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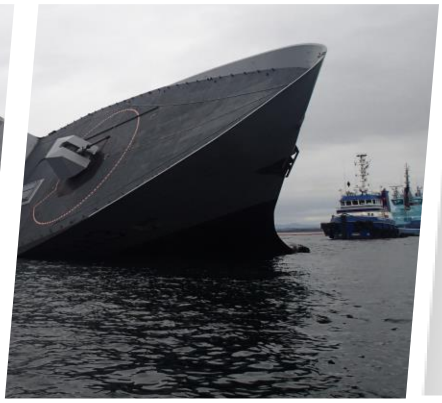

PART TWO REPORT ON THE COLLISION BETWEEN THE FRIGATE HNOMS ‘HELGE INGSTAD’ AND THE OIL TANKER SOLA TS OUTSIDE THE STURE TERMINAL IN THE HJELTEFJORD IN HORDALAND COUNTY ON 8 NOVEMBER 2018

NSIA has compiled this report for the sole purpose of improving safety at sea.

The object of a safety investigation is to clarify the sequence of events and root cause factors, study matters of significance for the prevention of maritime accidents and improvement of safety at sea, and to publish a report with eventually safety recommendations.

The Board shall not apportion any blame or liability. Use of this report for any other purpose than for improvements of the safety at sea shall be avoided.

This report has been translated into English and published by the Norwegian Safety Investigation Authority (NSIA) to facilitate access by international readers. As accurate as the translation might be, the original Norwegian text takes precedence as the report of reference

Photo (front page) of HNoMS 'Helge Ingstad': A. Ligaarden, Norwegian Armed Forces

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SUMMARY

Part 2 of the investigation

In the early hours of Thursday 8 November 2018, the frigate HNoMS ‘Helge Ingstad’ and the tanker ‘Sola TS’ collided outside the Sture Terminal in the Hjeltefjord. Approximately 10 minutes after the collision, the frigate ran aground, and subsequently sank. The frigate had a crew of 137, seven of whom sustained minor injuries.

In Part 2 of the investigation, the Norwegian Safety Investigation Authority has mapped the sequence of events after the collision until the frigate ran aground, and up until she was pushed towards the shore. Interviews with the crew have confirmed that they were under considerable acute stress during and after the collision, which affected their damage control efforts. The investigation has shown that a number of factors contributed to the incident, several of which were at the organisational and systemic level.

The incident

The collision caused considerable damage to the frigate, and for a period it was unclear whether anyone had died. What had happened, the scope of damage to the frigate and whether it would sink were also not clear. During the period between the collision and the grounding, the bridge crew were under the impression that neither steering nor propulsion could be controlled from the bridge. Other stress factors included the collision forces and the frigate’s angle of heel, damage to communication equipment on board, and the concurrent triggering of a number of alarms. It was also dark, and the accident happened at an hour when most of the crew were asleep. The situation was more complicated and unpredictable than anything the crew had been trained to handle. The navigators on the bridge believed they had tried every option available to stop the frigate before she ran aground, but to no effect.

Figure 1: HNoMS ‘Helge Ingstad’ after the collision. Illustration: CIAAS/NSIA

The damage sustained in the collision caused flooding of several compartments. After the frigate ran around, water also ingressed to the reduction gear room through the hollow propeller shafts. Eventually, the flooding was considered so extensive that the frigate was deemed to be lost, and it was decided to evacuate the crew. Doors, hatches and other openings in the frigate that were supposed to be closed to maintain stability and buoyancy were not closed by the crew at the time of evacuation. The frigate subsequently sank.

Damage control and stability

The investigation has shown that efforts to prevent the frigate from sinking and prioritisation of the right measures could have helped to gain control of the situation on board. For the crew to be able to consider actions other than those that were taken, however, they would have needed a better understanding of the frigate’s stability characteristics. Furthermore, they would have needed additional competence, training and practice, and better decision support tools than those that were available to them. Given the crew’s knowledge at the time, the situation they faced and the prevailing circumstances, it is, after all, understandable that a decision was taken to evacuate the frigate rather than put human life and health at risk.

Figure 2: Evacuation from HNoMS ‘Helge Ingstad’. Photo: Norwegian Sea Rescue Society

The crew attempted to pump water out of the vessel, but were never able to make effective use of the bilge system. The investigation has shown that, even if effective pumping had been initiated, the flooding would eventually have become too extensive for the system to handle the large volumes of water.

Doors, hatches and other openings in the frigate that were supposed to be closed to maintain stability and buoyancy were not closed at the time of evacuation. A shutdown of the frigate could have prevented her from sinking. In this context, stability calculations show that neither the grounding nor the flooding through the hollow propeller shafts was a decisive factor in causing the frigate to sink, as the failure to shut her down would have caused her to sink in any case.

Findings relating to organisational and systemic factors

- The Navy had not done enough prior to the accident to give the crew sufficient expertise in and awareness of the importance of shutting down the frigate and thereby ensuring her survivability.

- Lack of coordination between the Navy and the Norwegian Defence Materiel Agency's crisis plans meant that decision support was not organised or provided to the ship management at an early enough stage after the frigate had run aground.

- The Norwegian Armed Forces have not established a systemic approach to learning from undesirable incidents and improving safety management in a comprehensive and consistent manner. Previous accident reports have also clearly identified the need for learning and proposed measures that have not been adequately followed up or implemented. Responsibility for learning is largely left to the local level. As a consequence, there has been an absence of interdepartmental and organisation-wide learning.

- The crew's sea training lacked important elements. Too little time and not enough resources were devoted to realistic training in how to deal with complex damage control scenarios. Hence the crew did not have the skills required to deal with the scenario they experienced on the morning of the accident.

- The Navy had not made sure that the crew met key requirements on which the manning concept was based. This constitutes a vulnerability in relation to safe operation of the vessels and compromises the Navy's ability to produce combat-ready units.

- The scheme for supervision of naval activities in the defence sector appears to be fragmented and unclear. It does not adequately fulfil the mission of an overall, independent supervisory scheme. The Norwegian Safety Investigation Authority considers this to be unfortunate and that it has possibly had an impact on the safety of defence sector operations.

- The roles of authorities in the defence sector have not been adequately defined or organised, and maintaining sufficient independence can therefore be challenging for the Norwegian Defence Materiel Agency. The Norwegian Defence Materiel Agency has a dual role in that it is responsible for the requirements and regulations that apply to the materiel as well as for the technical safety of the Fleet. This blurs the boundaries, reduces independence and can lead to situations that have negative consequences for the operation of the frigates.

- Neither the Navy nor the Norwegian Defence Materiel Agency had sufficient knowledge about the implications of known technical nonconformities for the safe operation of the frigates. This means that, by not remedying the nonconformities, the Navy has operated the frigates without being aware of the total risk under which they were sailing. Several of the nonconformities had a direct impact on the sequence of events.

- There has been an imbalance between tasks and resources relating to the technical operation of the frigates. This had led to a gradual and subtle shift from what is considered good safety management to what has turned into an unstable situation.

- Though the Ship Safety and Security Act entered into force on 1 July 2007, overall and binding regulations are still lacking for the defence sector. Incomplete regulations and an unclear framework go some of the way towards explaining the inability to properly address safe ship operation.

Measures implemented and safety recommendations

The parts of the defence sector that were involved and the designer/shipyard have all carried out extensive work after the accident. They have conducted their own investigations, supported the Norwegian Safety Investigation Authority's technical examinations and studies, and initiated measures to address several of the identified safety issues.

Because several of the measures have not been implemented or completed, the Norwegian Safety Investigation Authority submits 28 safety recommendations based on the investigation. Several of the recommendations concern factors at the organisational and systemic level, including the following:

- **The Ministry of Defence** must take steps to clarify the regulatory framework for the sector for the purpose of ensuring ship safety. This includes clearly defining the roles of authorities, avoiding dual roles and establishing an overall, independent supervisory function for naval activities in the defence sector.

- **The Norwegian Defence Materiel Agency** must ensure correct prioritisation to be able to balance tasks and resources relating to the technical operation of the frigates.

- **The Norwegian Armed Forces** must establish mechanisms for organisational learning from undesirable incidents and accidents and to meet the Navy's need for better system support in the operation of the frigates.

- **The Royal Norwegian Navy** must review and conduct a risk assessment of the manning concept for the frigates, and take steps to clarify the prerequisites for the concept and how these are to be followed up. The Navy must evaluate and implement measures in its own training and exercise programmes to ensure that the frigate crews have the competence required to handle complex damage control scenarios. They must also take steps to ensure that the Navy has an overview of the risks associated with nonconformities, with a view to ensuring safe operation of the frigates.

- **The Norwegian Armed Forces Materiel Safety Authority** must conduct supervisory activities of the Norwegian Defence Materiel Agency and the Royal Norwegian Navy to ensure safe operation of the frigates through long-term good configuration management and updated technical documentation.

INTRODUCTION TO INVESTIGATION REPORT PART 2

The investigation is conducted in accordance with the Act of 24 June 1994 No 39 (the Norwegian Maritime Code) Chapter 18. The Marine Safety Investigation Unit of Malta and the Spanish Standing Commission for Maritime Accident and Incident Investigations (CIAIM) have also participated in the investigation as 'substantially interested states'; see Section 474 of the Norwegian Maritime Code.[1]

The investigation of the accident involving HNoMS 'Helge Ingstad' and 'Sola TS' is divided into two main parts:

- Part 1 looked into the circumstances leading up to the collision and is covered in 'Sub-report 1 on the collision between the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' outside the Sture Terminal in the Hjeltefjord in Hordaland county on 8 November 2018'.

- Part 2 looked into the circumstances from the time of the collision up until HNoMS 'Helge Ingstad' was pushed towards the shore by the tugboats. No further investigations were carried out of 'Sola TS' during this second phase. Nor does the investigation include the subsequent salvage operation.

The description of the sequence of events and the factual information used in part 2 of the investigation are based on interviews with the frigate's crew and other parties involved, in addition to technical investigations on board. Information has also been obtained from the Ministry of Defence, the Norwegian Defence Materiel Agency (NDMA), the Norwegian Armed Forces Materiel Safety Authority, the Royal Norwegian Navy, DNV GL and Navantia.

The Norweigan Safety Investigation Authority (NSIA) has had access to and used classified information as a part of the investigation. Such information can however not be published according to the Security Act, and as a result the defence sector has had to assess classification of the information. Not all information could be unclassified, which has resulted in some Appendices being classified as Restricted, se overview of Appendices[2].

The accident and the circumstances relating thereto are investigated and analysed in accordance with the Norwegian Safety Investigation Authority's (NSIA) framework and analysis process for systematic safety investigation.

The report is structured as follows:

- **Chapter 1 – Description of the sequence of events**, based on interviews with the frigate's crew and other parties involved, in addition to information from the navigation system and Integrated Platform Management System (IPMS) on board HNoMS 'Helge Ingstad'.

- **Chapter 2 – Factual information**, gathered throughout the investigation, including technical documentation of the vessel, relevant manuals, IPMS data, technical findings, applicable rules and regulations, findings from special investigations, etc.

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[1] To ensure national security, parts of the factual information are classified Restriced. Spain is considered "a substantially interested state" but was not able to get the required authorisation to access the classified documentation. Hence, CIAIM had to reject the opportunity to review the report before publishing.

[2] Appendices classifed as Resricted is marked with (R)

- **Chapter 3 – Analysis** of the sequence of events, including operational, human and technical factors. Underlying factors are identified and areas for improvement are discussed.

- **Chapter 4 – Conclusions** summarising the most important findings from the analysis in chapter 3.

- **Chapter 5 – Safety recommendations** based on the analysis in chapter 3.

1 Sequence of events

1. SEQUENCE OF EVENTS

1.1 Introduction

Sections 1.2 to 1.5 focus on describing the sequence of events after the collision and up until the frigate listed heavily to starboard at approximately 10:27, as a result of being pushed by the tugboats. The Norwegian Safety Investigation Authority (NSIA) has chosen to divide the sequence of events into the following parts:

- The sequence of events from the time of the collision until the frigate ran aground, with the focus on what happened on board HNoMS ‘Helge Ingstad’
- The sequence of events from the time of the grounding until evacuation was completed
- Description of the incident, focusing on the operational support from the shore-based organisation
- Brief description of the rescue operation organised by the Joint Rescue Coordination Centre.

1.2 Sequence of events from the time of the collision until the frigate ran aground

1.2.1 Moment of impact

At 04:01:15, HNoMS ‘Helge Ingstad’ collided with the tanker ‘Sola TS’. The first impact between the vessels was the tanker’s starboard anchor and the area forward of the frigate’s starboard torpedo magazine. The hawsepipe tore a large gash along the frigate’s starboard side. As a result, parts of the frigate’s side were ripped off and pushed inwards; see Figure 3 and Figure 4. The hull damage resulted in damage to and severing of a large number of cables, pipes, ductings, control panels, secondary switchboards, watertight doors, etc along the 46 m long damage area, as well as a broken seawater main.

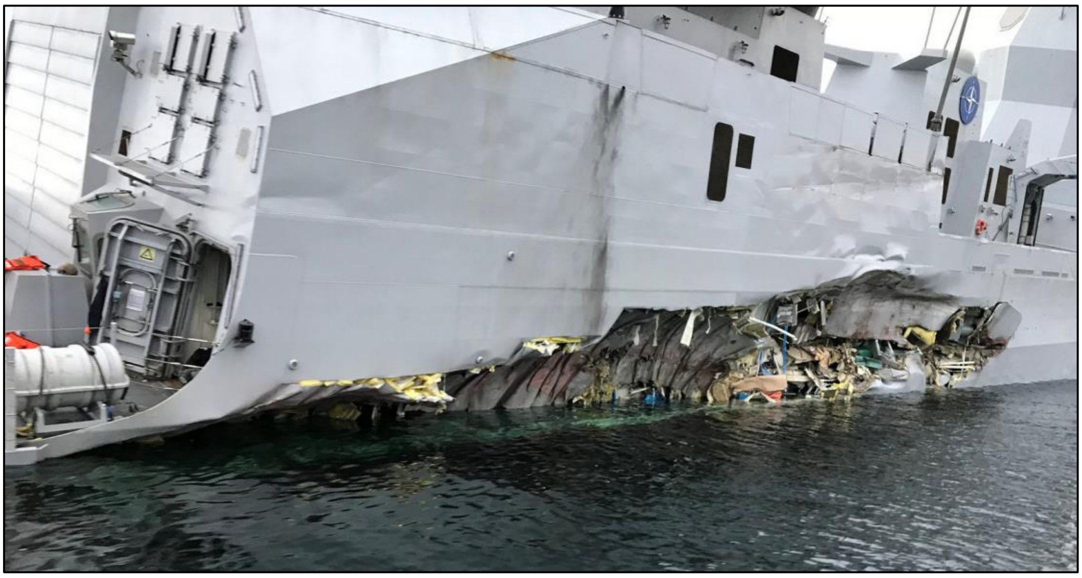

Figure 3: Damage along the frigate’s starboard side following the collision. Photo: The Norwegian Coastal Administration

Figure 4: The hawsepipe and the damage sustained by 'Sola TS'. Photo: The Norwegian Maritime Authority

The contact between the two vessels lasted approximately five seconds. The frigate started listing heavily to port at the same time as there was a rapid change of course to starboard. Fixtures and fittings were thrown about, and several of the crew members who were asleep fell out of their bunks. Many experienced the lights going out, but that the emergency lights came on relatively quickly.

Just after the collision, the pilot on 'Sola TS' notified Fedje VTS on VHF channel 80 that they had collided with a warship.

Few seconds after the collision, HNoMS 'Helge Ingstad' experienced 'black ship'[3] for about 10 seconds[4], until the power supply was back on parts of main switchboard 1. This caused many of the systems on board to shut down, and they needed to be restarted. Approximately 1 minute and 10 seconds after the collision normal power production for equipment not damaged by the collision was restored[4]. The systems were started up automatically or manually by resetting electric circuits and re-allocating equipment.

The aft conscripts berthing, located on 3 deck, was quickly flooded. Several of the conscripts found the doors to their cabins blocked, and some of them were therefore forced to evacuate by climbing out of the damaged area in the hull and up onto the deck above (2 deck). On 2 deck, some of the officers were trapped in their cabins and needed help to evacuate. Outside the machinery control room (MCR),[5] water was gushing out of

[3] Black ship – temporary loss of power generation from the vessel's generator sets, so that no power is supplied to any of the equipment they serve.
[4] NDMA NSD Technology Interpretation and validation of historical IPMS data after the HNoMS incident 8th November 2018, 08.11.2018, dated 2019-01-23
[5] When the general alarm is raised, the MCR functions as the (HQ1). After the collision, the MCR is therefore referred to as HQ1.

a severed branch line from the seawater main. Because of severed electrical cables, the crew considered it dangerous to move around in the damaged part of the frigate.

1.2.2 Bridge

After the collision, the officer of the watch (OOW) immediately ordered the bridge team to put on flashgear[6]. The OOW attempted to contact damage control headquarters (HQ1) on the audio unit[7] to get them to sound the general alarm,[8] but was unable to establish contact, see Figure 5. Based on observations of damages and flooding, HQ1 shortly afterwards, raised the general alarm over the PA system,[9] with a report of flooding on 2 deck.

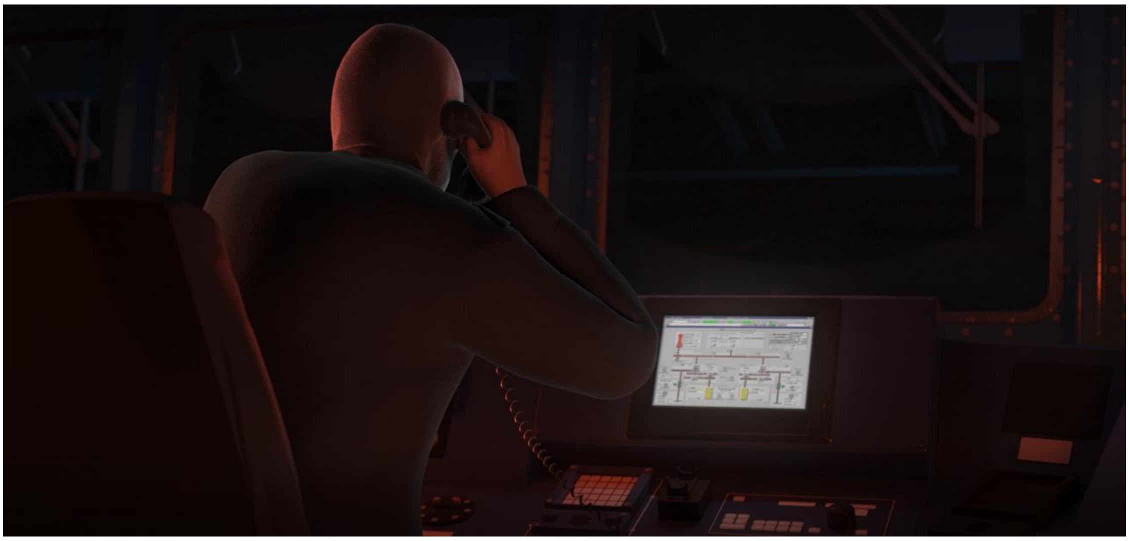

Figure 5: OOW attempting to contact HQ1 on the audio unit. Illustration: CIAAS/NSIA

The officer of the watch assistant (OOWA) started work on gaining an overview of personnel on board, while the starboard lookout (STBD LO) and the officer of the watch assistant trainee (OOWAT) went to their respective damage control stations elsewhere on the frigate.

At 04:03, the OOW called Fedje VTS on VHF channel 80 and confirmed that HNoMS ‘Helge Ingstad’ had collided. The OOW also stated that they had sounded the general alarm and were trying to gain control of the situation. The OOW explained that they had a crew of 134 on board (later corrected to 137), and that more information would follow shortly.

The OOW in the command information centre (OOW-CIC) and the relieved OOW (OOW-R) arrived on the bridge around that time, at approximately 04:03. The OOW-CIC looked to starboard and saw the tanker ‘Sola TS’, fully lit up from midship to astern, with a tugboat on the stern. Both wondered what had happened, but did not receive a clear answer from the OOW. The OOW then asked the OOW-CIC to attend to external communication. Furthermore, the OOW states that he asked the OOW-R to take over the

[6] ‘Flashgear’ consists of a flame-resistant hood and gloves that the crew put on when the action stations or general alarm is raised.
[7] The audio unit is the frigate’s primary means of internal communication.
[8] In times of peace, the general alarm is raised in all types of damage control situations (fire, grounding and leakages). In the event of that a fire and/or ingress of water is confirmed, the general alarm shall be raised to notify the entire crew.
[9] Public Announcement: The frigate’s loudspeaker system for broadcasting internal messages.

role as navigator. The positions that were manned on the bridge at approximately 04:03 are shown in Figure 6.

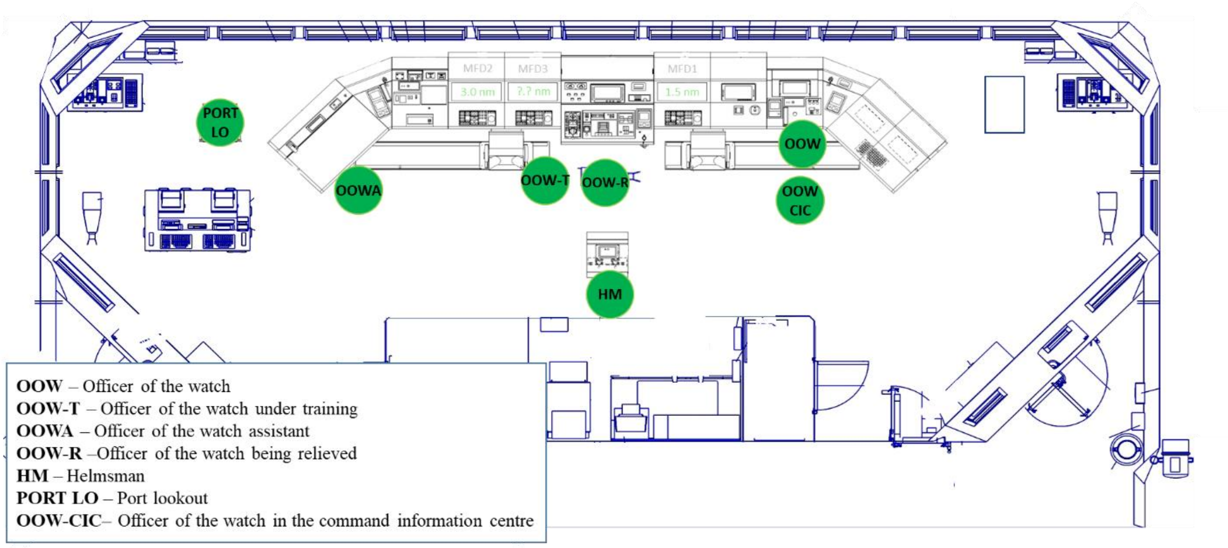

Figure 6: Positions manned on the bridge at approx. 04:03. Illustration: The Navy/NSIA

At approximately 04:04, the OOW-R set the AIS[10] to active transmission (mode 1) [11]. Shortly after the AIS was switched to active mode, the AIS lost its position input and therefore its last known position was transmitted instead of the actual position. The frigate's AIS symbol was displayed on 'Sola TS' at 04:04:29 and on the VTS screen at 04:05:19.

At approximately 04:05, the commanding officer (CO) and the executive officer (XO) arrived on the bridge after having stopped by the CIC. They spoke with the OOW in an attempt to clarify what had happened. The XO remained on the bridge, while the CO returned to the CIC a few minutes later.

During the period between 04:05 and 04:07, the crew made several attempts to control the propulsion system from the centre console. There was no response when they attempted to throttle back to stop the vessel, see Figure 7. They then attempted to use backup mode[12] and finally the emergency stop function, without this having any effect, since the communication cables were severed in the accident. The frigate was now about 0.5 nautical miles from the shore, moving at a speed of approximately 5 knots.

[10] Automatic Identification System: an anti-collision aid in maritime traffic.
[11] AIS mode 1 means that the vessel both transmits information and receives information about other vessels.
[12] An alternative way of controlling pitch from the centre console, hard-wired

Figure 7: Attempt to throttle back. Illustration: CIAAS/NSIA

The helmsman (HM) had the opinion that the rudder indicators were not working. The HM tried to turn the rudder handles to move the rudders, but did not register any change of course, and therefore notified the OOW that the rudder was not responding. The OOW confirmed receipt of the message from the HM.

The bridge attempted to contact the assistant on watch in the steering gear room via the sound powered telephone (SPT),[13] but believed that he did not hear what was said. The assistant in the steering gear room tried to convey to the bridge that the steering gear looked undamaged and that the pumps were running, but the message was not received by anyone in the bridge team. The assistant heard someone from the bridge speaking on the SPT, but did not receive any order concerning emergency steering from the bridge. The assistant remained in the steering gear room throughout the sequence of events, until the bridge team requested HQ1 to pull him out.

The bridge had still not established contact with HQ1 to request assistance to re-establish propulsion control. They attempted the ‘Engine’ conference circuit on the SPT without achieving contact with HQ1. The third officer of the watch (OOW3), which came to the bridge at approximately 04:07, made the others aware of the risk of running aground. The OOW therefore used the PA system to order *‘full astern’* at approximately 04:09. The message was received by two persons in HQ1, but not by the PCC[14] operator in charge of propulsion control. The PA order was not clear to the crew in the aft main engine room or the aft generator sets room.

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[13] Internal communication system that operates without electric power
[14] PCC – propulsion control console

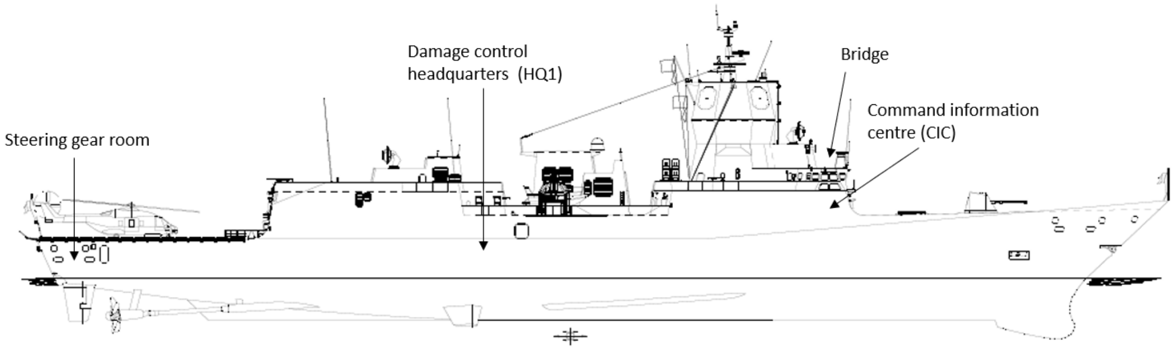


Figure 8: Different rooms described in the report. Illustration: NDMA/NSIA

At 04:08, HNoMS 'Helge Ingstad' called Fedje VTS and stated that they had collided with an unknown object, that they had lost propulsion and that they needed immediate tugboat assistance. Fedje VTS communicated this information to 'T/B Ajax'.

At 04:09, HNoMS 'Helge Ingstad' called 'T/B Ajax' on channel 16 to request assistance. 'T/B Ajax' responded that they were heading towards HNoMS 'Helge Ingstad' at full speed. 'T/B Ajax' was on its way to what they assumed to be the frigate's position, based on where the AIS signal was displayed on 'T/B Ajax' electronic chart and information system[15]. The frigate was actually further west, however, and still dimmed as she neared the shore north of the Sture Terminal.

At that point in time, the distance to the shore was less than 0.3 nautical miles. When the bridge team realised that they had lost control of the steering, were unable to control propulsion from the bridge and were unable to establish communication with the steering gear room or HQ1, the OOW decided to drop the starboard anchor. At 04:09, the bridge issued an order over the PA system to prepare the starboard anchor. Shortly afterwards, the OOW gave the order to drop the starboard anchor. Crew members came running to prepare the anchor, but before they were able to drop it, the frigate ran aground.

When the bridge team realised that grounding was unavoidable, '*brace-brace-brace'*[16] was announced over the PA system.

HNoMS 'Helge Ingstad' ran aground at N 60° 37.8' and E 004° 50.8' at **04:11:16**, ten minutes after colliding with 'Sola TS'.

Figure 9 shows the frigate's movements after the collision until the time at which she ran aground.

[15] Shortly after the AIS was set to active transmission, the AIS lost its position signals and therefore sent the last known position instead of the actual position.
[16] Commonly used phrase to prepare personnel to brace for impact.

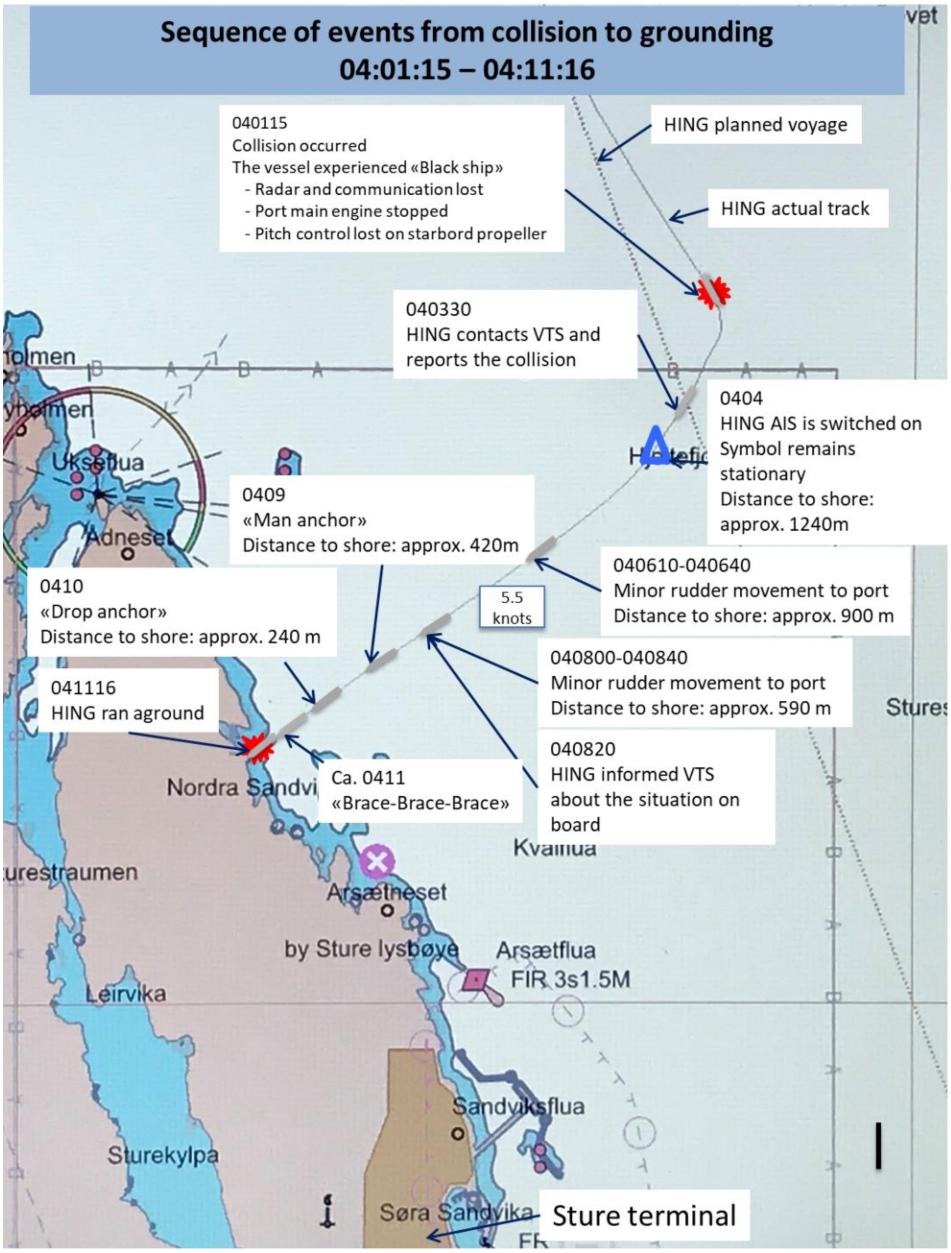


Figure 9: Schematic drawing of the frigate's movements after the collision until she ran aground. Illustration: NSIA

1.2.3 Command information centre (CIC)

After the collision, the OOW-CIC went up to the bridge to provide assistance. The weapon engineer officer (WEO, hereafter named CA)[17] and the operations officer (ORO), who had been woken by the heavy impact, were at their posts in the CIC when the CO arrived.

An attempt was made to contact the bridge via the audio unit, but it was not working. The operations officer therefore recommended the CO to go to the bridge. To start with, the CO decided that they should follow the procedures they had practised, and therefore remained in the CIC. At approximately 04:05, however, the CO went to the bridge to gain an overview of what had happened, and later returned to the CIC.

[17] At general alarm the WEO will assume the role as command advisor (CA), see section 2.5.2.3

The CA observed on one of the frigate's CCTV[18] monitors that there was some ingress of water in the aft generator sets room. It was observed that two of the conference circuits on the audio unit were down, including the circuit used to communicate with the marine engineer officer (MEO) in HQ1. The CA therefore asked personnel in the Weapon Section Base[19] to go to the radio station to re-establish internal communication. In the meantime, the CA called the MEO to get an update of the situation, but the MEO was still uncertain about what had happened and the scope of damage.

When the operations officer arrived in the CIC, he observed that the frigate was in the Hjeltefjord, and gradually realised that she was heading towards the shore at a speed of 5 knots.

Since the external communication system was down, the CO got hold of a mobile phone and went back to the bridge to call the Navy's duty officer to report the collision. The CO was on his way to the bridge when the OOW announced '*brace-brace-brace*' over the PA system and the vessel ran aground **at 04:11:16**.

Figure 10: The vessel heading towards shore after the collision. Illustration: NCIS[20]/CIAAS/NSIA

1.2.4 Damage control

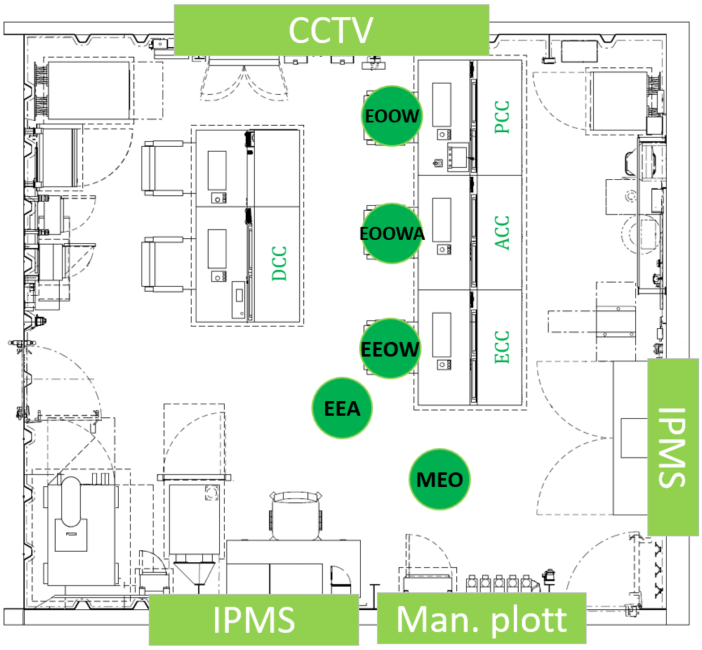
At the time the frigate collided, watch changes had recently taken place in the MCR/HQ1 (machinery control room/damage control headquarters), and several members of the relieved team were still present. They immediately understood that the situation was serious, but, to start with, they thought that there had been an engine explosion or explosion in an electrical switchboard. That was quickly ruled out. They then believed that the vessel had run aground. The engineer officer of the watch (EOOW) immediately asked the watch team to conduct inspections of the bottom compartments. The team quickly observed that parts of the starboard side were missing, and that there was a lot of water in the passage outside the MCR/HQ1. The EOOW immediately raised the general

[18] CCTV = Closed Circuit Television
[19] Weapon Section Base (WSB) is the weapons team that keeps an overview of the scope of damage, for example during an accident.
[20] NCIS = The Norwegian National Criminal Investigation Service

alarm over the PA system, with the message '*flooding*[21] *starboard side 2 deck – Safeguard'*.[22] When the watch team had left HQ1, the EOOW tried to establish contact with the bridge. He was unable to establish contact using the primary means of communication and noticed that it was 'down'. He then tried the phone, but did not succeed as the number for the bridge was engaged.

During the first minute after the collision, several of the operators in HQ1 left for other damage control stations. Of those originally present, the EOOW and the electrical engineer of the watch were the only ones remaining. The others either went to their designated damage control stations or conducted searches of the bottom compartments.

At 04:02:30, the key HQ1 positions were manned: MEO, the propulsion control console (PCC), the auxiliaries control console (ACC) and the electrical control console (ECC); see Figure 11.



EOOW – Engine officer of the watch
EOOWA – Engine officer of the watch assistant
EEOW – Electrical engineer of the watch
EEA – Electrical engineer's apprentice
MEO – Marine engineer officer

Figure 11[23]*: HQ1 positions manned at 04:02:30. Illustration: The Navy/NSIA*

The personnel in HQ1 observed that the port propulsion line was in emergency stop mode, while the starboard propulsion line was intact, apart from the automatic pitch control function which had been lost. There was indication that the vessel did not have sufficient power production[24]. The HQ1 personnel started working to improve the situation and the electrical engineer of the watch (EEOW) attempted to boost the power supply.

At approximately 04:02, ingress of water was confirmed in the supply department storeroom and the aft conscripts berthing, and removal of water was initiated using portable pumps. Several of the valves in the bilge system were flashing on the HQ1 control panel, indicating that remote operation from HQ1 was not possible. After

[21] Flooding is a term commonly used to describe ingress of water.
[22] Safeguard is a term commonly used to indicate that the announcement is not related to a drill.
[23] IPMS = Integrated Platform Management System
[24] Detailed technical information about the system is classified as "Restricted" under the Security Act by information owner the Norwegian Armed Forces and the NDMA

approximately one minute, the power supply was restored, and thereby also contact with the bilge system valves, for all machinery spaces except the aft generator sets room and the aft main engine room. Sections 2.6.10.3 and 2.6.10.4 describe in detail how the bilge system was operated during the event and the effect of the attempt of using the bilge system. Remote operation of many of the latter valves from HQ1 was unavailable throughout the sequence of events.

At approximately 04:03, ingress of water was also confirmed in the aft generator sets room. The engine assistant 2 (EA), who had reported to HQ1, went down into the aft generator sets room, his designated station according to the damage control roster.[25] The engine assistant attempted to open the motorised bilge valves in the aft generator sets room, but only managed to open two out of three.

After the collision, pressure was lost on the seawater line, and an attempt was made to restore seawater pressure in order to start the stationary bilge system. At approximately 04:05, the seawater main was isolated at the aft end of the forward main engine room, as the line was broken in parts of the afterbody. At approximately 04:08, the isolation valves between the forward main engine room and the bow thruster machinery room were opened to be able to use the bilge eductors in the forebody to remove water from the aft compartments. The CCTV monitors showed that all the machinery spaces were intact, except the aft generator sets room.

At approximately 04:06, HQ1 made a new attempt to contact the bridge by phone to gain an overview of the situation. When the attempt failed, a decision was made to focus on dealing with the flooding.

As crew members emerged from the damaged compartments and reported to HQ1, the seriousness of the damage became apparent. Personnel who had searched the bottom compartment also reported back, stating, among other things, that they had found no ingress of water in the forebody. In the afterbody, it was the aft conscripts berthing that had sustained the most extensive damage, and shoring was soon initiated in an attempt to stop the flow of water, at the same time as it was ensured that no personnel were left in the compartment. Considerable effort was required to get the conscripts up and out of the aft conscripts berthing via the port side ladder. Injured personnel were brought to the sickbay, which had been set up in the crew mess hall.

In the aft generator sets room, the engine assistant observed that it was dark and that there was water coming in on the starboard side of 3 deck, at the aft end of the room. The hole in the ship side was observed to be mostly above the waterline. Sparks were flying from cables in multiple places along the starboard side, and the engine assistant considered it too dangerous to go near these cables. Spouts of water were observed behind load centre 7[26] (LC7).

The engine assistant therefore attempted to contact HQ1 using the radio communication system, but only heard loud beeping noises when he pressed the key button. He also tried the sound powered telephone, but received no response from HQ1.

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[25] Damage control roster – an overview of each crew member’s designated station in the event of a general alarm.

[26] Distribution switchgear intended to ensure power supply to important consumers. The load centres can be supplied from both switchboards.

The engine assistant therefore went to HQ1 and asked for LS7 to be isolated, which was done at approximately 04:07. The engine assistant took a handheld UHF radio and returned to the aft generator sets room to continue dealing with the ingress of water. Shoring was challenging because of a large number of pipes in front of the damaged area and the size of the hole. Rag bags and packing material were therefore stuffed into the openings with the greatest inflow of water to reduce the flow. After a while, the engine assistant reported back to HQ1 from the aft generator sets room that they were able to handle the ingress of water.

While the personnel were busy working, '*brace-brace-brace'* was announced over the PA system. At that point in time, the engine assistant observed the water level in the aft generator sets room to be just below the tank top. Shortly after, the frigate ran aground.

Figure 12: The vessel heading towards shore. Illustration: NCIS/CIAAS/NSIA

1.3 Sequence of events from the time of the grounding until evacuation was completed

1.3.1 Bridge/CIC

After the frigate had run aground at 04:11:16, the bridge team considered that she stood on firm ground. At the same time, they received information that the stern was sinking and that flooding was increasing rapidly in the aft generator sets room. The frigate therefore notified Fedje VTS on channel 16 that they were grounded and needed immediate tugboat assistance. HNoMS 'Helge Ingstad' was informed that a tugboat was already under way.

HNoMS 'Helge Ingstad' then issued a distress call, but, due to considerable activity on the VHF channel, the message was not transmitted in full. At the same time, at approximately 04:11, the bridge sent a 'DSC distress'[27] call. At approximately 04:15,

[27] Distress message via the VHF Digital Selective Calling system

'T/B Ajax' notified Fedje VTS that they were unable to locate HNoMS 'Helge Ingstad'. Fedje VTS therefore assumed that the AIS signal was wrong and informed 'T/B Ajax' of the correct position.

At 04:16, the Norwegian Coastal Radio South called HNoMS 'Helge Ingstad' to inform that they were taking over coordination of the incident.

Some time after the grounding, the CIC established contact with HQ1 on the audio unit. The CIC gradually received more information about the scope of damage, including that personnel were trapped in their cabins and that the starboard torpedo magazine was damaged. A message was also received from HQ1 that three watertight compartments were flooded: the aft conscripts berthing, the supply department storeroom[28] and the aft generator sets room, but that the frigate's stability and buoyancy were under control. After discussing with the CO, the CA announced the command aim[29] over the PA system: 'Rescue personnel' – 'Salvage materiel' and 'Establish POB control'[30].

At 04:23, 'T/B Ajax' arrived alongside HNoMS 'Helge Ingstad', whose deck lights were now turned on. 'T/B Velox' followed close behind. 'Velox' made contact with HNoMS 'Helge Ingstad' and was asked to remain in standby. 'Ajax' also offered assistance, for example to set aboard pumping materiel. HNoMS 'Helge Ingstad' did not respond to the offer. Both 'Velox' and 'Ajax' had access to two bilge pumps (with a capacity of2100 l/min and 500 l/min, respectively) located at the Sture Terminal. These pumps could be brought out and used onboard the frigate.

When HQ1 received a message from the reduction gear room of water flooding in through the shafts in the reduction gear room, the MEO told the CIC that, if the fourth compartment was lost, the frigate could sink. Discussions whether to abandon ship took place at the same time as the effort to gain POB control.

At 04:24, POB control had been established, which was announced over the frigate's PA system and also reported to the Coastal Radio South.

Following an exchange between HQ1 and the bridge, the starboard main engine was tried stopped[31] at approximately 04:26, and a few minutes later, the bridge team observed that the frigate was moving astern.

During the same period, at 04:26, a command huddle[32] was held in HQ1, which resulted in the following priorities being recommended: '*De-emphasise propulsion – Focus on flooding'*. After a few minutes, as a result of rapid flooding of the reduction gear room, HQ1 recommended another prioritisation as follows: '*Maintain buoyancy – Maintain power production – Prepare to abandon ship'*.

The bridge team feared that the frigate would slip on the seabed and sink, and decided that they needed pressure on the stern so as to remain on firm ground. At 04:32, the tugboats were asked to push on the stern to prevent HNoMS' Helge Ingstad' from slipping into deep water. 'Ajax' attempted first, but switched places with 'Velox', which

[28] The frigate's central storage room.
[29] A commonly used term expressing the commanding officer's aim for the task to be addressed.
[30] Control of personnel on board (POB)
[31] The attempt to stop the starboard main engine is not registered in the IPMS
[32] Procedure for conveying structured information to the MEO, so that the MEO can make structured recommendations to the CO.

had a lower freeboard, as the frigate's stern was already low in the water as a result of the grounding and downflooding of the afterbody. The crew on 'Ajax' wondered whether it was possible to bring a towline on board, but HNoMS 'Helge Ingstad' reported that the Quarterdeck (Q-deck) was inaccessible for the crew. From 04:43, 'Velox' was pushing on the afterbody with a force of approximately 10 tonnes.

At 04:36, the following message was announced over the PA system: *'We have a large gash on the starboard side, running along the entire afterbody; the aft generator sets room is lost, the storeroom is lost, and the aft conscripts berthing is lost; there is also flooding in the gear and the aft main, and we are therefore prioritising these areas.'*

At 04:40, the frigate's priorities were communicated to the crew over the PA system:

- *Priority 1: Control flooding*
- *Priority 2: Maintain power production*
- *Priority 3: Prepare to abandon ship*

An order was therefore communicated from the bridge over the PA system to prepare to launch 'Sjøbjørn',[33] with the intention of assisting to move rafts during a possible evacution. 'Sjøbjørn' was launched at 04:48.

At 04:43, the CO made an announcement over the PA system, confirming that the frigate was grounded on a rock and that there were many vessels nearby, ready to assist. The CO also informed the personnel that a tugboat was pushing on the stern to prevent the frigate from slipping into deep water.

After a short while, at approximately 04:46, information was received from HQ1 that the reduction gear room was lost. The MEO therefore informed the CIC that it was no longer possible to guarantee the frigate's stability and buoyancy. As it was perceived that the frigate's list continued to increase, the CO decided to abandon ship on the MEO's recommendation. According to IPMS data, the list at this time was 4 degrees.

At 04:51:44, the CO announced the following message over the PA system: *'Attention on board, this is the commanding officer. We do not have control of the ship's stability, we are executing the abandon ship procedure, execute abandon ship.'*

At 04:51:58, HNoMS 'Helge Ingstad' reported on channel 16 that they were abandoning the ship, as they no longer had control of stability.

While the rest of the crew evacuated, the ship management gathered on the bridge to assess the situation as it developed. They had limited information about the seabed conditions around the frigate. They were uncertain about the best solution, including whether the frigate should be pushed further towards the shore, in which case there should preferably be no personnel on board. There were also reports of helicopter fuel leaking into the sea, in addition fire alarms[34] were perceived to have been triggered on board, of which caused additional concern. The frigate's list increased, and the boatswain who had been transferred to 'Velox' reported that the frigate's stern continued to sink. At

[33] 'Sjøbjørn' is the frigate's man-over-board (MOB) - boat of the type Sjøbjørn MK III

[34] Historical data from IPMS shows that no detectors were actually triggered, however, failures are detected and manual call points were triggered, probably due to short-circuits

this point in time, the remaining crew considered the flooding to be so critical that they needed to abandon ship.

At 06:05, the CO ordered everyone on the bridge to evacuate. Before leaving, they discussed whether to close the watertight hatches and bulkheads on 2 deck and whether to switch off the generators before evacuation. The MEO did not recommend going down into the vessel and no further shutdown was carried out.

At 06:32, the ship management evacuated to the rescue vessel ‘KG Jebsen’ and were transferred to the coast guard vessel CGV ‘Bergen’ together with two crew members from ‘Sjøbjørn’ and the boatswain who had been transferred to ‘Velox’. They arrived at 06:42.

1.3.2 Damage control

When the frigate ran aground, the two crew members in the aft generator sets room observed that the hole in the ship side came under water and that water was gushing in through the hole. They attempted to plug the hole with packing material, which had little effect. While shoring continued in an attempt to stop the flow of water, the engine assistant was asked via the UHF to open the isolation valve between the aft main engine room and the aft generator sets room so that the aft main engine room could be used to pump water out of the aft generator sets room. As the water level had risen rapidly since the frigate ran aground, the engine assistant was unable to reach the valve, which was located under the floor grate on 4 deck. The engine assistant reported back to HQ1. Efforts to stop the flow of water from the damaged area continued, but the level was rising rapidly, and when the water reached 3 deck, they decided to leave the room. They checked whether anyone was left in the room before it was evacuated.

Shortly after the frigate ran aground, at approximately 04:14, the ACC operator in HQ1 opened the suction valve in the bow thruster machinery room, and suction on the bilge eductor in that room dropped. The valve was not closed until 24 minutes later. During this period, it was not possible to produce a vacuum in the bilge eductors in the forward main engine room or the forward auxiliary machinery room, despite the fact that driving water was available in these compartments. The operator therefore reported back to the MEO that they were unable to initiate effective water removal.

Around the same time, the starboard ballast tank in the forward main engine room was de-ballasted. The ACC operator opened the valve to de-ballast the tank at 04:14 and closed the valve 23 minutes later. The operator also attempted to de-ballast the tank at the very front of the bow during the period 04:20–04:23, but the attempt was not registered as being effective.

At 04:18, personnel from the aft damage control station started to shore the aft conscripts berthing, which took ten minutes to complete. At the same time, the aft generator sets room was deemed to be lost, and personnel started shoring that room as well. At one point in time, there were information that water was ingressing to the steering gear room.

At 04:22, the first alarm indicating ingress of water to the reduction gear room was triggered. Personnel were sent to investigate the situation and subsequently reported that water was ingressing through the flexible coupling between the gear and the shaft.

At approximately 04:26, a command huddle was called. The MEO considered that problems could eventually arise related to the vessel's stability or buoyancy. Together with two rovers,[35] among others, the MEO assessed the situation and decided to focus on the ingress of water. They went on to study the carpet plot in the stability handbook, which showed three different statuses: 'acceptable stability', 'poor stability' and 'vessel lost'; see section 2.6.9.3 and Figure 13. The MEO had observed through the hole in the ship side that the sea was calm. In the MEO's assessment, considering the calm conditions combined with a conservative assessment of the damage length (including the steering gear room), 'poor stability' was acceptable for the time being. As a result of this assessment, the CIC was notified of the following recommended priorities: *De-emphasise propulsion – Focus on flooding.*

Figure 13: The carpet plot. Illustration: CIAAS/NSIA

In the reduction gear room, the engine assistant observed that the flexible coupling for the gear was under water on the starboard side and that the water level was rising rapidly. The personnel made attempts to start pumping and at the same time stop the ingress of water by driving wedges into the crack in the flexible coupling on the port side. Because access was difficult, they were only able to drive in five wedges, which did not appear to help. As the water crept up their legs, the crew realised that it was not possible to stop the leakage. The engine assistant therefore informed the MEO in HQ1 that they would lose the reduction gear room. Two portable FLYGT pumps had been rigged in the reduction gear room, but the water was still rising, so there was nothing more the crew could do. Problems operating the portable bilge pumps delayed damage control efforts, as cables and hoses for these pumps had been pulled through doors and hatches between watertight compartments.

The MEO observed at the CCTV that water was entering the reduction gear room through the shafts, however, he did not understand why such amounts of water could come out since the room was not a part of the damaged area. A complete flooding of this room in addition to the three or four aft compartments (if the steering gear room was included) was considered critical to stability. The MEO therefore recommended abandoning the ship. Based on this recommendation, the CIC issued the following priorities, which were

[35] Officers roving around the vessel to gain an overview of the situation

also announced over the PA system: *1. Maintain buoyancy, 2. Maintain generator operation, and 3. Prepare to abandon ship*. The MEO gave priority to stopping the flooding of the reduction gear room, while at the same time ordering the removal of water from all compartments where flooding was indicated.

After receiving confirmation of flooding of the reduction gear room, the MEO was informed that a certain amount of water was also ingressing into the aft main engine room. Water was coming in through the stuffing boxes for the drive shaft from the two diesel-operated main engines. Personnel were therefore sent to the forward main engine room to check the status, where they observed that some water was coming in through the bulkhead feedthrough for the gas turbine shaft. At the time when the forward main engine room was abandoned before evacuation, it was almost empty of water.

The MEO was then informed that the situation had deteriorated because they had lost and/or disconnected more of the power supply in the afterbody. Further efforts would therefore have to be based on emergency cable runs and extension cords, which would take time to rig. A report was also received of water coming in through the hull closure door[36] in the ship side.

The MEO consulted the carpet plot and concluded that the situation was extreme. The MEO feared that the six aftermost compartments were completely flooded (including the steering gear room). According to the carpet plot, the vessel status was therefore ‘vessel lost’, which was interpreted as ‘negative buoyancy’. The MEO assumed that the situation could develop slowly, but also feared that bulkhead shoring could fail and bulkhead doors collapse as a result of water pressure from behind. The situation could therefore quickly become precarious. The crew in HQ1 also discussed the possibility that something might happen to the tugboat and its ability to push on the stern, possibly resulting in the frigate sliding on the seabed and sinking rapidly.

Following an overall assessment, the MEO therefore recommended to the CO that they abandon the vessel. The assessment was also based on information that they had not been able to establish effective water removal and that water had started to enter the forward main engine room. Just as in the aft main engine room, a small amount of water was ingressing through the flexible joint in the bulkead (#107) around the drive shaft from the gas turbine. The CO therefore gave orders to abandon ship at **04:51:44**.

1.4 Operational support from land

The following sequence of events focuses on the shore-based organisation and describes what happened in connection with the measures initiated ashore. This includes notification of the shore-based organisation, mobilisation of the crisis management team, planning and implementation of operational support, and exchange of information between the parties that assisted during the operation up until the time when HNoMS ‘Helge Ingstad’ was pushed onto her side by the tugboats.

[36] Hull closure door with accommodation ladder at frame no 189 enabling direct access to deck 2 from a skiff. It has not been possible to verify this report.

1.4.1 The Norwegian Naval Operations Centre (NORNOC) and mobilisation of the crisis management team (CMT)

At approximately 04:15, the Navy's duty officer at the Norwegian Naval Operations Centre (NORNOC), in the following referred to as Duty Officer (DO) Navy, received a call from CO of HNoMS 'Helge Ingstad' stating that the frigate had collided in the Hjeltefjord, that they had lost control of steering and propulsion and then run aground. The CO of HNoMS 'Helge Ingstad' also stated that they had not gained POB control.

According to predefined criteria, the nature of the situation warranted mobilisation of the Navy's CMT. The team was intended to be a point of contact between the frigate and the shore-based organisation. DO Navy immediately started to notify in accordance with applicable procedures.[37] This included notification of the Navy's management and mobilisation of the CMT. The management was notified at 04:31 (voice message) and at 04:34 (text message). Mobilisation of the crisis management team was then prepared and a voice message issued by the Norwegian Armed Forces alarm service centre[38] (ASC) at 04:39. Since many members of the crisis management team were still embarked in conjunction with excercise Trident Juncture, the DO Navy also placed direct calls to other individuals, requesting them to support during the crisis.

At approximately 04:25, the DO Navy received a new update from the CO that HNoMS 'Helge Ingstad' had collided with a big ship, lost steering and run aground. He also stated that there were two civilian tugboats nearby, and that the number of injured personnel on board was seven. The DO Navy called several of the vessels that had recently returned after the exercise and asked them to prepare to assist. A message was also issued to all vessels over the classified radio communication system. Several vessels on their way to Haakonsvern Naval Base after Trident Juncture reported that they could be at the scene of the accident in the course of an hour. Sometime after 04:30, the DO Navy received a message from HNoMS 'Helge Ingstad' that they were preparing to abandon ship, followed by a second message, at 04:53, that they had started the evacuation.

The members of the CMT started arriving at NORNOC around 05:00, organising themselves in accordance with the crisis management plan. The chain of command was established as follows: Commander Norwegian Joint Headquarters (COM NJHQ) – Chief of Royal Norwegian Navy (CRNON) – CH OPS RNON with a separate line to the CMT. The CO of HNoMS 'Helge Ingstad' was directly subordinate to CH OPS RNON, while the CO of CGV 'Bergen' took over as on-scene coordinator (OSC). The fire service acted as OSC from the fireboat 'Sjøbrand' until CGV 'Bergen' arrived on the scene.

Seen from NORNOC's angle, it was the CO of HNoMS 'Helge Ingstad' who made all decisions concerning the frigate. It was the DO Navy who initially kept in contact with the CO of HNoMS 'Helge Ingstad'. Others had also contacted the CO of HNoMS 'Helge Ingstad', but it was later decided that the CMT would take over primary responsibility for contact with the CO. By now, the CMT had been informed of the extensive flooding on board, but had yet not formed a clear impression of the scope of damage.

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[37] NORCOP's crisis management team procedure, dated 4 June 2018 (exempt from public disclosure)
[38] The alarm service centre (ASC) is manned 24/7 and receives all notifications of undesirable incidents in the Norwegian Armed Forces.

1.4.2 Summoning of personnel from the NDMA Naval Systems Division (NSD)

The NDMA NSD's Emergency Response Officer (ERO) had been called at the same time as the crisis management team at 04:40 and arrived at NORNOC just after 05:00. On arrival, ERO informed himself of the situation and then initiated the notification procedure in accordance with the NSD's ERO instructions[39] and crisis management plan[40]. The possibility of mass mobilisation of NDMA NSD personnel using ASC from the NSD was not utilised, and the ERO started calling individuals on the list of emergency response personnel. Several members of the NSD's management team were away and could not be reached. He therefore called the ones he considered to be most relevant in the situation at hand, including heads of section and technical personnel. One of the first to be notified arrived at the IPS building[41] at around 06:15.

After being notified by the ERO, NSD's Chief of Staff (COS) arrived at NORNOC at approximately 06:30. The ERO, who was also responsible for the next-of-kin contact phone in case of an emergency, briefed the COS about the situation before leaving NORNOC to go to his duty location. The COS also acted as Chief of the Naval Systems Division as the latter was away on official business and currently unavailable.

As more NSD personnel arrived, they started rigging an ad hoc operations centre in the IPS building, instead of assembling the crisis management team at the location defined in the contingency plan. They considered the IPS building to be more suitable in the prevailing situation as that was where the various system experts had their day-to-day work. Over the next hour, key personnel in NDMA NSD critical to the first response were called by other colleagues who had received earlier notification, and asked to come to work immediately.

1.4.3 Organisation of land-based assistance on land and in the vicinity of the frigate

At approximately 06:00, the crisis management team held its first status meeting and assigned team roles. Personnel safety was a first priority, as the situation was still unclear due to the CMT not using the correct personnel overview. The second priority was to salvage the frigate, as there was a risk she would be completely lost. Third priority was environment and reputation. It was important to establish a platform for communicating with the media. The Executive Officer of the Fleet attended to that, as the personnel who were normally assigned this task were still engaged in exercise Trident Juncture.

