt	DES-MPH TL
Capt	CO HMS ENDURANCE
Cdr	SMEO DEVFLOT (Author of TI)
Cdr **U**	SMEO PORFLOT
Cdr	FMEO(SS)
Cdr	NCHQ CDR MPH
Cdr	Cdr TS RNSME
Cdr	Fleet SO1 HM
Mr	S&MO Team leader
Mr **Q**	S&MO (Author of S&MO incident Report)
Mr	MPH NA
Lt Cdr	NCHQ ME FF SO2/ ex FOST MEO1 (Author of SI)
Lt Cdr	LO/DCO HMS ENDURANCE
Lt Cdr **A**	XO in Command HMS ENDURANCE
Lt Cdr	OPS HMS ENDURANCE
Lt Cdr	Previous EO HMS ENDURANCE
Lt Cdr	Fleet SO2 HM
Lt **B**	EO HMS ENDURANCE
Lt **C**	EO2 HMS ENDURANCE
Lt	Ex EO HMS ENDURANCE
WO1	EWO HMS ENDURANCE
CPOET(ME) **D**	HMS ENDURANCE

CPOET(ME) **G**	HMS ENDURANCE
CPOMEM **J**	HMS ENDURANCE
CPOET(ME) **L**	HMS ENDURANCE
CPOET(ME) **E**	HMS ENDURANCE
CPOET(ME) **H**	HMS ENDURANCE
CPOET(ME) **F**	HMS ENDURANCE
CPOET(WE)	HMS ENDURANCE
POMA	HMS ENDURANCE
LET(ME) **K**	HMS ENDURANCE
LET(ME) **I**	HMS ENDURANCE
LS(D) **P**	HMS ENDURANCE
LET(WE)	HMS ENDURANCE

Annex B to
FLEET Legal 520/1/50
Dated 6 May 09

HMS ENDURANCE STRAINER CLEAN TIME ANALYSIS

	START TIME	FINISH TIME	TOTAL TIME mins	FLOOD RISK mins.	LOSS OF BALLAST mins.
IMPLEMENTED SEQUENCE					
ISOLATE V113	1500	1502	2		
SHUT V114	1502	1504	2		
CRACK OPEN LID	1504	1509	5	5	
REMOVE LID	1509	1515	6	6	
SHUT V6	1515	1517	2	2	2
DISCONNECT AIRLINES	1517	1520	3	3	3
REMOVE STRAINER	1520	1521	1	1	1
RECONNECT AIRLINES	1521	1524	3	3	3
OPEN V6	1524	1526	2	2	2
CLEAN BASKET	1526	1555	29	29	
SHUT V6	1555	1557	2	2	2
DISCONNECT AIR LINES	1557	1600	3	3	3
REPLACE STRAINER	1600	1601	1	1	1
RECONECT AIR LINES	1601	1602	1	1	1
OPEN V6	1602	1605	3	3	3
REPLACE LID	1605	1610	5	5	
TIME(Mins)			70	66	21
RISK ASSESSED SEQUENCE					
ISOLATE V113			2		
SHUT V114			2		
SHUT V6			2		2
DISCONNECT AIRLINES			3		3
CRACK OPEN LID			5	5	5
REMOVE LID			6	6	6
REMOVE STRAINER			1	1	1
REPLACE LID			5	5	5
RECONECT AIR LINES			1		1
OPEN V6			3		3
CLEAN BASKET			29		
SHUT V6			2		2
DISCONNECT AIRLINES			3		3
CRACK OPEN LID			5	5	5
REMOVE LID			6	6	6
REPLACE STRAINER			1	1	1
REPLACE LID			5	5	5
RECONNECT AIRLINES			3		3
OPEN V6			2		2
TIME (mins)			86	34	53
RE-DESIGNED SEQUENCE					
ISOLATE V113			2		
SHUT V114			2		
SHUT V6			2		2
CRACK OPEN LID			5	5	5
REMOVE LID			6	6	6
REMOVE STRAINER			1	1	1
SUBSTITUTE CLEAN STRAINER			1	1	1
REPLACE LID			5	5	5
OPEN V6			2		2
TIME (mins)			26	18	22