CGV 'Bergen' arrived in the area around 06:00, by which time most of the frigate's crew had been evacuated to the Sture Terminal, while the CO remained on board along with nine other crew members. The master of the coast guard vessel asked them to board CGV 'Bergen', based on the assumption that they would not achieve anything of consequence by remaining on board HNoMS 'Helge Ingstad'. He also considered that there was a high risk that the frigate would capsize.

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[39] NSD's ERO Intstructions (*Instruks for Beredskapsvakt MARKAP)*, adopted for use by the Naval Systems Division, 1 September 2017 – (Restricted)

[40] NDMA NSD Crisis Management Plan (*Kriseplan FMA MARKAP)*, adopted for use by the NDMA Naval Systems Division, 1 July 2017 (Restricted)

[41] The IPS building is an office building at Haakonsvern Naval Base where the Naval Systems Division's technical department is located. The building is located some distance away from where the crisis management team assembled.

At 06:10, NORNOC issued the following message over the classified chat channel: CGV *'Bergen' and units near HNoMS 'Helge Ingstad': Inform tugboats that HNoMS 'Helge Ingstad' must not be pulled off the rock. Repeat, must not be pulled off. Will then most likely sink.*' The background for the decision was experience gained from the 'Sleipner' accident[42], as well as the very limited information the CMT had received at this moment, and the CO's decision to evacuate the ship. At that time, the CMT had limited information about the extent of damage and whether there was water ingress in the forebody as a result of the grounding.

At 06:21, NORNOC came to the understanding that HNoMS 'Helge Ingstad' had a list of 30 degrees[43]. The IPMS[44] data, however, later showed that the list at that time was about 6 degrees. They also received a message that the CO and the remaining personnel would evacuate the frigate and assemble on board CGV 'Bergen', as they considered it unsafe to remain on board. From information gained, the CMT decided that the CO would remain in charge and make all decisions concerning the frigate. During this period, the Navy did not make any requests for expert assistance from the NDMA – NSD. At approximately 07:00, the NDMA NSD representative to the CMT judged it was not necessary to further recall personnel. Essential personnel from NDMA had been notified, and was either at work or underway.

At 06:32, the last group, consisting of the CO and nine other crew members, left the frigate. They were transferred to CGV 'Bergen' by the rescue vessel 'KG Jebsen', together with the two crew members who had been on board 'Sjøbjørn' and the boatswain who had been on board 'Velox' – in total 13 persons.

At 06:52, the CO of HNoMS 'Helge Ingstad' had set up his team on board CGV 'Bergen'. Over the next few hours, the CO of HNoMS 'Helge Ingstad' made all decisions concerning the frigate in consultation with the the CO of CGV 'Bergen', who had been appointed OSC.

NORNOC also wanted CGV 'Bergen' to use classified radio communication (J-Chat). The CO of CGV 'Bergen' was reluctant to do so due to a lack of resources, at the same time as he communicated with the JRCC and the Coastal Radio South as OSC, in addition to vessels and other resources in the vicinity of the frigate on VHF channel 16 and later on VHF channel 6.

At 07:13, the on-shore incident commander (IC) expressed concern that the torpedoes on board the frigate could pose a risk. Clarification was soon obtained from CGV 'Bergen' that there was no risk of the torpedoes exploding. The JRCC nonetheless decided to establish a 500-metre safety zone around the frigate, ordering all non-essential vessels to leave the zone and maintain safe distance to the frigate.

At 07:35, the on-site Incident Coordinator reported that all personnel from HNoMS 'Helge Ingstad' had been accounted for.

[42] The 'Sleipner' accident: The express boat 'Sleipner' foundered on 26 November 1999. The vessel slipped from the 'Bloksen' rock and sank. Sixteen people died.
[43] The Navy's report from the incident: «Erfaringer med hendelsen KNM Helge Ingstad», NORNOC, dated 28th January 2019
[44] Integrated Platform Management System, see section 2.6.4

The NSD's crisis management team was asked to determine the status of 'Sola TS' by contacting the shipping company. At 07:00, the team contacted DNV GL's Emergency Response Service (ERS) to obtain contact information for the owner of 'Sola TS'. ERS informed them that it was in the process of mobilising personnel to assist. At 07:19, ERS called back to inform them it had contacted the owners of 'Sola TS' regarding the request to disclose information to the Navy

Between 07:00 and 08:00, technical experts from the NDMA NSD and the Norwegian Defence Logistics Organisation (NDLO) got together at the NSD's's operations centre and started to form a picture of the situation. Live TV images that had started to come in were helpful, but they needed more exact information about the damage and the situation on board the frigate. They obtained this information by making direct contact with individual crew members. One of the crew members they contacted had played a key role in the damage control effort on board and was able to provide information about the scope of damage. They learned that 2 deck was damaged going aft from the machinery control room, and that the supply department storeroom, the aft conscripts berthing and the aft generator sets room were flooded and had been shored. Large amounts of water were also coming through the shafts into the reduction gear room. Nothing was said about status of watertight integrity during this conversation.

The leader of KNM Tordenskjold Naval Engineering and Safety Centre (KNMT NESC) was called by NORNOC before 0600 hours. The task given to NSC was to provide assistance the CO of HNoMS 'Helge Ingstad' and the appointed On Scene Coordinator (OSC). At the same time the NSD's operations centre also considered it necessary to dispatch personnel to the frigate quickly. At around 08:00, they therefore dispatched several employees to the Sture Terminal. They left at the same time as personnel from KNMT NESC and arrived at Sture around 08:30, when they made contact with the Navy's liaison officer on site. Some time after 10:00, they were transported to the scene of the accident. Their aim was to assess the condition of the frigate and the possibility of boarding and resuming damage control, securing and then salvaging the vessel. When they arrived at the scene, HNoMS 'Helge Ingstad' was being pushed over on her side by the tugboats.

Figure 14: Parts of the damage. Photo: CGV 'Bergen'

1.4.4 Implementation of measures to salvage HNoMS 'Helge Ingstad'

1.4.4.1 *Initial assistance from internal and external resources*

The NSD received permission from the NDLO/mercantile staff to requisition such equipment and resources as they considered important and reasonable with a view to salvage the vessel. They then started calling on both internal and external resources. They contacted several companies with expertise in diving, damage control and the possibility of securing the frigate on site. A broad range of resources were requisitioned, covering everything from obtaining leak mats, pumps and lifting balloons, welding equipment to make fastening devices and drill rigs to install fixtures for securing mooring wires.

1.4.4.2 *Information gathering*

For the NSD's operations centre, it was important to gain an overview of the situation on board to be able to resume damage control efforts. They initially knew little about the scope of damage, but had gained a reasonably good understanding of the damage by calling acquaintances who had been on board the frigate. To shield the CO of HNoMS 'Helge Ingstad', NORNOC decided that only the CMT could contact the CO. This was understood by the NSD's operations centre that all contact with the management on board HNoMS 'Helge Ingstad' should be via the CMT. They were also not allowed to speak with the crew, who had started arriving at the reception centre at Haakonsvern training facility and were to be shielded there. The NSD's operations centre nonetheless contacted personnel from the crew and got them to explain where the damage was, which compartments were lost when they left the frigate and the vessel's watertight integrity at the time of evacuation.

From the start there were limited contact between NSD’s operations centre and the CMT. The NSD’s operations centre gradually realised the importance of closer dialogue with the CMT to coordinate resources and the assistance that was being deployed to the frigate, and to gain a shared understanding of the situation. They therefore sent a liaison officer to the CMT at around 09:00. The liaison officer realised that the CMT had very limited knowledge of the extent of damage on board, and that the staff’s main focus was still on gaining an overview of and attending to personnel, in addition to dealing with next of kin and the media.

1.4.4.3 *Information from DNV-GL ERS regarding the vessels stability*

At 08:06, the Naval Systems Division’s crisis management team contacted ERS again for a brief update. No further information was provided about the extent of damage on board the frigate, so ERS started to work on stability calculations based on what could be ascertained from the TV images. The frigate’s load condition was unknown, and assumptions were made based on the stability manual that was prepared in connection with the classification of the frigate.

At 09:08, ERS contacted the Naval Systems Division’s crisis management team and received the following information about the extent of damage:

> *Compartments 1–5 from the stern had water ingress, the front and midship of the frigate (approx. frames 110–120) rested on the rock. There was 6 metres of water below the keel at the stern, at the aft perpendicular. Barges have been requisitioned, in addition to additional pump capacity, magnetic mats, welders etc.*

At 09:40, the ERS contacted the CMT again, with an oral stability assessment based on the frigate’s position in the water. The calculation showed that the frigate would float with a list of 17 degrees and an aft trim of 7.7 m. Most of the helideck would be under water. The calculations were based on the assumption that watertight integrity was intact, except in the damaged areas. There was also much uncertainty attached to the calculations as a result of the extent of damage and the frigate’s position on the rock.

At 10:00, the CMT called back with information about the fuel stock. The difference between the actual and estimated quantity did not make a significance difference to ERS’s calculations.

Figure 15: Tugs pushing HNoMS 'Helge Ingstad' towards shore. Photo: CGV 'Bergen'

1.4.4.4 *Tug operations to keep HNoMS 'Helge Ingstad' against the rocks*

In the period following the evacuation of the vessel, the focus was still on preventing the frigate from sliding into deeper water. There was little to be done from CGV 'Bergen' except to try to hold the frigate in the shoreward position with the aid of the tugboats. The CO of HNoMS 'Helge Ingstad', supported by his team and the CO of CGV 'Bergen', decided it was unsafe to send personnel on board. The CO and his team largely based their decisions on their own knowledge.

When the afterbody started to sink deeper and water started entering the helideck on the starboard side, the OSC and the CO believed it was important to try to push the frigate closer to shore as long as it was possible to maintain pressure on the stern. High tide was only a few hours away, which was an advantage in the operation. The OSC and the CO therefore agreed that the planned action was the most expedient option in the situation that prevailed.

Figure 16: From the salvage operation of HNoMS 'Helge Ingstad'. Photo: HNoMS 'Oddane'

Just after 08:00, the CMT received a message from the CO that they feared the frigate would slide off the rock and sink. On board CGV 'Bergen', it had been decided that the tugboats would push the frigate sideways towards the shore, while maintaining pressure on the stern. Consideration was given to deploying hawsers to secure the ship to the shore.

The OSC asked the tugboats 'Tronds Lax', 'Ajax' and 'Sleipner' to take up their positions on the port side of HNoMS 'Helge Ingstad' and gently start pushing the frigate towards the shore. Before the operation was initiated, the combat craft HNoMS 'Oddane' surveyed the water depths around the frigate. At 08:27, the tugboats started pushing the frigate towards the shore, while 'Velox' maintained pressure on the stern. This caused the frigate to rotate around the point at which it touched the submerged rock and turn more parallel to the shore, causing the stern to move to shallower water.

Around 09:00, the CMT received a message that the frigate was being pushed sideways. It was also reported that the frigate was in a stable position and that it was safe to board. Shortly afterwards, they received a counter message that it was still unsafe to board the frigate. The CMT said that only the CO could decide whether the frigate was stable enough to set personnel on board.

At 09:15 'Velox' stopped pushing on the stern, while the other tugboats maintained pressure on the ship side.

Figure 17: HNoMS 'Helge Ingstad' being pushed sideways by tugboats at 09:47. Photo: CGV 'Bergen'

At 10:27, while the tugboats kept pushing on HNoMS 'Helge Ingstad', the frigate suddenly heeled over to starboard. The IPMS data show that the frigate ended up with a list of around 30 degrees, after which the tugboats interrupted the operation. The afterbody then sank rapidly so that the shaft/rudder was lodged on the seabed.

Figure 18: HNoMS 'Helge Ingstad' listing heavily at 11:04 after having been pushed by tugboats. Photo: CGV 'Bergen'

1.5 The rescue operation and attending to personnel

At 04:11, the Joint Rescue Coordination Centre South Norway (JRCC) received the distress message from HNoMS 'Helge Ingstad'. At 04:13, the Norwegian Armed Forces' operative headquarters were asked to take steps to assist with all necessary resources from Haakonsvern Naval Base. At 04:15, the Coastal Radio South announced that it was taking over the coordination of the rescue operation. At 04:20, the JRCC asked for the local rescue coordination centre (LRCC) to establish a reception facility at Sture and to also notify the other emergency response services. During the period that followed, many vessels reported for duty and many were asked to sail towards the scene of the accident. When it was established that the frigate had control of POB and had initiated evacuation, the JRCC considered that the rescue operation had entered a new phase and that there was no longer any need for vessels other than tugboats and offshore vessels. All other vessels were therefore dismissed as from 05:17.

When the decision was made to evacuate the frigate, 'Velox' reported that they could take aboard all the personnel, and that the crew could board the tugboat from the helideck. The evacuation took place in a controlled manner without incidents. At 05:28, all personnel had been evacuated except ten members of the ship management, who remained on the bridge to make further assessments with a view to preventing the frigate from sinking. In addition, there were five crew members on standby on board 'Sjøbjørn', and the boatswain who was still on board 'Velox'.

At 05:37, 121 crew members had been transferred from 'Velox' to 'Ajax', which transferred them to the Sture Terminal. At approximately 06:15, the crew were set ashore at Sture, where they were registered and attended to by the on-site incident coordinator. At approximately 07:30, all crew members had been accounted for. Of the 137 personnel on board HNoMS Helge Ingstad, 121 had been taken to the Sture Terminal, including the 7 crew members who were injured, while 13 remained on CGV 'Bergen', and 3 sailed with 'Sjøbjørn' to Haakonsvern.

CGV 'Bergen' was on an assignment in the sea off Holmengrå when the incident occurred. When they heard on the radio that a frigate and a tanker had collided in the Hjeltefjord, the commanding officer onf CGV 'Bergen' was asked to come to the bridge. 'CGV Bergen' set full speed towards the Hjeltefjord, while informing the JRCC that they were on their way. ETA at the scene of the accident was at 06:10.

At 05:48, the JRCC asked the CO of CGV 'Bergen' to assume the role as on-scene coordinator (OSC) when they arrived at the scene of the accident. The message was communicated to all vessels in the area. En route to the frigate, CGV 'Bergen' started preparing equipment for external damage control and oil spill response.

Figure 19: Evacuation from HNoMS 'Helge Ingstad'. Photo: Norwegian Sea Rescue Society


Figure 20: The rescue operation on board HNoMS 'Helge Ingstad'. Photo: Norwegian Sea Rescue Society

At 05:22, the Navy's support organisation was mobilised and, at 05:33, orders were received to establish a reception centre at Haakonsvern military training facility and a next-of-kin centre in the Briggen building. The support organisation set up base at Haakonsvern from 06:00.

At 06:45, a support team consisting of five members (two psychologists, a doctor, a nurse and the army chaplain) was dispatched to Sture to attend to the crew. In the course of the morning, the crew were taken to the reception centre at Haakonsvern, where they were attended to by the support organisation.

CGV 'Bergen' had multiple exchanges with the CMT. Among other things, the number of personnel on the staff's list did not tally with the number stated to have been registered in the POB control on board. This meant that the number had to be verified, which took time. Exchanges also took place between the frigate's crew members assembled on board CGV 'Bergen' and the MEO that was on leave, but who had reported to CMT when he received a text message as part of the alarm centre's notification procedure. However, the communication between them stopped when the MEO got the understanding that further communication should only be between the CMT and the CO of HNoMS 'Helge Ingstad'.

2 Factual information

2. FACTUAL INFORMATION

2.1 Introduction

This chapter contains factual information about the vessel, the surroundings, the parties involved and organisational issues. A presentation is also given of special investigations and measures enacted after the accident. A summary of relevant previous accidents has been included in order to examine possible similarities with the accident involving HNoMS ‘Helge Ingstad’.

2.2 Damage to the vessel

2.2.1 Hull damage

In the collision with ‘Sola TS’, HNoMS ‘Helge Ingstad’ sustained extensive damage along the starboard side. After the accident, the damage was measured to extend from 60 mm aft of frame 182 to 160 mm forward of frame 107. This corresponds to damage length of approx. 46 metres, affecting 5 watertight compartments, most of which was above the initial damage waterline, see Figure 21. The damage caused rapid flooding of the aft conscripts berthing. In addition, the damage had started caused flooding the supply department storeroom and the aft generator sets room.

The gash in the frigate’s side broke 2 deck approximately at frame 150 (in the middle of compartment 10) so that compartments 12, 11 and 10 were exposed to flooding through the shell under 2 deck. As mentioned above, the damage extended longitudinally across compartments 9 and 8 (aft main engine room and reduction gear room), but these spaces were mainly intact below 2 deck.

As a result of the vertical width of the gash, the buoyancy between 2 deck and 02 deck was lost along the whole length of the gash. As a consequence of this, listing increased when the edge of 2 deck was submerged.

Figure 21: The damage on HNoMS ‘Helge Ingstad’. Illustration: NCIS/CIAAS/NSIA

It was also reported that water flowed into the AVCAT pump room.

2.2.2 Damage to other systems

At the torpedo magazine, the collision caused three torpedoes to be pushed inwards and partially out of their racks.

The 46 meter long damage area, which also extended into the vessel, caused a large number of cables, pipes, ducts, control panels, secondary switchboards, watertight doors etc in the afterbody to be severed and damaged. Outside HQ1 on 2 deck, the water flowed out from a ruptured branch line to the seawater main. The presence of several severed electrical cables made it dangerous to move in the space where the damage had occurred. This report does not include a full description of the damage, but damage of relevance to the sequence of events is referenced in section 2.9.7.

Figure 22: Damage to the seawater main aft of fire zone 4. Photo: NSIA

2.2.3 After the grounding

The grounding caused the afterbody of the frigate to be pressed down into the sea. Due to this, hull damages which had been above the waterline came under the waterline. This resulted in substantially increased water ingress in several compartments where the crew prior to the grounding had reported to have control over the water ingress. An illustration of the damage and the waterline prior to and after the grounding is set out in Figure 23.

Figure 23: The shell damage below the waterline. Illustration: NCIS/CIAAS/NSIA

The grounding therefore resulted in the damage control efforts becoming much more difficult.

2.3 Weather and sea conditions

2.3.1 General information

After the collision, the frigate turned to starboard to a course of approximately 230° towards the shore north of the Sture Terminal. The wind direction was largely the same, while the wind speed gradually decreased as the frigate came closer to the shore. IPMS data retrieved from HNoMS 'Helge Ingstad' showed a slightly higher wind speed than that recorded by Fedje weather station (7 m/s). A wind speed of 16.6 knots (~8.5 m/s) was registered when the frigate was on a shoreward course at approximately 04:04.

The report from Part 1[45] contains data from the weather stations in the area, provided by the Norwegian Meteorological Institute.

[45] 'Sub-report 1 on the collision between the frigate HNoMS 'Helge Ingstad' and the oil tanker 'Sola TS' on 8 November 2018 outside the Sture Terminal in the Hjeltefjord in Hordaland county', of 8 November 2019.

2.3.2 Information about sea currents from the Meteorological Institute

The Meteorological Institute has not measured sea currents in the area. The NSIA has obtained calculations based on a numerical ocean model with a grid of approximately 800x800 m; see the report from Part 1[45]. The model showed a northerly current moving at a speed of approx. 0.5 m/s in the accident location at the time of the accident. There is some uncertainty attached to model calculations of this kind. The Meteorological Institute assumes that the current direction in this case is correct, but that the speed is more uncertain.

2.4 Description of the waters

HNoMS Helge Ingstad collided in open waters with a depth of around 200 metres. North of the Sture Terminal, the depth decreased gradually towards the shore. At a distance of 600 m from the shore, the depth was 50 m, decreasing further when the frigate was 250 m from the shore. A shallow area (<10m) with several shallows of between 3 and 7 metres was located 150 m south-west of the frigate's course line. This area extended 300 m from the shore, was 80 m wide (E–W) and 150 m long (N–S). The Ådnesflua shallows (2 m) were located 800 m north-west of the frigate's course line and marked with a green pole on the northern side.

Where the frigate ran aground, the coastline was rugged with relatively steeply decreasing depths from 30 m at around 100–150 m from the shore. Apart from the above-mentioned area to the south of the site where the frigate ran aground, no nearby areas had a topography that was suitable for a controlled grounding.

The frigate ran aground just before low tide. On 8 November 2018 at 04:10, the Bergen tide gauge showed 45 cm above the hydrographic zero. Low tide was at 04:50 to 05:00, with a sea level at 38 cm. When the frigate was evacuated at 10:10, the sea level was 158 cm above the hydrographic zero, increasing to 166 cm at high tide from 11:00 to 11:10.

2.5 Manning, roles and shipboard organisation

2.5.1 Manning

The Nansen-class frigates, including HNoMS 'Helge Ingstad', are manned in accordance with the Lean Manning Concept (LMC). LMC and the background for the choice of manning concept are described in section 2.8.9.3.

HNoMS 'Helge Ingstad' had the capacity to accommodate a crew of 146. Because several people were on leave or temporarily absent on this particular voyage, there were a total of 137 persons on board on the day of the accident, including one guest.

2.5.2 Damage control organisation

The organisation and functions of damage control on board are described in the manual *SMP-17 (B) Håndbok for brann- og havariverntjenesten i Sjøforsvaret*[46]. The manual also describes principles and procedures related to fire safety and damage control in the Navy.

[46] SMP-17 (B) «Håndbok for brann og havariverntjenesten i Sjøforsvaret», revision B, dated 1. August 2018. The handbook is unclassified

According to the manual, the damage control organisation will vary on different classes and types of vessels, depending on the size and composition of the crew, and the vessel's structural design. An example of what a damage control organisation might look like on a large surface vessel is given in Figure 24.

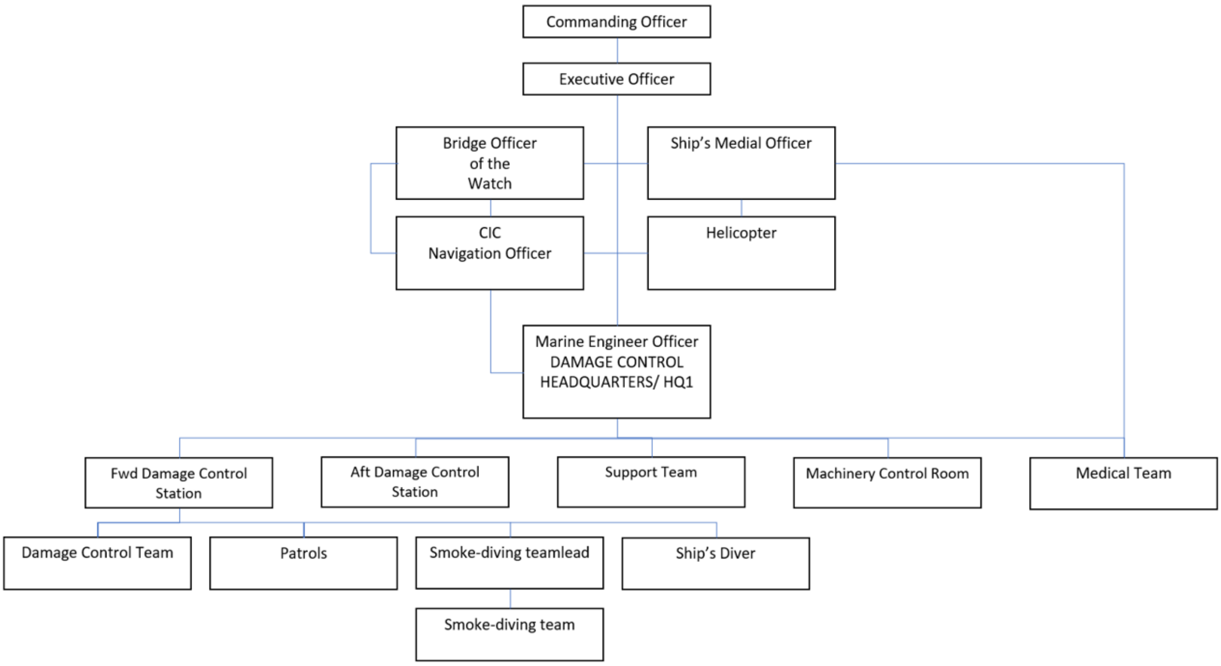

Figure 24: Example of damage control organisation on a large surface vessel (Norwegian only). Source: The Navy (SMP-17 (B))

The manual includes the following wording:

> *Damage control situations are situations with which most people are unfamiliar. Such unfamiliar and threatening situations can naturally give rise to rash and panic-like responses.*

In order to systematise information flow in the organisation and make the crew aware of the vessel's collective goal, different concepts have been introduced on several of the Fleet's vessels. The most important tool for describing what the commander wants to achieve is the 'Command Aim'. It enables decisions and prioritisation at the lowest possible level, and can only be set aside by a veto (command-by-veto). This is stated to be particularly important in the event that internal means of communication fail, but it also plays a decisive role in the information flow with a view to attending to the most important information first.

A 'command huddle'[47] shall be held at intervals of approximate seven minutes, to agree on what damage control actions should be prioritised.

The main roster constitutes an essential part of damage control response on board. According to SMP-17 (B), the roster is a tool intended to prevent a random first response and reduce the likelihood of panic and chaos. The roster describes the position and role of each crew member in response to the different shipboard alarms and ensures a collective,

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[47] A command huddle is best described as a brief status meeting in which the officers in charge of HQ1 and CIC report on status and priorities to the MEO and CA. The vessel's three topmost priorities are derived from such huddles (see SMP-17 (B)).

planned response on the part of the whole crew, regardless of CBRN state (watch system) and alarm condition. In the event of a general alarm, the crew shall take up their pre-defined positions as per the damage control roster, which forms part of the main roster.

2.5.2.1 *Shipboard roles and functions on HNoMS 'Helge Ingstad' in a damage control situation*

The CO has overall responsibility in a damage control situation and will normally take up position in the CIC. The CO is supported by advisers, including the command advisor (CA) and operations officer (ORO), and the MEO in the machinery control room (MCR), which in a damage control situation is referred to as the damage control headquarters (HQ1). The MEO has primary responsibility for damage control actions and recommends what should be given priority.

The subsequent sections describe important key functions on the bridge, in the CIC room and the MCR/HQ1.

2.5.2.2 *Roles on the bridge*

In a damage control situation, the bridge is normally responsible for regaining control of propulsion and steering gear, coordinating with external parties and evacuating the vessel on initiation of 'Abandon ship'.

In accordance with the damage control roster, the relevant personnel were designated and assigned the following roles when the general alarm was raised:

The **acting OOW** would continue in the role of OOW. The OOW continued in the same role throughout the incident.

The **OOW being relieved (OOW-R)** was to proceed to the bridge and act as OOWA. The NSIA has been informed that the crew on HNoMS 'Helge Ingstad' had been trained to practice a more flexible division of roles. As the frigate had three cleared OOWs, a practice had been established whereby the acting OOW at the time when the general alarm was sounded would continue in the role of OOW. The next OOW to arrive on the bridge would assume the role of navigator, while the third OOW to arrive on the bridge would step in as OOWA.

The acting Officer of the watch under training (**OOW-T)** would act as OOWA-2 on the bridge. The person in question did not step into this role after the general alarm was raised and left the bridge at approximately 04:26.

The **OOWA** would take up position as bridge lookout if the general alarm was raised. When the accident occurred, this person was assigned responsibility for POB control on the bridge.

The **XO** would proceed to the bridge/CIC in the event of a general alarm. The XO arrived on the bridge at 04:05 and remained there until the frigate ran aground. The NSIA has been informed that an arrangement had been established on board HNoMS 'Helge Ingstad' whereby the XO would proceed to the bridge if the general alarm was raised, for the purpose of assisting or taking over from the OOW. This arrangement had been established after the period of flag office sea training (FOST) in January/February 2018, and experience of the arrangement was favourable. The arrangement was not described in any procedure.

The acting **helmsman (HM)** would stay on the bridge as part of the support team. The person who stood at the helm when the collision occurred remained at the helm up until the frigate ran aground. The helmsman remained on the bridge until approximately 04:15.

2.5.2.3 *Roles in the command information centre (CIC)*

The command information centre (CIC) was the centre for control of the frigate's combat system. From the CIC, the frigate's crew could keep an overview of what was happening in the air as well as on and below the sea's surface. The CIC was also the room from which the commanding officer (CO) managed external operations and internal damage control situations.

In a damage control situation, the CIC was normally responsible for overall POB control, for informing relevant external parties and for supporting damage control efforts through the use of support teams.

In accordance with the damage control roster, the relevant personnel was designated and assigned the following roles when the general alarm was raised:

The **commanding officer (CO)** would continue in the role of CO and proceed to the CIC in the event of a general alarm. In a damage control situation, the CO would normally take advice from the MEO (HQ1 leader) and weapon engineer officer (who fills the role of command advisor). The CO's command aims in the present and similar situations is: Pri 1 – Personnel and Pri 2 – Materiel. The CO arrived on the bridge at approximately 04:05, but returned to the CIC after a few minutes. The CO came back on the bridge just before the frigate ran aground.

According to the damage control roster, the **weapon engineer officer (WEO)** would assume the role of command advisor (CA). The person in question assumed this role in the damage control situation and remained in the CIC for the duration of the incident.

According to the damage control roster, the **underwater warfare officer 1** would lead support team 5. The person in question was OOW-CIC[48] when the collision occurred and arrived on the bridge after approximately 1 1/2 minutes to provide assistance there.

According to the damage control roster, the **operations officer 1** **(ORO1)** would assume the role of OOW-CIC and notify external parties. The person in question assumed this role during the damage control operation and remained in the CIC up until the frigate ran aground.

According to the damage control roster, the **operations officer 2** **(ORO2)** would assume the role of rover in CIC. The person in question carried out several CIC tasks, but did not assume the role of rover.

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[48] Ref I-1100 (B) *Ekstern og intern kamp* section 1108.2.1.2. It is stated in a comment on the internal procedures that the operations officer who is on watch when an action stations or general alarm is raised shall remain in the nominal role of OOW-CIC.

2.5.2.4 *Roles in the damage control headquarters (HQ1)*

In a damage control situation, the machinery control room (MCR) will function as the damage control headquarters (HQ1). HQ1 is the central command centre led by the MEO. The MEO and damage control officer play key roles in the handling of damage control situations on board, and both were present in the MCR/HQ1. In addition, there were operators present at the propulsion control console (PCC), auxiliaries control console (ACC), electrical control console (ECC), and damage control console (DCC), see Figure 25.

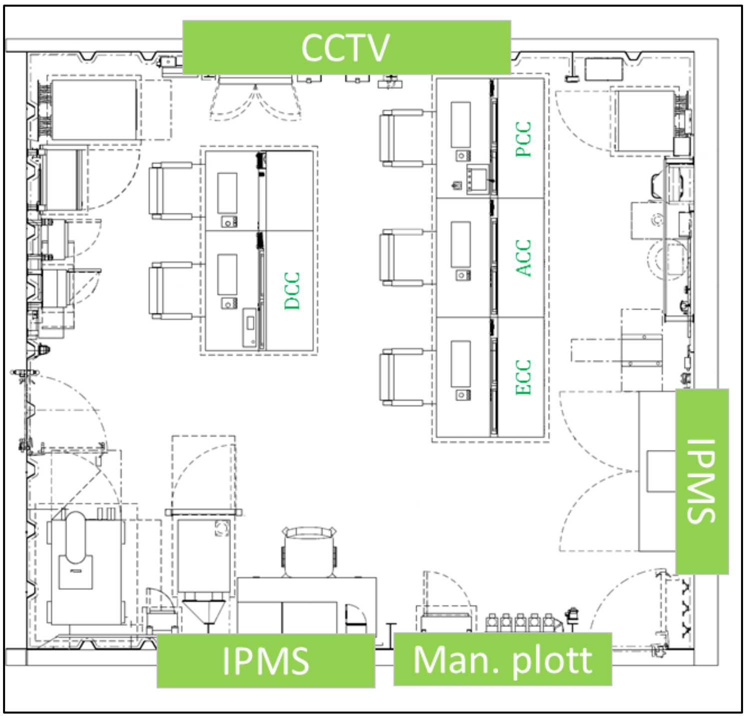


Figure 25: Configuration in the MCR/HQ1. Illustration: The Navy

Under the leadership of the MEO, the MCR/HQ1 is responsible for:

- Preventing flooding
- Restoring electricity distribution
- Maintaining steering control
- Restoring propulsion

In accordance with the damage control roster, the relevant personnel was designated and assigned the following roles when the general alarm was raised:

The **marine engineer officer (MEO)** would assume the role of HQ1 leader. The MEO is the commander's closest adviser in a damage control situation. The CO receives assessments from the MEO, conveyed by the CA. The person in question did assume the role of MEO in the damage control situation, but had previously held the role of first engineer on board. He had held the role of MEO since autumn 2018, because the frigate's regular MEO was on leave.

The **<u>first engineer (E1)</u>** would assume the role of leader for propulsion and auxiliary machinery. The person in question assumed this role in the damage control situation. This person had held the position of first engineer since autumn 2018, and had previously held the role of second engineer on board.

The **<u>damage control officer (DCO)</u>** would assume the role of leader for the damage control teams on board. The person in question assumed this role in the damage control situation. This person had held the role of damage control officer on HNoMS 'Helge Ingstad' since autumn 2018.

The **<u>first electrical engineer (EE1)</u>** would assume the role of coordinator for electricity production and electrical battle damage repair (BDR). The person in question assumed this role in the damage control situation. This person had filled the role of first electrical engineer since 2016.

<u>Rover:</u> According to the main roster, one person in HQ1 would have the role of rover. During the incident, there were two officers acting as rovers and reporting to HQ1. According to the main roster, one of them should have assumed a reporting role in the CIC.

2.5.2.5 *The series of shipboard manuals*

The series of shipboard manuals consisted of several modules that were meant to cover everything ranging from administrative to operational matters. Most relevant to the incident involving HNoMS 'Helge Ingstad' were the bridge manual (200 series), IPS manual (300 series) and the internal and external battle manual (1100 series). The sections below contain reference to relevant procedures. The procedures are also reproduced in Appendix B.

2.5.2.5.1 <u>P200 – Bridge manual</u>

Operational procedures have been prepared that the crew are required to use to handle incidents and emergency situations. The bridge manual consists of four parts:

- Bridge service instructions (I-200)
- Bridge service guidelines (V-200)
- Bridge service procedures (P-200)
- Bridge service checklists (L-200 series)

The preface to the bridge service procedures includes the following text:

> *We have a long-standing tradition of using procedures in the Norwegian Armed Forces, and these are natural and important cornerstones in all professions where precise communication is required.*
>
> *Procedures shall be learnt through practical application and become a natural means of communicating when they are properly memorised. This will free up thinking capacity, so that all operators can concentrate on finding out what should be said and done, rather than on <u>how</u> it should be said and done.*

The bridge service procedures manual includes procedures *P-230 Propulsion and power supply problems* and *P-233 Emergency steering*. These two procedures are of particular importance for this incident. The main content of these procedures is therefore reproduced in the following sections. In addition, *P-202 Verbal procedures* describes how information is to be communicated verbally.

In the bridge manual, checklists are kept under L-200 'Bridge service checklists', but these do not include any checklists for procedures P-230 and P-233. However, the frigate had prepared its own checklists for these procedures.

2.5.2.5.2 *P-202 Verbal procedures*

One of the sub-procedures describes verbal reporting in the event that the rudder fails to respond.

P-202.05.02 Reporting by the helmsman in the event of loss of steering

> *If the helmsman is unable to steer the ordered course, this must be reported to the officer of the watch immediately:*
>
> ***'Officer of the watch, unable to maintain course'***
>
> *If the rudder fails to respond, this must be reported to the officer of the watch immediately:*
>
> ***'Officer of the watch, rudder does not respond!'***
>
> *The officer of the watch will then initiate the emergency steering procedure; see P-233 in the bridge manual.*

2.5.2.5.3 *P-230 Propulsion and power supply problems and P-233 Emergency steering*

P-230.01 Purpose

According to the procedure, it is intended to ensure that immediate action is taken in the event of loss of propulsion, steering or power supply. All such situations are to be announced by the OOWA issuing the following message over the PA system:

> *Emergency manoeuvre x 3, bridge has lost steering/propulsion/power supply. Key personnel to proceed to their designated positions*

Key personnel include:

- The CO, XO and MEO take up position on the bridge
- The first engineer, first and second electrical engineers, and second and third engineers take up position in the machinery control room.
- The boatswain or boatswain assistant readies the anchor

The procedure goes on to define sub-procedures for different scenarios, such as:

- Loss of propulsion
- Loss of propulsion control
- Loss of steering
- Loss of power/ blackout

Some of the procedures are very lengthy, containing many points and large volumes of information. Several of the procedures became relevant on the day of the accident, as the incident had several consequences in the form of 'black ship', stop of one of the main engines, and problems with both propulsion and steering from the bridge. The following are considered to be the most relevant procedures (for more details, see Appendix B Emergency procedures):

- P-230 Propulsion and power supply problems
- P-230.01 Purpose
- P-230.02 Loss of propulsion procedure (engine failure)
- P-230.03 Loss of propulsion control procedure (engines still running)
- P-230.04 Loss of steering procedure
- P-230.05 Loss of power supply/blackout procedure
- P-233 Emergency steering
- P-233.01 Emergency procedure
- P-233.01.01 Initial response
- P-233.01.02 Emergency steering, position 1
- P-233.01.03 Emergency steering, position 2
- P-233.01.04 Communication between steering gear and bridge

Emergency steering and propulsion procedures shall be kept on the bridge. It cannot be confirmed with any certainty that this was the case, as these procedures were not taken into custody as part of the salvage operation.

2.5.2.5.4 P300 – Technical ship manual

Among other things, the manual contains emergency procedures and checklists for propulsion and steering. The manual has been classified as 'Restricted' under the Security Act, which means that further information may not be included here.

2.5.2.5.5 P1100 – Internal and external battle

The manual contains internal and external battle philosophy. The manual has been classified as 'Restricted' under the Security Act, which means that further information may not be included here.

2.6 The vessel

2.6.1 General information about the Nansen-class frigates

HNoMS 'Helge Ingstad' was a Norwegian-registered Nansen-class frigate, based at the Haakonsvern naval base in Bergen; see Figure 26. Materiel used in the defence sector is owned by the State represented by the Ministry of Defence and managed by the Norwegian Defence Materiel Agency (NDMA) on behalf of the owner. The equipment is made available to the Norwegian Armed Forces and other agencies, and shall be managed in accordance with the guidelines given.[49] The role of the shipowner was taken care of by the Chief of the Royal Norwegian Navy and responsible for ship operation was the Commander of the Fleet. The frigate was built by Navantia in Ferrol in Spain. HNoMS 'Helge Ingstad' was delivered in 2009 and was the fourth in a line of five frigates built and handed over to the Navy between 2006 and 2011. See section 2.7 for more details about the parties involved.

The Nansen-class frigates were subject to many requirements that formed the basis for their design. This applied to the exterior and interior as well as to technical installations. Requirements relating to speed, dimensions, survivability, action range, areas of

[49] Government guidelines: "Forsvarsdepartementets retningslinjer for logistikkvirksomheten i forsvarssektoren"

operation and warfare areas have all influenced the frigates' appearance and technical design. Technical systems with a bearing on the frigates' operation might have one or more backup systems. This redundancy was largely provided through having two or more parallel components or systems.

The Nansen-class frigates were designed to require a minimum number of crew. For that reason, HNoMS 'Helge Ingstad' was highly automated. The philosophy was that the failure of one system would cause another to start.

The vessel had a length overall of 133.25 m and breadth of 16.8 m. The propulsion plant consisted of two BAZAN BRAVO 12V diesel engines and one GE LM2500 gas turbine, with an engine power of 2 x 4.5 MW and 1 x 21.5 MW, respectively.

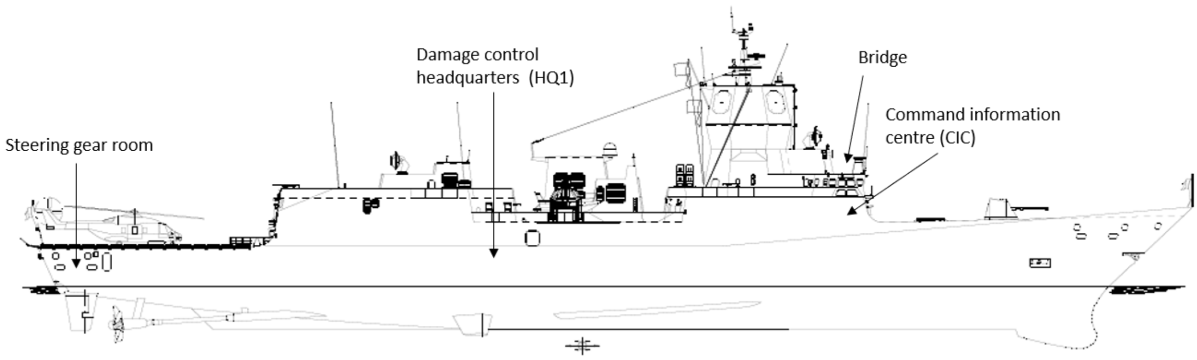


Figure 26: Outline drawing of a Nansen-class frigate. Illustration: NDMA/NSIA

2.6.2 Level of readiness and equipment protection

2.6.2.1 *Introduction*

In its *Handbook of fire and damage control in the Navy (SMP-17 (B))*, the Navy states that most naval vessels are designed and built to meet more stringent requirements for buoyancy, stability and pumping capacity than other ships. This is meant to ensure that the vessels should function and be able to utilise their weapons even when damaged or subject to extreme conditions. The vessels are also designed with a view to providing the crew with the best possible collective protection against CBRN[50] contamination. This is achieved by making it possible to close down the whole vessel or individual compartments.

According to SMP-17 (B), three factors are decisive for maintaining the vessel's watertight and gastight integrity:

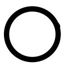
- Structural design
- Discipline[51]
- Maintenance

[50] CBRN is an international acronym for chemical, biological, radiological and nuclear materials and explosives.
[51] SMP-17 (B) states that: *'Experience of war has shown that maintaining strict watertight and gastight discipline is fundamental to the safety of the vessel. This is obviously also the case in peacetime, in the presence of possibilities of running aground, colliding or catching fire. In this context, discipline refers to user discipline, i.e. correct operation of closing devices at all times.'*

A naval vessel shall always operate subject to an ordered level of readiness and equipment protection level. The level of readiness indicates what posts to man, what watch scheme to use and, if applicable, what weapons to man. In addition, the vessel shall be closed down in accordance with the ordered equipment protection level. Equipment protection levels to be observed by the vessel are defined in RAR[52] III section 3.5.3[53]. Closing down in accordance with the ordered equipment protection level shall protect the vessel and personnel from the spread of inflowing water, fire, smoke or hazardous gases. A vessel's survivability in a crisis will depend on whether the levels of readiness are complied with.

2.6.2.2 *Marking of closing devices*

Important shipboard closing devices for damage control (doors, hatches, valves etc.) were supposed to be marked with the letters 'X', 'Y', 'Z' and 'M'. The letters were meant to indicate the required position of the closing device (open/closed) with reference to the ordered level of equipment protection.

- 'X': This letter was primarily meant for use below the 'damage control deck'[54] on doors, hatches, manholes and valves leading to tanks, storerooms, ammunition magazines and through bulkheads of importance for the vessel's watertight integrity. Closing devices marked with an 'X' must always be in the closed position.
- 'Y': This letter was to be used on the following closing devices not marked with an 'X':
  - Doors and hatches in watertight bulkheads below the damage control deck.
  - Hatches penetrating the deck below the damage control deck.
  - Doors and hatches leading to the exterior 1 deck.
- 'Z': This letter was to be used on closing devices that would normally have to be kept open for optimum operation of the vessel over longer periods in order for the crew to enjoy the greatest possible degree of comfort. This letter was also to be used on closing devices on 01 deck and the decks above.
- 'M': This letter was meant to indicate that the closing device was under the control of a specific officer or user. Unauthorised personnel were not permitted to operate the closing device.
- : A black 'O' on the tag meant that no light must be emitted from this opening during dimming.
-  : A yellow tag meant that the opening was to be kept closed in the CBRN damage control state.

[52] The Norwegian Armed Forces' own technical Rules and Regulations for Surface Vessels of the Royal Norwegian Navy
[53] *Damage Control Level of Readiness RAR III section 3.5*
[54] Deck 2 is the damage control deck on Nansen-class frigates.

2.6.2.3 *Equipment protection levels*

The following equipment protection levels were defined:

- X-RAY: The lowest permitted level. All closing devices marked with an ‘X’ must be closed. Closing devices marked with a ‘Y’ or ‘Z’ could be kept open. This equipment protection level was to be used alongside the quay in peacetime.
- YANKEE: All closing devices marked with an ‘X’ or ‘Y’ must be closed. Closing devices marked with a ‘Z’ could be kept open. This equipment protection level was to be used alongside the quay in wartime and when at sea in peacetime.
- ZULU: This was the highest level that could be ordered (when it was likely that the vessel could be damaged). All closing devices marked with an ‘X’, ‘Y’ or ‘Z’ must be closed. This level of protection was to be used in situations of war. According to SMP-17 (B), ZULU automatically comes into play if the action stations[55] or general alarm is raised. When equipment protection level ZULU is ordered, openings marked with a ‘Z’ must be closed and openings marked with an ‘X’ or ‘Y’ must be checked to verify that they are closed.

Table 1: Matrix showing the different equipment protection levels. Source: SMP 17 (B)

ORDERED SAFETY LEVEL	MARKING LETTER		
	X	Y	Z
XRay	Closed	-	-
Yankee	Closed	Closed	-
Zulu	Closed	Closed	Closed

2.6.2.4 *Marking system on handover of the frigate*

On handover of the frigate, the marking system was documented in ‘Book of main systems[56] – Annex A, Chapter 11’. All closing devices were supposedly marked in accordance with those lists. Such marking is also described in the Integrated Platform Management System (IPMS). The IPMS also has a scheme for supporting the operator in that the system could be operated at the different protection levels (‘X’, ‘Y’, ‘Z’). This meant, for example, that the bilge system and power supply setup could be defined accordingly.

2.6.2.5 *Marking and closing on HNoMS ‘Helge Ingstad’ on the day of the accident*

According to information received from the NDMA, work on a proposal to change the marking system had started as early as in 2012. The work had been ongoing during subsequent years and still remained to be completed at the time of the collision. At the time of the collision, it was Revision C of the marking plan, dated 1 October 2017, that

[55] When the action stations alarm is raised, the vessel is immediately readied for combat.
[56] Technical manual issued by Navantia: ‘The Book of Main Systems has been prepared to provide the Vessel's commanding officers of the F-310 type Frigates with rapid reference manual containing a description of the governing standard for the vessel and its systems, as well as lists of the Vessel's main data’.

applied on board HNoMS 'Helge Ingstad'. Appendix C (R)[57] contains the marking plan together with an overview of open and closed doors/hatches at the time when the frigate was evacuated.

Some of the input that resulted in Revision C to the marking plan were based on feedback from the professional environment in FOST, where it was pointed to the favourable experience from many other NATO countries of introducing additional marking of doors/hatches in addition to XYZM marking to mark doors and hatches important to watertight integrity. All doors and hatches between watertight compartments were marked red in the marking plan, revision C, but this was not implemented on board. Such marking was missing, however, between compartments 12 and 13 (Rev. C). The NDMA has stated that this was an error in the marking plan, and that this has been rectified in subsequent revisions.

HNoMS 'Helge Ingstad' was the only vessel that applied the actual marking plan (rev. C). Corrections had not been made in the IPMS to reflect the change of markings in accordance with Revision C, and Revision C with the overview provided has not been found to include marking of other closing devices than doors and hatches.

A change order[58] relating to the marking system was issued by the NDMA in June 2017 on the grounds that the markings were perceived as random and were therefore not observed on board the vessels. It was furthermore stated that this could lead to several challenges that could also have an adverse effect on safety.

In principle, the other Nansen-class frigates were to use Revision B of the marking plan. The information received by the NSIA indicates that neither the NDMA nor the Navy had any overview of configurations used on the other frigates, as it appears that vessel-specific changes had been introduced on each of them.

During the NSIA's interviews, it emerged that little use was made of the predefined protection levels in IPMS during drills and exercises, and they were also not used on the day of the accident.

The morning of the accident, HNoMS 'Helge Ingstad' was sailing subject to normal sea watches and ordered equipment protection level 'Y'; see section 2.6.2.3. The investigation has shown some breaches of the equipment protection level (see section 2.6.9.4.3) and that the marking plan allowed that doors between watertight sections was open at equipment protection level Y. When the collision occurred, the general alarm was raised in accordance with the frigate's main roster, but, in accordance with normal practice on board the frigates, orders were not issued to change the equipment protection level. The equipment protection levels in SMP-17 are absolute and require closure of doors and hatches to ensure optimal protection under all conditions, see section 2.6.2.3. For the frigates, however, another practice based on favourable experience from FOST, was used. In FOST and many other NATO countries it was common not to close immediately to ensure fast and efficient transportation of material between compartments and decks to the damaged area.

From the time of the collision until the frigate was evacuated, some of the spaces that were lost were closed and attempts were made to shore them in the closed position. No

[57] Classified Restricted under the Security Act
[58] Appendix A to ECP/EO No 376, dated 16 June 2017

attempt was made to close other closing devices and fittings in these spaces, and there was no further shutdown from protection level ‘Y’ to ‘Z’. Nor was this carried out when the vessel was evacuated. See Appendix C (R)[59] for an overview.

2.6.3 Maintenance – criticality level

The vessels are maintained according to criticality level. The criticality level is a value that indicates how important it is to carry out the procedure. There are four criticality levels, with level 5 as the highest:

- Non-Critical (level 2)
- Mission Critical (level 3)
- Vital (level 4)
- Last Resort (level 5).

2.6.4 Integrated Platform Management System (IPMS)

The IPMS system is a control and monitoring system consisting of standard hardware and software components. The crew can use the IPMS to control and monitor most of the shipboard systems. The IPMS is an important tool, not only under normal operating conditions, but also in demanding situations such as hands to action stations or after an accident.

The IPMS saves analogue values to the history log every ten seconds, so that certain details may be lost in the transient period. Digital variables (change of status and alarms) are always registered in real time.

The NSIA has gained access to the IPMS data that were stored on board HNoMS ‘Helge Ingstad’ and has used these data in its investigation. Note that the IPMS shows a later time than the local time where the incident occurred (UTC+1). The collision occurred at 04:01:15 local time, or 05:00:36 IPMS time.

2.6.5 Power supply

2.6.5.1 *General description*

The frigate’s power supply consisted of four diesel-fuelled generators that supplied two main switchboards (1S and 2S) from which electric power was distributed to various consumers and load centres. The chosen design with four generators and two main switchboards meant that the system consisted of two autonomous zones.

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[59] Classified Restricted under the Security Act by information owner the Norwegian Armed Forces and NDMA

Figure 27: Power production status prior to the collision, shown in IPMS. Screenshot: NSIA

The main function of the generator system was to generate electric power for the vessel's systems. The system was designed to start and supply the main switchboards automatically according to demand and consumption. The main switchboards could be configured in combined mode or split mode. In combined mode, main switchboards S1 and S2 would be interconnected and the generators would supply power to both switchboards. If the switchboards were split, S1 and S2 would be physically separated and be supplied by separate generator sets.

The main switchboards were designed so that individual equipment units or faulty components would not trigger a complete blackout on board. In design terms, this was ensured by switches that would open to avoid a 'black ship' condition.

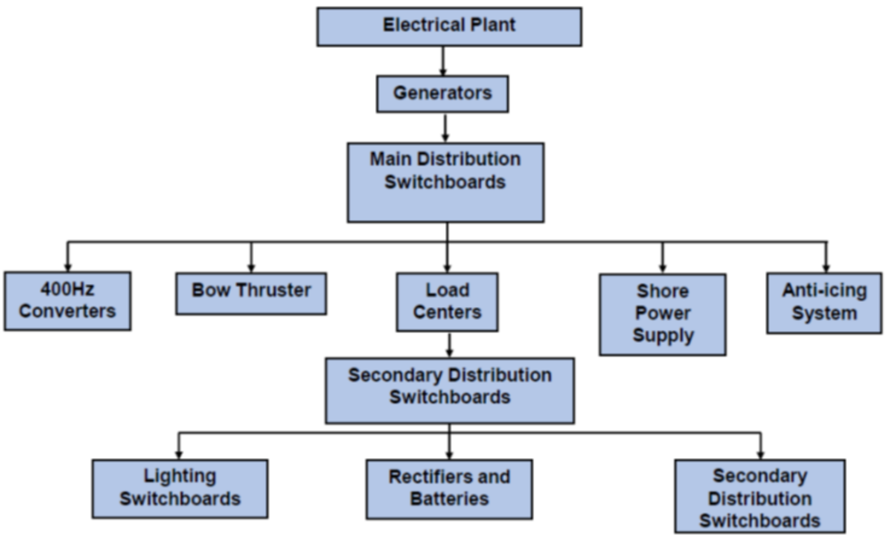

Figure 28: Overview of electricity distribution on board. Source: NDMA

The main switchboards supplied electricity to various load centres and some big consumers; see Figure 28. The load centres were distributed around the frigate and generally supplied electricity to equipment in the vicinity of where they were located. All important consumers that were normally connected to a load centre would also have an alternative voltage supply. The load centres were normally supplied from the closest main switchboard, but could be supplied from the alternative switchboard by automatic or manual switching.

The load centres (LC)[60] on board supplied electricity directly to consumers or for further distribution from distribution cabinets. The normal and alternative voltage supply for the various consumers were placed as far apart as possible. This was intended to ensure a high degree of redundancy in the event of damage to the vessel or equipment. The switches used to select normal or alternative power supply could be of an automatic or manual type. The switches could be operated from the IPMS or locally.

2.6.5.2 *Corrective action orders applying to the main power supply system*

In 2015, one of the other frigates experienced ‘black ship’ while sailing with the switchboards in combined mode. Based on that incident, a CAO[61] was issued in which the frigates were ordered to sail with the switchboards in split mode. At the time of the accident, HNoMS ‘Helge Ingstad’ was sailing with the switchboards in combined mode; see Figure 27.

2.6.6 <u>Rudder control system</u>

2.6.6.1 *Introduction*

The vessel had two rudders, located aft of the propellers and slightly offset from the shaft line.

The rudder control system included several redundant solutions designed to maintain control and ensure functionality, and thus be able to manoeuvre the frigate even if the system was degraded.

2.6.6.2 *Steering position and rudder indicator*

The rudders were controlled by separate steering gear units in the steering gear room, one on the starboard side and one on the port side. Each steering gear unit had two electrically operated hydraulic steering gear pumps. During normal operations, each steering gear unit would be supplied by one of the pumps. The other would be on standby. During the voyage under consideration, all four steering gear pumps were in operation. The steering gear pumps could be started in emergency modes both locally and from the IPMS. It was possible to control the rudders from four positions on the bridge, from the propulsion control console (PCC)[62] in the MCR and from the steering gear room; see Figure 29.

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[60] The number of LCs is classified Restricted under the Security act by the information owner the Norwegian Armed Forces and the NDMA

[61] In practice, a corrective action order (CAO) is a nonconformity whereby, based on an assessment in the handling process, a given unit of equipment must be handled in a specific way for a given period of time. It typically entails a prohibition or limitation on use, up until such time as the equipment has been modified or replaced.

[62] Separate joystick on the PCC desk.

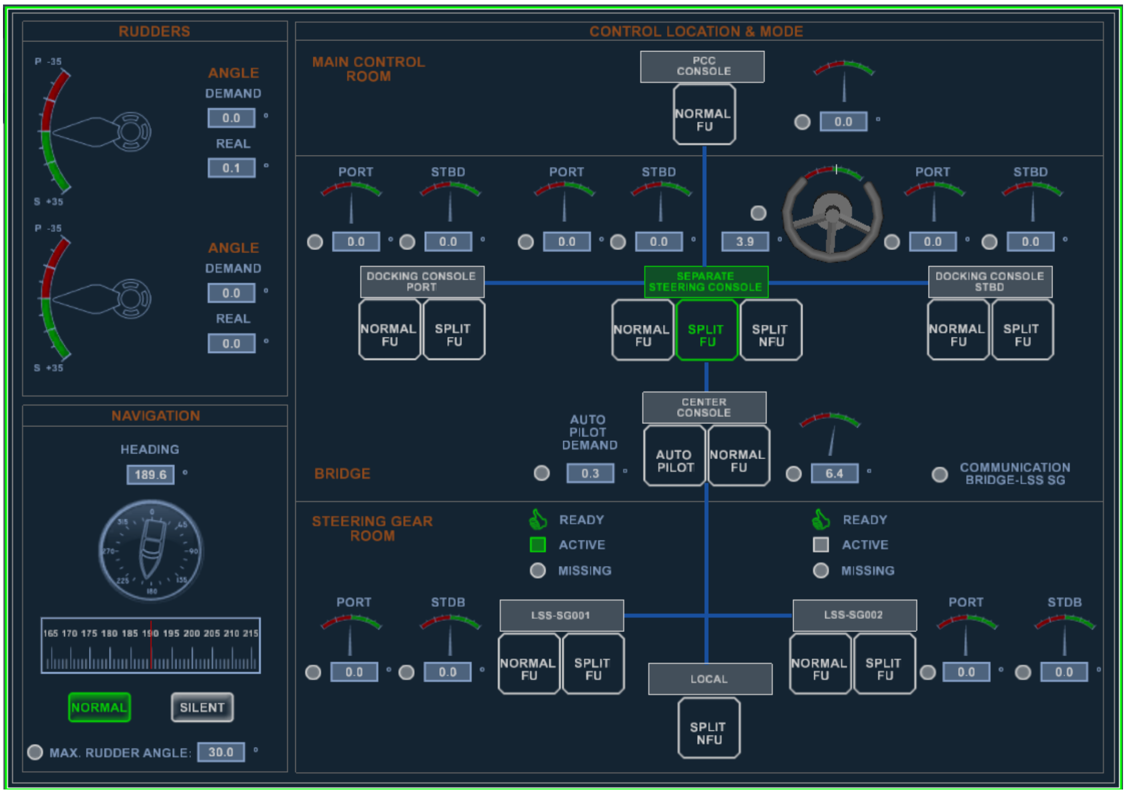


Figure 29: The positions on board from which the rudders can be controlled shown in IPMS. The screenshot shows that control of the rudders was set to SSC after the collision (at approx. 04:03). The rudder control was set to SSC before and after the collision. Screenshot: NSIA

From the separate steering control console[63] (SSC) on the bridge, the rudders could be controlled individually (Split FU) or jointly (Normal FU). In the event of loss of control, it was possible to initiate an emergency mode referred to as Non-Follow Up (NFU), an independent steering function from normal mode. In the event that NFU did not work, emergency steering would be initiated from the steering gear room.

The bridge and steering gear room had several rudder indicator displays showing starboard and port rudder angle, respectively; see Figure 30. Rudder angles could also be seen on the MFD display at the helmsman's position on the SSC; see Figure 31, and on IPMS, see Figure 32.

Figure 30: Rudder angle indicators showing starboard and port rudder angle, respectively. Photo: NSIA (from HNoMS 'Thor Heyerdahl')

[63] The helmsman's position

Figure 31: On the left: MFD showing speed, heading and rudder angle. On the right: Photo taken on HNoMS 'Helge Ingstad' after it was refloated. Showing SSC with tillers and MFD covered by Plexiglas, not to affect night vision negatively. Screenshot: The Navy. Photo: NSIA

2.6.6.3 *Rudder angle telegraph*

The rudder angle telegraph was a separate system that made it possible to issue rudder commands directly from the bridge to the steering gear room. The system could be operated in both single and dual mode, whereby the user on the bridge could control both rudders jointly or each rudder (starboard/port) separately. The communication lines for the starboard and port rudder telegraphs were routed along the starboard and port side, respectively.

2.6.6.4 *IPMS data – rudder control before and after the collision*

Figure 32 shows the rudder configuration before the collision. The rudders were controlled from the SSC and set to manual control in split mode ('Split follow up'). All four steering gear pumps were running.

Figure 32: IPMS configuration of steering and steering gear pump at 04:00:46, immediately before the collision. Modified creenshot: NSIA

After the collision, all four steering gear pumps stopped working for about 20 seconds, before pump 2 started up again. One minute and 13 seconds after the collision, all pumps were up and running again, with the exception of pump 3. After that, the rudders functioned in that condition up until approx. 04:08 when LC7 was disengaged. This caused one of the steering gear pumps connected to the port rudder to stop, so that each rudder was operated by one separate steering gear pump.

The IPMS logged rudder movement data, both tiller angles and relevant rudder angles. At 04:06:16, the rudder was set 5–7 degrees to port. The rudder angle was maintained for approx. 20 seconds. At 04:08:04, the rudder was again set 10–12 degrees to port. The rudder angle was maintained for approx. 30 seconds. Figure 33 shows console tiller angles and actual rudder angles for the starboard and port rudders.

Figure 33: IPMS data showing console tiller angles and actual rudder angles for the starboard and port rudders. Screenshot: NSIA

2.6.7 Propulsion

2.6.7.1 *Introduction*

The propulsion system on the Nansen-class frigates consisted of a gas turbine and two main engines in a combined diesel and gas (CODAG) arrangement, cross-connected via one primary and two secondary gears. From the secondary gears, propulsion power was transferred to two main shafts and on to the controllable pitch propellers (CPP). See Figure 34.

The diesel engines were normally used when in transit and when conducting manoeuvres.

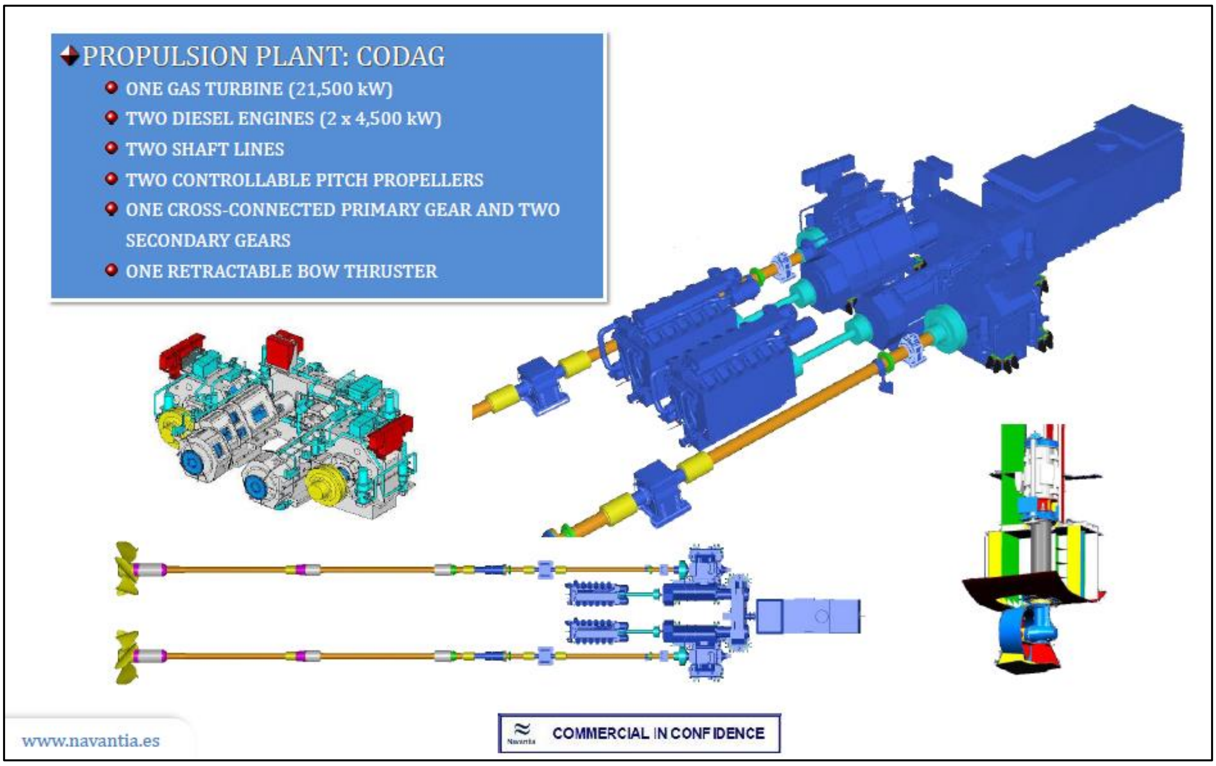


Figure 34: Schematic diagram of the propulsion plant. Illustration: Navantia

2.6.7.2 *Gas turbine (GE LM-2500)*

The gas turbine was supplied by General Electric (GE) and had a rated output of 21,500 kW.

2.6.7.3 *Main engines 1 and 2*

The propulsion engines were of the type IZAR BRAVO 12 and especially adapted for use on board naval vessels. The engines had been built under a licence, based on the Caterpillar 3612 model.

The IZAR BRAVO 12 engine was a 12-cylinder four-stroke engine with V configuration. It had a rated engine output of 4,500 kW.

2.6.7.4 *Main gear*

The main gear consisted of three gear units:

- The primary gear connected the secondary gears and the gas turbine.
- The starboard secondary gear connected the primary gear, the starboard propeller shaft and the starboard main engine.
- The port secondary gear connected the primary gear, the port propeller shaft and the port main engine.

2.6.7.5 *Available propulsion modes from IPMS*

The gear and propulsion system could be operated in several possible modes[64].

2.6.7.6 *Control and monitoring system*

The CODAG arrangement was designed in accordance with the DNV GL standard for unmanned engine rooms (E0), but this notation was not a part of the DNV GL classification. Both the gas turbine and main engines had local operator stations, which meant that they could be operated locally or remotely controlled from the IPMS. The CODAG arrangement was normally operated from the IPMS.

In the event of communication failure, the propulsion lines could be operated locally from several positions:

- LDPCP (Local Diesel Propulsion Control Panel)
- DELOP (Diesel Engine Local Operating Panel)
- IECLOP (Integrated Electronic Controller and Local Operating Panel)

The propeller plant could be operated from the above-mentioned positions. It could also be operated from the CPP LOP (Controllable Pitch Propeller Local Operating Panel) in the aft generator sets room. This position enabled local control of propeller pitch only but had no effect on the gas turbine and main engines.

Emergency stop of the propulsion plant was possible from several positions, including the centre console on the bridge. If emergency stop was activated, this would be shown visually in the IPMS (see Figure 35) and logged. A review of IPMS data gave no indication of emergency stop having been activated.

[64] Details on the propulsion modes are classified Restricted under the Security Act by information owner the Norwegian Armed Forces and the NDMA

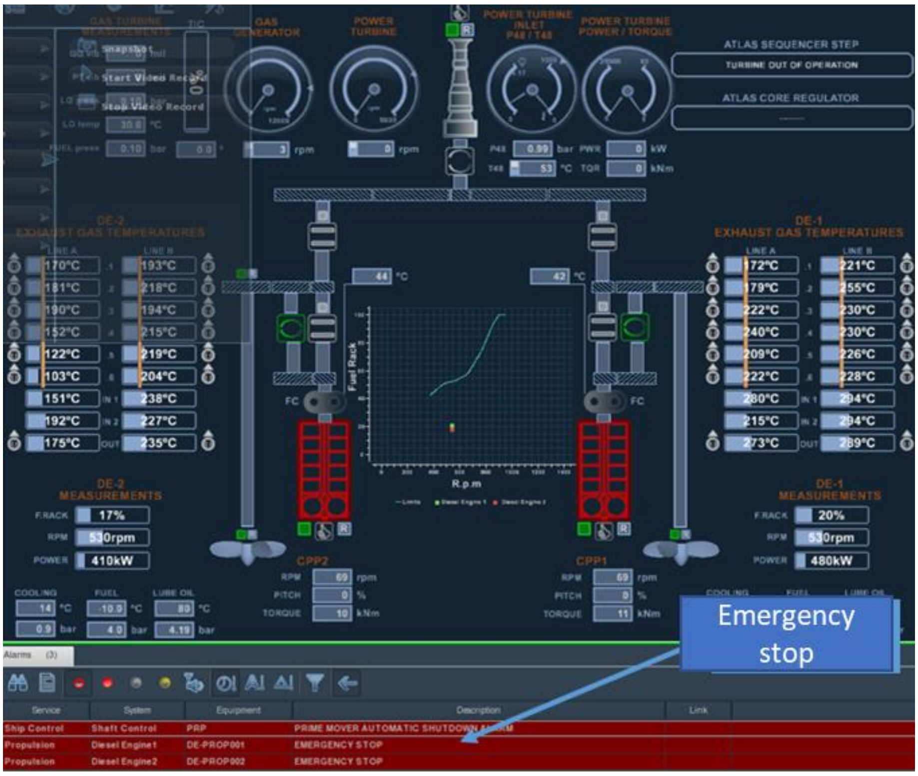


Figure 35: Emergency stop activation from the centre console on the bridge, shown in IPMS (from HNoMS 'Thor Heyerdahl'). Screenshot: The Navy, modified by NSIA

2.6.7.7 *Design of propulsion shafts*

There are some similarities between previous frigates designed and produced by Navantia for other navys and the F-310 frigates. The F-310 were largely designed based on specific requirements that made it necessary to assess different design solutions.

The specifications for the Norwegian frigates contained strict requirements for underwater acoustic signature and capacity for withstanding underwater explosions. Among other things, this resulted in the gears being elastically mounted and in the installation of a flexible coupling between the gear and propeller shaft.

The oil distribution box (OD box) was therefore placed at an intermediate shaft in the aft generator sets room, aft of the flexible coupling, instead of at the forward end of the gearbox as on the F-100 class Spanish frigates.

From the OD box, oil under pressure was directed via a double tube in the propeller shaft to and from a piston in the propeller boss for adjusting the pitch of the propeller blades. The double tube followed the piston movement and was connected to a feedback unit moving along the outside of the shaft; see Figure 36. The feedback unit sensed and transmitted the propeller pitch to the control system.

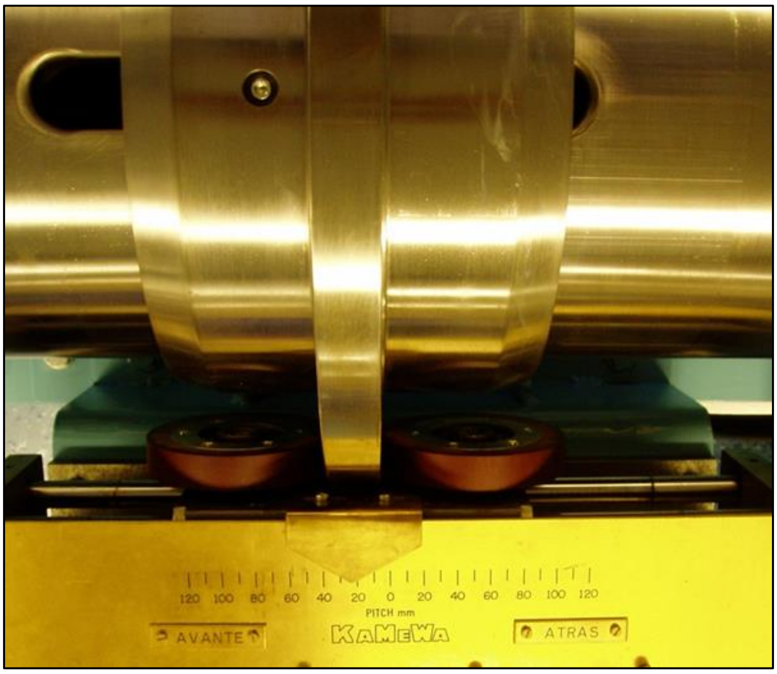


Figure 36: Aft intermediate shaft with feedback unit. Photo: NSIA

It was also decided to install a hollow intermediate shaft between the OD box and the gearbox, among other things to meet requirements for strength and the capacity to withstand shock loads. This hollow shaft had a bore diameter of 185 mm and extended from the aft generator sets room through the aft main engine room to the flexible coupling in the gear room.

When the accident occurred, water was observed to flow into the reduction gear room through this flexible coupling. The investigation showed that water could flow into the propeller shaft in the aft generator sets room via the groove for the feedback unit, and that the shaft had no seals between the feedback unit in the aft generator sets room and the flexible coupling in the reduction gear room. Figure 37 illustrates how water could flow via the aft generator sets room into the reduction gear room through the flexible coupling.

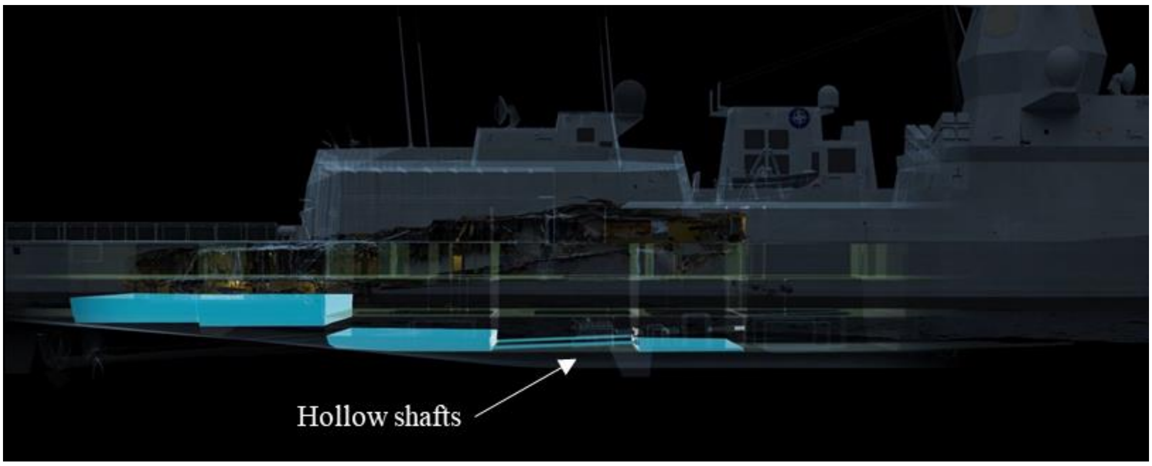


Figure 37: Water flowing via the aft generator sets room into the gear room through the flexible coupling. Illustration: CIAAS/NSIA

That the OD box with its openings into the hollow shafts compromised the frigate's watertight integrity was neither detected during design and building, nor during subsequent classification of the vessel.

It emerged during the investigation that steam from the low-pressure compressor had triggered alarms in the aft generator sets room and reduction gear room in 2013–2014. A new test was then carried out using smoke, and smoke came through the shaft. This finding was sent by email between the different crews' damage control officers. The investigation showed that the matter was not documented in the system for registering nonconformities. Neither has the NSIA information that this was followed-up elsewhere.

Notification was given of two critical safety issues in the AIBN's (now NSIA) preliminary report dated 29 November 2018.

Notification of critical safety issue MARINE No 2018/01

The Accident Investigation Board Norway recommends that the Norwegian Defence Materiel Agency, in cooperation with the Royal Norwegian Navy and the Norwegian Armed Forces' Materiel Safety Authority, conduct further investigations into the issues identified during the initial investigation and implement measures as necessary to address safety.

Notification of critical safety issue MARINE No 2018/02

The Accident Investigation Board Norway recommends that Navantia, the vessel's designer, conduct further investigations of the findings made during this initial investigation and to ascertain whether these findings also apply to other vessels. Furthermore, that Navantia issue a notification to relevant shipbuilding yards, owners and operators, advising on necessary measures to address safety.

After the accident, the NDMA has made corrections to the design, so that the watertight integrity of the frigates is now understood to be ensured; see section 2.11.5. Navantia has confirmed that this safety issue relates exclusively to the Norwegian frigates.

2.6.7.8 *Control of propeller pitch (CPP1 and CPP2)*

The frigate had two hydraulic units located in the aft generator sets room – one for each propeller. Each unit was equipped with two electric pumps for delivering pressure, one pump that would keep the pressure static and one air-operated pump in the event that the unit's power supply should fail.

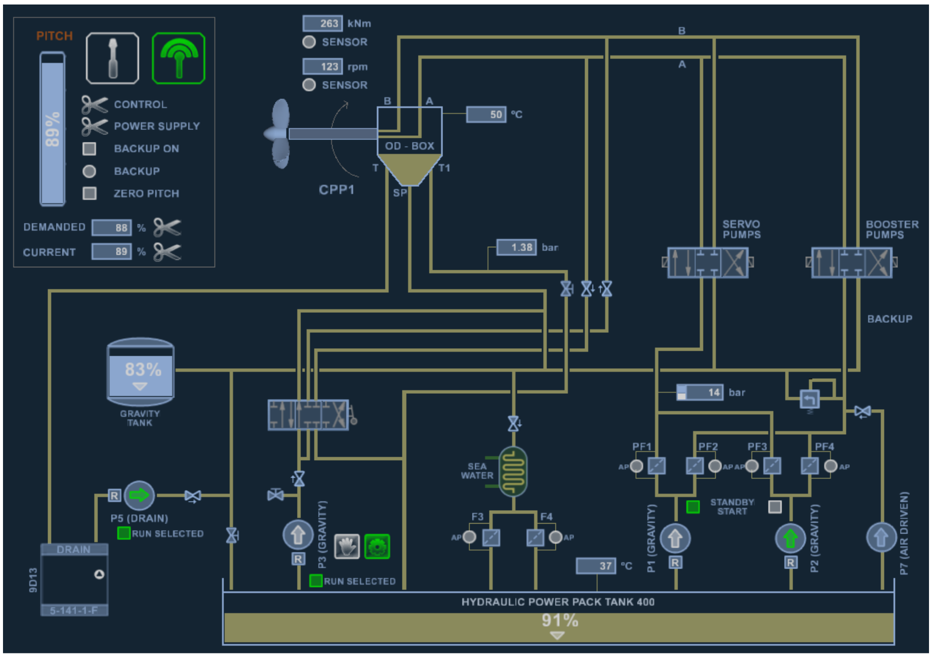


Figure 38: Starboard propeller (CPP1) immediately before the collision. Screenshot: The Navy/NSIA

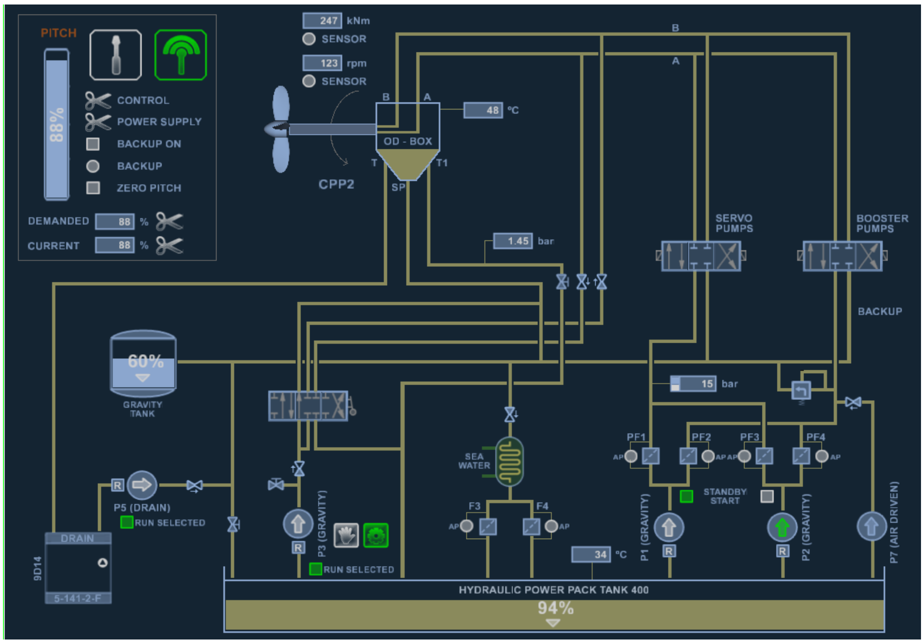


Figure 39: Port propeller (CPP2) immediately before the collision. Screenshot: The Navy/NSIA

2.6.7.9 *IPMS data – propulsion before and after the collision*

Until approx. 04:07, ‘Ship control’ was from the centre console on the bridge, after which control switched to ‘Local’, without such a switch being made from the LDPCP or IECLOP. Before the collision, the propulsion line was set to cruise mode, at 65% ahead thrust and with a speed over ground (SOG) of 17.1 knots; see Figure 40. ‘Ship control’ in the IPMS after the collision is shown in Figure 41.

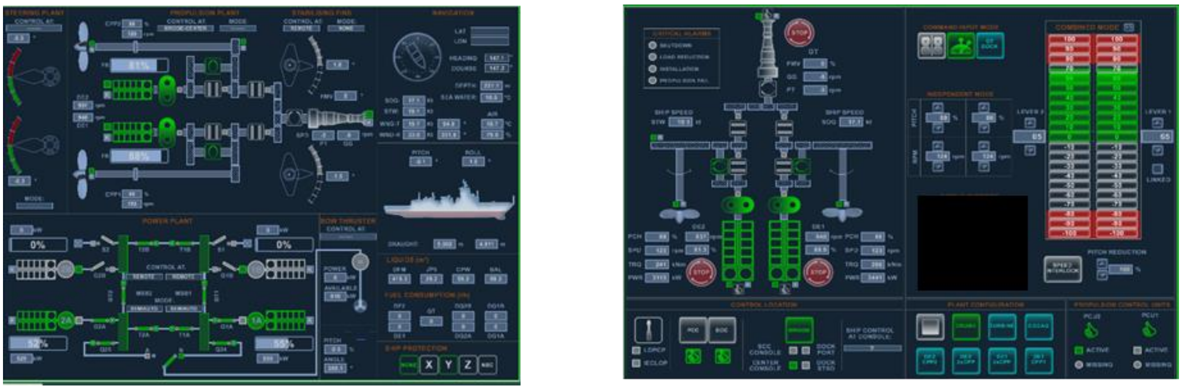


Figure 40: ‘Ship control’ in the IPMS immediately before the collision at 04:00:39. Screenshot: The Navy/NSIA

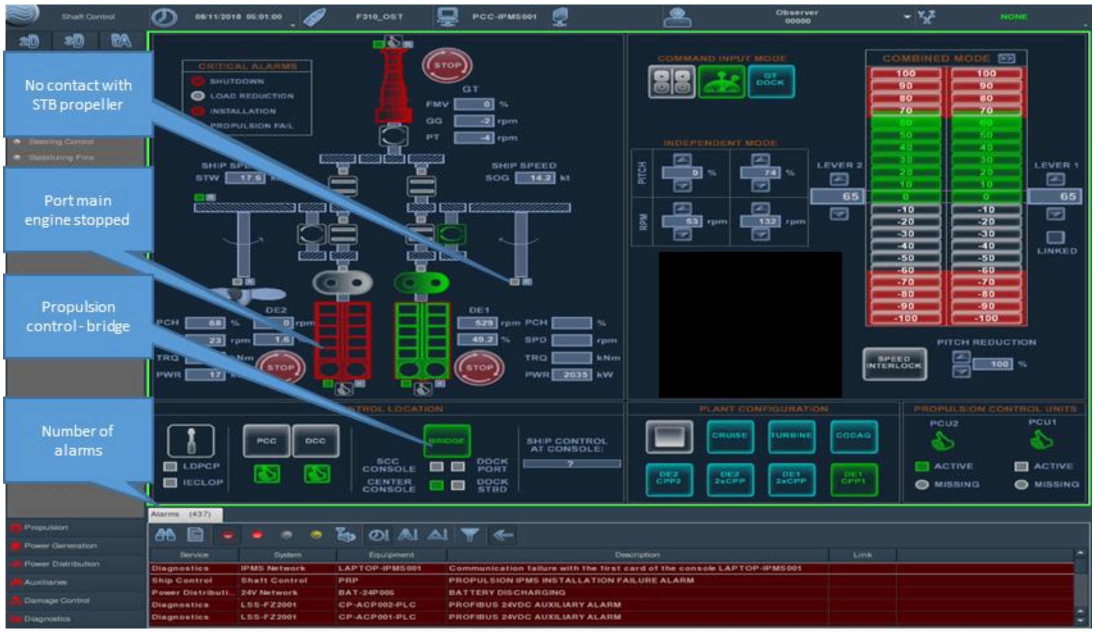


Figure 41: ‘Ship control’ in the IPMS immediately after the collision at 04:01:39. Screenshot: The Navy, modified by NSIA

<u>Port propulsion line</u>

After the ‘black ship’ condition, the two electrical lube oil pumps for the gears did not start, as the two load centres that supplied the pumps were without electric power. Both pumps were without power up until approximately 04:03. When the secondary gear lost lube oil pressure, an emergency stop signal was transmitted to the port main engine. When the engine stopped, the pitch of the port propeller was automatically reduced to 0% by the IPMS. After the ‘black ship’ condition, the pumps for the port propeller were automatically restarted. At approximately 04:07, the backup system was activated and the pitch automatically changed from 0% to -90%; see Figure 42. The direct cause of this change has not been determined. For further information about findings related to the port main engine, see section 2.9.7.

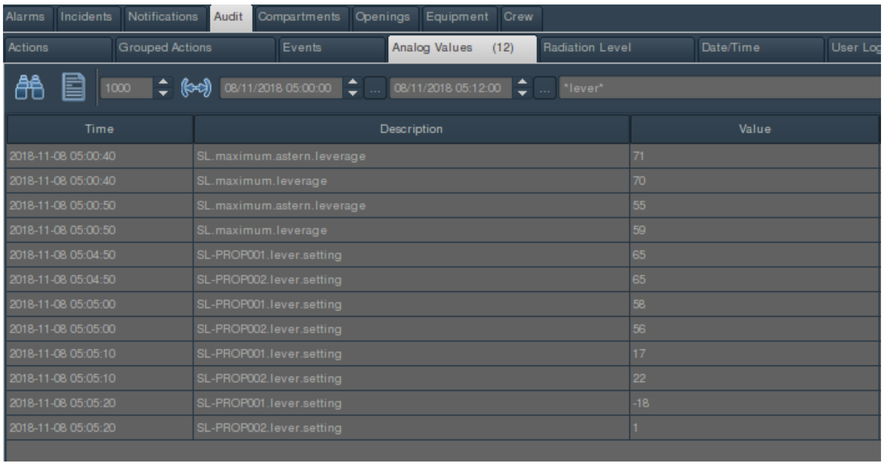
Figure 42: Change in pitch of port propeller, shown in IPMS. Screenshot: Navantia

<u>Starboard propulsion line</u>
After the collision, the starboard propeller lost communication with the IPMS as a result of collision damage; see section 2.9.7.4. This meant that remote control of the propeller's pitch from the IPMS was no longer possible. The starboard CPP therefore remained in the most recently set position (89%).

From 04:02:30 and until the frigate ran aground, she continued moving at 5–5.5 knots. The starboard main engine was running at low speed (460 rpm). After the grounding, the starboard engine continued to run, until it stopped at 04:26; see Figure 43. Attempts to stop the starboard main engine from IPMS is not registered.

Figure 43: Speed curves for the starboard and port propulsion lines, shown in IPMS. Screenshot: The Navy/NSIA

At 04:05:29, the throttle lever settings were changed from 65% to -18% (starboard) and 1% (port) from the centre console on the bridge; see Figure 44. This was without any effect, as the port main engine had stopped and there was no communication between the IPMS and the starboard propeller; see section 2.9.7.4.



Time	Description	Value
2018-11-08 05:00:40	SL.maximum.astern.leverage	71
2018-11-08 05:00:40	SL.maximum.leverage	70
2018-11-08 05:00:50	SL.maximum.astern.leverage	55
2018-11-08 05:00:50	SL.maximum.leverage	59
2018-11-08 05:04:50	SL-PROP001.lever.setting	65
2018-11-08 05:04:50	SL-PROP002.lever.setting	65
2018-11-08 05:05:00	SL-PROP001.lever.setting	58
2018-11-08 05:05:00	SL-PROP002.lever.setting	56
2018-11-08 05:05:10	SL-PROP001.lever.setting	17
2018-11-08 05:05:10	SL-PROP002.lever.setting	22
2018-11-08 05:05:20	SL-PROP001.lever.setting	-18
2018-11-08 05:05:20	SL-PROP002.lever.setting	1

Figure 44: Analogue throttle values in the IPMS after the collision. The time is stated as IPMS time. Screenshot: The Navy/NSIA

2.6.7.10 *Engine order telegraph*

The engine order telegraph was used for communicating engine orders. There were four engine order telegraph stations on board; see Figure 45.

- Bridge
- MCR
- Aft main engine
- Forward main engine

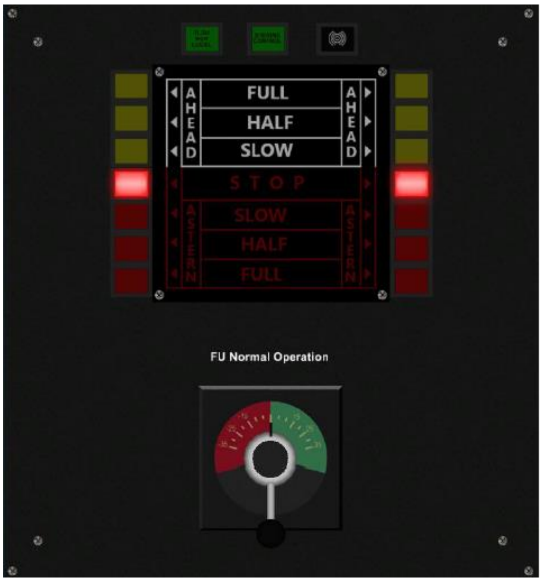


Figure 45: Engine order telegraph on the PCC in the MCR. Illustration: Navantia (IPMS Analysis of propulsion and steering plant control)

From the MCR, it was possible to select whether engine order telegraph orders should go between:

- Bridge – MCR
- Bridge – forward main engine/aft main engine

2.6.7.11 *Alternative propulsion*

The bow thruster[65] was an alternative secondary means of propulsion. It was included in the design as an alternative means of propulsion in the event that the main propulsion system was damaged or failed.

As a consequence of the 'black ship' condition, an auto-stop alarm was triggered on the bow thruster. The alarm remained actuated until after the grounding. The power supply to the bow thruster (switch Q24) was restored at approximately 04:09. For more details, see section 2.9.7.4.

The gas turbine was not in operation, but received an automatic emergency stop order as a consequence of the collision. The investigation has not found any technical indications that the gas turbine could not be restarted after the collision.

2.6.8 Communication systems

2.6.8.1 *Introduction*

The frigate was outfitted with several types of communication systems, so as to provide maximum redundancy.

2.6.8.2 *Communication systems on board.*

The frigate was fitted out with the following systems:

- Audio unit (AU)
- Sound-powered telephone (SPT)
- Telephone
- UHF
- PA

These systems are described in the following sections.

2.6.8.2.1 Audio unit (AU)

ASYM 3000A was the primary communication system on board, and could be used for both internal and external communication. It was a digital communication system that was operated using audio units. The system was set up with a total of 12 internal conferences, but the conference set-up on the various audio units varied from one location to another. The bridge, CIC and MCR had access to all conferences. The system had no backup power and if an audio unit lost power in a 'black ship' situation, the units would lose their conference allocation. Loss of power required reallocation of

[65] Time taken to lower and raise the bow thruster is classified Restricted under the Security act by information owner the Norwegian Armed Forces and the NDMA

conferences by pressing the test/lock button on the audio unit when the power was back on; see Figure 46.

The investigation showed that reallocation on the audio units could have been completed by approximately 04:05, on the assumption that the fuses were still in an ON-position, or were turned ON again.

Figure 46: Audio unit. Photo: The Navy

2.6.8.2.2 *Sound powered telephone*

The sound powered telephone (SPT) was used as a secondary means of communication, and for emergency communication in the event that the primary communication system failed. The system was operated by sound-waves and was therefore not dependent on a power supply. The system could be operated together with an audio unit or as an independent communication system. If the need arose, it was possible to interconnect several conferences, and this could be done from the MCR.

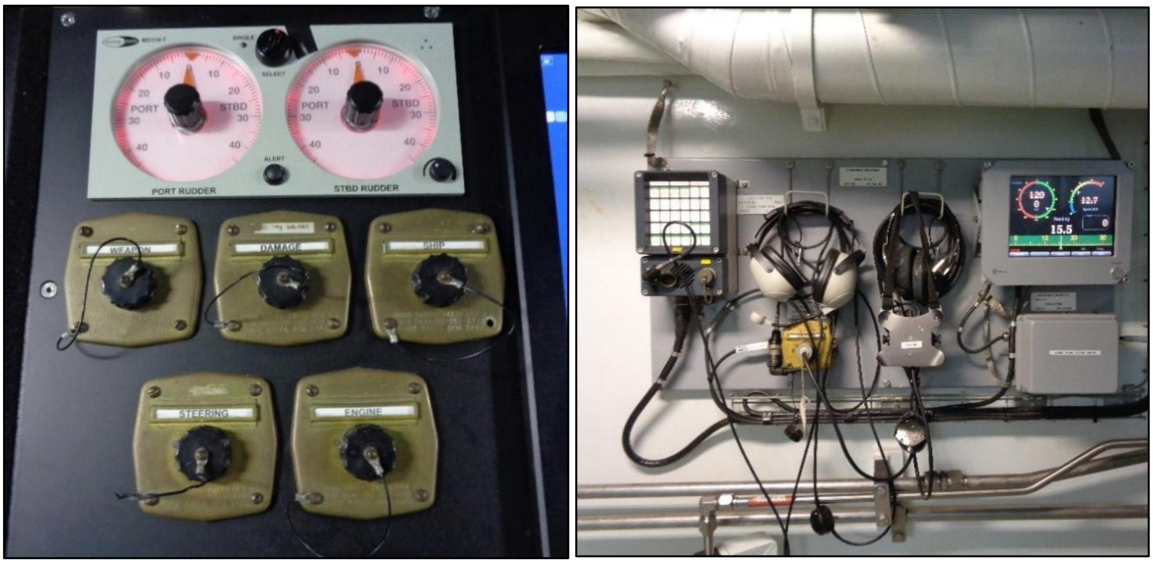


Figure 47: On the left: SPT and rudder angle telegraph on the bridge. On the right: means of communication and MFD display in the steering gear room. The photos are from a sister ship. Photo: NSIA

The SPT had five pre-defined conference circuits; see Figure 48:

- Ship
- Weapon
- Damage
- Engine – used for communication between the bridge and engine
- Steering – used for communication between the bridge and steering gear room

Figure 48: Conference box for SPT. Photo: NSIA

2.6.8.2.3 Telephone

The frigate had a separate telephone switchboard for both internal and external calls. Telephones were available on the bridge, and in the CIC and MCR, among other places. In a ‘black ship’ situation, UPS back-up would be provided for internal calls, but the possibility of making external calls would be lost. It would thus take 4–4½ minute before the phone could be used for external calls again.

2.6.8.2.4 UHF

The vessel had several sets of handheld UHF radios. These radios were primarily used by the damage control organisation. The UHF range was limited in some places inside the frigate.

2.6.8.2.5 PA system

The PA system was the frigate's collective information system. It was used for giving information to the whole crew over a loudspeaker system that would enable announcements to be heard regardless of location on board. The system was also used for the announcement of various alarms (general alarm, action stations etc.).

2.6.8.2.6 Other communication systems

Orderlies could be used as an alternative if other means of communications were unavailable.

Use of the rudder angle telegraph and engine order telegraph as alternative means of communication is described in sections 2.6.6.3 and 2.6.7.10.

2.6.9 Watertight integrity and stability

2.6.9.1 *Introduction*

The frigate's original stability manual was delivered by Navantia in accordance with the Rules and Regulations (RAR) of the Royal Norwegian Navy. In connection with follow-up of the contract between the NDMA Naval Systems Division[66] and the main contractor, the Naval Systems Division assigned LMG Marin to review Navantia's stability calculations.

It was subsequently decided that the frigates would be classified by DNV GL. For DNV GL to be able to carry out sufficient verification calculations and approve ship stability as part of the class entry process, the NDMA had to furnish documents on which the assessment could be based, in accordance with DNV GL's requirements for documentation. In 2014 NDMA Naval Systems Division engaged the marine architects and engineering company Polarkonsult AS to produce documentation for DNV GL. The first version of the documentation was sent to DNV GL 8 of December 2014. Through 2015 the documentation was revised based on comments from DNV GL, which issued their approval in 2016.

In connection with the approval, acceptance was granted for deviating from the intact stability requirement that the range of the GZ curve shall be at least 70 degrees. This is discussed in more detail in section 2.8.7. The NSIA has not received any justification from The Norwegian Armed Forces Materiel Safety Authority or the NDMA why this requirement was deviated from, which impact it made or which compensating measures were implemented. However, after the incident, the NSIA has received calculations from Navantia, showing that the deviation had little impact on the vessel's stability.

[66] At that time, the Naval Systems Division was part of the Norwegian Defence Logistics Organisation (NDLO). The NDMA was established as a separate agency under the Ministry of Defence in 2016, and the Naval Systems Division was transferred from the NDLO to the NDMA.

2.6.9.2 *Rules and regulations*

The most recent stability calculations were based on '*DNV Rules for Ships (January 2010) Part 5, Chapter 14 Section 5 (Class Notation +1A1 NAVAL) and Part 3 Chapter 1 Section 5*'. These rules were based on the original RAR.

Requirements for intact stability are set out in the above-mentioned rules from DNV GL, Section 5, C400; see Appendix D.

Section 5 D200 concerns requirements relating to the scope of damage, while Section 5 D 400 concerns requirements for damage survivability. The relevant requirements are reproduced in Appendix D.

The Nansen-class frigates are reported to have a waterline length (LWL) of 121.4 m. From above-mentioned regulations it follows that the vessel should be calculated for a damage length of 15% of the waterline length, corresponding to 18.2 m. In the worst-case scenario, this longitudinal scope of damage would affect up to three watertight compartments when placed anywhere along the length of the hull. Safety margins that have to be fulfilled by such a damage is described in Appendix D, section D.2.2. Larger damages than mentioned above will not necessarily result in sinking of the vessel, but that the safety margins as described in D.2.2. are not fulfilled.

2.6.9.3 *The frigate's watertight integrity*

The frigate was divided into 13 watertight compartments, made up by the following:

- Shell plates
- Bulkhead deck
- Transverse bulkheads

This partitioning divided the frigate into independent watertight compartments distributed over the vessel's length. 'Watertight compartment' was defined as follows in RAR III section 2.1.1:

> *A main watertight compartment is a compartment bounded by two adjacent main watertight bulkheads, shell and bulkhead deck. All other compartments bounded by main watertight bulkheads, watertight bulkheads, decks and shell are designated watertight compartments.*

Collision bulkhead was defined on the basis of criteria set out in RAR I section 3.6.1. The remaining main transverse bulkheads were designed based on the requirement of a longitudinal damage along up to 18,2 meters of the vessel's length. See further description in Appendix D.

The transverse watertight bulkheads extended up to the bulkhead deck. The damage control deck was where the damage control equipment and damage control stations were located; see Figure 49.

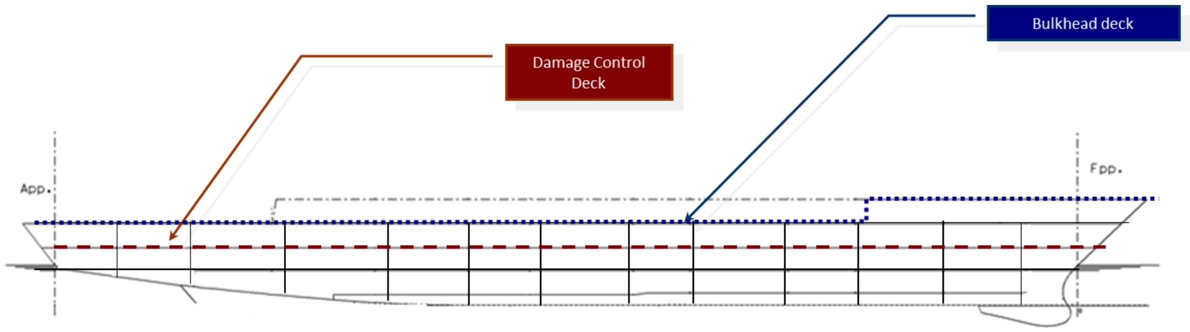


Figure 49: In blue: The bulkhead deck (1 deck) and watertight bulkheads which comprise the vessels watertight compartments. In red: Damage control deck (2 deck) is the deck below the bulkhead deck. Illustration: Navantia, modified by the NSIA

The stability handbook contained documentation of the Nansen-class frigates' intact and damage stability for all load and damage combinations required by the regulations.

The carpet plot[67] in the stability handbook had been prepared as an aid to the ship's crew to assess stability in relation to pre-defined damage combinations as required by the regulations. The diagram was used by drawing a vertical line from the bulkhead forward of the damage to the bottom of the diagram. A horizontal line was then drawn from this point to the bulkhead aft of the scope of damage. This point represented the ship's stability in a given damage scenario.

The diagram shows that continuous damage across three or fewer watertight compartments gave 'acceptable stability'. The diagram also shows that midship, and near the bow, acceptable stability could be maintained with continuous damage across four compartments. According to the diagram, continuous damage along a higher number of watertight compartments would result in 'poor stability' or 'vessel lost'. The carpet plot did not provide any information about non-continuous damage scopes.

2.6.9.4 *Quarterdeck (Q-deck)*

2.6.9.4.1 Introduction

The Q-deck on the Nansen-class frigates was the quarterdeck extending from frame 188 to frame 200 on 2 deck (damage control deck), and formed part of compartment 13. From the Q-deck, it was possible to enter a storeroom below. Other spaces below the Q-deck could be entered via lock chambers on the starboard and port side of 2 deck, respectively.

[67] Details on the carpet plot is classified Restricted under the Security Act by information owner the Norwegian Armed Forces and the NDMA

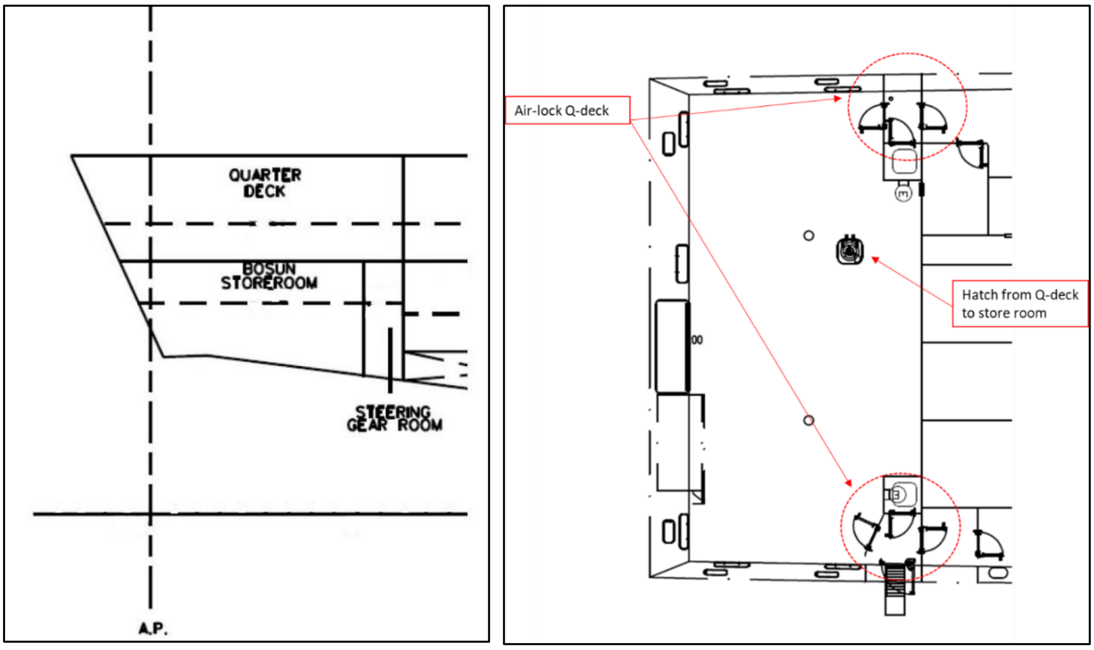


Figure 50: Schematic drawing showing where the Q-deck was located. Illustration:The Navy, modified by NSIA

There were several hatches and openings in this compartment. There were six mooring hatches and six work hatches that were normally kept closed when at sea. In addition there were spring loaded overpressure valves in bulkhead # 188 starboard and port, and in 1 deck there were several sealed wire penetrations. The overpressure valves were watertight only from one side (from section 13 to 12).

Figure 51: Spring-loaded over pressure valve. Photo: NSIA

The ATAS door (Active Towed Array Sonar) was used for launching the towed array sonar; see Figure 52. The hatch was hydraulically operated from a panel on the Q-deck. The ATAS door was left open while the sonar was in the water.

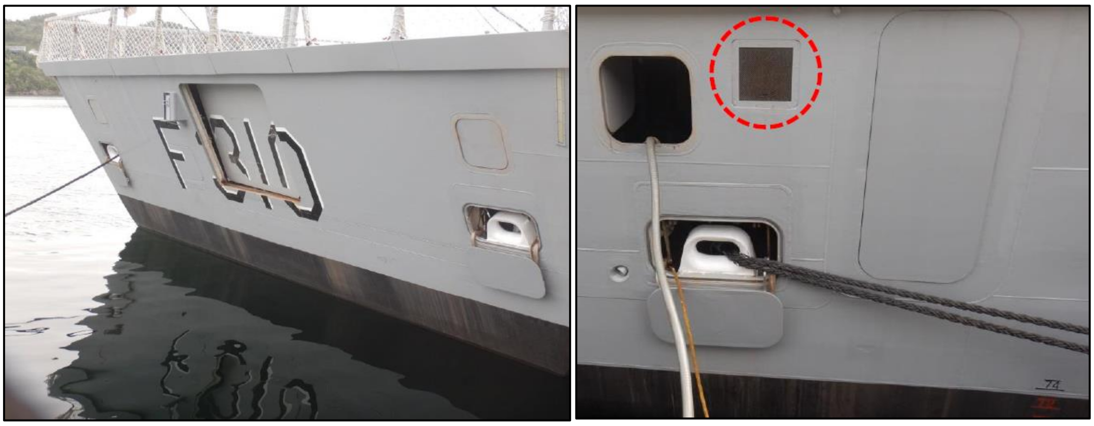


Figure 52: On the left: work hatches, mooring hatches and ATAS door in the stern. On the right: work hatch, mooring hatch and ventilation opening (marked with a red circle) on the starboard side). Photo: NSIA

2.6.9.4.2 Q-deck as buoyancy volume

The initial stability calculations for the Nansen-class frigates were performed by Navantia. When these calculations were delivered, the Q-deck was included in the buoyancy volume, and assumed to be watertight and weathertight.

In connection with follow-up of the contract between the NDMA Naval Systems Division and the main contractor, the Naval Systems Division assigned LMG Marin to review Navantia's stability calculations. LMG Marin reported back on its findings in November 2003. Among other things, it was pointed out that the vessel did not meet the RAR stability requirements in given damage conditions as the Q-deck could not be considered watertight. This was based on LMG Marin having been informed by the Naval Systems Division that the Q-deck could not be considered watertight because of the many hatches and doors in that compartment.

In February 2004, the NDMA Naval Systems Division reported back, stating that it had mistakenly informed LMG Marin that the hatches and doors to the Q-deck were not watertight. They should therefore be assumed to be watertight. In the updated report from LMG Marin, it was therefore concluded that the Nansen-class met the RAR requirements if the Q-deck was considered watertight.

The NDMA Naval Systems Division subsequently engaged the marine architects and engineering company Polarkonsult AS to produce stability documentation for DNV GL. In Polarkonsult AS's calculations, the Q-deck was also assumed to be watertight and included in the vessel's buoyancy volume.

According to the information provided by Navantia, all penetrations were watertight. This was confirmed in the specifications received for doors and hatches, without documentation of any structural tests being carried out to verify that this was indeed the case.

In the SOLAS section II-1/15.9 and 16.1[68] general requirements for watertightness of closures are described. Normally, the rules from a recognised class society will set the

[68] SOLAS is not applicable for military ships, however, it is used as an example for the practice used as basis for civilian ships.

requirements to testing and verification of watertightness. This includes a hydrostatic pressure test, or a structural analysis in addition to a pressure test of the gasket seal.

2.6.9.4.3 Operational Q-deck procedures

The Q-deck was an essential barrier that would contribute to keeping the vessel afloat in the event of damage to the afterbody; see section 2.9.2. This assumption was described in the frigate's stability handbook, but had not been made operational on board. It has emerged after the accident that the valves in the ventilation openings for the Q-deck were in the open position, even though they were marked with a 'Y' (closed at sea).

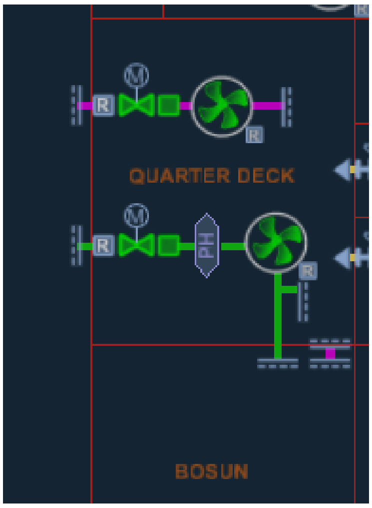


Figure 53: Extract from a screenshot from IPMS before the collision showing open ventilation ducts from the Q-deck. Screenshot: The Navy/NSIA

The work hatches, mooring hatches and ATAS door were not marked on HNoMS 'Helge Ingstad'. They were closed at the time of the accident. According to SMP-17 (B), shipboard openings with a bearing on the vessel's CBRN and damage control state shall be marked with letters.

The NSIA has been informed, however, that there were challenges involved in keeping the hatches closed on a sister vessel. It was stated that gaps would arise unless the hatches were secured properly with cleats. There had also been instances of damaged hatches and use of jack straps to keep them closed. In addition, the work of maintaining the hatches was demanding because they tipped outwards as a result of their design, which meant that they had to be removed or that the vessel had to be docked while maintenance was being carried out. As part of their maintenance routine, the Royal Norwegian Navy carried out tests of watertight integrity of doors and hatches. This included either chalk test of watertight seal, hose testing of frame (outside) or ultrasound. No deviations were identified before the event.

A test of the watertight integrity of doors, hatches and valves on Q-deck was carried out on board HNoMS 'Helge Ingstad' during the autumn 2020. The results of the test are presented in section 2.9.6.

2.6.9.5 *Stability calculator*

2.6.9.5.1 Background

The stability calculator on board HNoMS ‘Helge Ingstad’ had been developed and delivered by Navantia. During the project phase for the Nansen-class frigates, the software was fully integrated into Navantia’s IPMS control system.

The stability calculator was intended as a decision-making tool for the shipboard crew. The calculator was capable of reading sensor data from the vessel’s tanks and of indicating which compartments were being flooded in the event of damage.

Figure 54: The stability calculator in HQ1. Illustration: CIAAS/NSIA

2.6.9.5.2 Operational challenges with the stability calculator

The Navy and the NDMA have informed the NSIA that challenges relating to the calculator that was integrated in the IPMS control system had been reported both during the project phase and later on, during the operating phase. Navantia has informed that the delivery of the IPMS stability calculator was approved by the NDMA/Navy. The users have experienced problems with a high user threshold, difficult user interface, inaccurate sensing and challenges related to the interpretation of the regulations, which had to be dealt with before operationalisation of the calculator.

The NDMA has stated that, during the period from handover to operations until the incident in November 2018, neither the NDMA nor the Navy has devoted attention as necessary to the stability calculator, with regard to operation, maintenance, training and use.

2.6.9.5.3 The crew’s experience of the stability calculator

As part of the MEO course, three members of the crew on HNoMS ‘Helge Ingstad’ had prepared a project assignment dated 6 August 2017 in answer to the question of whether the stability calculator in the IPMS could be used in an action stations or damage control situation. The following was concluded:

- *Stability calculations are too poorly described in the Norwegian Armed Forces' regulations, manuals and publications. Furthermore, the information in some of the applicable documents is outdated and ready for revision.*
- *At present, no training or courses are held addressing the frigates' electronic stability calculator; it is thus left completely up to each individual vessel to decide how to address this. No active crew courses or training is currently offered in general stability calculations; shipboard competence is therefore based exclusively on individual experience and educational background.*
- *Courses in stability should be put into place. Training should focus on the frigates' electronic stability calculator, preferably by means of a set of user guidelines. Furthermore, there must be a uniform approach to how the calculations are to be carried out and organised.*
- *The stability handbook documents the stability of Nansen-class frigates in relation to DNV GL's class requirements. The handbook applies as long as inclining tests and displacement measurements are carried out every five years. This is the case for the Nansen-class frigates. The handbook as it appears today is very well suited for use in the case of continuous damage to several compartments. For non-continuous damage, on the other hand, the stability handbook is of little use.*
- *We have not been able to validate the stability calculator in the most recent version of the IPMS in relation to known load conditions described in the stability handbook. The reason for this is that there are too many errors in the software itself. We therefore recommend that the stability calculator be used for training purposes only until troubleshooting of the software has been completed.*
- *The stability calculator on HNoMS 'Helge Ingstad' has not been used much on account of lack of training in how to use the software and inadequate knowledge about stability. There should therefore be more focus on training. We also recommend that some changes be made to the user interface to simplify the data input process and to make critical information more visible.*

Shortly before the accident, the frigate's crew members who were authors of the project assignment had submitted a note of concern to the case officers in the NDMA about the stability calculator's reliability and the crew's competence in its use. The crew described this as having been a recurring and unresolved problem since 2006. The NDMA responded by saying that the plan was to resolve this technically through a current change order, without indication of an expected date of completion. For assistance with training, the crew were referred to the KNMT Centre for Naval Engineering and Safety (KNMT NESC) or Navantia.

As a consequence of the circumstances described above, the stability calculator was neither in use before nor on the day of the accident.

After the accident, the NDMA has initiated dialogue with Navantia for development of a new version of the software for the purpose of putting the stability calculator to use.

2.6.10 Bilge and seawater system

2.6.10.1 *System description*

The frigate's bilge pumping system was a combined main bilge system and bilge sullage system for day-to-day removal of bilge water and oily water. The term 'bilge system' as used in the following refers to this combined system.

The system was a vacuum pumping system and was designed in accordance with RAR III section 2.3.[69] The system was according to the Bilge and Ballast System Report[70] designed as follows:

> *The Main Bilge System provides the means for removal of flood water from the compartments below the damage control deck and is capable of controlling flooding generated by firefighting.*

The bilge system was also combined with the ballast system and connected to the seawater main system.

According to the maintenance schedules, the bilge system was classified as a safety-critical system. This meant that most maintenance procedures were described as having criticality 4 or 5; see section 2.6.3.

Drainage/pumping systems were installed in all areas with sprinkler systems:

- Areas on 1 deck and above: drainage directly overboard via deck drains and independent drainage pipes fitted with non-return valves.
- Areas on 2 deck: drainage directly overboard via deck drains and independent drainage pipes fitted with non-return valves, or pipes readied for connection of portable pumps or eductors[71]
- Areas below 2 deck: dedicated eductors or pipes readied for connection of portable pumps or eductors.

The bilge system consisted of six main eductors installed in the following machinery spaces:

- Bow thruster machinery room (eductor 1)
- Forward auxiliary machinery room (eductor 2)
- Forward main engine room (eductor 3)
- Reduction gear room (eductor 4)
- Aft main engine room (eductor 5)
- Aft generator sets room (eductor 6)

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[69] Rules and Regulations for Surface Vessels of the Royal Norwegian Navy, Damage Control and NBC protection, 19 February 1998
[70] Navantia: «Bilge and Ballast System Report, Doc no 529-2-35-001-0R», Rev A. dated 09/03/01
[71] An eductor is a pump that uses water under high pressure as motive force.

The bilge capacity[72] of each eductor and the total capacity of the bilge system is given by the Book of Main Systems. In addition, three independent smaller bilge systems with eductors had been installed in the steering gear room, the VLS module and the chain locker/windlass machinery room.

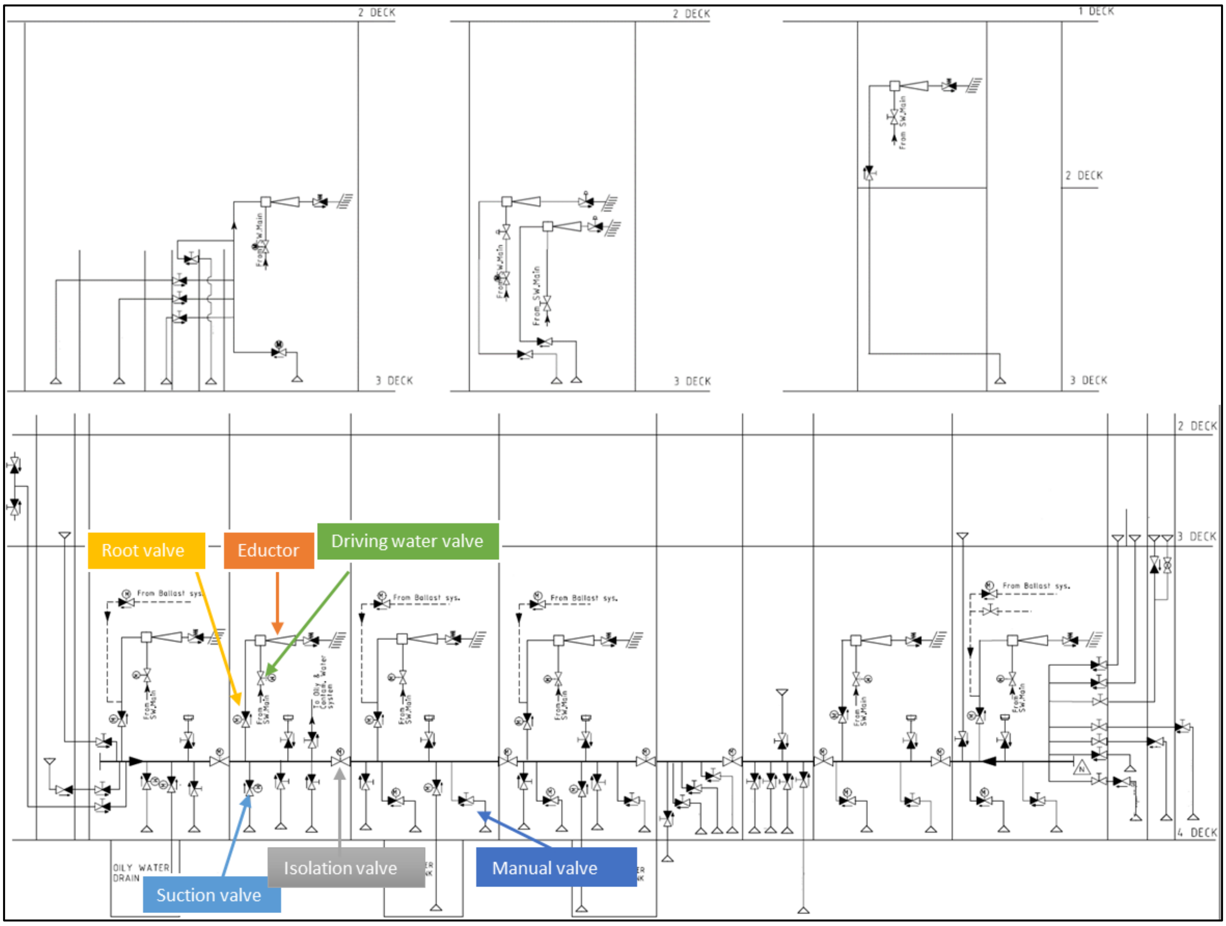

Figure 55: Bilge system[73] – Bilge system and the three independent smaller bilge systems. Schematic: Navantia, modified by the NSIA

The bilge system was operated by electric motorised control valves. These were installed between watertight compartments on the main bilge line (7 isolation valves), on each main suction line in each machinery space (6 suction valves), for each eductor (6 root valves) and each seawater main connection (6 driving water valves); see Figure 55. The valves could also be operated manually. The latter three types of valves were painted black, and there were three of them in each compartment; see Figure 55.

The system was also fitted with a number of additional suction valves. For the eductors to start and produce vacuum to remove water from the compartments by suction, motive force had to be supplied by opening the driving water valves on the seawater main. The bilge system was also used for removing waste water from the three oily water drain tanks.

[72] Details of the bilge capacity are classified Restricted under the Security Act by the information owner the Norwegian Armed Forces and the NDMA

[73] Details of the bilge system are classified Restricted under the Security Act by the information owner the Norwegian Armed Forces and the NDMA

The eductors were supplied with driving water from the seawater main system. The seawater main system was designed as a ring line carrying seawater under pressure in two mains loops – one on the port and one on the starboard side, respectively. The upper ring-line loop was located on the port side on 2 deck, while the lower ring-line loop was located on the starboard side below 3 deck; see Figure 56. The two ring-line loops were cross-connected. Pressure in the seawater main was maintained by six seawater pumps (one of which was a diesel-fuelled standby pump). The pumps delivered a pressure of 10 bar, which was fed to the eductors on opening the driving water valves.

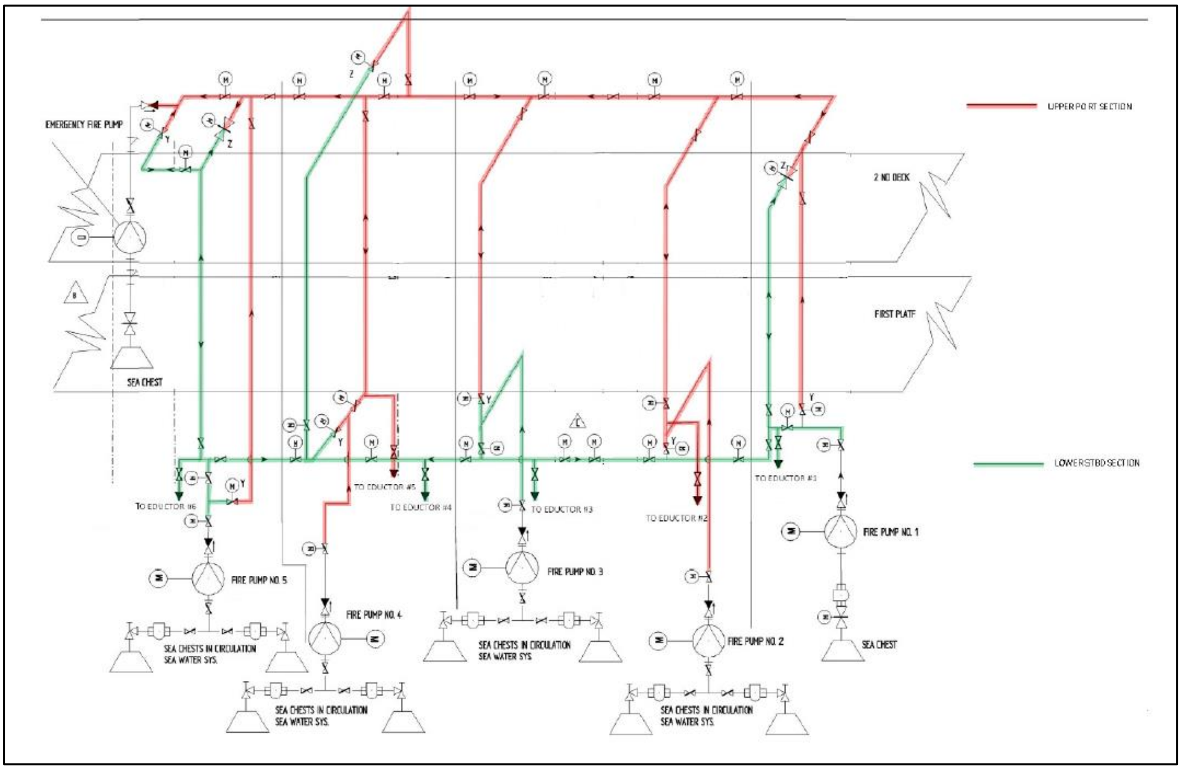

Figure 56[74]: Schematic diagram of seawater main and seawater pumps. Schematic: Navantia, modified by the NSIA

If the seawater main was damaged, the damaged section was to be isolated from the rest of the system by closing the appropriate motorised valves. First and foremost, all valves marked with a 'Y' (six) or 'Z' (three) must be closed and the seawater main system set to the 'Z' state, with at least two seawater pumps in operation – one connected to each of the main ring-line loops. The design was based on the assumption that the vessel would sail in 'Yankee' state when at sea, something that is also provided for in RAR III 3.5.3. The vessel normally sailed with open 'Y' valves, and this was also the case on the day of the accident.

Remote control of the bilge system and seawater system by closing/opening the motorised valves was primarily from the IPMS in the MCR. These valves could also be operated from local panels on 2 deck. The motorised bilge valves could also be operated manually from the machinery spaces in the event that the power supply failed. At the time of the accident, many of the bilge valves were located under bolted-down floor grates due to shock protection. These grates had to be removed for access; see Figure 57.

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[74] Details of the schematics are classified Restricted under the Security Act by the information owner the Norwegian Armed Forces and the NDMA

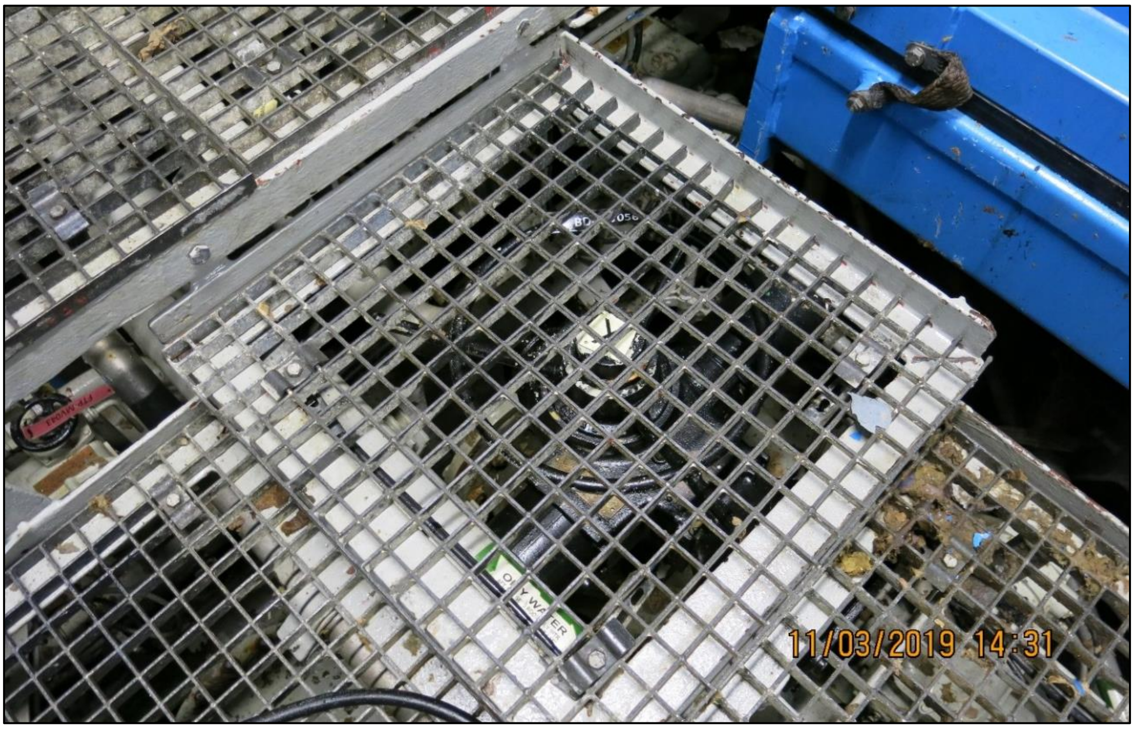

Figure 57: Suction valve (tag BD-MV056) in black, located under floor grate in the aft generator sets room. Photo: NSIA

The design of the main bilge system was based on the principle of survivability, redundancy and segregation.

- Survivability: The components are designed to withstand various scenarios such as underwater explosions, major ship movements and extreme weather conditions.
- Redundancy: The system is divided into several units, so that significant capacity remains even if one unit fails or is lost.
- Segregation: The various units are located in segregated watertight compartments and fire zones to reduce the probability of more than one unit being damaged in one and the same accident event.

In order for the system to function in damaged condition, all bilge valves marked ‘X’ must be closed.

In addition to the permanently installed bilge system, the vessel was equipped with 4 portable bilge pumps. These pumps were electrically driven with power supplies by means of 440/3 VAC outlets available in each watertight section. According to documentation received from Navantia, the four pumps could be fed from a single socket by means of a power splitter. The discharge hose for the portable pumps could be led overboard through DN65 discharge pipes available on 2 deck in each watertight main subdivision, at both sides.

2.6.10.2 *Operation and maintenance*

Navantia had prepared a maintenance schedule that included requirement for maintenance and regular testing of the system and its components. On that basis, the NDMA had prepared maintenance procedures referred to as 'job cards'. According to one of the job cards with criticality 5, a complete overhaul of the bilge system should be carried out every five years. According to another job card with criticality 4, motorised valves were to be tested every six months to verify that they closed completely (Job card I-52912-1). The crew found no faulty closing mechanisms in connection with the most recently completed valve routine in 2018.

2.6.10.3 *IPMS data from the seawater system*

This section describes important actions taken in relation to the seawater system. The description is based on IPMS data to which the NSIA has obtained access. IPMS data from the seawater system have also been analysed by Navantia and the NDMA after the accident, and some of the information that emerged has been used in this section. Further details can be found in the report[75] in Appendix E (R)[76].

After the collision, the pressure in the seawater main system fell to 0 bar. Loss of communication with several valves on the seawater main in the afterbody made it difficult to segregate the seawater main in the afterbody using the IPMS. Before the seawater main was isolated, the IPMS operator started seawater pumps N-1, N-2, N-3 and N-4, but there was no pressure build-up in the system because the seawater was being pumped into the ship through the damaged seawater main in the afterbody. The pressure reading at pump N-4 was 10 bar, but valve MV-FM058 was closed and could not be opened because the local control panel was damaged.

[75] F313 Accident, IPMS Data, Bilge and seawater fire main systems operation, 31 August 2020
[76] The reports in Appendix E are Navantia's interpretation of the event based on IPMS data, and is not assessed based on information from the crew. The reports are classified as Restricted under the Security Act.

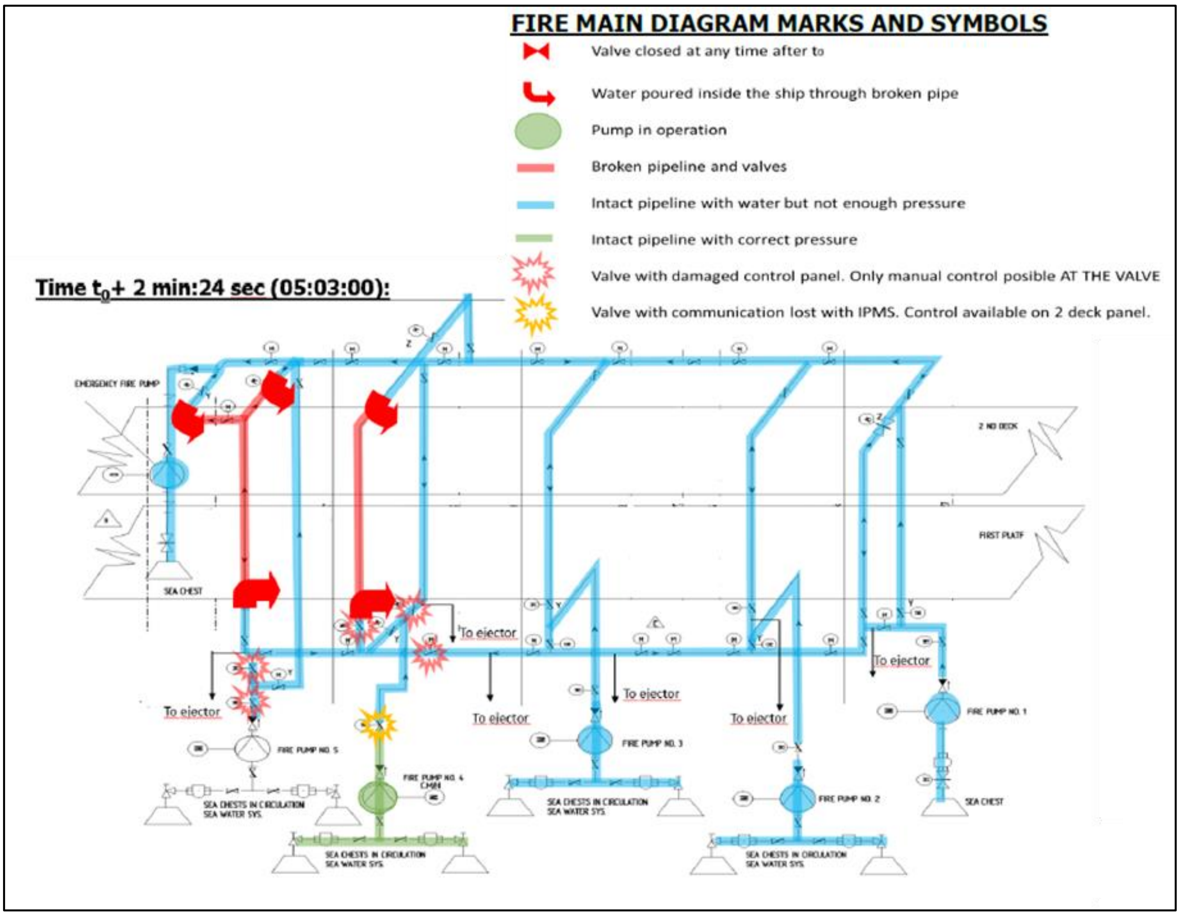

Figure 58: Schematic diagram[77] showing how water was being pumped into the ship as a result of failure to isolate the seawater main. Schematic: IPMS report, Navantia, modified by the NSIA

The seawater main was segregated at the border between fire zones 2 and 3 at approx. 04:05, by closing FM-MV047 and FM-MV165. One of the isolation valves (MV-FM047) was reopened from DCC 26 seconds afterwards, causing the pressure in the ring line to drop. The valve was then closed and opened and closed a final time at approx. 04:07, whereby the pressure in the forebody rose to 10 bar (forward main engine room, forward auxiliary machinery room and bow thruster machinery room).

Navantia has estimated that 110 tonnes of seawater was pumped into the ship before she was evacuated. The NSIA has not carried out separate calculations to verify this.

[77] Details of the schematic are classified Restricted under the Security Act by the information owner the Norwegian Armed Forces and the NDMA

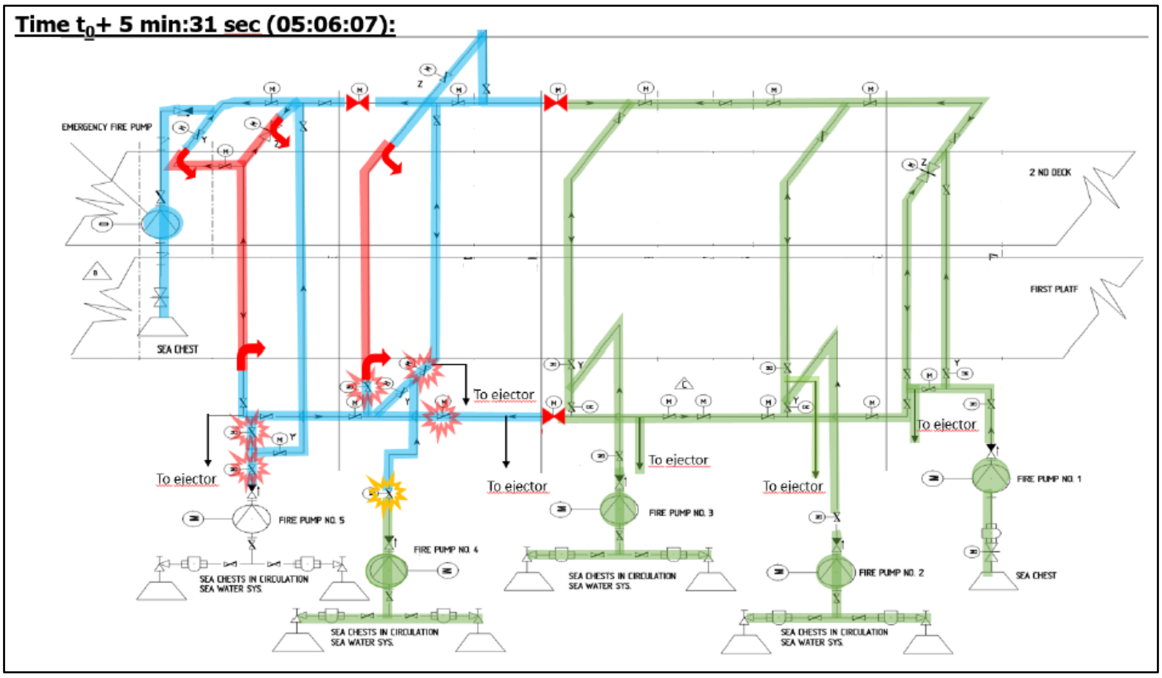

Figure 59: Schematic[78] diagram showing how the seawater main was isolated at approx. 04:06. Schematic: IPMS report, Navantia, modified by the NSIA

2.6.10.4 *IPMS data from the ballast and bilge system*

This section describes important actions taken in relation to the ballast and bilge system. The description is based on IPMS data to which the NSIA has obtained access. IPMS data from the ballast and bilge system have also been analysed by Navantia and the NDMA after the accident, and some of the information that emerged has been used in this section. Further details can be found in the report[75] in Appendix E (R).

Several bilge system valves lost communication with the IPMS immediately after the collision, without such communication being restored after the 'black ship' condition. Among others, isolation valve BD-MV046 in the aft main engine room, suction valve BD-MV049 to the eductor in the aft main engine room and suction valve BD-MV056 in the aft generator sets room were impossible to operate during the incident, both from the IPMS and locally from the panel on 2 deck, because of damage to local panels and loss of remote control from the IPMS; see Figure 60.

[78] Details of the schematic are classified Restricted under the Security Act by the information owner the Norwegian Armed Forces and the NDMA

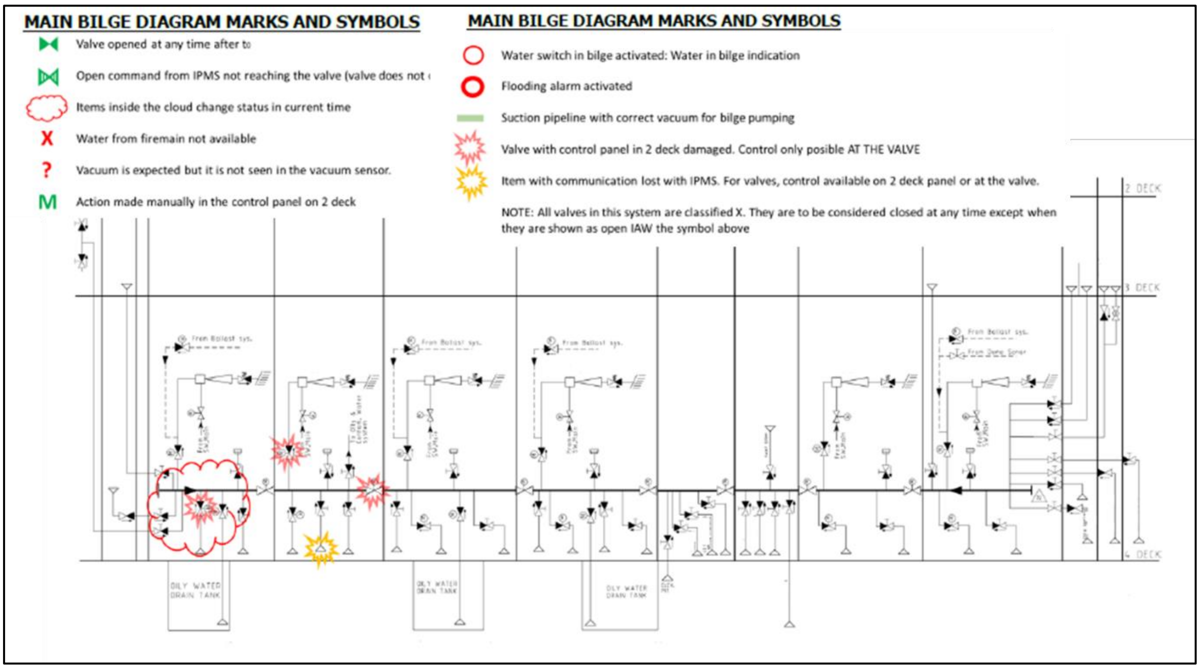

Figure 60: The isolation valve in the aft engine room, the suction valve to the eductor in the aft engine room and the suction valve in the aft generator sets room were impossible to operate from the IPMS and locally from the control panel on 2 deck. Schematic: IPMS report, Navantia, modified by the NSIA[79]

During the first two to three minutes after the collision, attempts were made to activate eductor 1 (bow thruster machinery room), eductor 4 (reduction gear room) and eductor 6 (aft generator sets room) from the PCC. Seawater pressure for the eductors was not established because the seawater main had not been isolated from the damaged section. At approximately 04:04, an attempt was made to open suction valve BD-MV056 in the aft generator sets room from the ACC, but it was not possible to operate this valve from the IPMS or from the local panel on account of the damage. Another unsuccessful attempt at the same was made from the DCC approximately two minutes later.

[79] Details of the schematic are classified Restricted under the Security Act by the information owner the Norwegian Armed Forces and the NDMA

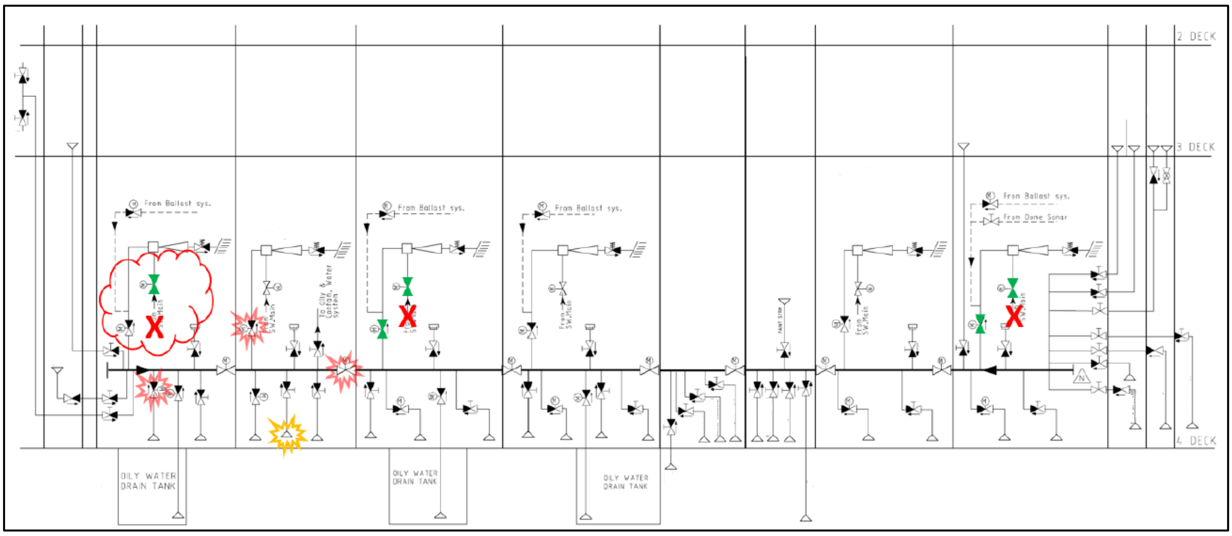

Figure 61: Schematic diagram of attempted activation of eductors 1, 4 and 6 from the PCC. Schematic: IPMS report, Navantia, modified by the NSIA[80]

Approximately 6 minutes and 20 seconds after the collision, the possibility to control isolation valve BD-MV05 between the aft generator sets room and aft engine room was lost since LS7 was disengaged. After isolation of the seawater main at approx. 04:07, the seawater pressure for eductor 1 rose to 10.2 bar, but there was little suction (only -0.16 bar). An attempt was then made to use eductor 4 to pump water from the ballast tanks in group 3 by opening valve MV-BAL019 from the ACC, but it did not succeed as seawater pressure had not been established in this compartment, which was part of fire zone 3. The valve was therefore closed after nine seconds.

At approximately 04:07, the isolation valves in the forward main engine room and bow thruster machinery room were opened from the PCC. The eductors in these rooms did not achieve the expected suction, except in the forward auxiliary machinery room. The suction valve to the eductor in the auxiliary machinery room, intended to isolate the eductor from the bilge line, was closed at the time, while the suction valves to the eductors for the other machinery spaces were open; see Figure 62.

[80] Details of the schematic are classified Restricted under the Security Act by the information owner the Norwegian Armed Forces and the NDMA

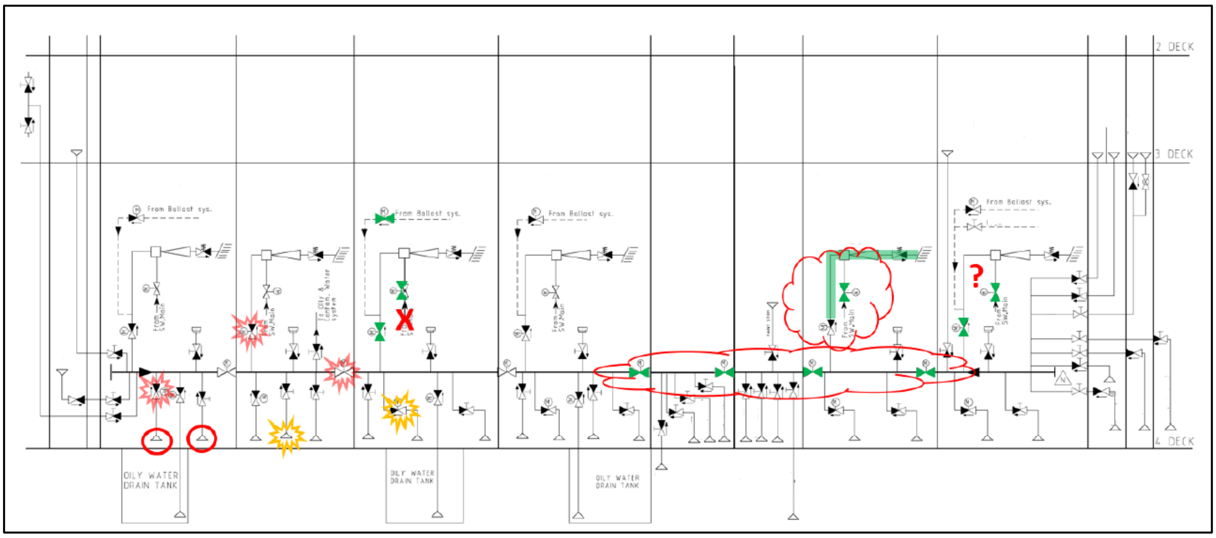

Figure 62: The schematic diagram shows open isolation valves on the bilge line at approx. 04:07. Schematic: IPMS report Navantia[81]

At approximately 04:08, suction valve BD-MV048 in the aft main engine room was opened from the PCC, and then closed five seconds later.

At approximately 04:14, the suction valve in the bow thruster machinery room was opened from the ACC and eductor suction from that room dropped from approx. -0.15 to -0.05 bar. 12 seconds later, the isolation valve BD-MV038 between the aft main engine room and the reduction gear room was opened from the DCC.

At approximately 04:14, the ACC operator started using eductor 3 to pump out 6.4 m^3 from starboard ballast tank 4H02. This took 23 seconds. It has been estimated that this amounted to the total volume of water that was pumped out from the ship from the time of the collision until she sank; see the Navantia report[75] in Appendix E (R). The same operator also made an unsuccessful attempt to empty forward ballast tank 9L01 by means of eductor 1.

Sufficient suction was also not achieved in the forward main engine room, with the exception of the forward auxiliary machinery room, where the suction valve to the eductor was closed. The ACC operator then opened the suction valve to the eductor in the forward auxiliary machinery room at approximately 04:28, whereupon the eductor suction in that room dropped (from approx. -0.9 to -0.1 bar).

At approximately 04:38, 24 minutes after the suction valve in the bow thruster machinery room had been opened, it was closed by the ACC operator. This causes the eductor suction to increase from approx. -0.05 to -0.2 bar. Isolation valve BD-MV015 for the bow thruster machinery room was then closed, and the eductor suction dropped once again (from approx. -0.2 to -0.1 bar).

The ACC operator then closed isolation valve BD-MV025 for the food waste system (at frame 77), whereupon eductor suction in the forward auxiliary machinery room increased from approx. -0.2 to -0.7 bar at approximately 04:43. The operator reopened the valve soon after, whereupon eductor suction in the forward auxiliary machinery room dropped

[81] Details of the schematic are classified Restricted under the Security Act by the information owner the Norwegian Armed Forces and the NDMA

to -0.2 bar. There are no records of further changes having been made to the configuration of the bilge system.

In its analysis of IPMS data for the seawater main system and ballast and bilge systems (see Appendix E (R)), Navantia concludes that none of the inflowing seawater was pumped out by means of the bilge system.

2.6.10.5 *Bilge system nonconformities*

The bilge system on the Nansen-class frigates, and hence on HNoMS 'Helge Ingstad', had outstanding nonconformities reported by the vessels, and DNV GL had commented on the bilge system nonconformities in connection with previous classification of the vessel type; see section 2.8.7.

Six nonconformities relating to the bilge system were identified in connection with the class entry process for the frigates in 2014. The NDMA considered that five of these nonconformities needed to be rectified and a change proposal was drawn up for alteration of the bilge system, with a deadline for preparing a technical solution in June 2017. One of the nonconformities in relation to the DNV GL class rules was that the bilge system should include a separate system for pumping out small volumes of water during normal operation, including oily water from the machinery rooms, and another system for pumping out large volumes of water from the machinery rooms. On HNoMS 'Helge Ingstad', these systems were combined in a single system.

The scope of the alteration of the bilge system was found to be so extensive that the work was suspended pending project funding and the establishment of a project organisation. These were never put into place, and the status of the system on the day of the accident was the same as at the time of class entry.

According to information provided by the NDMA Naval Systems Division,[82] the problem was also identified at some point during the project implementation, which caused a notification of need for alteration in 2004. According to the NDMA Naval Systems Division, the need for alteration was not acted upon and the design was approved by the project.

To ensure that the bilge system could also be used for training and exercise purposes, Navantia has informed the NSIA that they provided the NDMA/Navy with a procedure, and a special pipe spool to perform a bilge main rinsing. This should ensure that the system was clean before it was activated for training and exercise purposes, and remove the risk of discharging oily water overboard. According to Navantia the design together with this procedure was approved by the Navy/NDMA. According to the NDMA this procedure was not known or used in the organisation and not described in the Book of Main Systems. The NSIA has not investigated this topic further.

2.6.10.6 *General principles and requirements for vacuum bilge pump systems*

The NSIA used Aker Solutions as technical advisers on bilge systems. Representatives of Aker Slutions participated in the capacity test, see section 2.9.5, and provided general

[82] Norwegian Defence Materiel Agency, Naval Systems Division: 'The Norwegian Defence Materiel Agency's investigation after the accident involving HNoMS 'Helge Ingstad', Version 2.0 dated 7 May 2020

input relating the bilge system design compared to the regulations from the building of the ship. This is summarised in Appendix F.

2.6.10.7 *Relevant rules and regulations*

The bilge system was originally designed in accordance with RAR III[83], in addition to contractual requirements specified in the building contract between Navantia and the NDMA. RAR III section 2.3 contains requirements for bilge and ballast systems, and is not repeated in this report.

The regulatory requirements for bilge pump capacity were worded as piping and equipment design requirements and not as operational requirements that must be satisfied in a given situation in order to achieve an acceptable level of safety. The purpose of the requirements is thus to provide the designer and the shipbuilder with a parameter that can be used to define the given equipment on the basis of what the regulator believes to be sufficient system capacity.

There was an option in the regulations to install flooding pumps on board with large capacity for draining the engine room and other important rooms in the event of damage to the vessel. This was not installed on the Nansen class according to Navantia.

Requirements of relevance to this investigation are described below.

2.6.10.7.1 Total capacity

In RAR III, 2.3.5.1, the requirement for total bilge system capacity is described as follows:

$$Q = 6\sqrt{L(B + D)}$$

L = length of vessel between perpendiculars, in m
B = breadth of vessel, in m
D = depth of vessel to bulkhead deck, in m.

Figure 63: Required bilge system flow rate in accordance with RAR III, 2.3.5.1. Source: NDMA

Based on the main characteristics of the Nansen-class the formula resulted in a required capacity of 339 m^3/h.

2.6.10.7.2 System segregation

RAR III Chapter 2 describes requirements for system segregation. Among other things, it is stated in section 2.3.4.1 that a separate system shall be installed for day-to-day drainage of bilge water from machinery spaces and oily water from service tanks. It is also stated that the bilge water system shall not be connected to the main or auxiliary bilge system.

2.6.10.7.3 Valve status

Valve status is described in RAR III section 3.5.2:

> *Closure devices marked with an X must always be kept closed.*

[83] Version from time of contract award, June 2000

2.6.10.7.4 DNV GL class rules

In July 2010, a contract was signed for class entry of the Nansen-class frigates. Applicable DNV GL rules in 2010 formed the basis for the design review and thus also for the assignment of class. The rules that applied to the bilge system were the same as under the current rules, which are also reflected in RAR III.

2.7 Parties involved

2.7.1 Introduction

In this section, a brief description is given of the parties involved and their organisation, roles and responsibilities.

2.7.2 Norwegian Ministry of Defence

The Ministry of Defence is a government agency responsible for the development and implementation of Norwegian defence policy. In accordance with long-term goals for the development of the Norwegian Armed Forces, the Ministry of Defence draws up annual defence budgets with specific proposals for appropriations and investments in the Norwegian Armed Forces. Once the Storting has considered reports and propositions, the Ministry of Defence is responsible for following up the Storting's decisions through governance of the activities of subordinate agencies. This includes drawing up regulations where warranted by law or regulation. The Ministry of Defence has overall responsibility for maritime safety in the defence sector.

2.7.3 Norwegian Armed Forces Materiel Safety Authority

The Norwegian Armed Forces Materiel Safety Authority is organised under the Ministry of Defence, reporting directly to the secretary general on technical and administrative matters. The Authority is charged with supervising that the safety of materiel is ensured where the defence sector is exempted from civil legislation or regulation, or assigned independent responsibility. This applies to military seacraft, aircraft and vehicles, weapons, ammunitions and explosives. The Authority does not conduct supervisory activities in areas where other government supervisory bodies are authorised.

2.7.4 Norwegian Armed Forces/Royal Norwegian Navy

The Royal Norwegian Navy is the branch of the Armed Forces that upholds Norway's power at sea. The Navy is led by the Chief of the Royal Norwegian Navy, whom the Chief of Defence Norway has authorised as the competent authority for naval operations and relevant legislation. The Navy consists of the Naval Staff, the Fleet, the Coast Guard, the naval bases, the Navy's Medical Corps and the HNoMS 'Harald Haarfagre' Basic Training Establishment at Madla in Stavanger. The Fleet is the Navy's operative force, while the Coast Guard is the State's primary enforcement authority at sea in times of peace.

Up until the accident, the Navy's five frigates, including HNoMS 'Helge Ingstad', were at the Fleet's disposal.

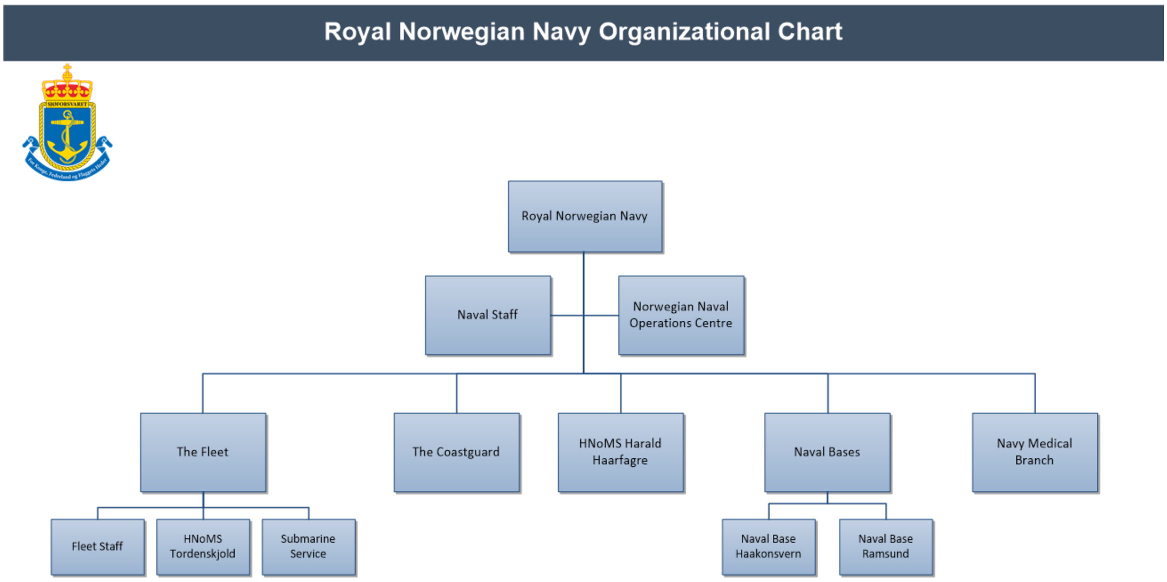

Figure 64: Organisation chart of the Royal Norwegian Navy 2018 (Norwegian only). Illustration: The Navy

2.7.5 Norwegian Defence Materiel Agency

The Norwegian Defence Materiel Agency (NDMA) is an administrative body under the Ministry of Defence with delegated ownership management authority for defence sector materiel.

The NDMA is responsible for the safety of materiel in the defence sector, and for ensuring that the procurement, management and disposal of materiel takes place in accordance with acts and regulations. The NDMA is also responsible for facilitating operations to enable optimum management of materiel in terms of factors such as materiel safety, technical performance, availability and total lifetime costs. This is done through establishing requirements, approval and inspection of technical factors, and advising on materiel management in the defence sector.

The NDMA also has roles related to the Ship Safety and Security Act, among others. This is described in greater detail in an agreement between the Navy and NDMA.

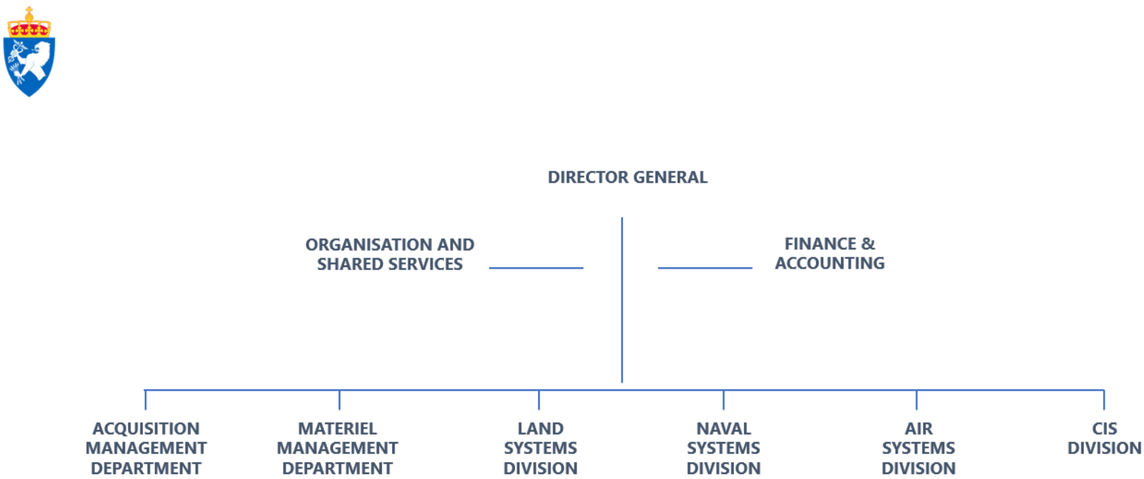

Figure 65: Organisation chart, NDMA 2018. Illustration: NDMA

2.7.6 DNV GL Group AS

DNV GL is a risk assessment and classification company offering classification, certification, technical risk and reliability assessments together with software, data processing and independent advisory services to the maritime sector, the oil and gas sector and energy sector.

2.7.7 Navantia

Navantia is a Spanish state-owned company engaged in the design and building of military and civilian vessels. In the year 2000, Navantia signed a contract with Norway for delivery of five Nansen-class of the type F-310. The frigates were built by Navantia in Ferrol in Spain. HNoMS ‘Helge Ingstad’ was the fourth in a line of five frigates built and handed over to the Norwegian Navy between 2006 and 2011, and was delivered in 2009.

2.8 Safety and security arrangements for the frigates

2.8.1 Introduction

This section describes military ship safety and security arrangements of relevance to the accident. It addresses the overall framework for safety and security management as well as roles, supervision and class entry. It does not address all applicable rules and requirements, but describes the regulatory framework that is deemed to be relevant to the analysis of the incident.

2.8.2 Framework for safety and security management

2.8.2.1 *The Ship Safety and Security Act*

The Act of 16 February 2007 No 9 relating to ship safety and security (the Ship Safety and Security Act) entered into force on 1 July 2007, replacing the Seaworthiness Act.

The purpose of the Act is to safeguard life, health, the environment and material assets by facilitating a high level of ship safety and safety management, including preventing pollution from ships, ensuring a fully satisfactory working environment and safe working conditions on board ships, as well as appropriate and timely supervision of ships; see Section 1 of the Ship Safety and Security Act.

The Act applies to Norwegian and foreign ships in Norwegian territorial waters, and Norwegian-registered ships outside Norwegian territorial waters. Regulations specify what ships are subject to the requirement for supervision.

Section 6 of the Act regulates the general duties of the owner, and states that the owner has an overall duty to ensure that the construction and operation of the ship are in accordance with rules provided for in or pursuant to the Ship Safety and Security Act.

Section 7 of the Act regulates the owners’ duty to establish, implement and further develop a safety management system. No exemption is granted from Section 7 for the Norwegian Armed Forces’ ships. Nonetheless, the ISM Code and the Regulations of 5 September 2014 No 1191 on a safety management system for Norwegian ships and mobile offshore units do not apply to the Norwegian Armed Forces’ ships. That does not relieve the defence sector from the obligation to comply with the requirement for a safety management system laid down in Section 7 of the Ship Safety and Security Act. The Navy has used the ISM Code as a point of departure for the development of its safety management system.

Chapter 3 of the Act addresses technical and operational safety. Section 9 states that a ship shall be so designed, constructed and equipped that it, according to its purpose and trade area, provides for the satisfactory protection of life, health, the environment and material assets. It goes on to state that the Ministry (in this case the Ministry of Defence) may issue regulations on how ships shall be designed, built and fitted out in order to meet the requirements for, among other things:

a) hull strength and watertight integrity;
b) stability and buoyancy;
c) machinery and electrical installations;
d) fire safety;
e) navigational equipment;
f) communication equipment;
g) life-saving appliances.

2.8.2.2 *‘The Delegation Regulations’*

By the Regulations of 16 February 2007 No 171 on delegation of the King's authority and appointment of a supervisory authority (the Delegation Regulations), the King's authority under the Ship Safety and Security Act was delegated to the Ministry of Trade, Industry and Fisheries, the Ministry of Defence and the Ministry of Climate and Environment, with specification of the scope of delegated authority. The Norwegian Maritime Authority (NMA) was appointed supervisory authority under Section 41 of the Ship Safety and Security Act. The Ministry of Defence has exempted the defence sector from Section 41, however, and the sector is thus exempt from supervision by the NMA.

The Ministry of Trade, Industry and Fisheries has not been delegated authority ‘for ships belonging to the Royal Navy or ships used in such service’; see Section 2 third paragraph, letter f). The Ministry of Trade, Industry and Fisheries and the Ministry of Climate and Environment issue joint assignment letters to the NMA. By virtue of the Ministry of Climate and Environment's delegation under Sections 4 and 5 of the Regulations, the NMA is nonetheless authorised to supervise the environmental safety of ships belonging to or used in the service of the Norwegian Armed Forces.

2.8.2.3 *Regulations in pursuance of the Ship Safety and Security Act*

More than 100 sets of regulations have been prepared in pursuance of the purpose of the Ship Safety and Security Act for various categories of ships/mobile offshore units comprised by the Act. They address the shipowner/operational manager's duties, safety management, technical and operational safety, working environment and personal safety, environmental safety, readiness for security attacks and acts of terrorism, and supervision. The Ministry of Climate and the Environment has delegated regulatory authority in the field of environmental safety to the NMA.

2.8.2.4 *The 1668 Regulations*

The Regulations of 29 June 2017 No 1668 (the ‘1668 Regulations’) relating to the application of the Ship Safety and Security Act by the Ministry of Defence's subordinate agencies regulate the defence sector's exemptions from the Act, the owner and operational manager, internal rules where the sector is exempted, and the Ministry of Defence's supervisory authority.

These Regulations apply to all ships in the defence sector, other than those used for welfare or leisure purposes, and to all agencies under the Ministry of Defence. The Regulations replace the Regulations of 29 June 2007 No 819 on exemptions from the provisions of the Act of 16 February 2007 No 9 relating to ship safety and security for 'ships belonging to the Navy or ships used in such service' (the ‘Exemption Regulations').

Under Section 3 first paragraph, the Norwegian Armed Forces' ships are exempt from certain provisions.[84] In the second paragraph, it is assumed that, where no exemptions apply, the provisions of the Ship Safety and Security Act with pertaining regulations are applicable up until such time as they are replaced by internal rules adopted by the Ministry of Defence; see Section 4. This entails that the regulations apply where the Norwegian Armed Forces’ ships are not explicitly exempted in the regulations.

Section 4 'Internal rules' states that the Ministry of Defence shall establish internal rules to replace the regulations from which exemption is granted under Section 3 first and second paragraphs. The purpose of the Ship Safety and Security Act constitutes a guide to the content of internal rules and such rules shall only deviate from the Act and its regulations insofar as this is necessary. The grounds for any such deviation shall be stated.

2.8.2.5 *The Ministry of Defence's guidelines*

The Ministry of Defence has issued guidelines, including for the logistics area, materiel management, investment, materiel safety and environmental management.

They govern logistics planning and implementation (see NATO's definition of logistics) by the Ministry's subordinate agencies, including what is required of the agencies, and the allocation of roles, responsibility, authority and tasks. Among other things, this is intended to ensure that the requirements of the Ship Safety and Security Act are met, and that requirements also apply to vessels and maritime materiel not regulated by the Act.

The guidelines apply to all materiel and logistics in the defence sector. They apply to all the Ministry of Defence's subordinate agencies and also to the Norwegian Armed Forces Materiel Safety Authority and to maritime materiel not regulated by the Ship Safety and Security Act.

2.8.2.6 *Guidelines for materiel safety in the defence sector ('Retningslinjer for materiellsikkerhet (RMS)').*

The guidelines for materiel safety in the defence sector are issued by the Ministry of Defence and apply to the defence sector as a whole. RMS partly describes a set of requirements for safety management, and roles and mechanisms for addressing materiel safety in all agencies and at all levels of the sector. RMS also defines a framework for the Materiel Safety Authority's supervisory activities over and above what is described in the

[84] The Navy's ships are exempt from Sections 5, 23 to 25, 41, 43 to 44 and 46 to 70 of the Ship Safety and Security Act and from regulations adopted in pursuance of these provisions.

instructions for the Head of the Materiel Safety Authority. RMS is an important part of the basis for the Authority's supervision.

2.8.2.7 *Materiel management directive*

The Director General of the Norwegian Defence Materiel Agency (NDMA) has issued a materiel management directive (*Direktiv for materiellforvaltning*). The directive sets out requirements that undertakings in the sector must comply with to ensure proper management, including of the safety of ships and other materiel.

The directive applies to all defence sector agencies. It also applies to non-defence sector agencies and businesses that borrow or use materiel over which the NDMA exercises ownership management.

The materiel management directive is an operationalisation of the tasks assigned to the agency by the Ministry of Defence and related requirements and expectations. The emphasis is on defining requirements and not on describing how they are to be met. Most of the requirements set out in the materiel management directive are based on requirements that already existed and formed the basis for materiel management before the establishment of the NDMA. In its capacity as competent authority, the NDMA has clarified the requirements, however.

The primary tasks of the competent authority are to define requirements for and approve and inspect materiel. RMS requires administrative approval and follow-up of materiel. Such approval shall be based on an approval of the safety of the materiel. In the materiel management directive, this is specified in more detail as technical and administrative approval. The materiel is deemed to be approved by the competent authority when technical and administrative approval is granted. Before materiel requiring technical and administrative approval is put to use, approval for use must be issued by the authorised person in the agency that will use it. In order to issue approval for use, the agency must, at minimum, be able to document compliance with procedures and provisions that ensure compliance with materiel safety requirements, proper materiel management etc. In addition, all personnel who will use, maintain or otherwise manage the materiel must have completed necessary training in accordance with the requirements of the competent materiel authority, including that they must satisfy formal qualification and certification requirements. The approval for use shall include specification of any requirements for limitations on use, procedures for monitoring factors with a bearing on the safety of the materiel, and how operational responsibility is ensured.

An essential key measure that was introduced with the establishment of the NDMA was the establishment of procedures for issuing corrective action orders (CAO). These can consist of prohibitions on use or requirements for different types of actions or limitations on how to use the materiel. The measure was introduced to increase awareness of the focus on safety and to elevate the safety perspective to the agency management level. The NDMA’s executive management would thus get an overview of specific provisions issued with a view to following up the materiel.

2.8.2.8 *Corporate governance directive (Director General of the NDMA)*

In an internal directive on corporate governance in the NDMA, the Director General of the NDMA has described the system for managing the safety of NDMA materiel, including that:

- The NDMA procures, exercises ownership management of and phases out materiel that is constructed and designed so that personnel are protected against injuries to life and health when using it, including accidents, repetitive strain injuries and exposure that can give rise to health problems in the long term.
- The NDMA complies with requirements provided for in or in pursuance of acts, regulations, rules or instructions.
- The NDMA has processes and procedures of generally high quality in place to support the safety of materiel at all times.
- The NDMA establishes, complies with and systematically continues to develop a safety management system in order to minimise the number of undesirable incidents and reduce risks associated with the use, operation and maintenance of materiel.
- Risks relating to materiel safety are followed up in an efficient and safe manner.
- The NDMA is perceived as an agency that instils thrust, by the authorities, owner, employees, users and society at large.
- The NDMA has established activity reporting (materiel safety) that ensures that the agency's management has a timely and correct overview of, and management and control of, risks relating to materiel safety at all times.

2.8.2.9 *Instructions for heads of divisions (NDMA)*

The Director General of the NDMA has issued a set of instructions describing the primary tasks, responsibilities, authority and authorisations of heads of divisions in the NDMA. The Head of the Naval Systems Division is delegated responsibility and authority to ensure materiel safety in accordance with the Ship Safety and Security Act, as well as the safety of maritime materiel not regulated by the Act.

2.8.2.10 *Corporate management directive (Chief of Defence)*

The Chief of Defence has issued a directive on corporate management in the Norwegian Armed Forces, in which the following are addressed:

a) clarification of roles, responsibility and authority in the Norwegian Armed Forces;

b) requirements for overall management of the Norwegian Armed Forces through management by objectives, performance management and risk management;

c) internal control to ensure compliance with overarching rules and regulations, provisions and instructions for corporate management and goal attainment through efficient resource utilisation.

2.8.2.11 *Directive on safety management requirements (Chief of Defence)*

The Chief of Defence has issued a directive on requirements for safety management (*Direktiv- Krav til sikkerhetsstyring*), which applies to the Norwegian Armed Forces' activities in Norway and abroad. The purpose of the directive is to ensure consistent attention to and continuous improvement of safety in the Norwegian Armed Forces through systematic safety management.

The directive contains overall requirements for roles and responsibilities within the different disciplines and activities intended to protect the operative capabilities of the Norwegian Armed Forces and the basis for such capabilities (materiel, natural environment, personnel, information, infrastructure and activity).

2.8.2.12 *Instructions for the Chief of the Navy*

The Chief of the Navy has been delegated roles, responsibility and authority by the Chief of Defence through a set of instructions for the Chief of the Navy (*Instruks for sjef Sjøforsvaret*), including responsibility as 'company owner' as defined in the Ship Safety and Security Act and its Regulations for all the Norwegian Armed Forces' vessels, with the exception of those belonging to the Chief of the Intelligence Service.

The Navy has interpreted the requirement for risk assessments in the Ship Safety and Security Act in relation to its own safety regime and operations, and uses the risk management tools in the operation of its vessels.

2.8.2.13 *Instructions for the Chief of the Fleet, Commander of the Coast Guard and naval base commanders*

By use of identical wording in these instructions, the Chief of the Navy delegates responsibility and authority under the Ship Safety and Security Act and its Regulations, including responsibility and authority as operational manager for the Navy's own vessels.

2.8.2.14 *Agreement between Chief of the Navy and Head of the NDMA Naval Systems Division*

Compliance with the Ship Safety and Security Act is regulated in Appendix A to the Agreement between the Chief of the Navy and the Head of the NDMA Naval Systems Division.

The agreement describes coordinated action by the Navy and the NDMA with specification of priority tasks and deliveries. It is intended to ensure uniform, coordinated prioritisation of the parties' activities in pursuance of common goals. Among other things, the agreement regulates the Naval Systems Division's responsibility and duty in relation to the Navy's operational manager to ensure compliance with the technical safety framework in accordance with the requirements of the Ship Safety and Security Act.

The agreement applies to the Chief of the Navy, Chief of the Fleet, Commander of the Coast Guard, naval base commanders, the NDMA and the Head of the NDMA Naval Systems Division.

2.8.2.15 *RAR and NRAR*

2.8.2.15.1 *RAR and DNV HSLCNSC*

The Rules and Regulations for Surface Vessels of the Royal Norwegian Navy (RAR) used to apply to the design and building of Norwegian military surface craft. These rules and regulations applied to the building of the Nansen-class frigates and constitute a valid basis for their design.

RAR gradually became outdated and lacked requirements for the operating phase. In 1998, it was therefore decided to draw up a set of rules and regulations for the Norwegian Armed Forces' naval vessels in cooperation with DNV, consisting of the RAR rules supplemented by relevant requirements from DNV's own rules. The work was completed in 2000 and was entitled DNV HSLCNSC[85] (High Speed Light Craft, Naval Surface Craft).

These rules and regulations, as updated up until 2010, have formed the basis for DNV's classification of military seacraft. The rules and regulations were applied to the building of the Nordkapp-class offshore patrol vessels and the Nansen-class frigates, among others, and constitute a valid basis for their design.

2.8.2.15.2 *National naval standard (NRAR)*

In order to fulfil the Norwegian Armed Forces' requirements in its role as rule owner, it was decided to establish a separate set of Royal Norwegian Navy Standard Requirements and Regulations (NRAR) consisting largely of former RAR requirements that were not included in the DNV rules.

NRAR is a national naval standard that defines the Norwegian Armed Forces' acceptance criteria and requirements for design, building, surveying, validation, verification and testing of Norwegian naval and offshore patrol vessels, including requirements for hull (i.e. arrangements, strength, integrity and stability), machinery installations, auxiliary systems, electrical systems and deck and interior equipment. NRAR applies to newbuilds as well as to vessels in the operating phase, and includes defined military systems.

A new NRAR was adopted in 2006, with a new structure that included regulations relating to naval seaworthiness certificates (SJP-72 – 'Forskrifter for Sjøforsvarets Fartssertifikat' from June 2001), and more extensive requirements for a Naval Administration. An updated version of NRAR entered into force in 2007, replacing NRAR 2006 and SJP-72 from 2001. NRAR was most recently updated in July 2013.

2.8.3 Roles

Under the Ship Safety and Security Act,[86] the Ministry of Defence has overarching responsibility for ship safety and security in the Norwegian Armed Forces. The 1668 Regulations regulate the application of the Ship Safety and Security Act by the Ministry's subordinate agencies. Delegation of authority under the Ship Safety and Security Act shall take place by written agreement between the parties.

The Ministry of Defence has issued guidelines for materiel management in the defence sector. The purpose of these guidelines is to fulfil the Ministry of Defence's responsibility as owner of the materiel and to contribute to proper materiel management by the agencies. The guidelines include overriding guidelines on materiel management in the defence sector, and main principles, focusing on responsibility, authority, tasks and control procedures. The guidelines describe how functions and responsibilities are divided between the Ministry as owner of the materiel and the agencies as managers and

[85] Ref. «The Royal Norwegian Navy Standard Requirements and Regulations Part 0, General Information and Requirements January 2007»

[86] Ship Safety and Security Act Section 2 third paragraph (f) and fourth paragraph. Delegated to the Ministry of Trade and Industry in accordance with the Ship Safety and Security Act by the Delegation Regulations of 16 February 2007 No 171.

users of the materiel. Materiel management comprises activities in connection with procurements, follow-up procurements, storage, distribution, use, maintenance, alteration and phasing out of materiel and materiel systems.

Heads of the NDMA and defence agencies are responsible for ensuring that ship safety and security are followed up within their respective organisations. The heads of agencies are also responsible for designating an operational manager.[87] The operational manager may use others to execute the tasks that fall under his area of responsibility, but may not delegate overall responsibility for ship safety under the Ship Safety and Security Act.[88]

The operational manager is principally responsible under the Ship Safety and Security Act.[89] The operational manager is responsible for operation of the ship. He has overall responsibility and an overall duty to follow up and ensure compliance. As a result of the requirement for designating an operational manager,[90] the terms 'company owner' and 'owner' have few practical consequences in the defence sector, where the operational manager has the role of 'owner'.[89] The Chief of the Navy is 'company owner' and thus 'owner' of all the Norwegian Armed Forces' ships with the exception of those belonging to the Intelligence Service.[91] The Chief of the Navy is the competent authority for naval operations and responsible for rules and regulations relating to operational safety and security.[92] The Chief of the Fleet, Commander of the Coast Guard and naval base commanders are appointed operational managers for own vessels.[90]

Annual agreements are entered into between the Chief of the Navy and the Head of the NDMA Naval Systems Division, which regulate the NDMA's deliveries to the Navy. This is intended to ensure that the Naval Systems Division meets the requirements for technical safety (duty to ensure compliance) and availability to the ships. The Head of the Naval Systems Division therefore has an independent and concrete duty to take action to ensure that all technical materiel requirements and ship safety requirements are met. Responsibility for technical safety includes responsibility for hull strength and watertight integrity, stability and buoyancy, machinery and electrical installations, fire safety, navigational equipment, communication equipment and life-saving appliances.[93]

The operational task of meeting the statutory requirements for technical safety is outsourced to the NDMA.[94]

The Ministry of Defence has assigned the Director General of the NDMA overall responsibility for materiel investments and management in the defence sector.[95] The NDMA is the competent technical authority charged with ownership management of all defence sector materiel and responsible for meeting requirements for technical safety

[87] Letters from the Ministry of Defence of 14 February 2008 (2005/00925-37/FD I 4) and 9 March 2017 (2015/3097-22/FD III 4)
[88] The 1668 Regulations and letter from the Ministry of Defence of 9 March 2017 (2015/3097-22/FD III 4)
[89] The Ship Safety and Security Act Section 4
[90] The 1668 Regulations Section 2
[91] Instructions for the Chief of the Navy
[92] Letter from the Ministry of Defence of 9 March 2017 (2015/3097-22/FD III 4) and the directive for naval activities (*Direktiv for sjømilitær virksomhet*)
[93] The Ship Safety and Security Act Section 9 and Cooperation Agreement between the Navy and the NDMA Naval Systems Division
[94] Orders and guidelines from the Ministry of Defence, and the Ministry of Defence's letter of 9 March 2017 (2015/3097-22/FD III 4); see Agreement between the Chief of the Navy and the Head of the NDMA Naval Systems Division on compliance with the Ship Safety and Security Act
[95] Instructions for the Director General of the NDMA

under the Ship Safety and Security Act.[96] This entails that, in defence sector areas of a technical, process-related, system-related and administrative nature, the Director General of the NDMA has been assigned authority to outsource tasks that fall under the agency's areas of responsibility. All users of the Ministry of Defence's materiel, whether they belong to the defence sector or not, are required to comply with the requirements of the competent materiel authority.[97] The Head of the Naval Systems Division is the competent technical authority and exercises ownership management of maritime materiel on behalf of the Director General of the NDMA.[98] This means that the Naval Systems Division is charged with defining requirements and technical frameworks, which includes initiation, approval, attention to, decisions on, certification, authorisation, testing and inspection of technical aspects. The Naval Systems Division is also authorised to impose sanctions and to approve deviations.

The Director General of the NDMA designates an operational manager for ships designed and built for use in the sector.[99] The Head of the Naval Systems Division holds this role.[100]

2.8.4 Independent regulatory authority for military seacraft

The International Maritime Organization (IMO) refers to those who are responsible for implementing the IMO conventions for civilian shipping as 'maritime administrations'. In Norway, this responsibility is vested in the Ministry of Trade, Industry and Fisheries, which has in turn delegated the responsibility to the Norwegian Maritime Authority (NMA).

The NMA is the maritime administration responsible for inspection/surveys, verification and certification of Norwegian shipowners and ships in accordance with the International Management Code for Safe Operation of Ships and Pollution Prevention (the ISM Code). It is the NMA, or a recognised organisation (RO) approved by the NMA, that carries out inspections/surveys, verifications and certification. An RO will normally be a classification society.[101]

The certificate of approval of a civilian undertaking's compliance with the ISM Code is referred to as a document of compliance (DoC). The document of compliance issued to a civilian ship as proof that the shipping company and shipboard management operate the ship in accordance with the approved safety management system is referred to as a safety management certificate (SMC). DoC and SMC each have a period of validity of five years provided that mandatory intermediate audits are carried out and approved.

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[96] The Ministry of Defence's guidelines for logistics activities and Cooperation Agreement between the Navy and the NDMA Naval Systems Division

[97] Directive for materiel management of 15 October 2018 Chapter 2.

[98] Instructions for heads of divisions from the Director General of the NDMA

[99] The 1668 Regulations Section 2

[100] Agreement between the Chief of the Navy and the Head of the NDMA Naval Systems Division on compliance with the Ship Safety and Security Act

[101] The IMO Code for Recognised Organisations (RO Code) is a standard that will assist maritime administrations in achieving harmonised and consistent global implementation of requirements established by the International Maritime Organization (IMO) for the assessment and authorisation of recognised organisations (ROs). The Code provides maritime administrations with harmonised, transparent and independent mechanisms that can assist in achieving consistent and effective supervision of ROs and in clarifying the responsibility of organisations authorised as ROs for maritime administrations and the total scope of authorisation.

The ISM Code and the Regulations of 5 September 2014 No 1191 on safety management systems for Norwegian ships and mobile offshore units do not apply to the Norwegian Armed Forces' ships, but the Navy has nonetheless used the ISM Code as a point of departure for the development of its own safety management system.

For military ships, NATO has issued the Naval Ship Code (NSC) as a 'standard recommendation', a code that was developed by the International Naval Safety Association (INSA), of which Norway is a member. The NSC can be seen as the naval equivalent of IMO's SOLAS Convention. While those responsible for implementation of the conventions for civilian shipping are referred to as 'administrations' by IMO, the NSC refers to and defines the 'Naval Administration' as a government-appointed state agency responsible for safety regulation of naval ships.

In Norway, the Ministry of Defence has not defined, established or appointed a 'naval administration' that can act as an independent regulatory and supervisory authority in connection with the operation of naval vessels.

2.8.5 Supervision and control of ship safety and security in the sector

By way of instructions from the Ministry of Defence, the Norwegian Armed Forces Materiel Safety Authority is tasked with supervising the defence sector to ensure that materiel safety requirements are met in areas where the sector is exempted from civil law and regulations or assigned independent responsibility. The Materiel Safety Authority currently comprises a staff of 11 persons, and has a dedicated advisory group on military shipping. The Materiel Safety Authority is organisationally subordinate to the Ministry of Defence, which is also the owner of HNoMS 'Helge Ingstad'. The Materiel Safety Authority reports on administrative and technical issues to the Ministry's Secretary General.

Up until 20 November 2019, the Secretary General approved the risk-based annual plan, unplanned assignments and any deviation from the annual plan proposed by the Head of the Materiel Safety Authority. Under the new instructions, the Secretary General no longer has this role.

The Materiel Safety Authority is tasked with supervising military seacraft, aircraft and vehicles, weapons, ammunitions and explosives. The Materiel Safety Authority has a relatively uniform approach to supervision in all these fields, with the exception that it used to issue seaworthiness certificates for the Norwegian Armed Forces’ vessels. The Authority issued such documents up until 2018, when the NDMA started issuing naval seaworthiness certificates. Under the 1668 Regulations, the Ministry of Defence is responsible for supervision of ships for which subordinate agencies have operational responsibility. The Ministry shall also supervise operational managers.

The Ministry of Defence decides the detailed rules for such supervision. The Ministry has not introduced such rules as required under the Ship Safety and Security Act. Supervision by the Materiel Safety Authority is therefore carried out on the basis of internal sector regulations. This means that the Materiel Safety Authority only has legal authority to supervise materiel safety, as provided for in the instructions for the Head of the Authority and the guidelines for materiel safety in the defence sector (*RMS*). In practice, this means that there is currently no supervision of defence sector ships as required under the Ship Safety and Security Act and its Regulations, which, among other things, are meant to ensure a safe and secure working environment, technical and operational safety, a safety management system, working environment and personal safety, environmental safety and readiness for security attacks and acts of terrorism.

The main basis for the Materiel Safety Authority's supervision is found in RMS. Those guidelines do not include a full set of requirements for a safety management system. Nor do they cover all aspects of safety; they were drawn up with a view to covering necessary requirements for materiel safety during the materiel's lifetime. The Materiel Safety Authority's supervision in accordance with those guidelines is primarily based on what steps the organisations in the defence sector have taken to comply with the requirements and the extent to which the requirements are met. The main focus is thus on what is referred to as system supervision, and not on physical inspection of materiel. Spot checks are also carried out of the materiel to ensure that the management system works as intended and that the departments comply with the rules that are set.

Since the RMS guidelines cover the defence sector as a whole, they serve as a framework and basis for supervision regardless of which agency is being supervised. In addition, other sector or agency-specific regulations are used, depending on the chosen topic and what agency/organisation is being supervised. The directive on requirements for safety management in the Norwegian Armed Forces (*Direktiv – Krav til sikkerhetsstyring i Forsvaret*) is one such set of relevant regulations used for supervision of the Norwegian Armed Forces' organisation. The directive was issued by the Chief of Defence and applies to all branches of the Armed Forces. Hence, the document describes requirements that apply to safety management in the Armed Forces, but not to the NDMA. The directive is a high-level document in that it applies to all activities of the Norwegian Armed Forces, and contains requirements for the main components of a safety management system.

In addition to supervision by the Materiel Safety Authority, the competent sector authorities, including the NDMA, carry out inspections in their respective areas of responsibility, based on internal rules and regulation.

2.8.6 The Ministry of Defence and the defence sector's work on the Ship Safety and Security Act

Since the Ship Safety and Security Act entered into force in 2007, the Ministry of Defence and the defence sector have sought to establish a naval administration. This task also involves establishing rules to replace the provisions of the Ship Safety and Security Act from which exemption has been granted. The task has not yet been completed, but restarted after the accident with HNoMS 'Helge Ingstad', see section 2.11.1.

2.8.7 The Nansen class frigates – class entry and certificates

Up until 2018, the Materiel Safety Authority was responsible for issuing seaworthiness certificates (CoS) for the frigates. In early 2018, responsibility for issuing naval seaworthiness certificates (corresponding to CoS) was taken over by the Head of the NDMA Naval Systems Division.

A contract was signed in July 2010 for the classification[102] of Nansen-class frigates. HNoMS ‘Helge Ingstad’ was granted an interim certificate by DNV GL in November 2014, and the final class certificate was issued in March 2017.

In connection with the class entry and issuing of the class certificate, DNV GL also issued an ‘Appendix to Class Certificate’. The appendix contained a description of the class notations, design assumptions, and a list of all nonconformities accepted by the Materiel Safety Authority, which were referred to as navdists (naval distinctions).

The nonconformities that were listed in connection with the class entry survey were based on the results of a review of the design/drawings and onboard inspections. Some were issued as class requirements and followed up by the class, while others were issued as navdists to be followed up by the Naval Systems Division. The navdists were listed in 'Appendix to Class Certificate'.

The Materiel Safety Authority transferred the navdists listed by DNV GL to a list of ‘Deviations to Class Rules’, a list that also included the Naval Systems Division’s response to each navdist, which was accepted by the Materiel Safety Authority. Among other things, this applied to nonconformities relating to the bilge system, on the assumption that these would be rectified in connection with the next major overhaul.

In 2015, the NDMA Naval Systems Division (formerly the NDLO[103] Naval Systems Division) also applied (via Polarkonsult AS) to DNV GL AS for deviation from the regulatory requirement for a GZ range of at least 70 degrees. The Nansen-class frigates does not comply with this requirement as one downflooding point[104] will submerge before 70 degrees heel. It was pointed out in the application that an aft trim would ‘worsen this angle’. As grounds for the application, it was stated that ‘the NDLO Naval Systems Division has assessed this and approves it as a deviation’. DNV GL responded as follows to the application:

> *We noted that FLO MARKAP STA accepted the deviation of the intact stability requirement for range of GZ in DNV Rules for Ships (January 2011) Pt.5 Ch.14 Sec.5 C 402 d. This will be included in the appendix to Class Certificate*.

According to DNV GL, it was not uncommon for nonconformities with the class rules to be identified in connection with the classification of ships that were not originally designed and built to the requirements of a recognised classification society. In the case of the Navy’s vessels, the DNV GL rules allowed for applications for acceptance for navdists from the flag administration[105] and it was up to the NDMA to decide whether to accept the navdists as deviations. Based on the above circumstances, the Materiel Safety Authority issued a CoS that applied until 1 January 2018, when the NDMA Naval Systems Division started issuing naval seaworthiness certificates for the Navy’s ships.

The most recent CoS for HNoMS ‘Helge Ingstad’ was issued by the Materiel Safety Authority on 3 April 2017. On that occasion too, the list of navdists, including nonconformities relating to the bilge system that had not yet been rectified as expected,

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[102] DNV 1A1 Naval HELKD-SHF ICE-C NAUT-NAVY NBC-2
[103] Norwegian Defence Logistics Organisation
[104] Details of the downflooding point is classified Restricted under the Security Act by information owner the Norwegian Armed Forces and NDMA
[105] Referred to as the 'naval administration' by the NSIA; see section 2.8.4

was accepted by the Materiel Safety Authority on the assumption that these would be rectified in connection with the next major overhaul.

The naval seaworthiness certificate that was valid for HNoMS 'Helge Ingstad' at the time of the accident was issued by the NDMA Naval Systems Division on 30 August 2018. The nonconformities relating to the bilge system had still not been rectified at that time. Findings to do with the bilge system are described in more detail in section 2.6.10.5.

2.8.8 Nonconformity management

2.8.8.1 *Introduction*

Based on the safety management framework described in section 2.8.2, the Norwegian Armed Forces and the NDMA have each established its own safety management system. This section describes in brief how the Navy and the NDMA Naval Systems Division have established systems for handling undesirable incidents/nonconformities as part of their safety management.

2.8.8.2 *The system for handling nonconformities in the Navy*

Section 4.12 of the directive on requirements for safety management in the Norwegian Armed Forces describes requirements for handling undesirable incidents and nonconformities in the Norwegian Armed Forces. As part of its safety management, the Navy has established a process for reporting undesirable incidents. Among other places, this is described in instructions relating to the requirement for safety management in the Navy,[106] in instructions for incident handling in FIF,[107] and in a procedure for incident handling in FIF 3.0 in the Navy.[108]

The following is stated in the instructions relating to requirements for safety management in the Navy:

> *All undesirable incidents and conditions that the organisation can draw lessons from, or use as a basis for improvements, are to be reported in the Norwegian Armed Forces' reporting system*.

The instruction also state that a safety coordinator shall be appointed with responsibility for keeping an overview of reported cases and coordinating case processing. All naval branches are required to have a safety council for continuous improvement work; see the procedure for safety councils in the Fleet (*Prosedyre for sikkerhetsråd i Marinen*). The position of safety coordinator for the frigates was vacant in autumn 2018 and was not filled until after the accident. The safety councils shall seek to meet three times a year. In 2018, there was only one meeting of the safety council.

According the Norwegian Armed Forces' instructions, incidents shall be reported in the Norwegian Armed Forces' Defence Integrated enterprise resource planning (ERP) system (FIF), which is implemented in SAP. According to the instructions, the Norwegian Armed Forces' Chiefs of branches and joint departments and their direct subordinates

[106] *Instruks for krav til sikkerhetsstyring i Sjøforsvaret*, 1 November 2016
[107] *Instruks for hendelseshåndtering i FIF*, 20 June 2016
[108] *Prosedyre for hendelsesbehandling i FIF 3.0 i Sjøforsvaret*, 12 October 2016

shall establish routines and procedures as necessary to follow up and assure the quality of incident handling in FIF within their own organisation.

Sections 2.8.11 and 2.9.8.4 describe challenges relating to the nonconformity system.

2.8.8.3 *The nonconformity system in the NDMA Naval Systems Division*

The Naval Systems Division has described the process for handling nonconformities in its management system in the document *S7 Registrering av avvik*. Among other things, it describes how different types of nonconformities are to be registered and followed up in the Naval Systems Division, including how nonconformities after seaworthiness inspections, materiel inspections, materiel safety reviews, quarterly reports, supervision by the Norwegian Armed Forces Materiel Safety Authority, modifications or incidents in the Navy are to be registered, and by whom.

IFS is used as the software for registration and handling of nonconformities.

The document goes on to state that, based on a risk assessment of the nonconformity, the need for issuing a corrective action order (CAO) shall be considered.

Sections 2.8.11 and 2.9.7.6 describe challenges relating to the nonconformity system.

2.8.9 Competence management

2.8.9.1 *Introduction*

Regulations of 22 December 2011 No 1523 on qualifications and certificates for seafarers, in the pursuance of the Ship Safety and Security Act §16, applies for the defence sector, see section xx. Competence requirements for the Norwegian Armed Forces are described in section 4.8 of the directive on safety management in the Norwegian Armed Forces. Competence is an important element of safety, and competence requirements shall be defined and described as part of the safety management system. Competence requirements are intended to ensure that all ship personnel have the training and qualifications necessary to carrying out the tasks with which they are charged in a safe and proper manner.

In this way, the Navy shall ensure that every vessel is manned with qualified, certified and medically fit personnel in accordance with requirements provided for in both civil and military regulations, and requirements for instruction, training and formal clearances. Responsibility for competence management is delegated to the head of the Navy’s personnel section (N-1) (described in *Instruks for Sjef N-1 i Sjøforsvaret*).

The Navy claims that, even if individuals are replaced, the ‘collective competence’ will largely be maintained as long as no major replacements are made in a sub-team or team. In turn, this means that operational deployment of new recruits to a sub-team/team can take place quite soon.

This section describes those aspects of competence management in the Navy that have been found to be particularly relevant to the HNoMS ‘Helge Ingstad’ accident.

2.8.9.2 *Competence management tool*

FIF is used as the tool for competence management in the Norwegian Armed Forces. However, at the time of the accident, the code regime for competence management for the frigates had not yet been fully implemented. It was not possible to view a list of the vessel's total competence needs in FIF, which only allowed for viewing the competence of individuals. This was because the system did not support the respective levels of detail.

Findings from annual management reviews of the safety management system also showed that shortcomings/nonconformities had been reported for several years relating to competence management and the vessels' possibility of getting the required overview of competence status, competence requirements and related nonconformities (for further details, see section 2.8.11). In the absence of a functional tool for competence management, the vessels therefore prepared their own overviews showing the competence of the ship's crews and each unit/branch.

2.8.9.3 *Lean Manning Concept (LMC)*

In 2004, the Navy drew up a manning concept based on LMC for the frigates[109]. The description includes the following wording:

> *Among other things, LMC entails that Norway operates frigates with a crew of approximately half the standard crew size in NATO. The manning concept is nonetheless a solution for nations with limited budgets, where costs are assigned relatively great importance in relation to purely operational needs.*
>
> *If the assumptions behind the manning concept fail, the Fleet's ability to produce combat-ready units will be reduced.*

The manning concept for the frigates describes LMC as a vulnerable concept with several intrinsic limitations. The limitations have only minor consequences as long as the assumptions behind the concept hold true. The most important requirements that must be met in order for LMC to produce necessary combat power and performance are described in the concept and broken down into four groups:

- Activity-based requirements
- Personnel-related requirements
- Technological requirements
- Doctrine-related requirements

[109] The concept includes the frigates, helicopters, associated support systems and weapons, as well as the associated organisation

Some of the most important requirements described for the concept are listed in Table 2.

Table 2: Requirements for LMC. Source: The Navy

Requirements for LMC	
Requirement type	**Description of requirement type**
Activity-based	- LMC is based on the assumption that NATO's minimum requirements for the operative capacities of naval forces are complied with. - Efficient when sailing. Balanced activity programme whereby the vessels do not sail more than strictly necessary to establish or maintain the branch's operative capacity. The concept requires extraordinary effort on the part of the crew. - Efficient when stationary. LMC is based on the assumption that the scope of non-productive activity is reduced to a minimum.
Personnel-related	- Competence and experience management. The concept requires active and targeted personnel management - LMC is conditional on meaningful service during which personnel are offered opportunities for becoming professionals in their multi-functional work areas. - LMC is conditional on the vessels being supplied with a sufficient number of personnel with the requisite competence and operative experience at all levels of the organisation. The sailing frigates' capacity to perform and operate efficiently is therefore dependent on their ability at all times to man all functions with personnel having the requisite competence and level of experience. - LMC requires the establishment of organisational redundancy for handling vacancies. Vacancies entail a change of focus from operational to administrative tasks. The vessel's combat capabilities are immediately reduced, regardless of the level at which the vacancy occurs. - LMC is conditional on the crew having advanced academic qualifications. - LMC requires continuous team-building over time. - LMC relies on the assumption that each officer is over-qualified for the tasks of his subordinates, qualified for his own tasks and understands the tasks of his superiors. - Conceptually, LMC is hardly family-friendly and it requires that the personnel are highly motivated for the service on board.
Technological	- LMC is conditional on the vessel being adapted for operation by a minimum crew. This applies in particular to ship design, ship support systems and the degree of automation. A high degree of automation, particularly relating to damage control and technical operation of the ship, will reduce the work load on personnel.
Doctrine-related	- LMC is based on the manoeuvre doctrine and requirements for mission-based leadership. All officers on board must therefore be capable of independent action at all times in accordance with the CO's command aims and not depend on orders and directives.

2.8.9.4 *Manning plan*

Based on the manning concept for the frigates, a manning plan has been prepared for the Nansen-class frigates that describes how to man the combat systems and what competences are required.

The manning plan refers to important preconditions for the use of LMC. An excerpt from the manning plan is copied in here:

> *LMC describes the minimum crew, which is primarily dimensioned on the basis of the Norwegian Armed Forces' ambition to keep operating costs as low as possible. Hence the manning concept was not chosen as a result of being the operationally smartest and most efficient solution.*
>
> *LMC manning is optimised for the purpose of addressing the primary tasks on board and does not include redundancy; instead, many positions on board cover several function areas and are assigned additional tasks. This multi-functionality, combined with marginal manning, means that the vessel's operative combat capacity is directly based on qualitative as well as quantitative personnel production, where motivation, attitudes and levels of competence and experience are all critical factors. Multi-functionality places strict requirements on education, instruction and training, and entails a high workload and extensive effort. This could mean that individuals may be pushed to the limits of their capabilities. The concept is therefore basically neither personnel-friendly nor family-friendly.*
>
> *The combat system is extremely sensitive to vacancies. Vacancies and absences have an immediate impact on the system's combat capabilities at all levels of the organisation.*
>
> *The established multi-functionality makes it difficult to assign further tasks without adversely affecting the vessel's combat capabilities and endurance. This means that it will not be possible to realise the goal of continuous operation in all functions without weakening the vessel's endurance.*

The manning plan goes on to describe what manning is necessary on board the frigates. The most recent manning plan was from 2016. It states that it is the competence council that must be in control of any competence nonconformities. The following is described, among other things:

> *The frigate branch has established a competence council and pertaining procedures for handling nonconformities between 'must' requirements in job descriptions and the personnel's competence. The council was set up for the purpose of assessing the risk associated with any assignment of persons who do not meet the qualification requirements. The competence council shall keep continuous control of the status with respect to courses completed, and certificates and clearances held by each crew member, compared with the formal requirements of job descriptions and competence criteria. Potential nonconformities shall be considered by the council.*

The manning plan goes on to describe how personnel councils must be in control of competence management across the frigate crews. The following is stated, among other things:

As a basis for optimum competence management across the frigate crews, branch personnel councils shall be held whenever it is deemed necessary – at least every six months. The personnel councils also serve the purpose of ensuring that executive officers and department managers on board have a uniform perception of the facts relating to personnel status (with respect to individuals and the crew as a whole). Good dialogue between the ship management teams and the N1 section is important in order to realise desired synergies. The personnel councils are fundamental to the planning of postings/assignments internally and across crews, based on branch-wise career and service plans.

2.8.10 Instruction and training in damage control situations

2.8.10.1 *Royal Norwegian Navy Training Establishment KNM Tordenskjold*

The KNM Tordenskjold naval training establishment (KNMT) is responsible for all function-oriented instruction, sea training and reviews/final inspections of navy personnel. Regulations of 22 December 2011 No 1523 on qualifications and certificates for seafarers, in the pursuance of the Ship Safety and Security Act §16, applies for the sea safety part of this training.

Through function-oriented instruction, KNMT aims to ensure that navy personnel gain sufficient discipline skills and in-depth competence. KNMT is also responsible for sea training and reviews/inspections of vessels and crew. KNMT consists of five centres organised under the Chief of the Fleet.

Up until 2016, the frigate branch was responsible for support to and control of the frigates. When the Navy was reorganised in 2016, the frigate branch as an organisational element was removed, which also meant that the frigate branch's training centre (FFVTS) was closed down. The tasks of FFVTS were transferred to the Fleet Warfare Centre and the Centre for Naval Engineering and Safety (NSC), both departments under KNMT. Other tasks, such as planning and follow-up of resources, were taken over by other Navy units. Much was followed up and seen to by the vessels themselves, however.

The NSIA has been informed by the Navy that the commanding officer is required to continuously assess the crew's training level and may, if necessary, report on any need for training support or courses. The commanding officer is responsible for maintenance of necessary skills. The Chief of the Fleet may order a new inspection of the vessel if a low level of training is suspected.

2.8.10.2 *The sea training concept (OPUS)*

The crew on the Nansen-class frigates are evaluated as they follow a structured practical safety training path in accordance with the Navy's training concept OPUS. The path consists of exercises and tests related to different topics through OPUS levels I to VI and results in a safety review at OPUS level III, followed by a final inspection at OPUS level V;[110] see Table 3.

[110] The final inspection is a test of what the vessel as a whole is capable of compared with the requirements that apply to a fully operational frigate.

The purpose of OPUS is training, organisation and equipment of forces[111] (crews and materiel) to a high standard, so that they are capable of performing national and international assignments. It is the Commander of KNMT who, on behalf of the Chief of the Fleet, quality assures that the crew and materiel achieve the objective defined for each OPUS level; see Table 3.

Table 3: Description of OPUS level. Source: The Norwegian Navy

<table>
<tr><th>Level</th><th>Primary objective</th><th>Inspection/review</th></tr>
<tr><td>OPUS I</td><td>Safe operation of the vessel alongside the quay. Personnel and materiel ready to set to sea. Team competence and condition of materiel assessed as being SAFE on completion of NorMASC.[112]</td><td rowspan="3">Safety review</td></tr>
<tr><td>OPUS II</td><td>Basic operational sea training for safe passage.
Completed structured, safe and targeted training towards OPUS III.</td></tr>
<tr><td>OPUS III</td><td>Passed checks in fire and damage control, navigation, machinery, electro, seamanship and medical support for safe passage during peacetime operations.
The combat platform is capable of addressing national missions, including safe operation of all sensors and weapons.</td></tr>
<tr><td>OPUS IV</td><td>Completed targeted training in internal and external combat with a view to optimum preparation for NorOST[113] at OPUS V level.</td><td>Training for final inspection</td></tr>
<tr><td>OPUS V (NorOST)</td><td>Passed final inspection at FOST (Flag Officer Sea Training) in the UK with the grade ‘Satisfactory’ or better. Ready for combat and participation in international operations.</td><td>Every four years: Final inspection (renewed clearance after 18 months)</td></tr>
<tr><td>OPUS VI</td><td>Adapted to sea training and evaluation (review) for completing specific assignments or maintaining skills in specific areas.</td><td></td></tr>
</table>

According to the KNM Tordenskjold naval training establishment (KNMT), OPUS does not contain requirements for a certain number of damage control exercises or their content, but exercises in handling complex damage control scenarios shall normally be conducted once or twice a year while the vessel is at sea. In addition, exercises shall be completed in individual skills, including in the candidate’s own discipline and as part of a team.

[111] All activities that contribute to making military resources ready for deployment in accordance with operational requirements, and that contribute to such resources being capable of completing the missions assigned. This includes education and training, the development of tactics, organisation of forces and specification of materiel resources. Training, organisation and equipment of forces takes place through day-to-day activities and in connection with building up combat force.

[112] NorMASC = Norwegian Material and Safety Check, carried out to assess crew competence level

[113] NorOST is completed at FOST in the UK

2.8.10.3 *Completion of OPUS for HNoMS 'Helge Ingstad'*

HNoMS 'Helge Ingstad' was manned from 1 August 2016 and completed OPUS as shown in Table 4.

Table 4: Overview of sea training programme (OPUS) for HNoMS 'Helge Ingstad'

Level	Completion of sea training programme (OPUS) for HNoMS 'Helge Ingstad'
OPUS I	Completed August–November 2016
OPUS II	
OPUS III	
OPUS IV	Completed autumn 2017
OPUS V (NorOST)	Completed NorOST at FOST in the UK January–March 2018, achieving the grade 'Very satisfactory'.
OPUS VI	Not relevant to the incident under consideration.

As part of the sea training, an activity (referred to as F7) was carried out for the purpose of preparing the crew for handling major and complex damage control situations at sea. An activity was also carried out that entailed emergency operation of technical systems, the purpose of which was to enable the crew to operate various technical systems and have procedures in place for safe emergency operation.

2.8.10.3.1 <u>Relevant findings from the KNMT report following the safety review in 2016</u>

- Support from the shore-based organisation during the period of sea training had been considerably poorer than desired. This meant that there had been no support for training in discipline areas that would subsequently be subject to review. Limited access to qualified personnel and the reorganisation in 2016 were mentioned as reasons for this.

- The level of experience was described as highly variable, with low priority with regards to manning and a recently composed crew. It was pointed out that there were nonetheless experienced personnel on board and that the crew were conscientious and willing to learn.

- Two findings were made concerning closure of watertight doors and fittings during fire and damage control exercises. In exercise 03 (fire), the CO ordered equipment protection level ZULU, but a critical finding was documented in that not all doors were properly closed. In exercise 06 (flooding and fire), it was pointed out that, 'up*on abandoning ship, large parts of the vessel were left open. It is advantageous to close down the vessel when she is abandoned*.'

- It was concluded that OPUS I–III had been completed with all checks being passed.

The NSIA has requested relevant scripts (detailed descriptions of exercises/scenarios) and evaluation forms for relevant damage control scenarios from the OPUS sea training programme, but these have not been saved in the Navy's systems and are thus unavailable.

2.8.10.3.2 <u>Relevant findings from the FOST reports following final inspection, NorOST 2018</u>

After the five frigates had completed NorOST over a five-year period, FOST prepared a summary of main priorities for each frigate. In the case of HNoMS 'Helge Ingstad', the following were described as two of five main priorities:

- *Resolve issues surrounding the Ship's automated stability calculator in IPMS which prevent it from supporting the Command in the event of a major flooding accident.*
- *Owing to the high turnover rate of conscripted personnel, HING will need to focus on integrating the crew members to ensure that skills and standard operating procedures (SOPs) refined during OST are not significantly diminished.*

Furthermore, the following was concluded regarding all five frigates:

- *Poor stability management and calculation*

2.8.10.3.3 *Relevant findings from the KNMT reports following final inspection, NorOST 2018*

- The frigate was manned without vacancies and with experienced and qualified personnel in all management positions. It was pointed out that there was a need for increased manning in parts of the damage control organisation and for reallocation of personnel in order to handle complex damage control scenarios.
- The crew had received minimum sea training support during the OPUS IV period. It was pointed out that the crew were nonetheless highly motivated and able to operate independently with a view to internal training.
- Reports show that basic knowledge, particularly relating to fire and damage control, could have been better.

2.8.10.4 *Sea training and status after NorOST 2018*

According to the Navy's internal investigation report,[128] 51 crew members had been replaced after NorOST in 2018. That corresponds to 37.5% of the frigate's crew at the time of the accident. In spring 2018, a planned two-month period of maintenance, base, inspection and certification (VBKS) was completed at Haakonsvern before the crew resumed sailing and were tested in a FORACS[114] check, followed by the *Shark Hunt* exercise in the Northern Norway and subsequent sea training for NATO service.

According the Navy's internal investigation report;[128] it emerged that, after NorOST, the frigate sought to maintain its exercise level through conducting at least one comprehensive exercise every week while at sea. The exercises were to involve the crew as a whole and focus on combat (action stations exercise), damage control or a combination of the two. The exercises were documented in the vessel's exercise logs. Shipboard training was not registered in any central competence management system.

In September 2018, HNoMS 'Helge Ingstad' became part of SNMG1 (Standing NATO Maritime Group 1). This meant that the possibility of conducting exercises involving the crew as a whole were fewer than planned and that it was difficult to conduct activities requiring emergency manoeuvring (loss of propulsion and loss of steering). Nonetheless, according to the exercise logs, one damage control exercise involving the whole crew was nonetheless conducted every month from August to October 2018.

[114] FORACS (Forces Sensor and Weapon Accuracy Check Site) is a ship testing and calibration site.

As there were fewer major exercises, the training level had to be maintained by means of Sub Team Training,[115] and this is reflected in the frigate's exercise logs. Sub Team Training consists of exercises in which individual parts of the ship's organisation conduct exercises in their respective areas under the leadership of individual team leaders. In addition, the frigate participated in Trident Juncture 2018 (TRJE18) from August to November, which also meant that the number of activities involving the crew as a whole was lower than planned. As a result of the above, coordinated training of the vessels damage control organisation was reduced and there was less training of the vessel's damage control management organisation than previously.

It some of the interviews with crew members from HNoMS 'Helge Ingstad', it emerged that, prior to the accident, there had in practice often been too little time to practise damage control scenarios in which multiple things went wrong at the same time. A demanding sailing programme often stood in the way of the crew being able to stop the ship in open waters and simulate loss of propulsion and steering, possibly in combination with other exercise elements. When carrying out damage control exercises, it was desirable to take account of the sailing programme as well as the crew's need for rest. As a result, the exercise scenarios were often limited and adapted to those needs.

2.8.10.5 *Function-oriented instruction, courses and training at the KNM Tordenskjold naval training establishment*

The NSIA has requested information about what function-oriented instruction, courses and training were available at KNMT for the crew on board HNoMS 'Helge Ingstad' prior to the accident. This is described for the relevant systems in the following sections.

Please note that in the wake of the accident, KNMT NESC has revised and adapted several courses; see section 2.11.3.

2.8.10.5.1 *Navigation and bridge systems*

Following the reorganisation of the Navy in 2016 and closing down of the frigate branch's training centre (FFVTS), there were hardly any vessel-specific courses in navigation and bridge systems. Where such courses was held, they were held on the initiative of the individual ship/squadron. In such cases, the Navy's topmost competence centre for navigation (NavKomp) supported the initiative by providing instructors and also beeing responsible for checking the ship's navigational competence level. The KNMT did not offer vessel-specific training over and above generic training to cadets in simulators and on schools ships.

All OOWs taking sea watches should also be checked in the three-part evaluation of navigational competence in accordance with the OPUS cycle and tables. The check comprised practical sailing skills and theoretical tests, and paid little attention to competence in navigation and propulsion systems.

2.8.10.5.2 *Rudder and propulsion systems*

There had been very few vessel-specific courses in rudder and propulsion systems for navigators.

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[115] Sub Team Training is an activity for the purpose of training specific sub-teams or organisations

Engineers started their vocational training by attending a foundation course at KNMT NESC. The foundation courses included general information about the vessel design and mode of operation, including a brief introduction to the rudder and propulsion system.

KNMT NESC did not offer any vessel-specific instruction or training in rudder and propulsion systems for personnel assigned to the frigates before they took up service on board. This was meant to be addressed by the vessel's crew through OPUS. Nor did KNMT NESC offer any specific IPMS courses. KNMT NESC had a complete IPMS-simulator at its disposal, which, according to KNMT, was used sporadically by the crew.

During inspections/reviews, the focus was not on individual competence, but rather on testing collective competence through exercises to verify that the ship's competence was adequate overall. Checks were carried out of watch teams, in addition to random checks of individuals.

In connection with OPUS I to OPUS III, KNMT normally provided both practical and theoretical support relating to rudder and propulsion systems, and the vessel was required to independently perform emergency procedures on the various systems. Knowledge of rudder and propulsion systems was only checked to a very limited extent during normal operation, as this was presumed to be well-known on gaining clearance as an OOW. In connection with safety inspections, the focus was on checking emergency procedures for steering and propulsion, and on seeking to test all the watches (normally based on a 3-watch system) in these areas.

2.8.10.5.3 Intact and damage stability

According to KNMT, requirements for navigators' stability competence were defined in STCW. Furthermore, the Navy's need for such competence was described in Royal Norwegian Naval Academy's courses 'Design, stability and buoyancy' and 'Loading, unloading and stowing at the operational and management level'. NavKomp did not offer any vessel-specific courses or training in intact and damage stability.

According to KNMT, requirements for engineers' stability competence were defined in STCW. KNMT NESC offered technical courses in frigate damage control. The Navy's MEO courses were mandatory in order to become a MEO, and intact and damage stability was a part of the course. The NSIA has been informed that stability was sometimes given low priority because of operational needs. Hence it cannot be guaranteed that all MEOs have received such instruction, even though it was a requirement.

KNMT NESC did not offer any vessel-specific courses covering only stability. Stability handbooks for the relevant vessel class were, however, handed out and tasks from these were given in other courses.

The individual navigator or engineer officer's stability competence was not tested as part of the OPUS programme. In connection with the safety review (OPUS III) and general inspection (OPUS V), the ship management's understanding of stability challenges was tested during damage control exercises (peacetime scenarios) and combined combat/damage control exercises (wartime scenarios). During these exercises, it was primarily the damage control officer, MEO, CA and CO, alternatively the first engineer and XO, who were to assess the consequences of flooding for stability. The carpet plot from the stability handbook for the Nansen-class frigates (SJP-2000) was used for this purpose (SJP-2000).

2.8.10.5.4 *Equipment protection level and marking system*

Knowledge of what to close down and how it affects stability were covered by KNMT NESC's basic boating course, which must be taken by all crew members before they serve on board. This knowledge was then to be followed up on board, including through the exercise programme.

SMP-17 (B) describes the impact of closing off systems and the importance of complying with the ordered equipment protection level in order to safeguard the vessel and crew against the spread of inflowing water, smoke and hazardous gases. The marking plan that applied to HNoMS ‘Helge Ingstad’ is described in section 2.6.2.5.

2.8.10.5.5 *Communication systems*

Training in different communication systems on board was provided as part of KNMT NESC's basic boating course. This knowledge was then followed up on board, including through the exercise programme.

It has emerged from interviews that, prior to the accident, exercises were seldom held in which several or all means of communication were unavailable at the same time. This was because the concurrent failure of all means of communication was deemed to be unlikely. Regular exercises were held to deal with the loss of individual means of communication, in which alternative means of communication were employed when the primary means of communication became unavailable.

2.8.10.5.6 *Bilge system*

KNMT NESC did not offer any courses that specifically addressed the bilge system, but it was reviewed in general common courses, for example the basic technical course for frigates. No simulator training was available for navigators to practise how to address error modes/damaged bilge system.

No specific competence checks were carried out relating to bilge systems. Such competence was subject to a general check as part of the safety review of the crew as a team. No check was carried out of whether individuals were in possession of such competence. In some cases, checks were carried out of individuals' operational/task-solving abilities.

Tests were normally not conducted of individuals' knowledge of competence relating to the bilge system, but personnel in the ship's technical department were tested in their understanding and use of the system during damage control and combined combat/damage control exercises in connection with the safety review (OPUS III) and general inspection (OPUS V). At the same time, it was also part of the training and clearance regime for all personnel in the ship's technical department. They were required to be capable of both understanding and using these systems before they were cleared.

2.8.11 Findings from annual management reviews of the safety management system

The Fleet management conducts annual reviews of the Navy's safety management system. The review is based on input from the various ship commanders and heads of department. The management reviews of the Nansen-class frigates for the final three years preceding the accident (2016–2018) show that the following was reported, among other things:

<u>Personnel and resources</u>

- Lack of consistency between job instructions, manuals, competence needs and available instruction/courses.
- One ship reported that a substantial amount of work had been carried out to define competence requirements for all positions on board, but that compliance with these requirements was unfortunately poor.
- No expedient tool existed to get an overview of a vessel's competence requirements or to verify that the vessels were actually manned with the requisite competence.
- No good tool/system is available for following up competence nonconformities.

<u>Documentation</u>

- It takes too long for changes to be implemented in the manuals.
- In particular, the quality of the ship's technical manuals is too poor and it is not used much on board.
- Following the reorganisation of the Navy, there is uncertainty about who should follow up and actually update the manuals, as the staff unit that used to see to this is discontinued. Some uncertainty also prevails about where the most recent version of the manuals can be downloaded from. It is perceived as a challenge that this task is transferred to an operative seagoing vessel.
- One vessel expressed concern about the new organisation of the Navy. The question was raised whether the new organisation would be capable of continuing to update the manuals and provide sufficient support for sea training and exercises.
- Some frigates reported that shore-based personnel lack the knowledge, experience and time to follow up the documentation work. Where major revisions are required, the frigates lack the time/capacity to do so alone.

<u>Incident reporting</u>

- How to report incidents is largely known, but there is an expressed wish to learn more about the use of incident reporting in FIF 3.0. Some frigates call for clear guidelines on the incident reporting process. Opinions vary with respect to whether all undesirable incidents are reported.
- Opinions varied as to whether the frigates received sufficient response to reports of undesirable incidents.
- The individual frigate would like to see that more of the actions taken after reported incidents were formally published by the NDLO/NDMA and that an overview of actions was made available.

- The safety council has been reported to function in that cases are elucidated. Some actions seem to be stopped in the system, however, somewhere outside the control of the frigates, and it is questioned whether this is due to lack of funds or because the incidents/actions are not taken seriously enough.

2.8.12 Findings from DNV GL's safety study

As part of the Norwegian Armed Forces' internal investigation of the HNoMS 'Helge Ingstad' incident, DNV GL conducted a survey of the safety culture in the Fleet and among the Navy's executive staff. The work was documented in a separate report[116] in 2019. See also the report from Part 1. The report identified three basic assumptions, which were used to describe strengths and challenges relating to the safety culture of the Fleet and Navy's executive management; see Figure 66.

BASIC ASSUMPTIONS IN THE CULTURE

1. **Our work consists of taking risks in connection with operations and exercises**
2. **Safety is ensured through our procedures and good preparedness**
3. **Safety is always ensured at vessel level**
4. **We always strive to perform well in operations**
5. **I want to perform well and be promoted**
6. **Clearance is proof of competence**
7. **We have full control**
8. **Distinctions and promotions are based on good performance during operations and exercises**
9. **Our rules may be deviated from**

Figure 66: Nine basic assumptions identified in the report (Norwegian only). Source: DNV-GL

Some relevant findings from the report are cited below. They are based on the crew's perception of own safety culture:

Procedures:

> *Safety is perceived as being adequately integrated through procedures and highly competent individuals. Safety is also perceived by personnel as being ensured through good preparedness in that individuals are given training and exercises in coordinated action with others, for example for the purpose of fire and damage control. The purpose of training and exercises is for individuals to assimilate characteristics that enable them to handle different unforeseen situations so that military and operative functions can be maintained.*

Great trust in the use of procedures to ensure safety was also identified as a challenge associated with the safety culture, however:

[116] Norwegian Defence Logistics Organisation (NDLO): *Kartlegging av sikkerhetskultur i Marinen og Sjøforsvarets ledelse*, report no. 2019-5227, dated 19 June 2019.

Safety is ensured through our procedures and good preparedness – common/known risks can be ignored.

In general, the personnel feel that they have been properly instructed in the importance of staying alert at all times in order to be able to correct errors and make necessary changes as you go, particularly when the work situation changes. They are encouraged to stay alert and to think 'what if?'.

Even if they have been trained to check against a plan or procedure, they do not always perceive the necessity of looking out for the unexpected or of continuously using new information (over and above plans and procedures) to adjust their own and other people's decisions.

Command and control:

They have great trust in each other and in officers and the ship management. To questions relating to how they address safety, the conscripts typically reply that 'Our superiors have full control and know what they are doing'. As a result of good competence building, the clearance system and specialised training, each individual places great trust in himself and others to perform tasks properly and safely.

The Navy is also very good at building trust in the individual's own abilities. There is careful selection and assessment for different roles, on the part of the basic training establishment and upwards through the organisation. Together with high requirements for instruction, training and exercises, this creates a strong perception of and confidence in being able to handle different situations individually and together.

Weaker competence management:

Several people have pointed out that follow-up and management of competence has become more of a challenge because the task of updating information about competence is now assigned to the individual ship. Up until the reorganisation in 2016, this was done by a dedicated shore-based unit. The competence management system is complex and not very user-friendly. This has resulted in ships having chosen to use their own documents to keep an overview of competence.

Decentralisation can weaken competence management. The challenge becomes even greater when the task is transferred to ships that have limited capacity to perform this task. Weaker competence management will weaken the ability to maintain and build robustness in the organisation. This is a challenge that is common to all vessel types, with the exception of those belonging to the submarine branch, where shore-based support for competence management has been retained.

Fragmented safety management responsibility:

The major reorganisation that was carried out in 2016 has had positive effects in the form of more days of sea service. The vast majority have mentioned that the changes have affected their workday, particularly in terms of their capacity for performing new tasks they have been charged with as a result of the reorganisation. Nobody has confirmed that an evaluation was carried out of how the changes could have negative impacts on safety work and safety management. During the interviews, it was pointed out in particular that shore-based support resources had been *weakened, at the same time as tasks had been transferred to the squadrons and vessels.*

It is potentially a major challenge that extensive organisational, task or capacity changes can lead to substantial loss of safety management. Failing to consider what will be affected by a planned major change entails a risk of losing something that works well. Possible examples are loss of special competence in risk and safety disciplines, on which the organisation depends, loss as a result of tasks being transferred to persons who lack the competence or time to perform them, or loss of information about risks whereby overviews are lost.

Rules and regulations and compliance:

As a result of the possibility of using exceptions under current regulations, together with lack of clarity on the part of the Navy about how to observe and apply rules and regulations, many people feel that 'the rules and regulations do not apply to us'. This cultural aspect can affect the safety of personnel and vessels in that it underpins the perception that 'it is acceptable to push the limits to deliver on our commitments', and thereby, without being aware of it, exceed what would have been the acceptance limits or tolerance criteria for risk. The possibility of building understanding and knowledge of risk acceptance criteria is lost if no criteria exist against which to measure the progress made. Intentional and documented breach of an acceptance criteria, and making an informed decision about the risk entailed, would provide a better basis for learning and understanding risk than 'breaching the limits' without being aware of it as a result of 'diffuse and invisible limits'.

Learning from incidents:

Lack of processing of near-misses as a result of vacant positions prevents uniform follow-up and assessment of improvement potential in addition to sending an unfortunate signal to the vessels regarding the importance of reporting near-misses.

The above observations can, as a result of unreported near-misses, deprive the Navy of important information regarding the risks perceived by the vessels. This could result in there being no or only a limited basis for assessment and for implementing necessary risk reduction measures to prevent incidents in future.

The Navy appears to have no system in place to actively use feedback from incident reporting to learn and improve safety management in an overall, consistent manner. Organisational learning refers to systematic reflection on improvement potential, both at the individual and organisational level. It appears that much of the responsibility for learning is left to the vessels themselves, and that lessons learnt are not necessarily passed on to the rest of the vessel group or the rest of the organisation.

2.8.13 The Auditor General's findings

The Office of the Auditor General (OAG) has investigated the frigates' operative capacity. According to the report[117] the purpose of the investigation was to determine whether the Norwegian Armed Forces had established frigates in line with the Storting's

[117] *Riksrevisjonens undersøkelse av fregattvåpenets operative evne, Ugradert sammendrag av Dokument 3:13 (2015–2016)*

decision, and clarify the reasons for any weaknesses or shortcomings and their consequences for the branch's operative capacity. Findings of relevance to the HNoMS ‘Helge Ingstad’ incident are cited below:

- *There are weaknesses relating to the technical condition. In addition, the personnel and competence situation is a challenge. There are differences in technical condition, manning and competence between the frigates. The vessels with the highest priority are in best condition, but there are weaknesses on all the vessels. The OAG considers this to be a serious matter.*
- *The OAG is also of the opinion that it warrants criticism that the Ministry of Defence has failed to adequately secure a balance between missions and available resources in the Norwegian Armed Forces in line with the intentions of the Standing Committee on Foreign Affairs and Defence.*
- *In Proposition to the Storting No 384 (2012–2013), the Committee stressed the importance of using a realistic personnel framework and striking a balance between tasks and the need for personnel.*
- *Personnel coverage is low compared with the current level of ambition. Challenges relating to key personnel with critical competence weaken the amount and quality of the training. There are also challenges related to complementing the core crew in connection with missions that are demanding in terms of personnel.*
- *The basic training for the frigates is good, but it is a challenge to maintain the level of training over time because of personnel rotation within the fleet structure. There are plans for a transition to a team structure, where the crew will be kept together for longer than they do at present. The OAG believes that this can reduce the challenges relating to manning.*
- *Sufficient sea training and instruction are important for building competence among the crew. In the case of some of the ships in the fleet structure, the training status is rather poor according to internal reports.*
- *The OAG considers the deficiencies relating to manning, competence, sea training and instruction to warrant criticism.*

As a consequence of these findings, among others, measures were enacted in the Navy whereby shore-based personnel were re-assigned to the vessels; see also section 2.8.10.3.1.

2.8.14 Leadership, command and control in the Navy

2.8.14.1 *Introduction*

This section provides a description of relevant aspects of the Norwegian Armed Forces’ leadership philosophy and what it entails. This is important to be able to understand cooperation and interaction on board.

2.8.14.2 *Background*

In military history, the relationship between central coordination of own divisions' efforts and the ability to make changes and adapt to the war situation as it changes has been the subject of discussion for more than 200 years.

According to the document setting out the Chief of Defence's leadership philosophy (*Forsvarssjefens grunnsyn på ledelse i Forsvaret* – FGL) (Norwegian Armed Forces, 1 June 2012), the avalanche accident in Vassdalen valley in Nordland in 1986 inspired a similar discussion in the Norwegian Armed Forces, where one of the main questions was the relationship between central control and local adaptation:

> *Is it expedient for the Norwegian Armed Forces to have a rigid form of organisation and chain of command whereby a local commander must ask for permission to change an assignment that he or she considers to represent a danger to life? Should it not be possible for the person on site, with the best overview of the situation, to order personnel to leave the area?*

The debate led to a reform of the military leadership philosophy and practice, and mission-based leadership (MBL) (also known as 'mission command') became one of the cornerstones of the new philosophy. Accordingly, it became the new ideal for all military leaders to think and act independently in accordance with their superior's command aim: 'The right action at the right time in the right situation'. The leadership philosophy document summarises the preconditions for 'right action at the right time' in the context of MBL in one sentence:

> *Executing a mission in a complex context requires a clear aim, good situational awareness and decentralised leadership to ensure that the right action is taken at the right time (p. 7).*

2.8.14.3 *Education*

The Norwegian Naval Academy trains its cadets to practise mission-based leadership (MBL). What this entails is described in the Navy's leadership training philosophy ('Man the Braces! Naval Operational Leadership and Leadership Training. Leadership training philosophy of the Royal Norwegian Naval Academy, Bergen 2009):

> *MBL is based on the assumption that, in most cases, a decentralised organisation is the most expedient way to achieve the flexibility required to deal with the uncertainty of operations. MBL has room for initiative, flexibility and speed to tackle shifting circumstances in a coordinated manner. The philosophy also provides for the possibility of utilising the creativity of the entire organisation, not just among the commanders, which is conditional on mature teams. The objective is for the person with the best overview of the situation (situational awareness) to act independently in accordance with the command aim. MBL entails that subordinates are assigned a mission they need to find out how to solve in accordance with their superior commander's intention (p. 44).*

2.8.14.4 *Command aim*

The Naval Academy's leadership philosophy (2009) states that:

> *The governing principle of MBL is the mission. The intent is the glue that makes the entire organisation act co-ordinated. It is therefore crucial that the teams obtain a common understanding of the intension (p. 45).*

2.8.14.5 *Trust*

The Norwegian Armed Forces' maritime operations doctrine (Naval Staff, 2015, Bergen) emphasises that:

> *The cornerstone of military leadership based on mission-based leadership is trust. Trust is the key to decentralisation, to unplanned interaction, the key for taking advantage of competence, the key for initiative and vigour. Trust must exist on different levels – it has to be personal between those who interact personally, rooted in a common dedication to each and the mission to be solved. The necessary willingness to assume responsibility is also included here (p. 123).*

2.8.14.6 *Command and control (K2)*

The Chief of Defence's leadership philosophy defines what lies in the two fundamental concepts of command and control.

Control entails a continuous overview, direction and coordination of the units by whom the mission is being solved. This includes collection, processing and exchange of information, so as to ensure that everyone has the same picture of the situation. Control also entails use of information for planning and executing a mission.

Command means that the 'commander leads through a combination of leading by example, persuading and commanding' (p. 6). Through formally assigned power (rank, position), the commander leads by making decisions that translate his own superior's command aim into effective action. In the leadership philosophy document, leadership is defined as 'influencing subordinates to solve the mission'.

The technical expertise at the Naval Academy in Bergen defines command as the formal authority of a military leader to assign tasks to subordinate units. The concept of control also covers the question of how a leader is to receive information about the status of the battles, so that he can coordinate and correct the actions taken, i.e. give appropriate orders adapted to the course of events.

The essence of MBL is to save time. In order to save time, superior commanders should emphasise what is to be done and why (command aim), so that the subordinates understand the purpose of what they are doing, allowing them to solve missions as independently as possible. The execution should, as far as possible, be left to the subordinates. This places great demands on the organisational culture and individual competence.

2.8.15 Operational support

Both the Navy and the NDMA had procedures, plans and instructions in place for crisis management that were applied during the incident. A comprehensive set of plans and procedures that the organisation is familiar with and has practised, and that can be effectively implemented, normally saves time in a crisis situation.

The two organisations' plans were not coordinated.

2.8.15.1 *The Navy*

According to predefined criteria, the nature of the HNoMS Helge Ingstad incident warranted summoning of the Navy's crisis management team (CMT). NORCOP has established its own procedure for the CMT.[118] The procedure included notifying the Navy's management and summoning of the CMT.

The main focus of the crisis management plan was personnel, next of kin, the environment and reputation.

The Navy's plans for establishing a CMT did not specify requirements for vessel-specific technical competence. Nor were there any requirements for competence relating to stability or utilisation of such competence in the NDMA Naval Systems Division or the NDLO. The CMT consists of Navy personnel only.

2.8.15.2 *The NDMA Naval Systems Division*

The Naval Systems Division's plans provide for a scalable mobilisation depending on the seriousness of the situation, and necessary authorisations have been issued to enable rapid notification and mobilisation.

The Naval Systems Division has established notification plans that include a set of instructions for the on-call duty officers in the Naval Systems Division[39] and a crisis management plan for the Naval Systems Division.[40] In a damage control situation, the Division shall establish an organisation with sufficient resources to provide technical expertise and guidance when the NDMA's materiel is involved.

2.8.15.3 *DNV GL ERS*

Emergency Response Service (ERS) is a consultancy service offered by DNV GL. ERS can provide advice and guidance in connection with marine incidents and accidents, primarily relating to stability and hull strength.

The service is based on available stability models, strength models and drawings.

In 2014 and 2015, there was contact between the NDMA Naval Systems Division and DNV GL ERS to consider enrolment of the Nansen-class frigates in ERS. The process came to a halt as a result of questions relating to information security in connection with the handling of classified vessel information.

[118] NORCOP's crisis management team procedure, dated 4 June 2018 (exempt from public disclosure)

Because DNV GL had classed the frigates, ERS was nonetheless in possession of vessel information that was used in connection with ERS's calculations on the morning of 8 November 2018.

2.9 Special investigations

2.9.1 Introduction

In the period after the accident, several surveys were carried out on board to establish the frigate's condition at the time when she sank and the status of various systems. Extensive analyses of IPMS data have also been conducted. The following sections describe the most important findings of these investigations.

2.9.2 Stability calculations carried out by the NSIA

The NSIA has carried out damage stability calculations for HNoMS Helge Ingstad using the ShipShape program. The calculations are documented in Appendix D. The purpose of the calculations has been:

- To understand and verify the sequence of events and assess the frigate's survivability independent of the design criteria (see section 2.6.9.2) after the collision. The NSIA has therefore assessed the consequences of hollow propeller shaft, effect of grounding and the effect of insufficient shutdown[119].

- To show the possibility for implementing measures to prevent the vessel from sinking in this and similar situations. The NSIA has therefore also evaluated the effect of shutdown of the vessel, the importance of Q-deck as a buoyancy volume and the effect of the grounding.

Calculations are performed from the time of collision up until HNoMS 'Helge Ingstad' was pushed towards shore by the tugs. The calculations take into consideration actual damage from the collision, see section 2.2.1 and Appendix D. Damage inflicted by the tugs are not taken into consideration since the calculations show that the vessel would have sunk as it was left upon evacuation, regardless of impact from the tugs or other damage inflicted after the acciddent.

The frigate's load condition at the time of the accident is described in Appendix D. Downflooding points and shutdown state of the frigate at the time of evacuation is described in Appendix C2 (R)[120]. The main findings from the calculations are presented below. These must be seen in light of the analysis in chapter 3.

The NSIA's stability calculations show the following main findings:

- Failure to shut down upon evacuation, see Appendix C2 (R), shows that the vessel sinks

- A shutdown of the vessel to upheld watertight integrity at the time of evacuation could have prevented the frigate from sinking.

[119] Shutdown means closing all watertight, closeable openings, such as doors, hatches etc.
[120] The reports are classified Restricted under the Security Act

- The grounding was not decisive in causing the frigate to sinkas the failure to shut her down would have caused her to sink in any case.

- The flooding of the Q-deck had a considerable negative effect on the frigate's survivability, but was not decisive in causing the frigate to sink.

- The hollow propeller shafts had a negative effect on the frigate's stability, but were not decisive in causing the frigate to sink.

- Cross-flooding between interconnected tanks had a negative effect on the frigate's stability, but was not decisive in causing the frigate to sink.

- The frigate would have started drifting had she not been held in place by the tugboats. There are no indications that the frigate would have sunk more quickly as a consequence of this. A complete shutdown would still have been required to prevent the frigate from sinking.

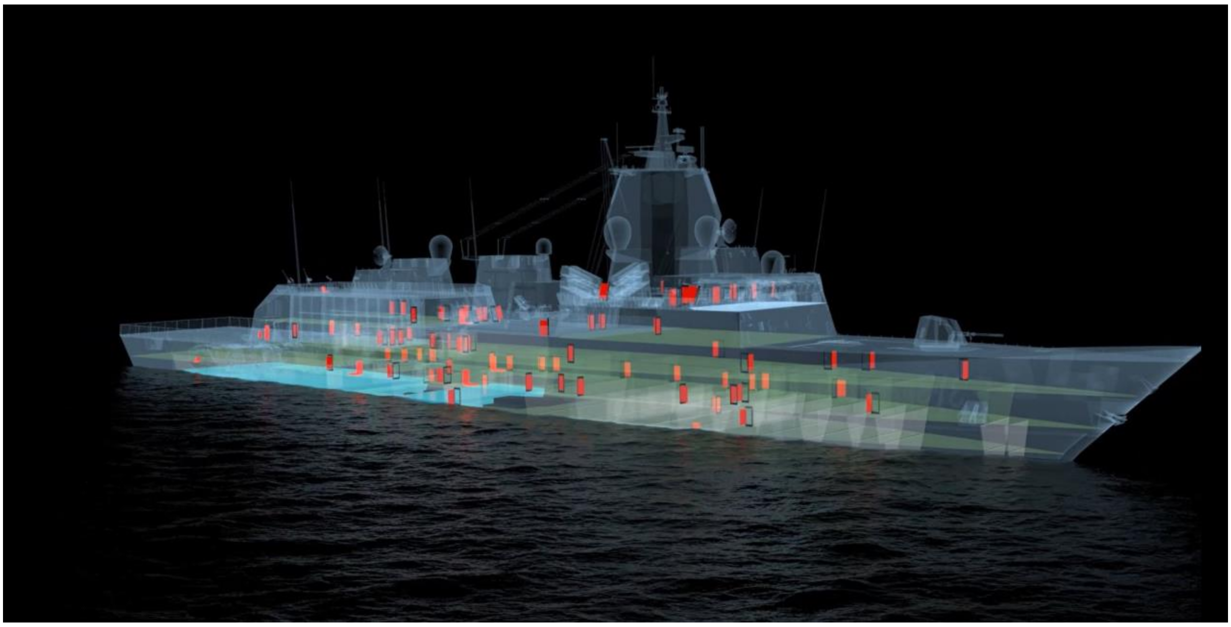

Figure 67: Doors and hatches that were open when the vessel was evacuated. Illustration: CIAAS/NSIA

The NSIA's stability calculations have shown the following relating to the sequence of events:

- Situation just after the collision: The lowest point at which the frigate sustained shell damage in the aft generator sets room (compartment 10) after the collision lay 260 mm above what was the waterline just before the collision. The shell damage in compartments 11 (conscripts berthing) and 12 (supply department storeroom), respectively, lay below the waterline,see Figure 68. It is presumed that section 12 was filled slower than section 11, however this will not effect the main conclusions.

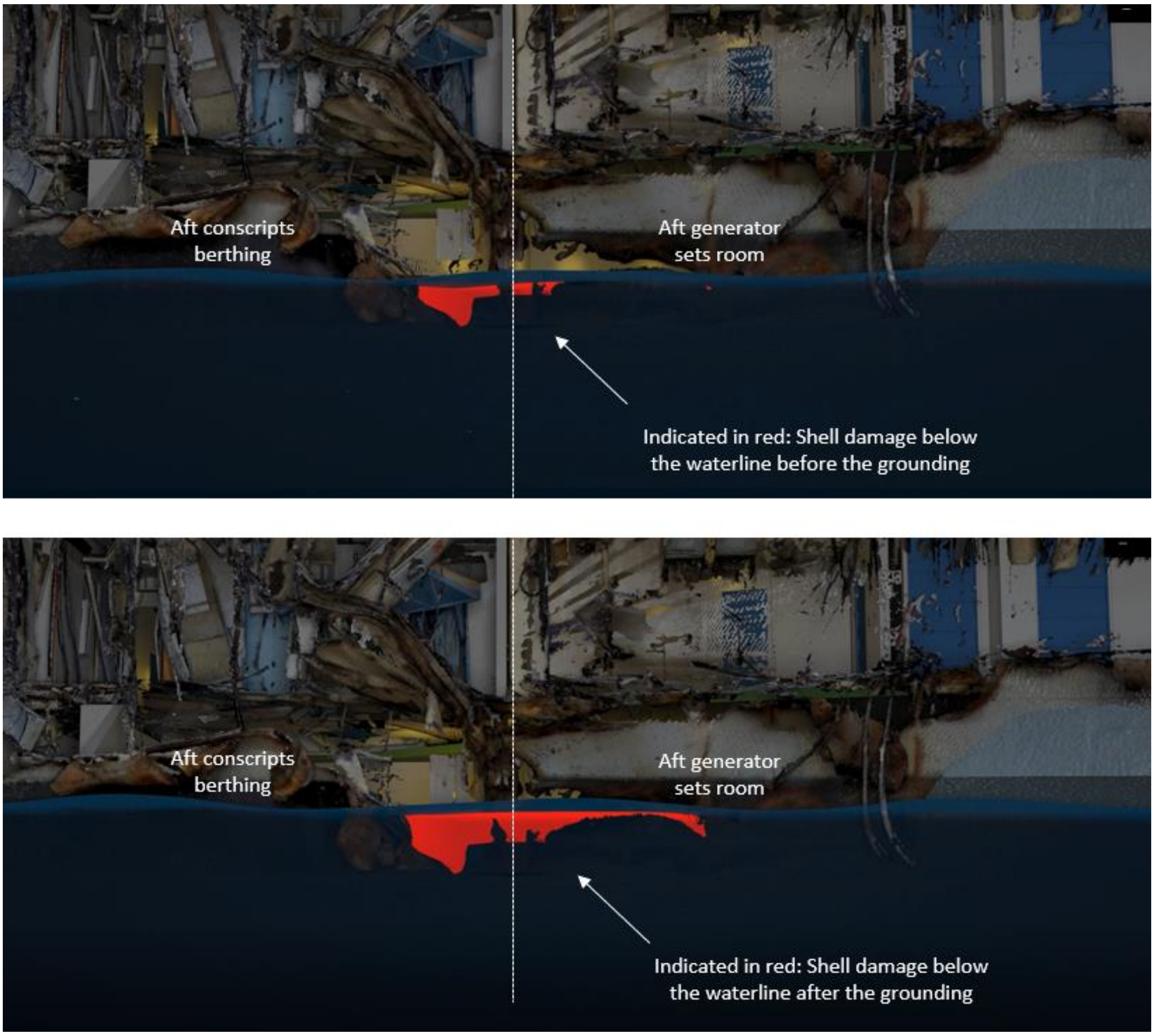

Figure 68: Shell damage relative to the waterline before and after grounding. Illustration: NCIS/CIAAS/NSIA

- At 04:07:40, one of the crew members in the aft generator sets room saw that the waterline was more or less on level with the edge of the damage to the shell. Subsequent calculations have shown that the ‘damage freeboard’ was approximately 100 mm, which supports the crew’s view that the ingress of water to the aft generator sets room was under control up until the frigate ran aground.

- Calculations have shown that a reactive force from the seabed acted on the forebody when the frigate stopped with her bow on the seabed, which increased the frigate’s aft trim. The calculations show that, at that point in time, the damage to the aft generator sets room extended 150 mm below the waterline, which indicates rapid flooding of the aft generator sets room. This was also observed by the crew member in the aft generator sets room. The situation deteriorated and the crew quickly lost control of the flooding. In turn, this led to flooding of the reduction gear room through the hollow propeller shaft.

The calculations are further discussed in section 3.

2.9.3 Manoeuvrability tests

Three tests were conducted with a view to investigating the frigate's manoeuvrability after the collision. The first test was conducted on board HNoMS 'Roald Amundsen' after the reconstruction voyage. The test was not documented, and the result is therefore not verifiable. Tests 2 and 3 were conducted on board 'HNoMS Otto Sverdrup'.

The first test was conducted under calm wind and wave conditions, while the final test was conducted under more or less the same conditions as on the morning of the accident. Both tests showed that the frigate was capable of manoeuvring away from danger and avoid running aground. The result showed that a turn to port was an option up until 04:07:45. When 3 out of 4 steering gear pumps were up and running at 04:02:29, this resulted in a room for manoeuvre of approximate 5 minutes.

Configurations during the tests:

- Port propulsion line: 0% pitch and no shaft rotation
- Starboard propulsion line: 60% pitch and RPM 70 (shaft)
- Speed through water at start of test: 5 knots
- Rudder angle: port 35˚ and starboard 35˚
- Wind direction: red 90˚ (port beam reach), virtually the same as on the morning of the accident
- According to IPMS data from the frigate, the wind speed on the morning of the accident was approximately 8.5m/s, and efforts were made to conduct the test under similar conditions.

The results of the tests are summarised in Table 5, and Figure 69 illustrates a starboard and port turn, respectively.

Table 5: Results of manoeuvrability test[121]. Source: The Navy

Manoeuvre	Last possibility of manoeuvre [time]	Speed [knots]	
		SOG	STW
Port turn	04:07:45	5.5	5.6
Starboard turn clear of Ådnesflua	04:03:50	4.7	5.3
Starboard turn shoreside of Ådnesflua	04:05:07	5.2	5.6

[121] Even though the radar was inoperative after black-ship, the MFD had chart underlay on MFD1 which showed the same information as MFD2 and 3, and where the vessel was located.

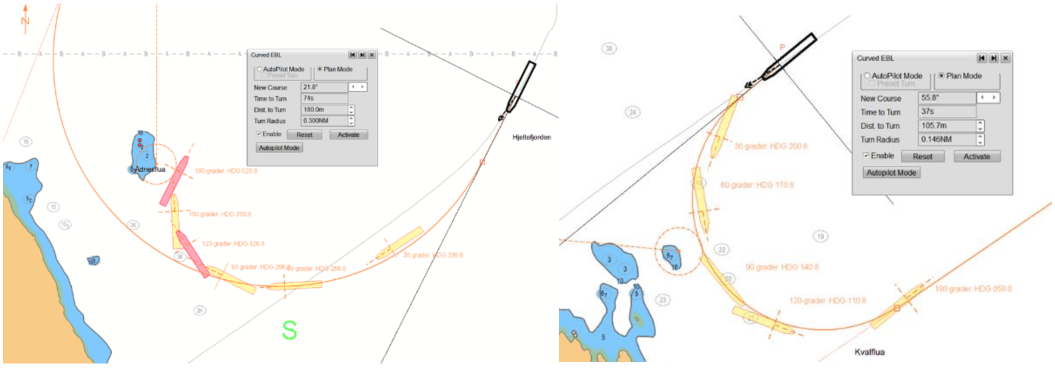

Figure 69: Illustration of starboard and port turn, respectively. Schematic drawing based on tracking with 'HNoMS Otto Sverdrup'. Source: The Navy

2.9.4 Status of valves and testing of bilge system

An inspection of all the bilge valves on board HNoMS Helge Ingstad was carried out in February/March 2019 to determine their status (open/closed). Two tests of the system were also conducted to investigate why pumping was ineffective. The inspection of the valves and the tests on board HNoMS Helge Ingstad were conducted by the NDMA in the presence of representatives of the NSIA. It is highly probable that the status of the valves represents the state of the bilge system at the time when the frigate was evacuated.

2.9.4.1 *Status of valves*

All the isolation valves were open, except isolation valve BD-MV015 between the forward auxiliary machinery room and the bow thruster machinery room, isolation valve BD-MV046 between the aft main engine room and the reduction gear room, and isolation valve BD-MV055 between the aft generator sets room and the aft main engine room.

In addition, several suction valves in spaces that had been flooded were found to be closed, more specifically suction valve BD-MV056 in the aft generator sets room, suction valve BD-MV048 in the aft main engine room and suction valve BD-MV032 in the forward main engine room.

2.9.4.2 *Summary of the tests*

The tests have shown that the capacity of the frigate's bilge system after the collision with 'Sola TS' was very limited. Three valves were identified that did not seal:

- BD-MV010 – main suction from bow thruster machinery room
- BD-V116 – manual suction valve in the food waste treatment room
- BD-V027 – manual suction valve in the pyrotechnics magazine

The reasons why the three valves did not seal were probably as follows:

- BD-MV010 – the limit switch in the motorised valve was not calibrated correctly, which meant that the valve did not close properly even though it was presented as closed in the IPMS.
- BD-V116 – Had not been closed.
- BD-V027 – Most likely defective valve seat causing it not to seal properly.

Failure of these three valves made it impossible to produce sufficient vacuum, and thus pumping capacity.

2.9.5 Bilge system capacity test

A capacity test of the bilge system on board 'HNoMS Thor Heyerdahl' was conducted on 23–24 January 2020. The system is identical to that on HNoMS Helge Ingstad. The purpose was to test the bilge line to obtain a basis for the bilge capacity to be compared to the specification established for the vessel class. The test should among others verify if the total capacity was obtained through a main bilge pumping point utilising six eductors. The test was planned and conducted by the NDMA Naval Systems Division and the Navy. Navantia also participated in the test. The NSIA used Aker Solutions as technical advisers on bilge systems. Representatives of Aker participated in the test and provided input relating to the bilge system design.

The NDMA Naval Systems Division has classified the findings of the test as *Restricted* under the Norwegian Security Act. The NDMA has summarised the results of the test in the document *Vurdering av resultat fra kapasitetstest lensesystem Nansen-kl, rev A, 04.02.2020* ('Assessment of result from capacity test of bilge system, Nansen class')[122].

Aker Solutions made the following observations and findings in the test:

- The observed pumping rates were too low for the purpose of the test and hence not according to the specification established for the vessel class. The deviations were sufficient to conclude that they cannot be attributed to the accuracy or uncertainty range of the test.

- The test also found shortcomings in that some valves could not be reset to the defined normal position or remotely operated from IPMS. These were the most serious observations as they suggest that the system could not be controlled as intended. If local closure or opening of the valves was not available in a real-life situation with flooding, this could disable or significantly affect the performance of the system.

- The IPMS and concurrent local vacuum and drive media pressure readings at the eductors were found not to correspond, so that it could not be ascertained with any certainty whether the system worked as intended.

- The control system did not have any parameters/instrumentation to confirm the pumping rate or that pumping was effective.

Aker Solutions' assessment is documented in Appendix F.

The NSIA received a report from Navantia February 26th 2021 documenting their observations and findings from the test. According to Navantia, the bilge system delivered according to the regulations and the test was not representative to affirm the actual bilge capacity.

[122] Results from the test are classified Restricted under the Security Act by information owner the Norwegian Armed Forces and the NDMA

Aker Solutions concludes that the observed pumping rates were too low for the purpose of the test and hence not according to the specification established for the vessel class. The deviations were sufficient to conclude that they cannot be attributed to the accuracy or uncertainty range of the test.

2.9.6 Testing of the watertight integrity of the Q-deck

Tests to verify watertight integrity of the Q-deck have been performed. Relevant valves, doors and hatches were maintained and function tested prior to applying a water pressure corresponding to water immersion.

Findings from these tests show that the ATAS door was not watertight when it was pressure tested. A standard hose test, using a fire hose did not indicate any leakage.

2.9.7 The NDMA's technical investigation

2.9.7.1 *Introduction*

The NDMA Naval Systems Division has conducted a technical investigation of the accident;[123] see Appendix G. The report is divided into the following three parts:

1. Technical investigation and document review
2. Safety management and process review
3. The salvage operation (separate report)

There are four appendices to the report. Appendix C[124] to the report is a technical sub-report on the technical findings made on board the frigate after the accident. The Naval Systems Division has classified the report as *Restricted* under the Norwegian Security Act. Several of the findings in the report have been declassified by the NDMA. Relevant findings are described in sections 2.9.7.2 to 2.9.7.5.

Appendix D[125] to the report is a technical sub-report on safety management. Relevant findings are described in section 2.9.7.6.

The conclusions below are taken from the NDMA's investigation. Direct quotes are reproduced in italics.

2.9.7.2 *Communication*

The NDMA has examined the communication systems on board, focusing mainly on communication between the bridge and the machinery control room and between the bridge and the steering gear room. The focus was on the period between the collision and the grounding, during which it was essential to gain control of propulsion and steering. The following was found to be the case, except during the 'black ship' period:

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[123] The NDMA Naval Systems Division: *Forsvarsmateriells tekniske undersøkelse etter ulykken med KNM Helge Ingstad* ('The Norwegian Defence Materiel Agency's technical investigation of the accident involving HNoMS 'Helge Ingstad'), version 2.0, dated 7 May. 2020

[124] Technical report – *Teknisk undersøkelse av ulykken med KNM 'Helge Ingstad'* ('Technical investigation of the accident involving HNoMS 'Helge Ingstad') Rev 1.4, 3 Dec. 2019

[125] The NDMA Naval Systems Division: Appendix B – *Sikkerhetsstyring, Teknisk undersøkelse av ulykken med KNM Helge Ingstad* ('Safety management, Technical investigation of the accident involving HNoMS 'Helge Ingstad'') version 1.0

Audio unit (AU)

> *It is highly unlikely that the audio unit worked in the steering gear room due to a [broken] communication cable to the CCU [as the cable ran along the starboard side]. Nor can it be ruled out that the power supply to the audio units in the steering gear room (starboard and port) was missing.*

Sound-powered telephone (SPT)

> *On the basis of tests and findings, we cannot find any defects or faults that indicate with a high probability that the sound powered telephone did not work after the collision.*

2.9.7.3 *Steering gear system*

Steering positions

The technical investigation has shown that, when the power returned to the main switchboard 1SB at 04:01:32, one of the pumps in the steering gear room (port) started automatically. It was then possible for the frigate to use the port rudder. As from 04:02:22, three of four pumps in the steering gear room were up and running, and the frigate could operate both rudders from the bridge.

> *A review of historical IPMS data has not found any indications that the chosen means of steering control (Split FU on SSC) did not work.*

> *Because of the cable routing, it is likely that 'C-1LA122: communication NFU between LSSSG001 and BRIDGE' is damaged or defect so that NFU on the starboard rudder would not have worked. Based on historical IPMS data, the investigation has not made any findings suggesting that attempts were made to activate NFU.*

Rudder angle indicator

It is highly likely that the starboard rudder angle indicator did not work, including the displays – one in the steering gear room and three on the bridge. No technical findings have been made that indicate that the port rudder angle indicator did not work after the collision.

Rudder angle telegraph

> *The starboard rudder angle telegraph has most likely not worked after the collision. No technical findings have been made that indicate that the port rudder angle indicator did not work.*

Multi-function displays (MFD)

> *The MFDs in the steering gear room had no power supply and did not work. No findings have been made that indicate that the remaining MFDs did not work.*

2.9.7.4 *Propulsion*

Starboard propulsion

When RTU 4112 failed immediately after the collision, the starboard propeller could not be operated remotely via the IPMS due to loss of communication. Hence, it remained in the most recently set position, with an 89% forward pitch. Damaged communication cables were found after the frigate was refloated, which means that the bridge was unable to control the starboard propulsion by throttling or use of back-up mode. Because of the lack of feedback from the starboard pitch controller after the collision, it is uncertain whether the hydraulic pumps were supplied with 440 volts. However, no technical findings have been made to suggest that the starboard propeller could not have been operated locally from the aft generator sets room, where the pitch could have been adjusted using air in the emergency mode.

The fluid coupling (FC) for the starboard main engine opened at 04:26:02, without any command having been issued from the IPMS. The most likely explanation of why the fluid coupling opened is the slip alarm that was triggered, which can be seen in conjunction with the low rpm of the engine. It cannot be ruled out that the water coming through the shafts affected the outcome.

Port propulsion

The fluid coupling (FC) for the port main engine disengaged immediately after the collision. The port main engine automatically shut down as a consequence of low oil pressure to the port secondary gear, and remained shut down throughout the sequence of events. The NDMA technical investigation has not concluded[126] with respect to why the port main engine started to empty the fluid coupling, but the lube oil pumps for the gears stopped during the temporary blackout when the two load centres (LC5 and LC6) supplying the pumps were disconnected and the mechanical oil pump attached to the gear lost its power transmission because the coupling was emptied. Up until 04:02:22, both pumps were without power. No faults or defects have been found to suggest that the port propulsion line could not have been started after the collision. Nor have any faults or defects been identified relating to communication with the port propulsion line.

Extensive efforts by the NDMA, Heinzmann and Navantia after the accident have not succeeded in explaining why the fluid coupling of the port shaft line was emptied.

Control of CPP1 and CPP2

> *CPP1 could not be operated in normal or back-up mode. This seems to have become the case immediately after the collision with 'Sola TS'. The alternative is local control via the panel in the aft generator sets room. The pitch is changed directly on solenoid valves with the aid of air or electric pumps. Based on the findings, local valve control with the aid of electric pumps does not appear to have been possible after 05:07:02 [04:07:41 local time], when air had to be used.*

[126] Navantia's technical analyses, see Appendix E4, concludes that the disengagement of the fluid coupling was likely due to a micro-closing of a relay contact in the engine's local operating panel, as a consequence of the shock loads and vibrations derived from the collision. This has not been subject to further investigation by NSIA as it is not critical for the safety recommendations in this accident report.

No findings indicate that the CPP2 could not be controlled in normal or back-up mode up until 05:05.42 [04:06:21 local time]. It is uncertain whether it would have been possible, after that time, to operate CPP2 from the local panel in the aft generator sets room by setting CPP2 to local mode, thereby in theory overriding the demand signal if the oil distribution (OD) box was not filled with water. Exactly why the fault of -100% demand on the CPP2 arose is unclear, but it was possible a result of disturbances in the profibus network[127]. Nor can it be ruled out that it was a result of seawater in the OD box.

Bow thruster

A bow thruster alarm was triggered on the IPMS when the vessel experienced a temporary blackout ('black ship'). This places no physical restrictions on use of the bow thruster, but the servo pump for the HPU must be restarted in order to stop the alarm. This was verified in a test on board a sister ship.

In a 'black ship' situation, main switchboards 1 and 2 will split into four parts and the supply for the bow thruster normal/alternative Q24/Q25 will be isolated. In other words, the supply to the bow thruster will have to be re-established before it can be used. In this case, Q24 was not connected until [04:08:53], which meant that the bow thruster could not be used until then. In addition, the switchboard was only supplied by one of the generators (DG1B) at [04:08:53], which prevented start-up of the bow thruster, which required 1 megawatt.

The second generator (DG1A) was not connected to the switchboard until [04:13:53], in other words after the frigate ran aground. One explanation for this is that, after the 'black ship' situation, the switches for that generator (QG1A) needed to be manually reset on switchboard 1.

No technical restrictions have been identified that would have prevented this from being done sooner to make the bow thruster available. The rest of the switchboard had been fully combined [04:02:28].

Engine order telegraph

No technical findings have been made to suggest that the engine order telegraph did not work.

2.9.7.5 *Bilge system and seawater line*

The collision with 'Sola TS' did not affect the ring main until it entered the aft generator sets room on HNoMS Helge Ingstad. Many minor branches were damaged, but this is deemed to have been of little consequence. Aft of the aft generator sets room, the scope of damage would have made segregation/isolation very difficult. In purely technical terms, it would have been possible to move the segregation of the seawater line further astern than zone division 2/3 at frame 90, so

[127] According to Navantia's analysis of the IPMS data, the most likely cause for the port propeller pitch to be set to full astern is that the back-up control cable was broken by the collision, and the two wires for the «pitch-back» control were short-circuited. Therefore, when the back-up mode was selected automatically after the accident, a constant «pitch back» signal was received by the pitch control unit, like the «pitch back» button was continuously pressed. This is not further investigated by the NSIA as it is not critical for the safety recommendations in this accident report.

as to supply driving water for the bilge eductors in the reduction gear room and the aft main engine room.

Findings from examinations of the bilge system are described in section 2.9.4.

2.9.7.6 *Safety management*

Relevant findings from Appendix D – Safety Management are reproduced below:

There is very little use of the nonconformity system as described in the management and control system. Several nonconformity types are not registered in the system at all. This makes it impossible to obtain a complete overview of the nonconformities the NDMA's Naval Systems Division is responsible for following up. The reasons for this are stated to be a lack of focus/measurement by the management, and that the tool used for follow-up of nonconformities is not very user-friendly.

In the Navy's experience, the Norwegian Armed Forces' Defence Integrated Management System (FIF) does not provide the necessary overview of incidents, which is why shadow records of incidents are kept in Excel.

2.9.8 The Navy's internal investigation

2.9.8.1 *Introduction*

The Navy has conducted its own investigation of the incident.[128] According to the report, the investigation has mainly focused on mapping nonconformities and their causes for the purpose of identifying systemic risk factors in accordance with the given remit.

Relevant findings are described in the sections below.

2.9.8.2 *Technical factors and design*

There are several outstanding nonconformities relating to the frigates' main power system. Corrective action orders have been issued on several occasions due to faults and defects in the system. Prior to the collision, the frigate sailed with the main switchboards in combined mode, which is in accordance with the design. However, the investigation has shown that the combined mode was an important factor in causing the 'black ship' situation on the frigate shortly after the collision.

At the end of the third quarter of 2018, 19 maintenance procedures at criticality level 5 had fallen due without being completed on HNoMS Helge Ingstad.

2.9.8.3 *Resources and personnel*

Some of the manning function for the Fleet's vessels is left up to the vessels themselves, in connection with any vacancies that arise. The fact that this is not managed by the operations organisation may be in conflict with the purpose of the ISM Code concerning necessary support for the vessel's commanding officer. Combined with incomplete documentation of minimum requirements for manning

[128] The Royal Norwegian Navy: *Rapport etter forsvarsintern undersøkelse av alvorlig hendelse med KNM Helge Ingstad i Hjeltefjorden 8. november 2018* ('Report from the Navy's investigation of the serious incident involving HNoMS 'Helge Ingstad' in the Hjeltefjord on 8 November 2018')

and safety competence, responsibility for ensuring that vessels are adequately manned is in practice left to the commanding officer.

The SAP tool is not designed to keep an overview at all times of the collective competence situation on board vessels.

The Navy has set fewer absolute requirements for manning and competence than warranted by the complexity of the vessel's operations. Safe operation and handling of contingencies on board the Fleet's vessels is largely based on thorough and documented collective sea training, founded on learning from the experience of Norway and its allies, personal acquaintanceship between colleagues and joint training of teams, and to a lesser extent on documented individual competence. It is likely that the vessels are occasionally manned by personnel who do not possess the competence needed to fill all the roles they are expected to fill on board, or that important safety functions, whether intentionally or unintentionally, are not manned by competent personnel. The risk increases as a result of an established practice whereby personnel frequently change positions, especially in connection with the handling of vacancies as they arise.

2.9.8.4 *Reports and analyses in the event of nonconformities, accidents and hazardous incidents*

The annual management review of the safety management system in January 2019 found a significant backlog of reported incidents and nonconformities. According to the head of safety, this was due to inadequate case processing capacity in both the Navy and the NDMA.

Near-misses are reported to a very limited extent. A backlog of reported incidents and nonconformities prevents corrective and preventive actions from being implemented.

Long case processing times and/or lack of feedback also increase the risk of undesirable incidents occurring before corrective or preventive action is implemented, and can also contribute to weakening confidence in the incident reporting system.

Different reporting cultures between the departments and under-reporting can give the management a skewed view of the safety situation in the departments, which in turn means that case processing resources are not expediently utilised. If there is no culture for reporting near-misses, the organisation will not be able to learn from such incidents either. This reduces the ability to identify risk and introduce preventive measures.

2.9.8.5 *Documentation*

Lack of control of the vessels being informed of any changes and of updated documentation being available on board, combined with the case backlog, defeats the purpose of ISM 11.

The fact that the vessels themselves must manually update the file structure for vessel documentation, combined with a lack of readily accessible information about changes that have taken place, means that the Fleet's management is unable to ensure that the departments have updated and correct information available at all times. This can have a negative effect on the organisation's capacity for systematic learning across departments and vessels.

Lack of awareness of changes to important documents or operational modifications without corresponding updates of documentation may have a decisive impact on safety on board if the changes require changes to be made to the current practice for safe operation.

2.9.8.6 *Radar*

A switchgear cabinet lost its power supply, causing the X-band and S-band radar to fail, together with the starboard rudder angle indicator on the bridge and the information display in the steering gear room.

The blackout also interrupted radar transmission and caused the navigation lights to go out. Furthermore, the emergency procedures for these events were not implemented. Active radar transmission could have informed the crew that the frigate was heading towards the shore, and navigation lights could have informed vessels nearby of the frigate's position.

2.9.9 Navantia

Navantia has carried out several detailed assessments and analyses of IPMS data for several of the technical conditions and systems on board after the incident; see Appendix E (R).

2.10 Relevant previous accidents

2.10.1 Introduction

Findings from investigations of previous accidents in the Norwegian Armed Forces have proved relevant to findings made in connection with the accident involving HNoMS Helge Ingstad. The most relevant findings are summarised below.

2.10.2 Grounding, 'HNoMS Oslo', 1994

On 24 January 1994, the frigate 'HNoMS Oslo' ran aground on Skjerskaget north-east of Marstein lighthouse in the Korsfjord. Two officers fell overboard, one of whom died. The next day, the frigate sank while she was being towed through Bakkasundet sound, at a depth of approximately 20 metres.

An investigation board was appointed by the Chief of the Western Norway Naval District (NAVDIST WEST). The board submitted its report on 28 April 1994[129].

Relevant findings and conclusions from the report are reproduced below:

- Shutdown to maintain watertight integrity:
  - *The shutdown of the frigate was incomplete and contributed to the vessel subsequently sinking.*
  - *Regular control of the ordered damage control state must be carried out – including by physical and manual verification that bolts and cleats are fastened.*

[129] Rapport fra *undersøkelseskommisjonen* etter KNM Oslos havari og forlis 24./25. januar 1994 ('Report from the investigation of the accident involving 'HNOMS Oslo' on 24/25 January 1994'), Part 1 (report)

- Exercises:
  - *The high demand for frigates from many different parties and for many different purposes means that there is not enough time to complete all the exercises needed to fully ensure safety.*
  - *The weeks dedicated to safety training in the vessels' sea training programme must be 'sacred' and not be displaced by other activities.*
  - *The frequency of unannounced safety reviews of the vessels must be increased with a view to quality assuring the personnel's knowledge and training level, and the quality assurance process in itself must improve so that all weaknesses are identified.*
- System understanding and use of emergency procedure:
  - *In the board's view, it is important that personnel who are to serve on board Oslo-class frigates are aware that things may go wrong and of the importance of an overall system understanding and a preventive approach, as well as clearly prioritised emergency procedures in case of an accident.*
  - *In the board's view, consideration should be given to establishing emergency procedures in the form of directives, to reduce the likelihood of a similar accident in future.*
- Emergency response:
  - *In connection with inshore and coastal voyages, emergency response preparations must be made by ensuring that existing backup systems are ready for operation and can be activated quickly in the event of an engine failure.*
- Communication and roles:
  - *The necessity of giving clear/concise orders must be emphasised. The same applies to the issuer's responsibility for following up the order and the recipient's responsibility for giving feedback.*
- Stability assessments:
  - *The board completely disagrees with the ship management's conclusions regarding the vessel's stability and buoyancy at the time of evacuation, and therefore struggles to understand the commanding officer's salvage plan. Based on the described level of flooding, stability has been improved and buoyancy is sufficient.*
  - *During the maritime inquiry, the commanding officer of 'HNoMS Oslo' clearly expressed that he was in command of the frigate throughout, up until the time when she sank, even though the crew had abandoned the vessel. The decisions that were made during the process were clearly influenced by what the commanding officer had experienced earlier that night. For him, it was of paramount concern to avoid further injuries or loss of personnel. No one can disagree with that aim, of course, but the commanding officer had probably added*

an extra safety margin to his decisions based on what he had gone through earlier that night.

2.10.3 Fire on board 'HNoMS Orkla', 2002

On 19 November 2002, a fierce fire broke out on board 'HNoMS Orkla', resulting in loss of the vessel. A committee of technical experts was appointed by the Chief of the Norwegian Defence Logistics Organisation (NDLO) to investigate the incident. The expert committee submitted its report to the Chief of the NDLO on 6 June 2003.

Relevant findings and conclusions from the report are reproduced below:

- Safety management:
    - *The technical expert committee recommends that the Royal Norwegian Navy, in its safety management of future building projects, make more use of recognised risk assessments in the choice of technical solutions where deterministic regulatory requirements cannot be applied. The establishment of third-party inspections is recommended for both the newbuild and operating phases. A considerable strengthening of the SDD process[130] is a possible solution for this purpose. The project was not subject to review by an independent third party or supervisory authority capable of taking a critical look at the project with 'fresh eyes'. This led to inadequate verification, inspection and supervision.*
    - *Based on the lack of uniform rules for the vessel type, it would have been natural, at the start of the project, to conduct a more systematic safety study, similar to that performed during the construction phase for offshore installations. This type of analysis would have been particularly useful in the process when the RAR regulations were adapted to the project. No such analysis was carried out. This enabled partial solutions to be established and design details to be selected that, individually, may not have had a decisive impact on the vessel's overall fire safety, but the combination of which proved to be disastrous.*
- Competence and training:
    - *Despite considerable training, deficiencies in the maintenance of the lift fans' shaft system had become apparent at an earlier stage. It is likely that verification of the effects of training and qualification of necessary competence in critical areas have been insufficient with regard to the degree of detail and repetition. This is largely a result of frequent crew replacements in addition to a weak tradition for documentation, analysis of records and trend monitoring over time.*

2.10.4 Personnel injury on trial voyage, HPRIB, 2010

On 26 May 2010, during a trial voyage with a new type of Special Operations Craft (HPRIB), the skipper lost control of the vessel while making a hard turn to port at high

[130] A self-imposed certification process for the purpose of certifying materiel and vessels to a safety level that, as a minimum, meets the intentions of relevant civilian standards.

speed, near Langøya in Horten municipality. Six of the ten passengers were thrown out of the craft, one of whom died.

An investigation board was appointed by the Chief of the Norwegian Armed Forces' operative headquarters to investigate the incident. The board submitted its report on 11 June 2010.

Relevant findings and recommendations from the report are reproduced below:

- Safety procedures/culture and follow-up of competence:
  - *Development of good safety procedures for operating HPRIBs and RIB materiel in general, including the performance of risk assessments, development of procedures/checklists, competence requirements, restrictions on use and safety briefs.*
  - *It is recommended that the Chief of the Naval Staff clarify and follow up factors relating to technical responsibility for materiel needs, competence requirements and the operation of small craft in the Norwegian Armed Forces, and help to develop a good safety culture for the operation of small craft throughout the organisation.*
  - *The NDLO should quality assure the progress of project P5819 (HPRIB), including the performance of a risk assessment for further testing of the materiel that addresses the need for competence requirements, restrictions on use and any materiel-related measures that can improve the safety of personnel on board. The board recommends that the NDLO management take greater responsibility for establishing a good, firmly rooted safety culture at all levels, and for verifying compliance with this culture.*
- Risk assessments:
  - *Caution must be exercised in the event of nonconforming activities during project work and in connection with commissioning of materiel. An official, written approval procedure should be implemented that describes the activity and sheds light on pertaining risks, and management should be involved in the approval process.*
  - *The board cannot see that the NDLO has enclosed documentation of a risk assessment in connection with its recommendation of temporary approval of materiel, although the NDLO has performed various risk assessments that have resulted in restrictions on use during the test period.*

2.10.5 Grounding, CGV 'Andenes', 2013

On 3 December 2013, CGV 'Andenes' ran aground at Rødbergodden in Troms county, resulting in extensive but repairable damage to the craft. The vessel managed to come off the rock and was able to continue under its own steam to Tromsø approximately 23 minutes later.

An investigation board was appointed by the Chief of the Norwegian Armed Forces operative headquarters to investigate the incident. The board submitted its report in October 2014.

Relevant findings and recommendations from the report are reproduced below:

- Recommendation to the NDLO: *'To initiate a process, in consultation with the captain of CGV 'Andenes', with a view to making the bridge equipment more user-friendly and minimising light pollution.'*

- Stability:

  - Recommendation to the captain: *'Take the initiative to receive instruction in use of the load distribution calculator, which provides direct feedback on the vessel's intact and damage stability. The NDLO Naval Systems Division/IPS can assist in providing training in the use of the calculator and stability assessments in general.'*
  - *The decision to pull the vessel off the rock using own engine power most likely prevented more extensive damage and other potentially fatal consequences.*
  - *After the grounding, a stability assessment was carried out in relation to the damage sustained by the vessel. The assessment was based on the crew's knowledge obtained from the stability manual and general knowledge about the vessel class. The conclusion was that the vessel was safe as long as there was no damage in the machinery spaces or further aft, which is considered particularly critical. The Nordkapp-class vessels are fitted out with a load distribution calculator that can be used to calculate the vessel's actual stability in a damage situation. The calculator was not used because the crew had not received necessary instruction in how to use it. Based on the requisite knowledge, the calculator can be a very useful tool for identifying changes in the vessel's stability as a result of damage.*

2.11 Implemented measures

2.11.1 The Ministry of Defence

The NSIA has received information about measures taken by the Ministry of Defence after the accident. They are reproduced below.

> *In October 2019, the Ministry of Defence appointed a working group tasked with reporting on the need for and proposing internal rules and regulations to replace the rules of the Ship Safety and Security Act. The working group comprises representatives of the NDMA, the Armed Forces, the Materiel Safety Authority and the Ministry of Defence. The working group has also taken advice from external legal experts on the Ship Safety and Security Act. In addition, the Ministry has invited the Ministry of Trade, Industry and Fisheries, the Ministry of Climate and the Environment and the Norwegian Maritime Authority to participate in a reference group for the work. The working group has made good progress and submitted two sub-reports in autumn 2020: one on roles, responsibility and authority (Sub-report 1) and another on supervision and development of rules and regulations (Sub-report 2). The sub-reports have been distributed for internal consultation in the defence sector and to the reference group. The purpose of the consultation has been, among*

other things, to receive input on the financial and administrative consequences of the working group's recommendations.

The working group is now working on Sub-report 3, which will address working hours and hours of rest in the Navy. The work of reporting on the need for and proposing internal rules and regulations to replace the provisions of the Ship Safety and Security Act is given high priority by both the Ministry of Defence and its subordinate agencies. Based on the working group's findings and recommendations, the Ministry will submit proposals for necessary regulatory amendments and ensure that internal rules and regulations are put into place in the defence sector, where this is necessary.

2.11.1.1 *Report on supervision in the defence sector*

Work has been ongoing since August 2020 to look into supervision in the defence sector in general, and ship safety is a natural part of this work. The work is led by the Armed Forces Materiel Safety Authority, with participants from the Ministry of Defence, the Armed Forces and the NDMA. The work centres on areas where the sector, unlike society at large, is exempt from laws and regulations.

The working group looking at the Ship Safety and Security Act has also assessed the supervisory scheme for ship safety, and submitted a recommendation in that regard. The recommendation is taken into account in the general assessment of the defence sector's supervisory scheme, so that an overall solution can be achieved that effectively contributes to safety in the sector. The need for making changes to the supervisory scheme has thus been acknowledged.

2.11.2 Materiel Safety Authority

The NSIA has received information from the Norwegian Armed Forces Materiel Safety Authority that they have planned a supervisory activity relating to the frigate configuration autumn 2021. This was originally scheduled to take place in 2020, but was postponed because of the pandemic. An activity is also initiated to look into supervision in the defence sector in general, see section 2.11.1.1.

2.11.3 The Norwegian Armed Forces

2.11.3.1 *Introduction*

The NSIA has received information about the measures taken by the Norwegian Armed Forces after the accident. These are reproduced in the sections below.

2.11.3.2 *Stability competence and related decision support tools*

The stability calculator in the Integrated Platform Management System (IPMS) had been updated and verified against an approved stability model, tested on board one of the frigates and approved with deviations. During a stability course in February 2021, however, the calculations were in some cases found to be somewhat conservative. Work has been initiated to rectify this. The frigate crews may use the stability calculator as is, subject to the known limitations as mentioned.

A new version of the stability manual has been prepared. The manual will be subject to some adjustment and quality assurance before it is submitted to DNV.

Stability courses have been introduced and several courses have been completed, including for key personnel categories of the frigate crews. The course is being revised, so that it can also be adapted to other classes of ships. The course addresses the application of relevant tools, including the stability calculator.

The NDMA has issued corrective action orders relating to shutdowns, which are observed by the Navy. Further competence needs are being surveyed. Other relevant courses/training that address or should address damage stability and how shutdowns affect frigate survivability are adjusted continually.

2.11.3.3 *The bilge system*

Work has been initiated to identify the need for competence relating to the bilge system. Courses, training and documentation will be updated as necessary. In relevant existing courses, instruction in the bilge system will be strengthened as an immediate measure. The Navy has introduced a procedure for verifying that the system does not leak. Valve tightness and status are now checked regularly.

Prior to and during the accident, there was no segregation between the emergency bilge system the bilge system for day-to-day removal of oily water. After the accident, these systems have been segregated on board all the vessels.

2.11.3.4 *The crisis management team – decision support, stability competence and coordination with the NDMA*

The Navy has signed agreements with external suppliers who will strengthen the Crisis Management Team's stability competence and provide decision support and such resources as may be required in connection with salvage operations. The agreement comprises damage control readiness and training. The Navy's contingency plans have been further developed in light of the lessons learned from the accident. The plans have been coordinated with the NDMA Naval Systems Division and tested through damage control exercises

2.11.3.5 *Systemic approach to learning from incidents and following up nonconformities etc.*

The Navy has a system in place for systematic follow-up of incidents, nonconformities, near-misses and accidents, which is described in section 2.9 of the instructions for safety management in the Navy ('Instruks for sikkerhetsstyring i Sjøforsvaret. – ISM 9 Hendelseshåndtering'). The procedure for handling incidents in the Navy describes how incidents are to be reported and followed up.

The Navy's approach to following up incidents is in line with the Armed Forces' overarching system. The overarching system description has been in place throughout, but there is improvement potential when it comes to technical support, compliance and effectiveness. The Coast Guard has implemented UNISEA as its technical platform for safety management, including for incident reporting. Consideration is now being given to whether the same system can be used by the vessels in the Fleet.

The Navy currently has a good overview of nonconformities with a negative impact on safe operation. This is achieved through use of existing technology and mitigating measures in cooperation with the NDLO and NDMA. An element of coordinating *management has been established for the frigates, with a board that is chaired by the Chief of the Navy and comprises representatives of the Navy, the Fleet, the NDLO and the NDMA. This has resulted in the development of a common perception of risks. There is greater situational awareness and better coordination between those involved.*

The Armed Forces have initiated work to improve safety management, safety management tools and experiential learning among its own ranks. At the same time, the Ministry of Defence has assigned the Armed Forces the task of developing a system that addresses corresponding needs in the defence sector. The work is scheduled to be completed in the course of 2021. The introduction of technology support has been ongoing for several years. Configuration management, logistics management and maintenance management are parts of the same system. The frigates are among the biggest materiel systems for which such technology support is to be rolled out, and this work has started. The system will take several years to roll out. Meanwhile, the new and old systems have to be operated in parallel. Experience of other materiel systems indicates that a substantially better overview of the status of factors that impact safety is gained once FIF/SAP has been introduced and quality assured, and rendered other systems superfluous.

2.11.3.6 *Technical documentation and manual*

The NSIA has found that there have been challenges relating to the availability of technical documentation for some systems on board the frigates. Technical documentation comes under the NDMA's area of responsibility. The Cooperation Agreement between the Navy and the NDMA Naval Systems Division has been revised, and goals relating to technical safety have been defined and are being pursued.

Before the accident, there were differences between the manuals of the individual ships in the class. It was not clear who was responsible for updating the manuals and this had given rise to local solutions on board each ship. The Navy has prepared a standard manual structure that applies to all vessels. The manuals have been updated, and were in place for the frigates in July 2020. A system has been established to ensure continual updating of safety-critical matters in the manuals. A new revision of the manuals will take place in the course of 2021.

2.11.3.7 *Other areas in which measures have been initiated but not completed*

- *Updating of the bilge system*
- *Revision has been initiated of the training regime (OPUS)*
- *The manning concept is being revised*

Several of the challenges that have been identified after the accident require cooperation within the sector. The Armed Forces, the NDMA and the Ministry of Defence cooperate as necessary, to ensure that the Navy's vessels are operated at an acceptable level of risk.

2.11.4 The NDMA

2.11.4.1 *Introduction*

The NSIA has received information about the measures taken by the NDMA after the accident. These are reproduced in the sections below.

2.11.4.2 *Strategic and organisational measures*

2.11.4.2.1 Ownership management project

The NDMA has set up a dedicated implementation project referred to as the 'ownership management project' to ensure overall follow-up and prioritisation of the many safety recommendations and measures that have been identified in the various investigations. The project is intended to improve the quality of the agency's ownership management, including of the frigates. The measures include:

- *Improving the NDMA's safety management system, including links with the Navy's safety management system.*
- *Establishing a common perception of the status of nonconformities between the Navy and the NDMA.*
- *Improving follow-up of nonconformities (nonconformity handling).*
- *Reviewing and updating technical documentation.*

The NDMA also finds that the establishment of an element of coordinating management for the frigates with participants from the Navy, NDLO and NDMA has resulted in better coordination between the agencies and has, generally speaking, provided a more consistent superstructure for following up operational and project-related activities relating to the frigates

2.11.4.2.2 Systemic approach to learning from incidents

The NDMA is working to improve the agency's incident learning, and has established a more systemic approach to that end. It entails reviewing more incidents, in order to determine whether any systematic faults contribute to incidents, and implementing targeted measures to combat any underlying root causes and systemic deficiencies that could trigger sequences of events. The purpose is to identify any need for measures over and above those that are identified in connection with individual incidents.

2.11.4.2.3 Cooperation across agencies

The NSIA sees that the NDMA and the Armed Forces cooperate closely on following up the safety recommendations, having established working groups and various forums for collaboration. Such cooperation is important as the recommendations are partly addressed to both agencies and to some extent require that they draw on each other's competence.

2.11.4.2.4 Updated contingency plans

Contingency plans and procedures for mobilising the crisis management team, support from the shore-based organisation and communication with relevant parties have been audited and updated. According to information from the NDMA, there is *even better coordination with the Navy, and exercises and training have been conducted together with the Navy and DNV GL.*

2.11.4.3 *Measures addressing materiel*

After the accident, the NDMA has implemented several measures based on the findings that have been made. These include:

- *Measures to ensure watertight integrity*
- *Measures to improve the bilge system*
- *Measures relating to the stability tool*

2.11.4.3.1 Watertight integrity

According to information from the NDMA, several measures have been implemented to ensure watertight integrity in response to those factors that had an impact on watertight integrity. Among other things, the hollow shafts have been fitted with blind flanges and steps have been taken regarding doors and hatches. Work has also been initiated to update the marking system that indicates what doors and hatches should be closed at all times.

2.11.4.3.2 Stability and related decision support tools

The NDMA states that the stability calculator and pertaining software have been updated and tested on all the ships. New software has been installed and the calculator was examined by Navantia in cooperation with the NDMA Naval Systems Division in November 2019. The effort to improve the stability calculator is ongoing.

2.11.4.3.3 Bilge system

The NDMA has identified factors with a bearing on the bilge system and, based on findings made after the accident and existing nonconformities, it has initiated improvements, including that the instructions for use of the system have been updated. Furthermore, the maintenance plan for the frigates has been updated with new and revised maintenance procedures for the bilge system, principally for better verification of technical system availability. In addition, a pre-study has been initiated together with Navantia to get an overall assessment of the bilge system. Consideration is being given to speeding up implementation in cooperation with the Navy by setting up a dedicated project for the scope of alterations to the bilge system. The NDMA is continually considering further measures in cooperation with the Navy, including for the purpose of building knowledge and competence relating to understanding and using the system.

2.11.5 Navantia

Navantia has informed the NSIA that the yard's safety and quality management system has undergone major changes since HNoMS 'Helge Ingstad' was designed and built in the mid-2000s. Among other things, the safety management framework has been extended to include more detailed safety analyses, internal and external audits etc.

Among other things, Navantia has implemented two new measures in the design process to prevent similar safety problems as a result of breach of watertight integrity:

- *Update of the Design Instruction Document with inclusion of new equipment to check that: "propulsion shafting is provided with the required elements that ensure that watertightness of penetrations through hull plating and watertight bulkheads is maintained, both at the external surface of the shafts by means of sterntube or bulkhead seals, and through the inner bore of the shaft by means of plugs or caps as needed to avoid that the hollow shaft could connect two different watertight compartments".*
- *Inclusion of new review procedures in the safety and quality management systems. Under the current safety and quality management systems in place, specific reviews will be conducted for controlling potential interconnections of watertight compartments by means of hollow shafts or similar components. These reviews will be carried out as part of the independent Safety Audits and the detailed Quality Gates that are planned for any current and future constructions.*

Appendix E contains a summary of the safety measures and barriers received from Navantia.

3 Analysis

3. ANALYSIS

3.1 Introduction

3.1.1 Investigation methods and structure of the analysis

The analysis of part 2 of the investigation is structured in accordance with the NSIA's investigation method[131], Figure 70.

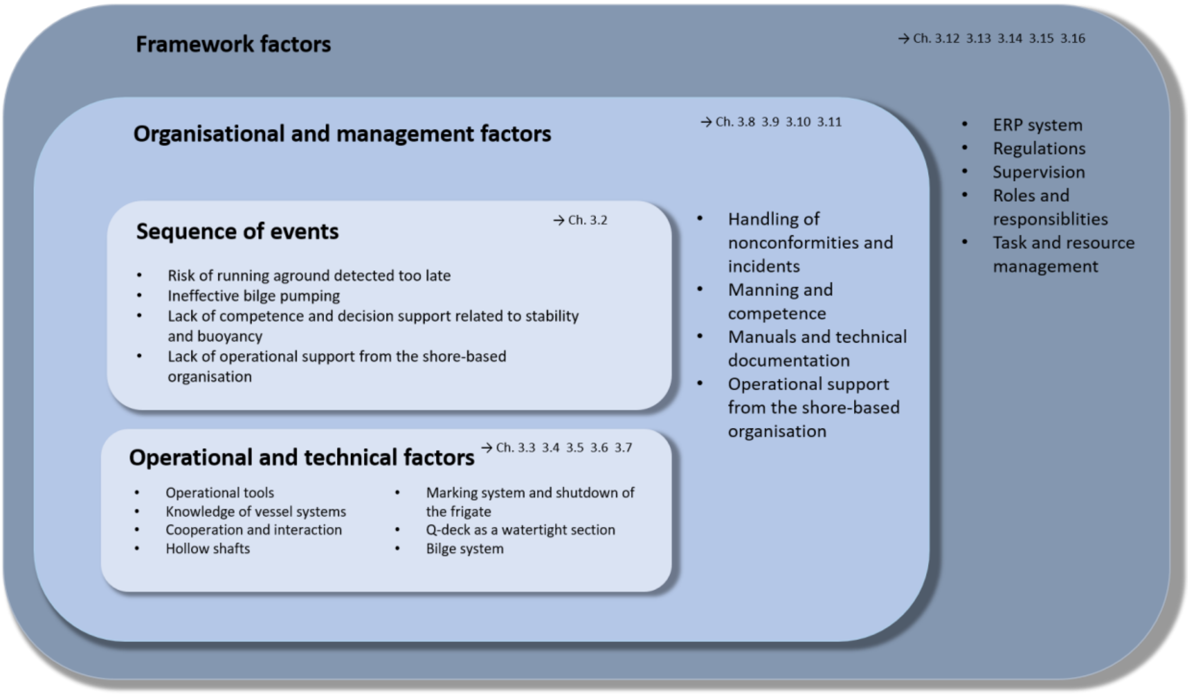

Figure 70: Method of structuring the analysis in accordance with the NSIA method. Illustration: NSIA

The analysis in this chapter starts with an assessment of the sequence of events for the purpose of explaining how the incident occurred and developed. The incident is then assessed with the focus on the crew's cooperation and understanding of the situation.

Parts of the analysis address operational and technical factors relating to support tools for damage stability, levels of readiness, equipment control levels, shutdown state, the role of the Q-deck, watertight integrity and bilge system.

The analysis goes on to consider operational support from the shore-based organisation, nonconformity and incident handling, competence management, instruction and sea training, manuals and technical documentation, and the consequences of a defence integrated enterprise resource planning (ERP) system.

Finally, the analysis considers the different framework factors, including overall and binding regulations, the supervisory schemes, dual roles in the defence sector and resource management.

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[131] NSIA: '*The AIBN's Framework and Analysis Process for Systematic Safety Investigations (the AIBN method)', 2nd edition, January 2018. The Accident Investigation Bureau Norway (AIBN) has since changed its name to the Norwegian Safety Investigation Authority (NSIA), and the method is now referred to as 'the NSIA method'*

3.2 Assessment of the sequence of events

3.2.1 Introduction

The NSIA has discussed the sequence of events for the purpose of explaining what factors contributed to the frigate running aground, factors relating to ineffective bilge pumping, stability and buoyancy assessments and operational support from the shore-based organisation.

HNoMS 'Helge Ingstad' had no VDR[132] or other system for automatic audio-recording. Some manual audio-recording was initiated some way into the sequence of events, but only after the frigate had run aground. The NSIA therefore points out that the assessment of the sequence of events is largely based on interviews with the personnel involved, in combination with data from the frigate's navigation system and integrated platform management system (IPMS).

It is important to note that information obtained from interviews reflect human limitations, particularly relating to sensory and memory capacity. People also do not fully perceive their surroundings all the time, nor do they remember all they have seen, heard and understood. Interviews are conducted within a limited time period, and sometimes this can also limit the transfer of information. In addition, memory changes with time.

The NSIA has therefore sought to compare data from different sources in an attempt to confirm or rule out memory-based information.

3.2.2 Factors contributing to the grounding

3.2.2.1 *Common stress reactions influenced the crew's performance*

When the tanker and the frigate collided, no one on board was certain whether anyone had died. Furthermore, it was not clear what had happened, how much damage had been sustained or whether the frigate would sink. Other stress factors were the impact force of the collision and the frigate's heeling, the damage to means of communication, steering and propulsion, and the many alarms that went off simultaneously. It was also dark, and the situation was more chaotic and unpredictable than anything the crew were trained to tackle. Interviews with the crew have confirmed that many experienced the situation as dramatic and potentially dangerous. There is therefore little doubt that many crew members experienced considerable stress during and after the collision.

The NSIA sees the actions of the crew in light of this. It is likely that the problem-solving capacity and cognitive flexibility of many crew members were reduced after the collision. As an example, acute stress, combined with insufficient training, probably contributed to the possibilities of preventing the frigate from running aground were not fully utilised.

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[132] Voyage Data Recorder

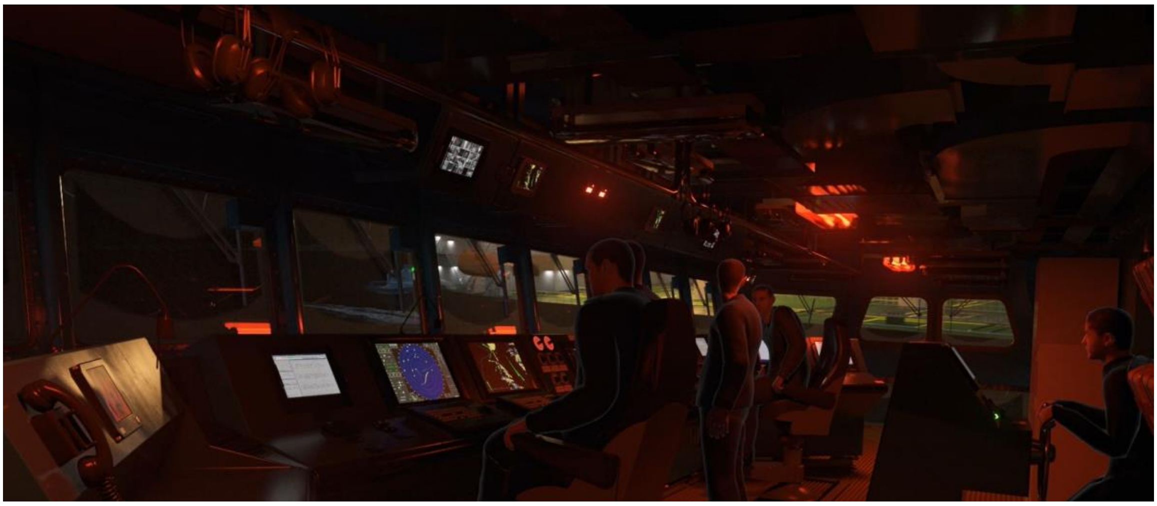

Figure 71: The bridge after the collision. Illustration: CIAAS/NSIA

3.2.2.2 *Understanding of the situation immediately after the collision*

During the period between the collision and the grounding, the bridge team found that neither steering nor propulsion could be controlled from the bridge. They also found that they had lost communication with the damage control headquarters (HQ1), so that they did not have the possibility of requesting HQ1 to initiate local operation of the propulsion system. The officer of the watch (OOW) was under the impression that emergency steering was not available from the bridge, and they were not able to establish communication with the steering gear room to steer the rudders from there. The navigators on the bridge believed they had made every possible attempt to stop the vessel, without any of them having any effect.

The investigation has shown that, after being in charge on the bridge when the collision occurred, the OOW, like many others on board, experienced a reaction that included elements of both thought and emotion. The OOW was considered to be highly skilled, but had only held clearance as OOW on a frigate for a few months. He had just experienced an astonishing, dramatic and potentially traumatising event, and was marked by this. As is both common and to be expected in dramatic situations, he experienced a stress reaction, a manifestation of an automatic mobilisation mechanism that is meant to help dealing with demanding situations.

In some respects, the bridge team's situational awareness was inadequate, the main communication system had failed and it was completely dark on the bridge. The situation was thus different from anything that their training had prepared them for, and the actions taken on the bridge were clearly not very systematic. This is discussed in more detail in section 3.10.3.

Immediately after the collision, the OOW's attention was on how the collision could have occurred, and he was also concerned about any injuries that the crew might have suffered – whether anyone was fatally or serious injured. He was also repeatedly asked what had happened by those who arrived on the bridge, which drew time and attention away from the OOW's most important task, namely to ensure safe navigation. This may also have contributed to increasing the OOW's stress level.

In the NSIA's opinion, the OOW was so marked by having been in charge on the bridge when the collision occurred that his capacity to ensure safe navigation of the frigate was reduced. Even though the OOW believed he had delegated navigational tasks to the officer of the watch being relived (OOW-R), he was still the commander in charge on the bridge. The NSIA is therefore of the opinion that it would have been a better solution in this situation to let the OOW be relieved by somebody else rather than to continue to be responsible for the safe navigation of the frigate.

3.2.2.3 *Use of emergency procedures*

The emergency procedures were most likely available on the bridge; see section 2.5.2.5. They had been used by the crew during exercises with HNoMS 'Helge Ingstad’ and were meant to be used in real-life situations. In the NSIA’s opinion, activities on the bridge prior to the grounding reflect that there was no systematic performance of the emergency procedures.

While some actions were taken in accordance with the emergency procedures, others were not performed at all, such as a PA announcement ordering an emergency manoeuvre or initiating use of the bow thruster. That the emergency procedures were not followed may have caused that effective measures to avoid grounding were not taken in due time. The bridge team did not immediately detect the risk of running aground, which meant that nobody in HQ1 was informed of this risk. Hence, HQ1 gave priority to dealing with the ingress of water rather than to taking action to prevent the frigate from running aground.

Unclear communication in the bridge organisation may have been another reason why the emergency procedures were not resorted to immediately and used systematically. The OOW intended to assign the role of navigator to the OOW-R. However, it was the OOW-R’s understanding that the OOW did not want him to assume a specific role. Rather, he believed he should make himself available for the OOW and be assigned tasks by him. The OOW-R correctly assumed that the OOW first wanted him to gain control of propulsion and steering. But he also assumed that safe navigation was not necessarily part of the task he had been assigned, which was incorrect, given the OOW’s intention of assigning him the role of navigator. This misunderstanding may have contributed to why the OOW-R, while taking certain actions, did not implement the emergency procedures in any systematic way.

Training and exercises in emergency procedures are normal situations for the watch teams on the bridge and in HQ1. In the NSIA’s opinion, a collision with subsequent degradation of the propulsion system should therefore automatically have caused the OOW to take immediate action by ordering an emergency manoeuvre (P-230.01), and then implementing the emergency procedure for propulsion (P-230.02 and P-230.03). The engineer officer of the watch (EOOW) should automatically have taken action to ensure that the ship had sufficient propulsion (P-300.1.2 Emergency procedures).

The procedures contain a specific description of how to regain control of propulsion and steering. Regular training in emergency procedures by the watch teams on the bridge and in the MCR is intended to enable them to translate their competence and skills into immediate action when the situation so demands. The NSIA believes that the actions taken by the crew to regain control of propulsion and steering indicate, among other things, that the emergency procedures had not been sufficiently assimilated.

Figure 72: HNoMS ‘Helge Ingstad’ heading towards shore after the collision. Illustration: NCIS/CIAAS/NSIA

The bridge team eventually understood that grounding was imminent, but had the understanding that the propulsion system could not be operated in normal or back-up mode, and that the emergency stop function did not work. This situational awareness resulted in the order ‘Hard astern’ being announced over the PA system. Such an announcement was not in accordance with the emergency procedure and not something that had been covered in exercises on board. In addition, the announcement was not perceived by key personnel in the HQ1. This explains why the HQ1 did not attempt to carry out the request «Hard astern» conveyed over the PA system.

Some of the bridge team members have referred to the dramatic, unfamiliar, unclear and highly stressful situation in which they found themselves as a possible explanation of why the emergency procedures were not implemented in any systematic way. There was great contrast between the incident and previous training exercises, as described in more detail in section 3.10.3.1.

The NSIA also sees the time factor between the collision and the grounding as a contributory factor. Only ten minutes passed from the time of the collision until the frigate ran aground. In the course of this limited time window, the crew were required to understand what had happened and what lay ahead, to decide what action to take and to take such action.

3.2.2.4 *Leadership as a factor in the incident*

As the situation was perceived as far more complex than any that previous exercises had prepared them for (see section 3.10.3.1), combined with a relatively low level of experience in parts of the crew, the NSIA believes that the OOW and the rest of the bridge team were very much in need of guidance and clear instructions from the commanding officer (CO) and the executive officer (XO) regarding what specific actions should be taken in order to regain control over the ship’s movements. Such distinct guidance from the most experienced officers was not provided in the period between collision and grounding, as the CO took it for granted that standard procedures for regaining the steering were being carried out.

Although this in itself can be construed as being in line with the Norwegian Armed Forces' management philosophy "assignment-based management," the NSIA finds that the bridge team's performance in this very uncommon and demanding emergency shows that they were in need of direct assistance from the CO or the XO. As an example, it would have been useful had the CO or the XO reminded the bridge team to implement the emergency procedures. However, when the XO entered the bridge, his perception of the situation was that the OOW-CIC in effect had taken over command as OOW on the bridge. The XO found this to work well, and therefore never considered to take over command on the bridge himself.

The NSIA's appraisal is that more guidance from the CO or the XO could have contributed to better coordination of the bridge team's efforts, and to effective measures against grounding being implemented in time.

In the NSIA's opinion, during the time that passed between the collision and the grounding, the CO placed more trust in the bridge team and left more up to them than warranted by their level of competence and experience, their teamwork training and the governing documentation on the bridge.

However, the bridge team's performance prior to the grounding should also be considered in light of the fact that – as it became clear afterwards - they only had about 10 minutes at their disposal after the collision until the vessel would run aground. On account of the extent of the damages, the dark, and human reactions to the collision, it was hard for the bridge team to collect information about the status of the vessel, and take effective measures to gain control over propulsion and steering.

Even with guidance from the most experienced officers on board, one cannot conclude that the crew would have managed to avoid the grounding in the time available, given the complex and demanding situation in which they found themselves.

3.2.2.5 *Lack of communication*

Because of the much reduced communication between the bridge and HQ1, situational awareness in HQ1 remained inadequate until the grounding was a fact. Since the MEO and the others in HQ1 had not been informed by the bridge of the risk of running aground, they gave priority to preventing flooding and increasing the power supply rather than to initiating local control of the propulsion system. Subsequently,this lack of information had a major impact on the sequence of events.

3.2.2.6 *Funtion of the CIC up until the frigate ran aground*

The CIC was manned in accordance with the frigate's programme and planned activities before the collision. In the NSIA's view, it appears that there were problems in setting up the CIC organisation after the collision. It took time before the organisation implemented systematic measures to gain an overview and/or control of the communication challenges that arose after the collision and the black ship situation. This delayed communication and there was hardly any flow of information to the rest of the crew. After the collision, the OOW-CIC went up to the bridge to assist, which meant that no handover was carried out when the WEO and the operations officer (ORO) arrived in the CIC. The NSIA believes that, given the situation, the OOW-CIC did not have material information to hand over and that he needed to obtain information by going to the bridge.

In the NSIA’s assessment, the CIC organisation did little to prevent the frigate from running aground. One of the CIC’s most important tasks was to safeguard command and control in the organisation and to ensure a necessary flow of information to support effective leadership and prevent uncertainty and fear from spreading among the crew. Continuously updated and detailed information was of vital importance to this effort. Loss of communication systems and chaotic conditions immediately after the collision prevented updated information about the situation from being communicated to the crew. Information updates could have caused the damage control organisation to change its priorities and actions, whereby the grounding could have been prevented.

3.2.2.7 *Utilisation of technical resources available to avoid grounding*

Appendix H addresses the technical resources that were available in the situation, without the crew realising or understanding that this was the case. The purpose of such an assessment is not to point out what the crew should have done, but to consider what safety lessons can be learnt by the Navy through reviewing the technical resources that were available in the damage control situation.

3.2.3 Ineffective bilge pumping

3.2.3.1 *Operation of the bilge system after the collision*

The status of all valves was checked during an inspection on board after the frigate had been refloated, and the suction valve (one of the three black bilge valves) in the aft generator sets room was found to be closed. It has not been possible to ascertain why this particular valve was closed, but since it was located under a bolted-down floor grate (see Figure 57), the reason why it was not opened manually may have been that it was not readily accessible to the crew. Because of the severed cables, remote operation of the valve from HQ1 or the local panel on deck 2 was also not possible.

After the frigate was refloated, both the driving water valve and the root valve in the aft generator sets room were found to be open. Given that the seawater main was broken in this area, it would not have been possible to use the eductors in the forebody to pump out water from the aft generator sets room.

Given that the seawater main was not isolated, there was also no driving water pressure for any of the eductors to create a vacuum. Pumping was thus not possible. The seawater main would have had to be isolated as close as possible to where it was damaged, to enable the greatest possible number of eductors to be used for removing water from the aft generator sets room.

Data from the IPMS show that several seawater pumps were started before the seawater main was isolated. This meant that, for a period of time, seawater was being pumped into the vessel through the damaged seawater main. This is not considered to have been a decisive factor in causing the vessel to subsequently sink; see section 2.9.2. After approximately five minutes, the seawater main was segregated at the transition between fire zones 2 and 3, after the isolation valve had been opened and closed several times from the DCC. The segregation meant that the aft generator sets room, aft main engine room and reduction gear room were not supplied with driving water for producing a vacuum in the eductors in these rooms. Use of the bilge eductors in the three foremost compartments was thus the only option for removing water from the aft generator sets room.

After HNoMS 'Helge Ingstad' was refloated, the scope of damage to the seawater main was reviewed and compared with IPMS data, showing that it would have been technically possible to isolate the seawater main further aft; see section 2.9.7.5. This would have made driving water available to five of the six eductors. Through investigations conducted after the accident, it has emerged that it would have been possible to isolate the seawater main by closing all valves marked with a ‘Y’ or ‘Z’, in addition to four valves around the damaged area.

There may be several reasons why the frigate did not sail in the ‘Y’ state and why the crew were not able to segregate the seawater main further aft, as discussed in more detail in section 3.4.

At approximately 04:07, the isolation valves in the forward main engine room and between that room and the bow thruster machinery room were opened so that the bilge eductors in these rooms could be used for pumping water from the aft generator sets room. But the eductors in these rooms did not achieve the expected vacuum, except in the forward auxiliary machinery room. The root valve in the auxiliary machinery room, isolating the eductor from the bilge line, was closed at the time, while the root valves for the other machinery spaces were open.

Tests carried out of the bilge system (see section 2.9.4) show that the two manual suction valves in the food waste treatment room and the pyrotechnics magazine were not properly closed and drew in air. This contributed to insufficient vacuum in the eductors that had open lines to these valves. Since the root valve in the auxiliary machinery room was closed against these valves and had sufficient driving water pressure, vacuum was achieved in this particular room.

Because the crew were unaware that these two manual valves were open, they probably found it incomprehensible when vacuum was not achieved in the three eductors that now had driving water pressure. The manual valves were not displayed in the IPMS and could only be checked by physical inspection of their status. These valves were marked with an ‘X’ (see Figure 73) and should have been closed in accordance with the marking system.

Figure 73: Example of manual bilge valve marked with an ‘X’ in the bilge system. Photo: NSIA

It was not possible to open the isolation valve in the aft generator sets room after the grounding, as it quickly became submerged in water and possibility of remote operation was lost due to disengagement of LS7. In theory it was possible to use emergency cables to the cabinet to control the valve from 2 deck, however, due to the unclarified situation, this was not done. This meant that it was impossible to pump out water from the aft generator sets room by use of eductors in compartments forward of that room. There was no possibility of operating the valve manually from a higher level should the remote control function fail and a valve become submerged in water.

The grounding resulted in parts of the damage in the aft generator sets room came under the waterline, which led to increased flooding and that the crew lost control of flooding of the room. Further efforts to bilge the room with the stationary bilge system would therefore not be possible.

Figure 74: Example of isolation valve. Photo: NSIA

At approximately 04:14, the suction valve in the bow thruster machinery room was opened, and it was only closed approximately 24 minutes later. This meant that the valve drew air during that period and that sufficient vacuum was not produced in eductors with an open line to this valve. It has not been possible to ascertain why this valve had been opened. As it turned out, however, it made it even more difficult for the crew to understand why vacuum could not be achieved in the three foremost bilge eductors.

When the suction valve was closed, the vacuum in the eductor increased slightly, but the system had an open line to the two manual valves that remained open. Furthermore, investigations and tests carried out after the incident (see section 2.9.4) show that the motorised suction valve in the bow thruster machinery room did not provide a mechanical seal, even though the valve was displayed as closed in the IPMS. This meant that the valve drew in some air and that sufficient vacuum was not produced in the eductor. The eductor was thus unable to achieve maximum pumping capacity. Possible reasons why the valve did not seal mechanically are presented in section 2.9.4.2.

The crew continued to troubleshoot the system by closing the isolation valve between the bow thruster machinery room and the forward auxiliary machinery room. This caused the vacuum in the eductor in the bow thruster machinery room to be reduced once again as a consequence of the suction valve not being properly closed. At approximately 04:43, the isolation valve at frame 77 supplying the two leaking manual valves in the food waste treatment room and pyrotechnics magazine was closed. There are no records of further changes having been made to the configuration of the bilge system.

The investigation has shown that it was not possible to remove water from the aft generator sets room after the frigate ran aground, since the isolation valve towards the adjacent machinery space could not be remotely operated as a result of broken communication cables to the IPMS and lack of electrical power to the local panel on deck 2. Furthermore, the valve could not be opened manually because of the water that flooded in after the grounding. The seawater main was also broken in this area, which meant that the eductor in this room could not be used. In addition, it turned out that the suction valve had not been opened. In addition the stationary bilge system would not be able to handle the flooding as a result of parts of the damage came under the waterline after the grounding.

The investigation has shown that several valves in the bilge system that were meant to be closed were not properly closed. As it was only possible to check the two manual valves by physical inspection, this was a challenging task for the crew to solve. In principle, all manual valves were supposedly closed. It was probably because the valves did not seal properly that crew never understood why sufficient vacuum was not achieved in the three bilge eductors in the forebody, all of which were supplied with driving water pressure. Effective pumping of water from the reduction gear room would thus also not have been possible after the grounding.

The investigation has also shown that even with the damage inflicted to the seawater main in the collision, it would have been technically possible to segregate the seawater main further aft, see section 2.9.7.5. That could have enabled use of the eductor in the reduction gear room. It is nonetheless understandable that there were challenges involved in isolating the seawater main as the damage caused very many valves to be inoperable from the IPMS. The reason why the seawater main was not isolated further aft is discussed in more detail in section 3.7.1.2.

The investigation has shown that the ineffective use of the stationary bilge system was not a decisive factor in causing HNoMS 'Helge Ingstad’ to sink. This can be explained by the following:

- the bilge system capacity was not designed to handle the amounts of water entering the open downflooding points that became under the waterline as a result of damage

- stability calculations has shown thatfilling of the aft generator sets room and the reduction gear room was not decisive in causing the frigate to sink, even though it had considerable negative effect on the frigate’s survivability, see section 2.9.2.

Nonetheless, ineffective pumping did have a bearing on the sequence of events in the form of the psychological impact. The crew were unable to get the system to work, at the same time as they observed that the vessel was taking in a lot of water. A great deal of the HQ1 crew’s time and focus was spent on this. The flooding of the reduction gear room also had a bearing on the decision to evacuate the ship, when yet another compartment was flooded, as further described in section 3.2.4.

3.2.4 Stability and buoyancy

The aft conscripts berthing was soon flooded with seawater caused by the damage after the collision. In addition, the storeroom and aft generator sets room started to get filled, see Figure 75.

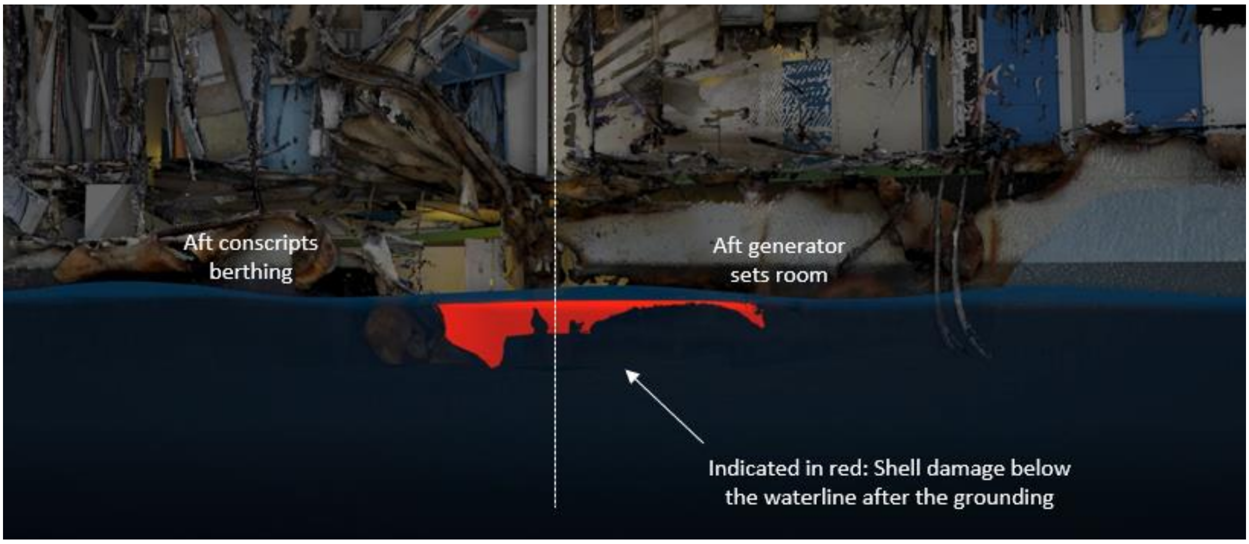

Figure 75: Shell damage below the waterline. Illustration: NCIS/CIAAS/NSIA

After the grounding, the marine engineer officer (MEO) received alerts that there was also flooding in the aft generator sets room. Three compartment had now been flooded (aft generator sets room, conscripts berthing and the supply department storeroom). At that time, the MEO believed it was possible to prevent the vessel from sinking, while he also started to realise that there was a possibility that they would not succeed. He used the carpet plot as a decision support tool, which indicated that the vessel would survive damage to three compartments. Despite this, the MEO suggested to the weapon engineer officer (WEO) to prepare for ‘Abandon ship’, as he realised that the situation might deteriorate.

The MEO had received indications that the steering gear room was flooded, but had also received information to the contrary. To be on the safe side, the MEO therefore included the steering gear room in his assessment, at the same time as he was aware that he still had some leeway in relation to the carpet plot, since the aft generator sets room was not completely flooded and it was unlikely that water was ingressing to the steering gear room. The MEO informed the CIC that he assumed that the ship could be salvaged. The MEO considered that, for the vessel to survive, the buoyancy of other watertight compartments had to be maintained.

HQ1 was then alerted to the flooding of the reduction gear room, see Figure 76. When the MEO was informed of water flooding into the room through the flexible coupling, he was faced with a new and unknown problem. The unexpected ingress of water to an undamaged compartment hit him hard in what was already a stressful situation. It also gave rise to uncertainty about the integrity of other watertight compartments, including the reduction gear room. The crew was of the understanding that the vessel would sink if the gear room was filled with water. The MEO therefore had to quickly revise his situational awareness, and hence also his assessment of risk, particularly relating to the health and safety of the crew.

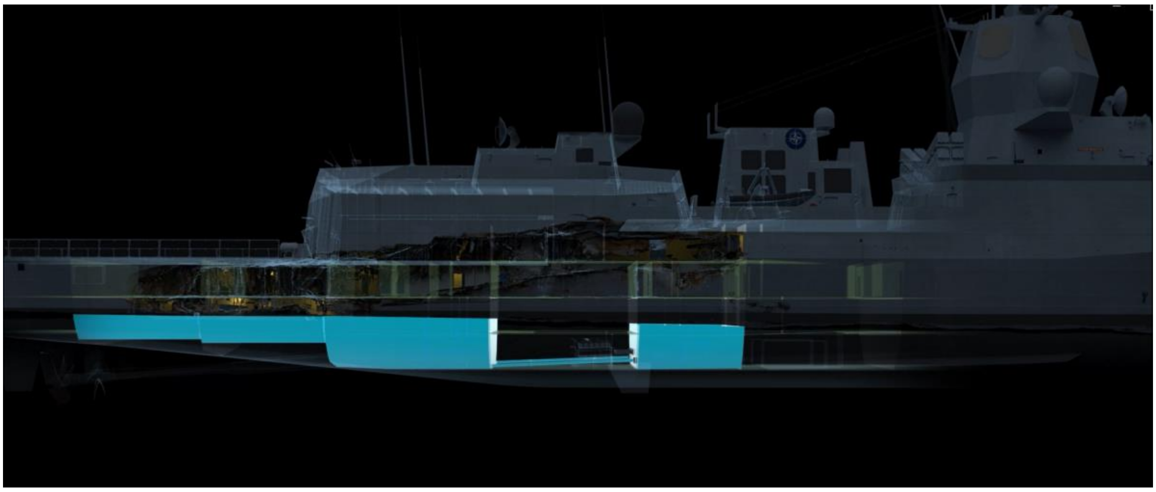

Figure 76: Water filling from aft generator sets room via hollow shafts to the reduction gear room. Illustration: CIAAS/NSIA

Flooding of the reduction gear room meant that the ship could no longer be considered to have sustained continuous damage as shown in the carpet plot. In other words, the MEO was now without suitable decision support, as the carpet plot did not cover the situation as was; see also section 2.6.9.3. Based on the damage and the information the MEO had about which rooms were flooded, he considered that there was a real risk of foundering and capsizing, which would entail a great risk of leaving too little time for all crew to abandon ship before she sank. He also started to receive information about ingress of water to the machinery spaces adjacent to the reduction gear room. The MEO saw this as confirmation of his assessment that the vessel might be lost. As a result of this assessment, the MEO therefore recommended to the ship management to abandon ship while there was still time.

The requirement to the vessel’s extent of damage, see section 2.6.9.2, comprised three continuous compartments. The MEO now had to assess flooding in four or more compartments, and the damage was not continuous. As the MEO lacked good decision support to assess the situation, the NSIA finds it only natural that the MEO considered that the vessel was lost and recommended to the ship management to evacuate the ship.

The grounding had the effect of considerably speeding up the flooding of the vessel. Preventing the grounding would have left more time for the crew to consider relevant actions to prevent loss of the ship. Failure to shut down would, however, cause the ship to sink, regardless of the grounding, see section 2.9.2.

The frigate was in a poor state of shutdown when it was evacuated, with several doors, hatches and other watertight openings left open. This resulted in gradual flooding through open downflooding points; see the description of shutdown state in Appendix C (R)[133]. Stability calculations carried out by the NSIA (see section 2.9.2) show that, had downflooding continued in the ship's shutdown state when evacuated, she would have sunk regardless of whether or not she had run aground. When the tugboats pushed the frigate sideways towards the shore, the situation escalated.

The investigation has shown, however, that a shutdown of the ship before evacuation could have prevented her from sinking. The grounding was not a decisive factor in

[133] ‘Classified as Restricted under the Security Act by information owner the Norwegian Armed Forces and the NDMA

causing the frigate to sink, as the failure to shut her down would have caused her to sink in any case. Further damage control, prioritising the most effective measures would have contributed to getting control of the water ingress. This would require better knowledge of the requisites for the vessel's stability and higher awareness of which volumes were buoyant and the importance of these. Damage control in the aft and forward main engine room, where there were minor leakages through seals, and on Q-deck would in this case be given priority, and not watertight sections that were already lost.

The NSIA believes that, for the crew to consider alternative actions to those that were taken, more competence, training and exercises would have been needed, in addition to better decision support tools than those to which they had access. The investigation has shown that there was little knowledge about stability on board and that it was primarily the MEO and one other who had any in-depth knowledge of intact and damage stability. This is discussed further in section 3.3 on decision support tools for stability. The CO found it too risky to order personnel down to improve the closing down, based on the information from the MEO and others concerning the stability situation.

The NSIA is of the opinion that the vessel should have been shut down to ensure watertight integrity after the collision and when the crew evacuated. As this was not performed and considering the available information at the time concerning the stability situation, and insufficient support for making informed decisions, it is understandable that the crew were not ordered back down into the vessel after evacuation.

3.2.5 Operational support

The NDMA Naval Systems Division's emergency duty officer was notified and called to join the Navy's CMT at the same time as Navy personnel. Within the next two hours all personnel critical to the immediate response was notified. Because the NDMA NSD did not use the Norwegian Armed Forces' joint alarm centre (ALS) for mass mobilisation of personnel, not all relevant competence was mustered at the earliest possible time. Based on experience, the NDMA favoured calling critical personnel directly and using colleague notification instead of initiating notification using the ALS. In general, neither the Navy nor the NDMA have personnel on-call, so notification, in particular during night, can be a challenge. Although the NDMA had a representative present in the NSS/CMT from 0500, the ad hoc operations centre in the NDMA NSD (NSD OPS) was not operational until around 08:00, approximately two hours after the CMT was established. This indicates that mass notification through the ALS in combination with telephone alert could have resulted in an earlier response.

The NSIA believes that broader and more effective notification and mobilisation of personnel in the NDMA NSD would have been possible within the framework of applicable plans. More people could have been convened by around 06:00, as was the case for the Navy's CMT.

Telephone communication between the operations centre and the NSD's representative to the CMT did not function in an optimum manner, and a liaison was therefore deployed to the CMT to ensure a better flow of information. Subsequently, more personnel from the NSD OPS joint the team at NSS/CMT. This improved the coordination and it became apparent that the two teams had to be co-located. The NSD OPS was thus co-located with the NSS/CMT from 1320 onwards

Early in the morning it was ordered that all communication to and from the CO HNoMS ‘Helge Ingstad’ should go through the CMT. This seems to have been interpreted to exclude all contact between NDMA NSD and the HNoMS ‘Helge Ingstad’ personnel. This imposed limitations on how information was obtained. Nonethelessm through direct contact with the crew members the NSD OPS was able to obtain information about the scope of damage, ingress of water and status on watertight integrity (shutdown state) – information that afterwards proved to be reasonably accurate. The information was made available to the CMT at around 09:00 when the NSD LO arrived NSS/CMT.

Based on this information, the CMT soon learnt that the watertight integrity on board the frigate was not satisfactorily maintained when she was evacuated. Individual members of the CMT pointed out that shutdown to maintain watertight integrity was important for the frigate’s survivability, but that it had to be based on knowledge about residual stability. The CMT relied on the crew’s assessment of the situation and extent of the damage, including assessment on the ship’s residual stability and the uncertainties to the level of watertight integrity. No internal calculations regarding the frigate’s float ability or residual stability were initiated which could have helped the CO in making his decisions.

NSD OPS made early assessments and implemented measures to salvage the vessel. In cooperation with the CMT resources were requisitioned and deployed to the emergency site, but did not arrive before the vessel were pushed sideways and heeled heavily. On its own initiative the NSD OPS sent personnel with ship technical, diving, and damage control competence to the emergency site, but they arrived too late to be able to give CO ‘Helge Ingstad’ advice on stability assessment and damage control. Information on these inititiatives were to a limited degree not communicated to the CO and OSC on board CGV ‘Bergen’.

Even though DNV GL ERS had not been assigned a role in the plans, it carried out assessments of the frigate’s stability that same morning. These assessments were based on information about the frigate that it was already in possession of, in combination with the television images. The calculations were forwarded to the CMT, but never reached the CO of HNoMS 'Helge Ingstad’ on board CGV ‘Bergen’.

The CO has subsequently expressed frustration over not receiving technical advice and assistance, and it was his understanding that, if the ship slipped into deeper water, it could sink very soon. The CMT’s decision that only the CO could grant permission to board the frigate, without having anyone to consult with in the shore-based organisation, meant that the CO had very limited basisfor his decisions.

The NSIA finds it unfortunate that information available in the CMT and NDMA NSD was not communicated to the CO. For further evaluation of operational support, see section 3.8.

3.3 Decision support tools for stability

3.3.1 Stability calculator and carpet plot

Stability calculations carried out by the NSIA after the accident support the assumption that the ship had considerable residual stability after evacuation; see section 2.9.2. During the incident, the MEO assessed the stability as being critical and recommended evacuation of the ship. This was based on the carpet plot in the frigate’s stability manual.

In the NSIA's opinion, the carpet plot in the stability manual was not very helpful for assessing survivability if the frigate was damaged in several places and such damage did not extend continuously over several watertight compartments. Damage in several places along the length of the hull must be assumed to be highly relevant on a warship. This was also described as a challenge in the crew's project assignment on the stability calculator. The project assignment was completed before the accident occurred; see section 0.

The frigate's stability calculator was not in use; see section 2.6.9.5.2. The NSIA was given a brief demonstration of the stability calculator by Navantia in February 2020, but has not conducted any test or gotten a full demonstration of the calculator. Hence, the NSIA does not know how sophisticated or user-friendly the stability calculator might have been. Nor has the NSIA assessed the expediency of integrating the stability calculator in the IPMS compared with an independent solution, but it assumes that such an assessment is carried out by the Navy and NDMA.

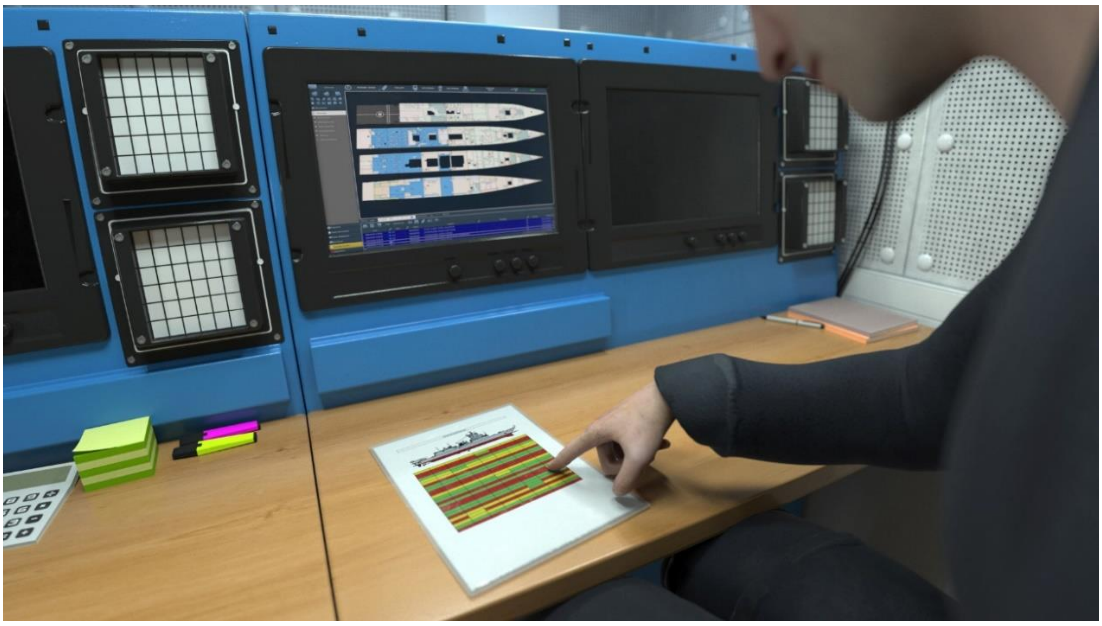

Figure 77: The carpet plot and the stability calculator. Illustration: CIAAS/NSIA

The NSIA believes that it might have made a difference to the sequence of events had the stability calculator been in use and the crew received regular training in how to use it to simulate complex damage scenarios. The crew would probably have obtained some assurance of the ship's survivability despite the flooding of more compartments than what the design criteria and carpet plot were based on; see 2.6.9.3. Assurance that the ship would not immediately capsize or sink would probably have made it easier to decide on actions to improve the situation to improve the situation, including where shutdown was most important, where the focus should be on pumping out water, transferring tank volumes and getting the ship pulled off the seabed.From the time the frigates were commissioned, both the Navy and the technical organisation[134] were aware that the crew felt that the stability calculator did not work in a satisfactory manner. The calculator was meant to serve as an important decision support tool in a damage control situation. The NDMA NSD has nonetheless stated that, during the period from handover to operations

[134] NDMA Naval Systems Division, formerly the NDLO Naval Systems Division

until recently, neither the NSD nor the Fleet has had sufficient focus on the stability calculator, with regard to operation, maintenance, training and use.

The crew on HNoMS 'Helge Ingstad' most recently sent a note of concern regarding the reliability of the calculator and the crew's skills in its use one month before the accident; see section 0.

The NDMA has partially explained the failure to follow up the functioning of the calculator and training in its use since the time that the frigates were being built by there being a shortage of resources for addressing important task in the Naval Systems Division.

According to the directive for safety management in the Norwegian Armed Forces (*Direktiv for sikkerhetsstyring i Forsvaret*), a shortage of resources shall not lead to a lowering of the safety level. The NSIA believes that the Norwegian Armed Forces/NDMA have prioritised ship operation over safety, which suggests a lack of mechanisms for safe ship operation; see section 3.9 and 3.16.

In investigations of previous accidents, there have also been findings related to stability competence and tools for making stability assessments; see sections 2.10.2 and 2.10.5.

The Navy has informed the NSIA that a stability course is held to enhance training relating to stability and a new revision of the stability calculator is implemented, see section 2.11.

The NSIA submits two safety recommendations to the Norwegian Navy concerning the use and functioning of the stability calculator; see Safety recommendations Marine no 2021/14T and 2021/15T in chapter 5.

3.4 Assessment of equipment protection level and shutdown state

Practice on board the frigates had been not to close down to Zulu upon general alarm, see section 2.6.2.5. This practice has not been further investigated, but the NSIA underlines the importance of having a practice that ensures the watertight integrity that is assumed in design.

The investigation has also shown that watertight doors on 2 deck and hatches between 2 and 3 deck were not properly closed and dogged before the vessel was evacuated see Figure 78 and Appendix C. As a result, watertight integrity and buoyancy were not adequately maintained and the frigate eventually sank. Calculations have shown that the failure to shut down to maintain the frigate's watertight integrity had a decisive impact on its survivability; see section 2.9.2. The failure to close and dog all watertight doors and hatches on HNoMS 'Helge Ingstad' on the night of the accident must be seen in the light of lack of competence and decision support related to stability and buoyancy; see sections 0 and 3.3. The crew deemed it critical to evacuate the frigate as soon as possible, as they believed there was a risk she would heel over. There was no systematic shutdown to upheld watertight integrity prior to evacuation.

Failure to shut down were also based on challenges related to cables and hoses for portable bilge pumps that were in operation when the frigate was evacuated, passing through doors and hatches to watertight compartments. These portable pumps were used since the crew experienced problems operating the permanently installed bilge system.

The situation was chaotic and stressful and they experienced challenges operating the pumps due to bends in long hosed filled with water.

The NSIA is of the opinion that use of the portable bilge pumps in this situation wouldn't have any effect to control the water ingress due to the limited capacity of the pumps. The investigation has shown that it was difficult to get an overview of the amount of water coming into the vessel and compare this to the available bilge capacity. The NSIA considers it to be important that the crew is aware of in which scenarios the portable bilge pumps can be expected to have an effect to avoid time spent on measures that has no effect during damage control.

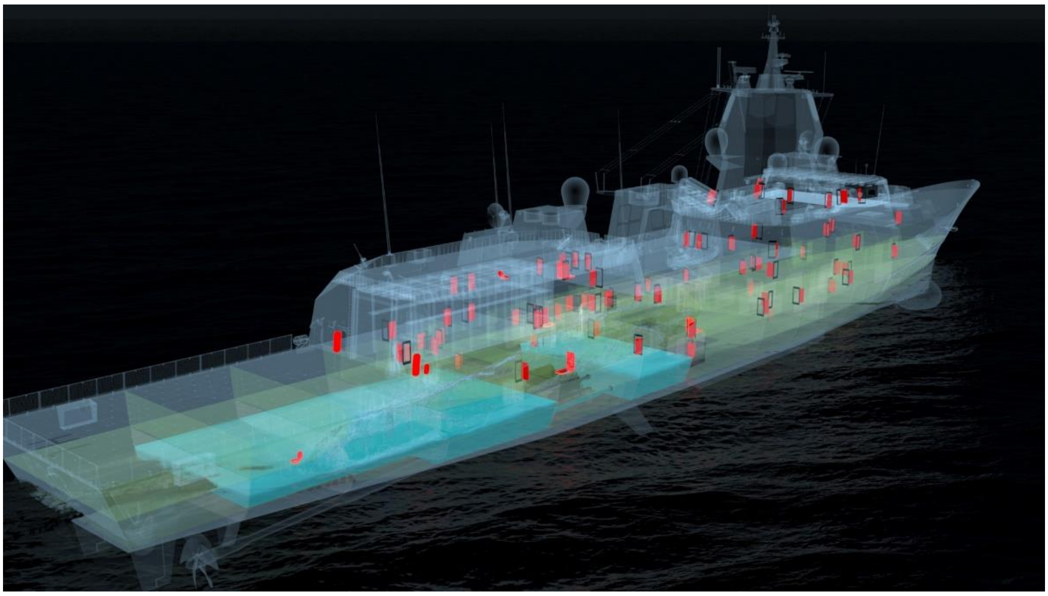

Figure 78: Breaches in watertight integrity on board. See Appendix C (R) for a complete overview of shutdown state. Illustration: CIAAS/NSIA

According to the HNoMS Tordenskjold training establishment, the crew should have learnt about the marking system and shutdown as part of the basic boating course. This knowledge should then have been translated into practice and maintained through the shipboard training programme; see section 2.8.10.5.4. To what extent shutdown was an important part of the training programme is uncertain, as the documentation describing the exercises has been shredded. A failure to shut down the frigate to the ordered equipment protection level was also pointed out in several of the scenarios covered in the safety review report from 2016; see section 2.8.10.3.1.

The investigation has shown that the crew were not aware of or competent to understand the importance of the shutdown state for the frigate's survivability: see section 2.6.2.5

The automatic shutdown option and IPMS operator support tools for shutdown according to a certain equipment protection level were not used. Several valves, hatches and doors that should have been closed during passage were found to be open, and were also open when the ship was evacuated; see Appendix C (R). A higher level of protection was not ordered when the general alarm was raised, because of challenges relating to damage control logistics on deck 2. The design was based on the assumption that damage control would be conducted from deck 2, which, in the event of extensive damage, could threaten the frigate's survivability in that hatches and doors that were meant to be closed would be left open.

The NSIA considers it to have had an important bearing on safety that the frigate was not in the ordered equipment protection level during passage and that this had not been registered. This is also made clear in SMP-17 (B), where the following is stated:

> *'Experience of war has shown that maintaining strict watertight and gastight discipline is fundamental to the safety of the vessel. This is obviously also the case in peacetime, in the presence of possibilities of running aground, colliding or catching fire. In this context, discipline refers to user discipline, i.e. correct operation of closing devices at all times.'*

Neither the Navy nor the NDMA as the shore-based support organisation had an overview of the configuration of markings on board the individual ships, and they were also not in control of the operational use of markings on board. The investigation has shown that, after the accident, several members of the shore-based organisation were nonetheless surprised that the frigate had not been shut down to ensure watertight integrity.

In the NSIA's view, not enough was done before the accident to provide the crew with sufficient competence and awareness of equipment protection and thus ensuring the frigate's survivability. The investigation has shown that this applied to the Fleet's frigate crews in general. The long time it took to process change proposals relating to markings, and the lack of control of configurations, indicate that inadequate resources have been assigned to this area at several levels of the organisation.

The Navy and the NDMA have pointed out that this can be partly explained by the reorganisation of personnel and a shortage of resources for follow-up work, knowledge dissemination and training. According to the Norwegian Armed Forces' safety management directive, a shortage of resources shall not lead to a lowering of the safety level.

The NSIA believes that the Norwegian Armed Forces/NDMA have prioritised ship operation over safety, which suggests a lack of mechanisms for safe ship operation; see section 3.9 and 3.16.

In connection with the investigation of previous incidents, ships have also been found to have sunk as a result of not being shut down; see section 2.10.2.

The Navy has informed that ongoing measures are enacted to strengthen the crew's competence on shutdown, see section 2.11.The NSIA submits two recommendations relating to improving competence relating to shutdown states and the use of portable bilge pumps; see Safety recommendations Marine no 2021/16T and 2021/17T in chapter 5.

3.5 The role of the Q-deck

The investigation has shown that, as part of a watertight compartment, the Q-deck was very important for the frigate's survivability. Calculations by the NSIA have shown that the frigate's buoyancy was considerably reduced by the flooding of compartment 13; see section 2.9.2. The Q-deck consisted of a great number of hatches and feedthroughs. Ventilation openings and other openings were found not to have been closed in accordance with the applicable equipment protection level. This caused flooding of the Q-deck when these openings were submerged. The open valve in the ventilation inlet on the starboard side contributed to the water filling of the Q-deck and the deck store below. For section 13 to be a watertight section, all hatches and penetrations must be watertight. This also applies to the spring-loaded overpressure valves, which are watertight only from one side.

It was also discovered that the design-phase assumption that the Q-deck would be watertight was not followed up after the frigates were commissioned.

The NSIA is of the opinion that adequate systems had not been put into place to ensure that this knowledge was conveyed to those who would operate the frigates when they were transferred from the project to the operating phase. The knowledge was fragmented and lost over the years, possibly as a result of underlying factors such as the reorganisation of the shore-based organisation and not giving priority to resources for follow-up work in the Navy and the NDMA.

This was despite the fact that the NDMA, as the competent authority, was aware of the importance of the Q-deck as a buoyancy volume at an early stage.

It has emerged during the investigation that the frigate crews in general knew little about the decisive importance of this compartment for survival in the case of damage to the afterbody. Nor had any particular operational procedures been established to ensure that all hatches, doors and openings were completely closed to make the Q-deck watertight in case of a general alarm. Furthermore, the work hatches, mooring hatches and ATAS door on HNoMS 'Helge Ingstad’ were not marked. There were no procedures or descriptions available for work on securing for sea on the Q-deck.

The sister vessels had also reported that there were challenges involved in keeping certain hatches on the Q-deck watertight. One possible reason was that, while they were in great need of maintenance, they were hardly maintenance-friendly, i.e. the hatches could not be repaired during passage and some had to be removed for repair.

The Royal Norwegian Navy’s routines for testing watertight integrity include chalk testing, ultrasound and hosing tests; it was only the test that included water filling with hydrostatic pressure, however, that revealed the leakages in the watertight door; see section 2.9.6. At the time of issue of this report, the examinations carried out to identify the cause of the leakage, indicate that it was caused by factors related to design and construction. Navantia contests this, claiming that the aftermost compartment was watertight at the time of delivery. Neither Navantia nor the NDMA has provided the NSIA with any documentation from the building phase or delivery to show that the ATAS door was watertight. This makes it difficult to conclude on this matter. The NSIA will not investigate this further, and leaves it up to the NDMA to follow up on the matter. Vessels built by shipyards in accordance with the rules of recognised classification societies must comply with requirements that ensure verification of watertight integrity; see section 2.6.9.4.2. HNoMS 'Helge Ingstad' was not built to the relevant class rules and, for that reason, the NSIA does not issue any safety recommendation to Navantia on this point.

In the NSIA assessment, the inclusion of the aftermost compartment (Q-deck) in the frigate’s buoyancy volume, given its significant number of closeable openings was in any case, from the outset, a technically demanding solution. It would not be possible to design and operate such a deck without making compromises, given that it is also meant to be a work deck where it is assumed that one of the hatches (the ATAS door) can be kept open while the ship is in operation. Factors relating to the frigate's built-in weapons capacity, technical capacity and operation affect the vessel's capacity for withstanding damage. These are matters that Navantia, the NDMA and Navy should all focus more on.

The NDMA has informed that a study is initiated to evaluate the current design and whether there is a need to incorporate requirements in applicable regulations, see section 2.11.

The NSIA submits four safety recommendations regarding how regulations can be developed so as to better ensure that naval vessels meet the requirements for watertight integrity, that design-phase assumptions are implemented and that watertight integrity of section 13 is ensured; see Safety recommendations Marine no 2021/18T, 2021/19T, 2021/20T and 2021/21T in chapter 5.

3.6 Watertight integrity between watertight compartments

Calculations carried out by the NSIA show that the flooding of the reduction gear room through the hollow propeller shafts had a negative impact on the frigate's stability, but that it was not a decisive factor in causing it to sink; see section 2.9.2. Combined with several other factors, the flooding of the reduction gear room had a negative psychological impact on the crew, however, and thus contributed to the decision to prepare for evacuation.

The NSIA has been informed that some of the crew were aware of the hollow shafts, but that this had not been processed as a nonconformity. Lack of reporting and follow-up of nonconformities are discussed in more detail in section 3.9.

The design and implementation of the hollow shafts on the frigates show that large and complex projects are very demanding in terms of interfaces between different disciplines. The investigation has shown that there was too little attention to these interfaces during the project phase. Navantia has implemented relevant measures to design-related safety problems in future; see section 2.11.5. Hence, the NSIA does not submit any safety recommendation to Navantia on this point.

3.7 Assessment of the bilge system

3.7.1 Operational factors

Information from the crew as well as IPMS data show that many attempts were made to start the bilge system, while none of them succeeded. Several actions indicate, however, that the crew lacked sufficient system competence and were not sufficiently coordinated in their operation of the system. This can be exemplified as follows:

- Registered IPMS data show that understanding how to isolate the seawater main took time, and that water was being pumped into the frigate via the damaged pipe for several minutes before the isolation valves for segregation of the damaged area were closed; see section 2.6.10.3.

- A function in the IPMS, designated 'Segregated in 2', will automatically isolate the seawater main from Yankee to the Zulu state when activated, ref. Appendix E1 (R) which could have contributed to isolation of the seawater main. No data have been found to suggest that this function was used.

- There were attempts to open several eductors before the seawater main was isolated; see section 2.6.10.4.

- There was an attempt to open the suction valve in the aft generator sets room before the seawater main was isolated; see section 2.6.10.4.

- IPMS data show that the suction valve in the bow thruster machinery room was opened immediately after the frigate ran aground, even though there was no ingress of water to this section. It was left open for 23 minutes and drew air into the system; see section 2.6.10.4.

- The DCC operator was charged with operating the bilge system. IPMS data show that the system was operated from the PCC and ACC in addition to the DCC; see section 2.6.10.4.

- Nobody was aware that the manual valves leaked and caused air to be drawn into the system.

3.7.1.1 *Awareness of system vulnerabilities*

Even though the bilge system was defined as a safety-critical system, it emerged during the investigation that there has been little focus on training on how to operate the system. This was largely a result of the bilge system also being used for pumping oily water from the machinery spaces and that there was some concern about the risk of environmental emissions. Given sufficient instruction and training, the NSIA believes that the vulnerabilities associated with open suction valves and their effect on the eductors could have been recognised at an earlier stage. The fact that some of the manual bilge pump valves were not properly/tightly closed during the incident suggests that the crew were unaware of this decisive system vulnerability.

3.7.1.2 *Instruction and training in IPMS operation of the bilge system*

The crew were not offered a special instruction programme or simulator training to become competent in IPMS operation of the bilge system to deal with a system failure in connection with an accident. The crew were given on-the-job training, chiefly concerned with operating an intact system on board. To be able to operate such a system under the circumstances that prevailed in the early morning when the accident occurred, with extensive damage, flooding and a high stress level, the crew would have had to be trained beforehand in how to deal with similar scenarios involving damage to parts of the system.

In the NSIA’s opinion, troubleshooting such a system without having received thorough instruction and training in how to operate the system amounted to a very difficult task. This meant that pumping activities were uncoordinated and characterised by lack of competence that could have been acquired through thorough instruction and training in dealing with simulated system failures. Why the crew had limited competence is discussed in more detail in section 3.7.3.

Measures are enacted by the Navy, in cooperation with the NDMA, to identify competence requirements, see section 2.11.

The NSIA submits one safety recommendation on competence relating to the bilge system; see Safety recommendation Marine no 2021/22T in chapter 5.

3.7.2 Technical factors

3.7.2.1 *Bilge system vulnerabilities*

The incident has shown that there were several vulnerabilities relating to the bilge system. The most important of these can be summed up as follows:

- Lack of segregation between the main bilge system and the bilge sullage system for day-to-day removal of bilge water and oily water. The design had nonetheless been approved by the project. This resulted in little training and instruction and thus inadequate control of the system, because vulnerabilities were not identified; see section 3.2.3.1. That the ship had no separate system for handling oily water was identified as a nonconformity in connection with DNV GL's class entry process.

- Several valves were located under bolted-down floor grates, which made it challenging to operate them manually if remote control failed, ref section 2.6.10.1.

- Two of the manual valves as well as one of the motorised valves did not seal properly, and it was virtually impossible for the crew to realise this during the incident. This caused air to be drawn into the system so that the available driving water did not produce sufficient vacuum in the eductors.

- It was not possible to operate the motorised valves manually from decks above 4 deck if remote control from HQ1 or from the local panel on deck 2 should fail. This meant that several of these valves became inaccessible given the rapidly rising water level, ref section 2.6.10.4.

Measures are enacted by the NDMA, in cooperation with the Navy, to improve the bilge system, see section 2.11.

The NSIA submits three safety recommendations relating to technical vulnerabilities; see Safety recommendations Marine no 2021/23T, 2021/24T and 2021/25T in chapter 5.

3.7.2.2 *Bilge system capacity*

The system was divided into multiple units with isolation valves between watertight compartments. This meant that, if an eductor failed due to damage in a watertight compartment, water could be removed from that compartment using an eductor from another compartment. There was an understanding in both NDMA and the Navy that the total capacity should be available in every main pumping point. This was also the purpose of the bilge capacity test to verify, see section 2.9.5.

From the capacity test performed of the bilge system it was concluded that the system total capacity was too low compared to the requirements for the vessel class, see section 2.9.5 The NSIA considers that the failure to meet the total capacity requirements was not of any consequence for the incident under consideration. This was because the pumping was never effective as a result of leaking valves drawing air into the system and of the seawater main not being isolated far enough aft to enable utilisation of all the five eductors that might have driving water available. In addition, the water ingress both in the aft generator sets room and the reduction gear room became considerable so that the system could not handle such amounts of water. The system was not designed with flood pumps with large capacity for draining among others engine rooms in the event of damage to the vessel, see section 2.6.10.7.

The NSIA nonetheless considers that it is a serious matter when a safety-critical system that may have a major impact on the ship's survivability does not deliver according to what was expected by the operator.

NSIA considers that it has to be clear for the crew which scenarios the stationary bilge system is expected to have an effect on, and what bilge capacity that will be available in different scenarios, this to avoid unnecessary efforts on measures that will not have an effect on damage control. Hence it is of great importance to review the actual required capacity of the bilge system. According to the NDMA Naval Systems Division, several operational and design measures relating to the bilge system have been implemented after the incident; see section 2.11. Several findings were nonetheless made during a capacity test on a similar ship in the early part of 2020; see section 2.9.5.

Measures are enacted by the NDMA, in cooperation with the Navy, to improve the bilge system, see section 2.11.4.

The NSIA therefore submits one safety recommendation concerning the need for bilge pump capacity; see Safety recommendation Marine no 2021/26T in chapter 5.

3.7.3 Organisational conditions

The organisational aspect is important when assessing the bilge system. There were vulnerabilities associated with the bilge system of which the crew had limited knowledge.

The investigation has shown that there had been little instruction in the bilge system prior to taking up service on board, and few and limited exercises in handling the context and complexity of a real-life major damage control situation. The NSIA considers it to be a serious matter that the shipboard crew was not better informed about a system defined as critical to safety.

Lack of competence among the crew was a result of, among other things, the system never having been repaired (see section 3.7.2.1). This led to inadequate exercises and training of the shipboard crew, without any compensatory action being taken to ensure that the crew were competent to operate the system.

The NSIA also believes that the failure to address and close bilge system nonconformities over several years had consequences for the safe operation of the frigates and suggests that overall safety management was lacking.

3.7.4 Weaknesses in the regulations relating to design and verification

On examination, the pipe lengths and dimensions, number of valves and complex system topology of the bilge system, with its many operational combinations, should warrant a mandatory requirement for more thorough documentation of actual system capacity. The purpose would be to ensure that the system was fit for purpose and sufficiently robust to withstand expected degradations.

It appears to be a weakness in the design regulations that they do not require additional documentation of complex systems, particularly where these are based on vacuum as the motive force (see Appendix F), and that the prescriptive requirements in the design regulations fail to distinguish between pressure and vacuum-based system designs.

In the NSIA's opinion, it is a weakness of the maritime design regulations that they do not contain requirements for achieving system capacity even though the stated maximum flow rate is not exceeded. The regulations have not been drawn up with sufficient attention to system complexity and obstructions. That necessitates additional requirements in the form of contract specifications in order to ensure a functional system with sufficient capacity.

For similar systems in future, the NSIA takes the view that the regulations must ensure that sufficient capacity for emergency bilge on any vessel is identified and hence is taken into account during design. Additional requirements for calculations and documentation of fitness for purpose should be included in the form of hydraulic flow analyses, full-scale tests or other suitable tests to document actual system performance.

The NSIA submits one safety recommendation concerning additional regulatory requirements; see Safety recommendation Marine no 2021/27T in chapter 5.

3.8 Coordination of operational support from the shore-based organisation

In the Navy's crisis management plans and instructions, there was little mention of what should be done to save a ship at risk of sinking. Even if it took time to get an overview of the personnel on board, the personnel were well looked after. The investigation has shown that the CMT did not obtain an adequate picture of the situation on board, including the scope of damage, shutdown state, buoyancy state and how stable the vessel was in grounded position. In addition, there were neither emergency response teams nor material ready at hand to manage a disaster of such magnitude.

The NSIA understands that it takes time to establish this overview and to mobilise personnel and materiel. In any emergency situation minutes can save the day, and the difficulties handling both personnel and materiel in parallel resulted that the latter was addressed to late. This was probably because the plans did not define saving materiel as a priority task for the CMT, that the plans for the two organisations were not coordinated, and that the coordination between the NDMA NSD and the Navy's CMT was hardly effective.

The CMT was not composed so as to include technical experts with the competence to provide support in damage control situations. This was reflected in the manning plan for the CMT. The CMT did not have enough competence in stability to be able to offer technical advice to the CO of HNoMS 'Helge Ingstad'. Nor did the plans name any Navy departments or personnel whose primary task in an accident and salvage situation would be to support the ship's crew in cooperation with the NDMA Naval Systems Division and the NDLO. However, the KNMT NESC was mobilised early with the task to support the CO and OCS at the emergency site. That personnel from KNMT NESC was underway to the emergency site was never communicated to the CO/OCS and thus never formed part of their decision basis.

In the early phase of the salvage operation, neither the CMT nor the CO of HNoMS 'Helge Ingstad' was aware of what external support could be provided by the NDMA

NSD, otheragencies and civilians. This might have been caused by difference in mission and tasks, lack of coordination between relevant plans and lack of previous cooperation between the staffs. As an example, NDMA NSD was not involved in the CMT's initial response, except from summoning of NDMA personnel.

Among other things, the NDMA NSD had put into place several ad-hoc measures, as for example leak mats and pumps, but these were not known to the damage control leadership on CGV 'Bergen'. Better knowledge of all the measures that have been initiated to salvage the vessel, could have influenced decisions made not to re-enter the vessel or to push the vessel against the shore.

It was not until later that day, when the NDMA NSD's operations centre was co-located with the CMT, that more effective information sharing became possible. Better cooperation during the first hours between the CMT, NDMA NSD OPS and the vessel leadership could have resulted in a better situational awareness among all players, and thus provided a better basis for decision-making.

The absence of specialised damage control competence in the CMT, combined with the lack of coordination between the NDMA NSD's contingency plan and the Navy's crisis management plan can possibly explain why the need for involving the NSD more actively in handling the crisis was not identified soon enough.

The investigation has shown that the ship management had limited knowledge of damage stability over and above what was described in the stability manual, and that they also did not have access to a functional decision support tool; see section 3.3.1. The frigate was therefore evacuated without effecting a shutdown, based on the crew's perception that the ship's stability was critical and that there was a risk of keeling over. Advice and guidance from external competent sources might have changed this perception, however. This would have been conditional on correct information being conveyed at the earliest possible time to the shore-based resources who were to provide operational support.

The investigation has shown that the Navy's CMT lacked sufficient in-depth competence related to stability. The NDMA Naval Systems Division had stability competence, but it was late in arriving and coordination with the CMT was poor.

In the NSIA's opinion, lack of coordination between the Navy and the Naval Systems Division's contingency plans contributed to the failure to arrange for and provide decision support at an early enough time after the frigate ran aground. Among others, this comprises information on the extent of damage to the vessel, including what sections that had water ingress, as well as status on the vessel's watertight integrity when she was evacuated. This, in turn, meant that the on-scene management had to make decision based on their own knowledge and limited information.

Measures are enacted by the Navy and the NDMA to further develop the contingency plans, see section 2.11.

The NSIA submits one safety recommendation to the Navy to cooperate with the NDMA on assessing their contingency organisations; see Safety recommendation Marine no 2021/28T in chapter 5.

3.9 Handling of nonconformities and incidents

The investigation has shown that there were several sets of circumstances identified before the accident that must be deemed to have constituted nonconformities, but which had not been reported or processed as a nonconformity by the NDMA or the Navy. The Norwegian Armed Forces' safety management directive states the following about nonconformities:

A nonconformity is defined as a failure to meet specified requirements. In practice, this means breach of laws, provisions, regulations etc. It goes on to state that:

> *The department shall have documented procedures and an organisational culture in place that ensure that accidents, occupational illness, sickness absence, undesirable incidents and nonconformities are reported and analysed, and that corrective and preventive action is taken.*

The NDMA Naval Systems Division's management system describes procedures for registration and follow-up of nonconformities.

The NSIA believes that several sets of circumstances that were found to exist in the present investigation fall into the category of nonconformities. They should therefore have been reported and analysed, and corrective and preventive actions should have been taken. Such nonconforming items include:

- Nonconformities in the bilge system identified in connection with the class entry in 2014 (registered, but not addressed). The lack of segregation between the frigate's main bilge system and the bilge sullage system for day-to-day removal of bilge water and oily water was also identified as a nonconformity by the technical experts in the NDMA (formerly NDLO) as early as in 2004.

- The stability calculator was not in use. The Navy and the NDMA had informed that challenges relating to the calculator had been reported both during the project phase and, later on, during the operating phase (registered in FIF and in a technical status report, but not repaired).

- Lack of overview of the individual frigates' marking system configurations and lack of uniform configuration (not registered in the nonconformity systems).

- Smoke had been observed to spread between watertight compartments, but this had not been followed up. After the incident, this was identified as a breach of watertight integrity via the hollow shafts (not registered in the nonconformity systems).

- The frigate did not comply with the applicable CAO to sail with the switchboard in split mode (not registered in the nonconformity systems).

There may have been several reasons why these nonconformities were not processed in the Navy or the NDMA Naval Systems Division's nonconformity systems. This was also pointed out in investigation reports after the accident, see sections 2.9.7.6 and 2.9.8.4.

It emerged in the NDMA's internal report that there was little compliance with the Naval Systems Division's nonconformity system, as described in the management system. This made it difficult to get a complete overview of the nonconformities. Lack of focus on use of the nonconformity system, failure to measure the extent to which the system was being used, and the users' lack of knowledge about the nonconformity system itself are referred as reasons for the Naval Systems Division's failure to comply with the process.

It has also emerged that one of the consequences of the reorganisation in 2016 was that the Naval Systems Division reassigned the functions that had been responsible for following up and processing nonconformities. New tasks and assignments left less capacity for case processing, whereby a backlog built up of unprocessed nonconformity reports. In the NSIA's opinion, the reallocation of personnel can probably partly explain why the Naval Systems Division did not have a good enough overview and control of nonconformities, something that is essential in order to ensure safe ship operation.

The Norwegian Armed Forces had also introduced a system for the Navy's reporting of incidents and nonconformities; see section 2.8.8.2. It has emerged from interview with naval personnel that they felt that the nonconformity and incident reporting system failed to give them the necessary overview of incidents, and that alternative support systems were therefore used to keep an overview of incidents and nonconformities.

A shortage of resources has emerged as another reason why reporting and follow-up of incidents and nonconformities on the part of the Navy was lacking. Lack of feedback to the ships on submitted reports had a negative impact on the will to report, which weakened the ability to learn from incidents. Lack of use of the nonconformity system has resulted in challenges related to keeping overview, follow-up and evaluation of incidents. This may have led to lack of evaluation and improvement of the nonconformity system itself. The NSIA has not investigated in detail the underlying causes that the nonconformity module in FIF had not been sufficiently utilized.

Another factor was that, where accident reports had been prepared, there were examples of them not having been used for organisational learning. Reports of previous incidents in the Navy have clearly pointed out the need for learning and also proposed measures, without the organisation having done enough to utilise this opportunity; see section 2.10. The aim of a common system was to give better learning, however, the effect is not further investigated by the NSIA.

The NSIA supports the finding made in the Navy's internal investigation that the Navy lacks a systemic approach with active use of feedback from incidents to learn and improve its safety management in an uniform and consistent manner. Learning is largely left to each individual ship. This meant that there was too little learning between frigates or across the rest of the organisation.

The incident with HNoMS 'Helge Ingstad' has brought to light several examples of a failure to report, follow up and close nonconformities. To a varying degree, inadequate handling of the above nonconformities contributed to the sequence of events and to the frigate finally sinking.

In the NSIA's opinion, this clearly illustrates the importance of a well-functioning nonconformity system, and that neither the Armed Forces/Navy nor the NDMA Naval Systems Division had a satisfactory process for handling incidents and nonconformities. In their internal reports after the incident, both the NDMA and the Navy pointed to the shortage of resources, training and tools as contributory reasons why the nonconformity and incident reporting systems did not work. According to the Norwegian Armed Forces' safety management directive, a shortage of resources shall not constitute grounds for lowering the safety level.

The investigation has made it clear that the organisations were not sufficiently informed of the potential consequences of certain nonconformities for safe ship operation. Several nonconformities had a direct impact on the sequence of events, while the consequences of not taking corrective action seem to have been unknown to and unidentified by the organisation, so that priority was also not given to addressing these nonconformities. Hence the Navy has operated the frigate without being aware of the total risk under which she was sailing.

Measures are enacted by the Navy, in cooperation with the NDMA, to get an overview of the risks for the frigates. These measures are ongoing, hence, the NSIA submits a safety recommendation concerning this issue, see Safety recommendation Marine no 2021/30T in chapter 5.

The Navy has, in cooperation with the NDMA, reviewed and improved registration and follow-up of undesirable incidents as part of the Navy's safety council, see section 2.11.

The NSIA therefore submits a safety recommendation concerning learning from incidents; see Safety recommendation Marine no 2021/29T in chapter 5.

3.10 Manning and competence

3.10.1 Introduction

HNoMS 'Helge Ingstad' was manned based on the lean manning concept (LMC); see section 2.8.9.3. Among other things, this meant that the crew was primarily dimensioned to meet the Norwegian Armed Forces' ambition to minimise operating costs. Important preconditions for the concept included a high level of competence and experience among the crew. Multi-functionality placed strict requirements on education, instruction and training, and the concept was vulnerable to vacancies. Such a concept thus defines premises for competence management.

The Norwegian Armed Forces' safety management directive includes the following text:

> *The department shall have set aside and ensured enough resources to attend to and improve safety. A shortage of resources shall not constitute grounds for lowering the safety level. By resources is meant personnel, materiel, personal protective equipment, financial resources, time, buildings, facilities, infrastructure and other resources of importance to safety. (Section 4.7)*

It goes on to state that:

> *The department shall have the competence necessary to ensuring safety. Competence requirements shall be defined and described for different positions. The departments shall seek to develop a good safety culture. (Section 4.8)*

The crew's competence was maintained and further developed through several activities after basic training, both in the form of function-related courses and training at HNoMS Tordenskjold (discussed in section 2.8.10.5) and shipboard instruction through the exercise programme (described in section 2.8.10 and discussed in section 3.10.3). The following sections address the exercise and sea training programme and the degree to which it accommodates the conditions for LMC (see section 2.8.9.3) and the requirements of the safety management directive.

3.10.2 Function-oriented courses and training at the HNoMS Tordenskjold naval training establishment

The investigation has made it clear that the crew lacked competence in several areas, such as intact/damage stability, watertight integrity and equipment control levels, the importance of the Q-deck, bilge system, IPMS, the bridge system and the use of means of communication. The investigation has revealed that there were few or no system courses and little or no simulator training at HNoMS Tordenskjold for the purpose of acquiring more in-depth competence in bridge and navigation systems, rudder and control systems, bilge and seawater systems and intact/damage stability. This was so, despite the fact that several of these areas had been defined as critical to the ship's survivability: see SMP-17 (B).

HNoMS Tordenskjold referred to the reorganisation of the Navy in 2016, for the purpose of transferring personnel from the shore-based organisation to operative crews so as to be able to man more ships, as one of the reasons for the lack of training. HNoMS 'Helge Ingstad' was manned in 2016, as a consequence of the reorganisation.

The NSIA believes that the Navy's decision to keep a maximum number of ships operative and conduct a tight sailing programme was one reason why low priority was given to system courses, simulator training in simulated system failures and exercises for the crew. It meant that the crew did not have the requisites to be able to handle the complex scenario they found themselves in on the morning of the accident, among other things in the form of sufficient system competence related to important technical ship systems.

Measures are enacted by the Navy to identify competence needs that will require revision of existing requirements, see section 2.11. The NSIA submits one safety recommendation concerning measures to improve the crew's system competence; see Safety recommendation Marine no 2021/30T in chapter 5.

3.10.3 Sea training on board

Shipboard training and instruction were a key to developing the crew's competence. The investigation has shown that several measures, resources and tools that, in principle, formed parts of the training and exercise programme were not implemented or fully utilised during the incident; see section 3.2.2. This included that the emergency procedures were not implemented immediately as a consequence of problems with the propulsion and steering. Means of communication were available, but were not used, and the ship was not shut down before she was evacuated.

One possible reason for this was that the number of major damage control exercises does not appear to have been in accordance with the frigate's own ambition of conducting at least one comprehensive exercise every week while at sea; see section 2.8.10.4. The exercise programme also showed that, particularly after the replacement of personnel in summer 2018, the focus was mainly on smaller and more concentrated exercises (sub-team exercises). This was also confirmed by members of the crew, who felt that the scenario they were faced with on the morning of the accident was far more complex than anything their training had prepared them for. Some said that the contrast in relation to previous exercises was so great that it was decisive for how they acted; see section 3.10.3.1.

3.10.3.1 *Realism in the exercise concept*

It emerged from interviews with the crew on HNoMS 'Helge Ingstad' that they felt they had benefited greatly from both the FOST programme and own exercises. There were nonetheless essential differences between the accident and the damage control exercises the crew had participated in. The contrast between the exercise scenarios and the reality with which the crew were faced on the morning of the accident is illustrated in Table 6 below.

Table 6: Essential differences between exercise scenarios on HNoMS 'Helge Ingstad' and the accident

Factor	Shipboard exercises on HNoMS 'Helge Ingstad'	The accedent with HNoMS 'Helge Ingstad' on 8th November 2018
Time	Damage control exercises were conducted in daytime between 08:00 and 20:00. Most of the crew were awake.	The general alarm was sounded at approx. 04:02. Many crew members were asleep and it took time before they were all fully awake and arrived at their designated stations. Reduced visibility because of the dark
Scope	The damage control exercises are generally limited in time and scope as a result of a tight sailing programme. Individual elements were selected and trained on.	Wide scope with a great many technical and operational challenges that had to be handled concurrently.
Waters	Damage control exercises were often conducted in open waters with a low risk of navigational incidents.	The incident occurred in cofined water with a higher risk of navigational incidents.
Ship	Without material damage or degradation, except those entered as exercise factors by the crew. Normal ship movement.	Damage causing extensive flooding, degradation of many systems, a great number of alarms and technical faults, all at the same time. Strong, abnormal movement of the ship when she collided.
Crew	The original crew was established in 2016. Conscripts are replaced in four contingents in the course of a year.	Since the final FOST inspection in March 2018, 37% of the crew had been replaced.
Means of communication	Exercises were held with one or two means of communication having failed, and the rest in working order. No exercises were based on loss of all communication between the bridge and HQ1/MCR.	The main means of communication was degraded and they did not manage to make use of the remaining means of communication between the bridge and HQ1 or the bridge and the steering gear room. They were unable to establish such communication before the vessel ran aground.
Propulsion and steering	Exercises in dealing with loss of propulsion and steering control from the bridge were mainly based on navigational safety being maintained by control of the machinery from the MCR. Limited damage control involvement of the OOW on the bridge. Extensive communication between the bridge and the MCR to get the machinery under control.	No communication between the bridge and the MCR to get the machinery under control. The OOW on the bridge had a central role in connection with the accident. The bridge team were exposed to an unclarified situation and a high level of stress.
Situational awareness	Much information available on the bridge, in the CIC and HQ1. As a rule, the bridge team was well informed in advance of who would do what during the exercise. They had seldom or never conducted exercises in which the bridge was unable to provide clear answers as to what had happened.	Little information available on the bridge, in the CIC and HQ1. The damage control officer had little training in a scenario of great uncertainty as to what had happened and what actions to prioritise. He was no more informed than the rest of the crew as to what had happened and what would happen.

	The damage control officer in HQ1 was always informed about how the exercises were to progress. That meant that he had an overview of the situation and of what actions were to be taken.	
Organisation and task allocation	Clarified on the basis of the damage control roster and own established practice	Unclear and unclearly communicated
Leadership, command and control	OOW was clearly in command on the bridge. The XO and CO would interfere when the need arose.	OOW was not clearly in command on the bridge. The XO and CO did not interfere.
Information about the status of personnel and materiel	Extensive	Limited Like the rest of the crew, it took time for the bridge team to understand what had happened and to determine the status of personnel and materiel after the collision.
Predictability in the situation	Moderate to high The damage control exercise scenarios in which the crew had participated were to a certain extent predictable. For example, the exercises had assumed a certain time interval between simulated hits to own ship, whereby the crew knew that nothing more would happen until after a given number of minutes. There was little use of unannounced exercises except during inspections and safety reviews.	Low The incident constituted a real situation without any form of predictability. Very little time passed between the collision and running aground.
The crew's stress level	Moderate. Performance-related – important to demonstrate own competence and mastery as individuals and as groups. Participants in an exercise know that it is not for real.	Very high. Marked by individual reactions such as stupefaction, frustration, confusion and fear, but also by a drive to action, courage and cooperation. The damage control effort after the collision was described as far more difficult than the most difficult exercises. A wide, complex and serious scenario where the crew were pressed for time in their attempt to, if possible, salvage the ship.
General situational awareness	This is an exercise – we are in control.	This is a real situation – we are not in control.
Assessment of stability	The NSIA has not received any details about how the ships assessed damage stability in the case of non-continuous damage to several compartments. Assessment of stability is included as an item in the exercise documentation.	Non-continuous damage. The carpet plot was used.
Shutdown/upheld of watertight integrity	According to reports from safety reviews, exercises have included shutdowns to upheld watertight integrity, but it has not been possible to document any details relating to this; see section 2.8.10.3.1. The report from the safety review in 2016 pointed out the failure to shut down the ship before she was evacuated.	There was no systematic closing and dogging of watertight doors and hatches upon evacuation
Risk to life and health of crew	Low.	Moderate to high.
The general effect of the situation on the crew	Performance promoting.	Performance promoting or performance hindering – individual differences.

As shown in Table 6, the damage control situation on the morning of the accident was far more complex and difficult, and, because it was a real-life situation, also more stressful than any exercise or safety review the crew had previously participated in, including FOST. It has become evident that elements such as a high stress level, the concurrent failure of several technical systems, time pressure, significant flooding, loss of communication and the fact that this took place in the early morning are elements the combined effect of which has not been adequately covered by any exercise scenario. The NSIA understands the crew to have been so strongly affected by the situation that they were only partially able to use what they had learnt through training and exercises.

In the NSIA’s opinion, the crew did not have a sufficient level of damage control competence when the accident occurred, despite the sea training activities they had completed. The crew’s perception of the wide differences between training and exercises on HNoMS 'Helge Ingstad’ and the challenges they faced on the morning of the accident, seen in conjunction with the outcome of the accident, gives grounds for questioning whether the crew had received the requisite training to master such a complex and time-critical damage control situation. The NSIA believes that this can be partially explained by deficiencies in important exercise elements (see Table 6), combined with a failure to devote enough time and resources to realistic exercises to master complex damage control scenarios on the frigate.

Measures are enacted by the Navy to revise the sea training concept (OPUS) for the surface vessels, see section 2.11.

The NSIA therefore submits one safety recommendation relating to sea training; see Safety recommendation Marine no 2021/32T in chapter 5.

3.10.4 Meeting the conditions for use of LMC

The OPUS training concept and the sea training programme for HNoMS 'Helge Ingstad’ are described in section 2.8.10. A large portion of the crew (37.5%) was replaced after FOST, by newly enlisted personnel as well as personnel who had recently left the training establishments and some with previous experience of frigates. In addition, several crew members changed position within the frigate organisation. LMC is based on continuous teambuilding over time, and on all functions having the requisite competence and level of experience at all times. The NSIA questions whether this was possible to achieve within the space of time that passed between FOST and the accident. The crew also failed to achieve the goal of at least one comprehensive damage control exercise per week (see section 2.8.10.4), which can possibly help to explain why the crew as a whole lacked sufficient damage control training.

Competence acquired through function-oriented courses and training at HNoMS Tordenskjold and shipboard training through exercise programmes are discussed in sections 3.10.2 and 3.10.3, respectively. The NSIA believes that several of the weaknesses that have been identified come into conflict with the basis for LMC, which describes vulnerabilities associated with too little competence, experience and teambuilding over time. It has not been demonstrated how the basis for LMC was to be addressed through clear requirements for competence, experience and personnel rotation. Nor has it been demonstrated what measures were implemented to ensure that the level of training achieved prior to personnel rotation was maintained after replacement of a significant part of the crew. Hence the NSIA cannot see that the crew on HNoMS 'Helge Ingstad' met the requirements on which the manning concept was based.

The investigation has made it clear that it was challenging, both for the shore-based organisation and responsible personnel on board, to keep an overview of personnel competence and qualifications from function-oriented instruction (courses and "on the job training"), see sections 2.8.9, 2.8.11 and 2.8.12. This is largely because the existing tool for keeping an overview of internal requirements, including status, nonconformities and follow-up of such function-oriented instruction has not been working effectively. It has also become clear during the investigation that there was a lack of consistency between job instructions, manuals, competence needs and available courses/instruction.

The NSIA believes that it will not be possible to fully meet the requirements for LMC relating to sufficient competence and experience, as long as an effective tool is not in place for competence management at the individual and crew level.

Measures are enacted by the Navy to revise the manning concept for the frigates. Plans are presented to introduce one extra frigate crew to ensure enhanced robustness, see section 2.11.

The NSIA therefore submits two safety recommendations relating to the manning concept and competence management tool; see Safety recommendations Marine no 2021/33T and 2021/37T in chapter 5 (ref. section 3.12).

3.11 Use and updating of the frigate's manuals and technical documentation

Procedures are described as natural and important cornerstones of the Norwegian Armed Forces' operations. The incident has shown, however, that important emergency procedures that could most likely have altered the sequence of events and prevented the grounding were not applied. It has emerged that, over a period of several years before the accident, the frigate crews have notified of manuals not being updated.

It was also not clear to the crews who was to follow up and actually update the manuals, as the staff level that attended to this had disappeared in connection with the reorganisation of the Navy. Transferring this responsibility to an operational vessel was seen as a challenge given what was already a tight sailing programme that included many tasks, where the ship was required to deliver combat force. The investigation has shown that, in an organisation where the importance of compliance with procedures is stressed, a failure to revise procedures and follow up the crew's perceived need for procedural changes caused the ships to implement their own solutions, local routines and procedures. This may have had a negative impact on loyalty to procedures and thus reduced the level of safety in the Navy.

The crews on several frigates had notified of the lack of configuration control and technical documentation updates. The investigation has also shown that it has not been possible to retrieve currently applicable documentation of certain systems on board HNoMS 'Helge Ingstad'. As the competent technical authority, the NDMA is responsible for ensuring that technical documentation is updated. Following interviews with NDMA and Navy personnel, the NSIA is left with the clear impression that they feel that, on the technical side, there is a wide gap between available resources and the tasks that need to be addressed, and that this has an impact on safe operation. The NSIA believes that prioritisation of good configuration control is an important prerequisite for safe operation of the frigates.

In addition to the shortcomings the NSIA has found related to documentation, the investigation has identified that neither the Navy nor the NDMA have had sufficient control of which technical documentation should have been protected and classified under the Security Act. Information security related to technical documentation for the frigates is not directly linked to preventive safety and not a factor that has affected this incident. It is, however, important to call attention to this finding and to correct it to ensure the frigates' safety in military operations. This is reported to the Norwegian National Security Authority, as the supervisory authority.

A new template structure was prepared in 2019 by the Navy for all vessel types. The manuals for the frigates were updated and available for the vessels in July 2020. A system to ensure continuous revision of safety critical issues in the manuals is established and it is planned for regular updates. Next revision is planned autumn 2021. The NSIA therefore does not submit any safety recommendations concerning this issue.

The NDMA has enacted project *ownership management* including configuration control and updating of technical documentation. The scope is not finalised and a strategy for implementation is currently reviewed, see section 2.11.The NSIA therefore submits two safety recommendations relating to updating of technical documentation; see Safety recommendation Marine no 2021/34T and 2021/36T in chapter 5.

3.12 Introduction of the Norwegian Armed Forces Defence Integrated ERP System

The introduction of an integrated ERP system, with new technical solutions, process changes and possible organisational changes, has been challenging for the Norwegian Armed Forces, and the implementation project, the LOS programme that was responsible for introducing the system, was discontinued before the whole solution had been put into place. As the owner with operational responsibility, the Navy was obliged to use processes, technology and to some extent also forms of organisation (PTO) that were sub-optimal for supporting operations. In some areas, the strategy to achieve a standard integrated ERP system for the Norwegian Armed Forces as a whole has contributed to the introduction of solutions that had a negative impact on operational safety in the Navy. This applies in particular to competence management (see section 3.10), nonconformity management (see section 3.9) and configuration management, where separate shipboard systems were introduced, in the form of Excel sheets to keep an overview of both nonconformity management and competence on board; see sections 2.8.11 and 2.8.12.

The Norwegian Armed Forces have taken steps to improve ERP reporting. The Navy's focus on safety work in the wake of the accident has, amongst others, led to an increase in incident reporting in ERP and closer cooperation with the NDMA to handle nonconformities. Steps have also been taken to build more competence in the area; see section 2.11.

In the NSIA's view, an integrated ERP system that does not work as intended constitutes a safety problem for the Navy's operations, and the NSIA therefore submits one safety recommendation on this point to the Norwegian Armed Forces in cooperation with the NDMA; see Safety recommendation Marine no 2021/37T in chapter 5.

3.13 Overall and binding regulations

The effort to establish overall, binding regulations for ship safety and security in the defence sector has been ongoing for a long time but has not yet been completed; see section 1.13.4. In the absence of an overall framework from the Ministry of Defence, subordinate agencies of the defence sector have had to develop and observe their own internal regulations. The absence of an overall framework is challenging when the subordinate agencies exercise both technical and operational authority and have operational responsibility.

The existence of clear rules and regulations that can be observed by the organisation is a prerequisite for safe operation. In the absence of clear rules and regulations, the consequence is that ships might be kept operative at the expense of safety, as was clearly indicated to be the case in this investigation. Furthermore, the absence of binding regulations means that the supervisory function was of limited value, as discussed in more detail in section 2.12.2. The NSIA believes that incomplete rules and regulations and an unclear framework have a negative impact on safe and secure ship operations.

The absence of an established naval administration in Norway makes objective and independent inspection, verification and certification difficult. This is particularly so when compared with the standards of the ISM Code for issuing documents of compliance (DoCs) to owners and safety management certificates (SMCs) to ships.

The NSIA cannot see that there are any special grounds for not having an unbiased and independent naval administration for the Norwegian Armed Forces' ships. Such a naval administration should preferably be organised so that it can function as a sufficiently objective and independent regulatory and supervisory authority. It should also be authorised to issue DoCs and SMCs, and to approve the use of ROs where necessary.

The Ministry of Defence has appointed a working group tasked with reporting on the need for and proposing internal rules and regulations to replace the rules of the Ship Safety and Security Act, see section 2.11.

The NSIA submits one safety recommendation relating to the lack of overall and binding regulations, see Safety recommendation Marine no 2021/38T in chapter 5.

3.14 Importance of an independent and overall supervisory scheme

The following is stated in Section 5 of the Regulations of 29 June 2017 No 1668 on application of the Ship Safety and Security Act by the Ministry of Defence’s subordinate agencies:

> *The Ministry of Defence shall conduct supervision of ships for which subordinate agencies have operational responsibility and of operational managers. The Ministry shall decide more detailed rules for such supervision.*

The Ministry of Defence has not delegated supervision in accordance with the Regulations. Supervision is carried out by the Materiel Safety Authority on the basis of internal sector regulations. This means that the Materiel Safety Authority only has legal authority to supervise materiel safety insofar as this is described in the instructions for the Head of the Authority and the guidelines for materiel safety in the defence sector.[135]

The Materiel Safety Authority, as set up by the Ministry of Defence, does not have the resources or the organisation required to exercise overall and effective supervision:

- The Materiel Safety Authority was set up with few resources.
- The Materiel Safety Authority has an inadequate regulatory framework and a limited mandate to supervise materiel. Hence the Authority is not empowered to oversee safety management systems, operational safety, environmental safety, the working environment, personal safety or readiness for security attacks and acts of terror.
- The Materiel Safety Authority is organisationally subordinate to the Ministry of Defence, which is the owner of HNoMS 'Helge Ingstad'. The Materiel Safety Authority reports on technical and administrative matters to the Ministry's Secretary General.

The investigation has shown that nonconformities relating to the bilge system and stability were not adequately followed up; see section 2.8.7. Lack of follow-up of the nonconforming bilge system (see section 3.7) meant that there had been little instruction or training in the system, which impacted the sequence of events as a result of inadequate system competence on the part of the crew. This supports the NSIA's assessment that the supervisory function in the defence sector is inadequate.

Following the accident, Navantia has prepared calculations showing that the nonconformity relating to the stability requirement was not decisive for the intact stability of the vessel. The NSIA will, however, point out that the nonconformity might have an impact on the VCG maximum curves, which introduces an inaccuracy in the calculations.

The NSIA has not received any documentation from the NDMA or the Materiel Safety Authority to explain the background to why the nonconformity relating to stability was accepted as a deviation, the importance of it or any compensating measures implemented. The Materiel Safety Authority still issued a certificate of seaworthiness (CoS) based on NDMA's recommendations. The NSIA considers that this is unfortunate, that it entails that the subject of supervision can be in control of how the regulations are understood and that it weakens the barrier function of inspections.

Because the authorities' roles have not been defined and organised by the Ministry of Defence in accordance with the Ship Safety and Security Act, the sector has been able to grant itself exemptions in this area.

Since 2018, the Head of the Naval Systems Division, as the competent authority, has in practice taken over the task of issuing documentation of the seaworthiness of ships in the form of naval seaworthiness certificates. This has further marginalised the supervisory role of the Materiel Safety Authority.

[135] *Instruks for sjef Forsvarets materielltilsyn*('Instructions for the Head of the Norwegian Armed Forces Materiel Safety Authority'), *Retningslinjer for materiellsikkerhet i forsvarssektoren* ('Guidelines for materiel safety in the defence sector')

In the NSIA's opinion, an overall, independent supervisory scheme is important in order to improve safety in any sector. This is perhaps particularly true in the defence sector, where complex operations are carried out that may be wholly or partially exempt from several sets of regulations, among other things relating to the framework for safe operation. Overall supervision by an authority requires a mandate and the resources and competence to oversee operations and materiel. In general, the tasks of a supervisory authority are to draw up regulations, approve and inspect vessels, materiel, organisations and individuals, and it must have the tools available to implement measures as necessary when it finds that rules and regulations are not complied with.

In August 2020, the Ministry of Defence initiated a project that, amongst others, should establish a model for consistent, overall supervision in the defence sector, including to ensure supervision of naval activity. The reports from the working group tasked with reviewing the need for and proposing internal rules to replace the provisions of the Ship Safety and Security Act are an important part of the basis for the project.

The investigation has shown that the scheme for supervision of naval activities in the defence sector appears to be fragmented and unclear. The Materiel Safety Authority has an inadequate regulatory framework and a limited mandate to supervise materiel. The Authority is not empowered to oversee safety management systems, operational safety, environmental safety, the working environment, personal safety or readiness for security attacks and acts of terrorism. It does not adequately fulfil the mission of an overall supervisory scheme.[136] The NSIA considers this to be unfortunate and that it has possibly had an impact on the safety of defence sector operations. The same issue is also analysed in an investigation after a military aviation accident, see NSIA. Report Defence 2021/02. The Ministry of Defence has acknowledged that there are challenges relating to the supervisory scheme and appointed a working group to look at alternative models.

The NSIA will submit one safety recommendation on this point relating to the supervisory scheme in the defence sector; see Safety recommendation Marine no 2021/39T.

3.15 Dual roles in the defence sector

The NDMA is tasked with defining requirements and issuing rules and regulations,[137] follow-up to ensure compliance with same, certification and testing, and processing and follow-up of nonconformities;[138] see section 2.8.3. It is also charged with managing operational tasks so as to meet statutory requirements for technical safety. The fact that the NDMA is required to fill all these roles blurs the boundaries, reduces independence and can bring about situations where the agency plays a dual role. In other parts of society, role confusion and dual roles are commonly avoided through setting up an unbiased third party to supervise activities in an objective manner and use sanctions to ensure compliance with rules and regulations; see section 3.14.

In connection with the class entry process, DNV GL was not appointed RO by an independent 3rd party, hence, had no authority or possibility of imposing sanctions. According to DNV GL, it is not uncommon for nonconformities with the class rules to be identified in connection with the classification of ships that were not previously designed

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[136] Report No 17 to the Storting (2003–2004) *Om statlige tilsyn*

[137] Directive for materiel management.

[138] Cooperation Agreement between the Navy and the NDMA Naval Systems Division

and built to the class rules of a classification society. According to the DNV GL rules, naval vessels can apply to the flag state administration for acceptance of navdists. However, no naval administration has been defined as having the role of 3rd party, or independent regulatory and supervisory authority in connection with the operation of naval ships. In practice, this means that nonconformities/navdists could be accepted by the NDMA itself, as in the case of the Nansen-class frigates.

In the NSIA's opinion, maintaining sufficient independence can be challenging for the NDMA, given the lack of a defined naval administration. The above-mentioned dual role can cause nonconformities to remain open without the imposition of operational limitations and without corrective or preventive actions being taken. Known nonconformities in the bilge system were never rectified because of a lack of project funds and resources. Separate approval was also granted for deviating from the regulatory requirement that the range of the GZ curve shall be at least 70 degrees; see section 2.8.7.

It is not possible to play such a dual role in relation to civilian ships, where, in the absence of repairs or compensatory measures, the impact of such nonconformities would have had consequences for the civilian seaworthiness documents. What makes this situation possible in the Norwegian Armed Forces is that the internal competent authority has several roles to play when it comes to the technical safety and security of military ships.

Regardless of whether it was the Materiel Safety Authority that issued a certificate of seaworthiness (CoS), or the NDMA that issued a naval seaworthiness certificate, the investigation has shown that both the Materiel Safety Authority and the NDMA had permitted the frigate to sail with serious and known nonconformities since the time she entered the class.

This means that the NDMA, which is not a supervisory body, is assigned certain tasks that in civilian shipping, are assigned to the supervisory body. At the same time as the NDMA, as an administrative body, is charged with ownership management of ships on behalf of the Ministry of Defence, it is also tasked with duties to ensure compliance with requirements for technical safety under the Ship Safety and Security Act. The NDMA can thus play a dual role that comes into conflict with the Ship Safety and Security Act.[139]

The NSIA submits one safety recommendation relating to the role of the NDMA; see Safety recommendation Marine no 2021/40T in chapter 5.

3.16 Task and resource management

The investigation has shown that the Nansen-class frigates were commissioned with what was perceived by the users as many faults and defects, which it has taken the Navy and the technical competent authority (now the NDMA) a long time to repair. Several of these deficiencies are still present. Examples include the frigate's bilge system, which has not been in accordance with regulatory requirements; the frigate's stability calculator, which the crew have been unable to operate; concealed faults relating to hollow shafts; faults in the electrical system (see section 2.6.5.1 on the CAO relating to combined versus split switchboard mode); and lack of follow-up of the marking system. The NSIA cannot rule

[139] Working group on ship safety, Sub-report 2 on supervision and regulatory developments (*Tilsyn og regelverksutvikling*), dated 28 August 2020

out the possibility of there being aspects over and above those identified in the present investigation that also consume organisational resources or will do so in future.

Navantia has informed that several of the issues perceived as faults by the Navy and NDMA have not been attended to. Therefore it has not been clarified whether it is an actual default or merely a perceived fault caused by lack of proper understanding or user fault requiring further training. The NSIA has not investigated further the contractual issues related to these aspects.

Frigate operations must be ensured by striking a balance between resources and tasks both in the Navy and in the NDMA's organisation. The ability of an organisation to balance task and resources in a successful operation without undesirable incidents reflects the safety of the operation. Any imbalances that persist over time can have consequences for safe operation.[140]

The NSIA has found several indications of imbalances in the management of resources and tasks related to the operation of the frigates. In its investigation of the frigates' operational capacity (see section 2.8.13), the Office of the Auditor General of Norway recommended that the Ministry of Defence improve the balance between assignments and available resources for the frigates, in terms of materiel and manning as well as competence. The Auditor General also pointed out that personnel coverage was low compared with the current ambition. Challenges relating to key personnel with critical competence weakened the amount and quality of the training; see section 2.8.13. Furthermore, it was pointed out that it was challenging to maintain levels over time because of personnel rotations.

The NSIA's investigation has shown that the NDMA has found it problematic to follow up important materiel defects, to maintain control of configurations and manage the handling of nonconformities. The NSIA's findings after interviews with personnel at different levels in the NDMA show that there has been a backlog of tasks relating to the technical management of the frigates for a long time. The NDMA's own technical advisers have pointed out that there is an imbalance between the tasks with which the NDMA is charged and the resources it has been allocated. That this situation has persisted for some time has possibly affected the norm for what is considered safe and secure operation. The constant backlog of tasks that are postponed or not attended to, combined with resources not being allocated, leads to a gradual and subtle shift from good safety management to a situation of instability.

As the frigates are manned based on LMC, optimised and efficient operation based on multi-functionality and high competence is a prerequisite. One of the measures to improve the situation following the Auditor General's criticism of the frigates' operative capacity was to introduce an additional frigate crew. This was done by transferring positions from the shore-based organisation to the operational part of the organisation, and thus manning and operating an additional frigate. The investigation has shown that this reduced support for the frigates when at sea, as the crew had to see to more of the tasks for which they had previously received support from the shore-based organisation; see also sections 2.8.10.5, 2.8.11 and 2.8.12. The Navy's own investigation after the accident revealed a tendency to moderate or remove mandatory requirements from job descriptions for frigate personnel, or to assign personnel to positions who did not fully

[140] Rasmussen, Jens. 1997. 'Risk management in a dynamic society: A modelling problem.' Safety Science 27 (2): pp. 183–213.

meet the requirements for those positions. The Navy's internal investigation team linked this tendency to a combination of increased requirements for operational deliveries and a shortage of resources. This is consistent with the findings of the NSIA's investigation.

LMC as a concept is vulnerable due to many requirements and restrictions and the Navy operates on the edge of what is required. This can challenge the concept and shift the boundaries for what is considered sufficient manning and satisfaction of the requirements for LMC.

The NSIA believes that an imbalance between tasks and resources relating to technical operation constitutes a safety problem, and submits one safety recommendation to the Norwegian Armed Forces to prioritise safe operation. See Safety recommendation Marine no 2021/41T in chapter 5.

4 Conclusion

4. CONCLUSION

4.1 Introduction

In this investigation, the NSIA has mapped the sequence of events after the collision, until the frigate ran aground and was subsequently pushed towards the shore. The investigation has shown that there were a number of contributory factors that caused the frigate to run aground and subsequently sink.

Figure 79: HNoMS ‘Helge Ingstad’ after the collision. Illustration: NCIS/CIAASS/NSIA

4.2 The investigations main findings

HNoMS 'Helge Ingstad' sustained major damage in the collision and concurrent flooding of several compartments. Given the crew's knowledge at the time, the NSIA considers it understandable that a decision was taken there and then to evacuate rather than put human life and health at risk.

Calculations carried out by the NSIA afterwards have nonetheless shown that the frigate could have been prevented from sinking, had she been shut down before she was evacuated. Stability calculations also show that the grounding was not a decisive factor in causing the frigate to sink, as the failure to shut down the frigate would have caused her to sink in any case. Further efforts to prevent the ship from sinking and prioritisation of the right measures could have helped to gain control of the ingress of water.

The NSIA believes that consideration of alternative actions to those that were taken would have required further competence, instruction and training of the crew and better decision support tools than those that were available.

4.3 Other findings

4.3.1 The situation immediately after the collision

a) The collision resulted in a severe damage to the vessel, over and above what she was designed to withstand.

b) The crew found themselves in a dramatic, unknown, complex, unclear and highly stressful situation. Only ten minutes passed from the time of the collision until the frigate ran aground. It was very difficult for the crew to understand what had happened, build adequate situational awareness, decide what actions to take, take such actions, and achieve the desired effect in the short time at their disposal.

c) The situation was completely different from anything that their training had prepared them for, and the incident contrasted greatly with the exercises they had participated in.

d) Lack of systematic implementation of emergency procedures.

e) The primary means of communication had failed and this made coordination all the more difficult.

f) The grounding was not decisive in causing the frigate to sink, but it caused more rapid flooding. That left less time for the crew to consider what actions to take to salvage the vessel.

4.3.2 Decision support, damage stability

a) The crew lacked a sufficient basis for assessing what measures could prevent the ship from sinking.

b) The carpet plot that was available on board was not very suitable to assessing the frigate's survivability when damaged.

c) There was little knowledge about stability on board the frigate, and it was only two of crew members who had in-depth knowledge of intact and damage stability.

4.3.3 Shutting down the frigate to maintain watertight integrity

a) Doors, hatches and other openings in the frigate that were supposed to be closed to maintain stability and buoyance, were not closed at the time of evacuation. As a result, watertight integrity and buoyancy were not adequately maintained, so that the ship eventually sank.

b) The CO decided it was unsafe to send down personnel to close more doors, hatches and other watertight openings.

c) Calculations have shown that the failure to shut down the frigate and upheld watertight integrity had a decisive impact on her survivability. The grounding was not a decisive factor in causing the frigate to sink, as the failure to shut her down would have caused her to sink in any case.

d) Neither the Navy nor the Norwegian Defence Material Agency (NDMA) as the shore-based support organisation had an overview of the systems for markings for shutting down individual ships, and they were also not in control of the operational use of markings on board.

e) Not enough had been done before the accident to provide the crew with sufficient competence and awareness of the importance of shutting down and thus ensuring the frigate's survivability.

f) There were also challenges with shut down due to cables and hoses for portable bilge pumps passing through doors and hatches between watertight compartments.

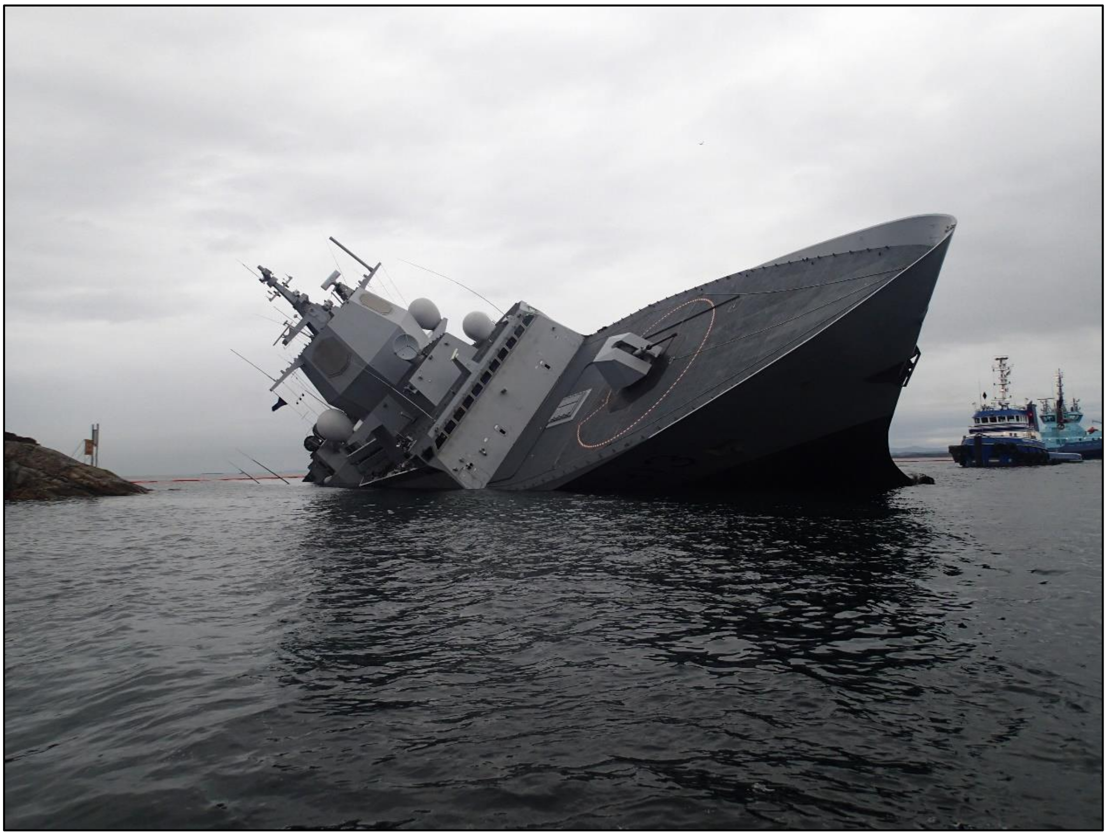

Figure 80: HNoMS 'Helge Ingstad' listed heavily to starboard at approximately 10:27, as a result of being pushed by the tugboats. Photo: CGV 'Bergen'

4.3.4 Q-deck

a) As part of a watertight compartment, the Q-deck was very important for the frigate's survivability, particularly in case of damage to the afterbody. The flooding of compartment 13 significantly reduced the ship's buoyancy volume, but it was not decisive in causing her to sink.

b) The deck was designed with a large number of closeable openings and meant to serve as a work deck where it was assumed that one of the hatches could be kept open during operation of the ship. The large number of openings is a vulnerable design and entails strict operational requirements.

c) The spring loaded overpressure valves on 2 deck compromised the watertight integrity of section 13.

d) The design-phase assumption that the Q-deck would be watertight was not followed up and implemented in the operating phase. Adequate systems had not been put into place to ensure that this knowledge was conveyed to those who would operate the vessel when the frigate was transferred from the project to the operating organisation.

4.3.5 Watertight integrity between watertight compartments

a) The flooding of the reduction gear room through the hollow propeller shaft had a negative impact on the frigate's stability, but was not the decisive factor in causing her to sink.

b) Combined with several other factors, it had a negative psychological impact on the crew, and thus contributed to the decision to prepare for evacuation.

c) The design and implementation of the hollow shafts on the frigate show that large and complex projects are very demanding in terms of interfaces between different disciplines. The interface was not sufficiently addressed in the project phase.

Figure 81: The helideck at HNoMS 'Helge Ingstad' under water on starboard side. Photo: CGV 'Bergen'

4.3.6 Bilge system

a) The pumping was never effective.

b) The crew lacked thorough system competence and there had been few practical exercises and little training.

c) There was a lack of segregation between the main bilge system and the bilge sullage system for day-to-day removal of bilge water and oily water. The design had been approved by the NDMA[141] without understanding the ensuing risk. This resulted in little training and few exercises in use of the system and in its vulnerabilities not being identified.

d) It was not possible to operate the motorised valves manually from decks above 4 deck if remote control from the damage control headquarters (HQ1) or from the local panel on deck 2 should fail. Several of the bilge system valves were located under bolted-down floor grates, which made it challenging to operate them manually if remote control failed.

e) There had been no regular verification, correction and/or calibration of the system. Several of the valves in the bilge system did not seal. Leaking valves considerably reduced the system's pumping capacity. The technical circumstances made it almost impossible for the crew to realise this during the incident.

f) The investigation has shown that the total pumping capacity on a sister vessel was not in accordance with the specification established by the NDMA for the vessel class during construction The bilge system had been defined as a safety-critical system, but it did not deliver the expected capacity.

g) The Navy and NDMA had unrealistic expectations to what the main bilge system could handle in an event of damage to the vessel.

h) In their present form, the regulations that apply to the bilge system do not take sufficient account of system complexities and obstructions. The frigates may therefore sail with a system that neither delivers the expected capacity nor meets actual needs that arise in a damage control situation, but still be in compliance with applicable rules.

4.3.7 Damage control support from the shore-based organisation

a) The officers in command at the scene had to make decisions based on their own knowledge and limited information. The investigation has shown that the CMT lacked sufficient competence related to stability. The NDMA had competence in stability, but it was late in arriving and coordination with the CMT was poor. Lack of coordination between the Navy and the NDMA's contingency plans was the reason why decision support was not arranged or provided for at an early enough time after the frigate ran aground.

4.3.8 Failure to learn from incidents

a) The Norwegian Armed Forces have not established a systemic approach for learning from undesirable incidents and improving the safety management system in an overall and consistent manner. A need for learning has also been clearly identified in previous accident reports, and measures have been proposed that have not been adequately followed up or implemented. Learning is largely a local responsibility.

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[141] Formerly the NDLO Navy

There is thus an absence of learning between departments or across the rest of the organisation.

b) Neither the Navy nor the NDMA was sufficiently informed about the potential consequences of known technical nonconformities for the safety of the frigates. The Navy has thus operated the frigates without being aware of the total risk under which they were sailing as a result of the unaddressed nonconformities. Several of the nonconformities were of direct consequence for the sequence of events.

4.3.9 Manning and sea training

a) There have been few or no system courses and little or no simulator training in the Navy to offer more in-depth competence in several technical systems. The sailing programme and operational ambition level have made it challenging to set aside enough time for courses and simulator training. This meant that the crew did not have the requisites to be able to handle the scenario they found themselves in on the morning of the accident.

b) Important elements were lacking in the crew's sea training. Not enough time and resources were devoted to realistic exercises in mastering complex damage control situations. As a result, the crew did not have the competence required to manage a more complex and time-critical damage control situation.

c) The frigates were not manned in accordance with important requirements for the LMC concept. It has also not been demonstrated how the basis for lean manning of the frigates was to be addressed through clear requirements for competence, experience and personnel rotation. This constitutes a vulnerability in the safe operation of these vessels and compromises the Fleet's ability to produce combat-ready units.

4.3.10 Documentation

a) It has not been possible to retrieve valid technical documentation of certain systems on board HNoMS 'Helge Ingstad'. Safe operation of the frigates is not possible without good configuration management and updated technical documentation.

b) Over a period of several years before the accident, the frigate crews have notified of the manuals not being updated. It was also not clear to the crews who was to follow up and actually update the manuals.

c) The frigate crews found their own solutions, local routines and procedures. This had negative consequences for both loyalty to procedures and the quality of the manuals, thereby lowering the level of safety in the Navy.

4.3.11 The Norwegian Armed Forces Integrated ERP System

a) The introduction of a standardised integrated ERP system with new technical solutions, new processes and possibly changes in the organisation has been challenging for the Norwegian Armed Forces. The standardisation for the Armed Forces as a whole, implies that the Navy, as the owner with operational responsibility, was obliged to use processes, technology and to some extent also forms of organisation that were sub-optimal for supporting operations. This has had consequences for the safety of naval operations in certain areas.

4.3.12 Framework

a) The scheme for supervision of naval activities in the defence sector appears to be fragmented and unclear. It does not adequately fulfil the mission of an overall, independent supervisory scheme. The NSIA considers this to be unfortunate and that it has possibly had an impact on the safety of defence sector operations.

b) The authorities' roles have not been adequately defined and organised, and maintaining sufficient independence can therefore be challenging for the NDMA. The NDMA has a dual role in that it is responsible for both the requirements and regulations that apply to the materiel and for the technical safety of the Fleet. This blurs the boundaries, reduces independence and can lead to situations that have negative consequences for the operation of the frigates.

c) There has been an imbalance between tasks and resources relating to the technical operation of the frigates. This had led to a gradual and subtle shift from what is considered good safety management to what has turned into an unstable situation.

d) Though the Ship Safety and Security Act entered into force on 1 July 2007, overall and binding regulations are still lacking for the defence sector. Incomplete regulations and an unclear framework go some of the way towards explaining why safe ship operation cannot be properly addressed.

5 Safety recommendations

5. SAFETY RECOMMENDATIONS

The investigation of this marine accident has identified 28 areas in which the Norwegian Safety Investigation Authority deems it necessary to submit safety recommendations for the purpose of improving safety.[142]

Safety recommendation MARINE No 2021/14T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The investigation has shown that the crew on board the frigate experienced that they lacked a functional decision support tool (stability calculator) throughout the sequence of events. The carpet plot that was available on board was not very suitable to assessing the frigate's survivability when damaged.

The Norwegian Safety Investigation Authority recommends that the Royal Norwegian Navy ensure that the frigate crews have a decision support tool available on board so as to be able to assess the ship's damage stability and survivability in any situation of damage.

Safety recommendation MARINE No 2021/15T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The investigation has shown that there was little knowledge about stability on board the frigate and that only two crew members had in-depth knowledge of intact and damage stability. As a result of this and the experienced lack of a functional decision support tool, the crew lacked a sufficient basis for assessing how critical the damage was.

The Norwegian Safety Investigation Authority recommends that the Royal Norwegian Navy strengthen its competence in damage stability and determine what members of the frigate crews shall have key roles relating to intact and damage stability.

Safety recommendation MARINE No 2021/16T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The investigation has shown that the frigate was not in the ordered equipment protection level during passage and was not shut down before she was evacuated. The crew lacked competence relating to damage stability and the importance of the shutdown state for the frigate's survivability when damaged. As a result, watertight integrity was not adequately maintained, so that the frigate eventually sank.

The Norwegian Safety Investigation Authority recommends that the Royal Norwegian Navy strengthen the frigate crews' awareness and competence relating to the importance of shutting down the vessel to maintain her watertight integrity and survivability when damaged.

[142] The investigation report is submitted to the Ministry of Trade, Industry and Fisheries and the Ministry of Defence, which will take the necessary steps to ensure that due consideration is given to the safety recommendations.

Safety recommendation MARINE No 2021/17T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The investigation has shown that challenges associated with cables and hoses for portable bilge pumps passing through doors and hatches between the frigate's watertight decks and compartments formed part of the background to why the frigate was not shut down. The investigation has also shown that it was difficult to gain an overview of the amount of water entering the frigate and to assess this in relation to the available pumping capacity.

The Norwegian Safety Investigation Authority recommends that the Royal Norwegian Navy, in cooperation with the Norwegian Defence Materiel Agency, define the scenarios in which portable bilge pumps can be expected to have an effect, and implement measures to maintain watertight integrity while also ensuring effective damage control.

Safety recommendation MARINE No 2021/18T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The investigation has shown that, as part of a watertight compartment, the Q-deck was very important for the frigate's survivability, particularly in case of damage to the afterbody. The deck was designed with a large number of closeable openings and meant to serve as a work deck in port and under certain combat operations. A design with several hatches, whereas, some should be kept open during operation, could be in conflict with the requirement to watertight integrity.

The Norwegian Safety Investigation Authority recommends that the Norwegian Defence Materiel Agency consider how relevant rules and regulations can be developed to better meet requirements for watertight integrity in combination with operational requirements.

Safety recommendation MARINE No 2021/19T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The Q-deck was designed with a large number of closeable openings. This is a vulnerable design where verification of the watertightness is a necessity for having control of the seaworthiness of the frigate. The investigation has shown that standard test methods for verification of watertight integrity of hatches and doors did not reveal leak points on Q-deck.

The Norwegian Safety Investigation Authority recommends that the Norwegian Defence Materiel Agency review established routines and methods for verification of watertightness to ensure control of the watertight integrity of the vessel.

Safety recommendation MARINE No 2021/20T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The investigation has shown that the design-phase assumption that the Q-deck would be watertight was not followed up and implemented in the operating phase. Adequate systems had not been put into place to ensure that this knowledge was conveyed to those who would operate the vessel when the frigates were commissioned.

The Norwegian Safety Investigation Authority recommends that the Norwegian Defence Materiel Agency, in cooperation with the Royal Norwegian Navy, review all design assumptions and take steps as necessary to ensure that these assumptions hold true during operation.

Safety recommendation MARINE No 2021/21T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The investigation has shown that the spring-loaded overpressure valves on 2 deck in section 13 compromised watertight integrity.

The Norwegian Safety Investigation Authority recommends that the Norwegian Defence Materiel Agency, in cooperation with the Royal Norwegian Navy, implements necessary measures to ensure watertight integrity of section 13.

Safety recommendation MARINE No 2021/22T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The investigation has shown that pumping never became effective on board the frigate. The crew lacked thorough system competence and there had been few practical exercises and little training in this area.

The Norwegian Safety Investigation Authority recommends that the Royal Norwegian Navy ensure that the frigate crews are competent enough and have sufficient training to operate the bilge system in any relevant situation.

Safety recommendation MARINE No 2021/23T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The investigation has shown that there was lack of segregation between the frigate's main bilge system and the bilge sullage system for day-to-day removal of bilge water and oily water. The Norwegian Defence Materiel Agency had approved the design without understanding the ensuing risk. This contributed, amongst others, to there being little training and exercises in use of the system and to its vulnerabilities not being identified.

The Norwegian Safety Investigation Authority recommends that the Norwegian Defence Materiel Agency, in cooperation with the Royal Norwegian Navy, address this nonconformity in the bilge system in compliance with applicable regulations.

Safety recommendation MARINE No 2021/24T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The investigation has shown that several of the valves in the bilge system, which is by the Norwegian Armed Forces defined as a safety critical system, were inaccessible to the frigate crew throughout the sequence of events. Several valves were located under bolted-down floor grates, which made it challenging to operate them manually if remote control failed. It was also not possible to operate the motorised valves manually from decks above 4 deck if remote control from HQ1 or from the local panel on deck 2 should fail.

The Norwegian Safety Investigation Authority recommends that the Norwegian Defence Materiel Agency, in cooperation with the Royal Norwegian Navy, perform a risk assessment to ensure sufficient access for manual operation of motorised valves in the bilge system for the Navy's vessels.

Safety recommendation MARINE No 2021/25T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The investigation has shown that several valves in the frigate's bilge system did not seal, which considerably reduced the system's pumping capacity. The technical circumstances made it almost impossible for the crew to realise this during the incident. The investigation also showed that regular verification, correction and/or calibration of the system were not carried out.

The Norwegian Safety Investigation Authority recommends that the Royal Norwegian Navy, in cooperation with the Norwegian Defence Materiel Agency, take steps to ensure that the valves in the bilge system seal in closed position so that the expected pumping capacity can be achieved.

Safety recommendation MARINE No 2021/26T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The investigation has shown that the total pumping capacity on a sister ship of the same design as HNoMS 'Helge Ingstad' was not in accordance with the specification established by the Norwegian Defence Materiel Agency for the vessel class. The bilge system had been defined as a safety-critical system, but it did not deliver the expected capacity.

The Norwegian Safety Investigation Authority recommends that the Norwegian Defence Materiel Agency, in cooperation with the Royal Norwegian Navy, assess the need for bilge pumping capacity and identity and take necessary steps on the basis of such an assessment.

Safety recommendation MARINE No 2021/27T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The investigation has shown that the Norwegian Defence Materiel Agency was unable to explain the background for their required bilge capacity, and how this was covered in the applicable regulatory requirement. The regulations in their present form do not take sufficient account of system complexities and obstructions. Ships may therefore sail with a system that neither delivers the expected capacity nor meets actual needs that arise in a damage control situation.

The Norwegian Safety Investigation Authority recommends that the Norwegian Defence Materiel Agency, in cooperation with the International Naval Safety Association, consider the need to impose additional requirements to the bilge system those in applicable regulations with a view to ensuring that capacity needs are identified and met, and system complexity is taken into account during design and in requirements to test the bilge systems.

Safety recommendation MARINE No 2021/28T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The investigation has shown that the Navy's crisis management team lacked sufficient competence relating to stability. The Norwegian Defence Materiel Agency had competence in stability, but it was late in arriving and coordination with the crisis management team was poor. Lack of coordination between the Navy and the Norwegian Defence Materiel Agency's contingency plans was the reason why decision support was not arranged or provided at an early enough time after the frigate ran aground. The officers in command at the scene therefore had to make decisions based on their own knowledge and limited information available.

The Norwegian Safety Investigation Authority recommends that the Royal Norwegian Navy, in cooperation with the Norwegian Defence Materiel Agency, review contingency plans, assess how crisis management should be organised and what competence is needed to provide early assistance and reduce the risk of loss of personnel or vessel in a critical situation.

Safety recommendation MARINE No 2021/29T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The investigation has shown that the Norwegian Armed Forces have not established a systemic approach for learning from undesirable incidents and improving the safety management system in an overall and consistent manner. A need for learning has also been clearly identified in previous accident reports, and measures have been proposed that have not been adequately followed up or implemented. Learning is largely a local responsibility. There is thus an absence of learning between departments or across the rest of the organisation.

The Norwegian Safety Investigation Authority recommends that the Norwegian Armed Forces establish mechanisms for organisational learning from undesirable incidents and accidents.

Safety recommendation MARINE No 2021/30T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The investigation has shown that neither the Navy nor the Norwegian Defence Materiel Agency was sufficiently informed about the potential consequences of known technical nonconformities for the safe operation of the frigates. The Navy has thus operated the frigates without being aware of the total risk under which they were sailing as a result of the unaddressed nonconformities. Several of the nonconformities were of direct consequence for the sequence of events.

The Norwegian Safety Investigation Authority recommends that the Royal Norwegian Navy, in cooperation with the Norwegian Defence Material Agency, take steps to ensure that the Navy gets an overview of risks associated with all nonconformities of consequence for safe operation.

Safety recommendation MARINE No 2021/31T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The investigation has shown that there have been few or no system courses and little or no simulator training in the Navy for the purpose of acquiring more in-depth competence in several technical systems. The investigation has also shown that the sailing programme and operative ambition level have made it challenging to set aside enough time for courses and simulator training. As a result, the crew did not have the requisites to be able to handle the scenario they found themselves in on the morning of the accident.

The Norwegian Safety Investigation Authority recommends that the Royal Norwegian Navy, in cooperation with the Norwegian Defence Materiel Agency, take steps to ensure that the frigate crews have the requisites required to operate all technical systems in all relevant situations.

Safety recommendation MARINE No 2021/32T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The investigation has shown that important elements were missing in the crew's sea training. Not enough time and resources were devoted to realistic exercises in mastering complex damage control situations. As a result, the crew did not have the competence required to manage a more complex and time-critical damage control situation.

The Norwegian Safety Investigation Authority recommends that the Royal Norwegian Navy evaluate and implement measures in its own training and exercise programme to ensure that the frigate crews have the competence required to handle complex damage control scenarios.

Safety recommendation MARINE No 2021/33T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The investigation has shown that the frigates are not manned in accordance with important requirements for the lean manning concept. It has also not been demonstrated how the basis for lean manning of the frigates was to be addressed through clear requirements for competence, experience and personnel rotation.

This constitutes a vulnerability in the safe operation of these vessels and compromises the Fleet's ability to produce combat-ready units.

The Norwegian Safety Investigation Authority recommends that the Royal Norwegian Navy review and conduct a risk assessment of the manning concept for the frigates and introduce measures as necessary to clarify the requirements for the concept and how they are to be followed up.

Safety recommendation MARINE No 2021/34T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The investigation has shown that it has not been possible to retrieve valid technical documentation of certain systems on board the frigate. Safe operation of the frigates is not possible without good configuration management and updated technical documentation.

The Norwegian Safety Investigation Authority recommends that the Norwegian Defence Materiel Agency, in cooperation with the Royal Norwegian Navy, review and update the technical documentation for the Nansen-class frigates, so as to achieve safe operation of the frigates.

Safety recommendation MARINE No 2021/35T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The investigation has shown that it has not been possible to locate valid technical documentation for some of the systems on board the frigate. Safe operation of the frigates is not possible without good configuration management and updated technical documentation.

The Norwegian Safety Investigation Authority recommends that the Norwegian Armed Forces Materiel Safety Authority conduct supervisory activities of the Royal Norwegian Navy and the Norwegian Defence Materiel Agency with a view to achieving safe operation of the frigates by ensuring long-term good configuration management and updated technical documentation.

Safety recommendation MARINE No 2021/36T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The investigation has shown that, over a period of several years before the accident, the frigate crews have notified of manuals not being updated. It was also not clear to the crews who was to follow up and actually update the manuals. This caused the ship crews to implement their own solutions, local routines and procedures. This had negative consequences for both loyalty to procedures and the quality of the manuals, thereby lowering the level of safety in the Navy.

The Norwegian Safety Investigation Authority recommends that the Royal Norwegian Navy initiate measures to update and implement the frigate manuals

Safety recommendation MARINE No 2021/37T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The investigation has shown that, as a result of the introduction of a standardised integrated enterprise resource planning (ERP) system for the Norwegian Armed Forces as a whole, the Navy, as the owner with operational responsibility, was obliged to use processes, technology and to some extent also forms of organisation that were sub-optimal for supporting operations. This has had consequences for the safety of naval operations in certain areas.

The Norwegian Safety Investigation Authority recommends that the Norwegian Armed Forces, in cooperation with the Norwegian Defence Materiel Agency, review the Royal Norwegian Navy's need for system support and take steps to ensure safe ship operation.

Safety recommendation MARINE No 2021/38T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The investigation has shown that, while the Ship Safety and Security Act entered into force on 1 July 2007, there are still no overall and binding regulations for the defence sector. Incomplete regulations and an unclear framework go some of the way towards explaining why safe ship operation cannot be properly addressed.

The Norwegian Safety Investigation Authority recommends that the Norwegian Ministry of Defence, as the authority with overriding responsibility for ship safety in the defence sector, take steps to clarify the regulatory framework for the purpose of ensuring ship safety.

Safety recommendation MARINE No 2021/39T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The investigation has shown that the scheme for supervision of naval activities in the defence sector appears to be fragmented and unclear. It does not adequately fulfil the mission of an overall, independent supervisory scheme. The Norwegian Safety Investigation Authority considers this to be unfortunate and that it has possibly had an impact on the safety of naval operations in the defence sector.

The Norwegian Safety Investigation Authority recommends that the Norwegian Ministry of Defence take steps to ensure an overall, independent supervisory function for naval activities in the defence sector.

Safety recommendation MARINE No 2021/40T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The investigation has shown that the Ministry of Defence has not adequately defined the authorities' roles, and it can be challenging for subordinate agencies to maintain sufficient independence, given the lack of a defined naval administration.

The Norwegian Defence Materiel Agency plays a dual role in that it is both responsible for requirements and regulations relating to the materiel and for ensuring compliance with technical safety requirements. This blurs the boundaries, reduces independence and can lead to situations that have negative consequences for the operation of the frigates.

The Norwegian Safety Investigation Authority recommends that the Norwegian Ministry of Defence take steps to ensure that responsibility for requirements and regulations is independent of responsibility for ensuring technical safety under the Ship Safety and Security Act.

Safety recommendation MARINE No 2021/41T

In the early hours of Thursday 8 November 2018, the frigate HNoMS 'Helge Ingstad' and the tanker 'Sola TS' collided outside the Sture Terminal in the Hjeltefjord. The frigate subsequently grounded and sank. The investigation has shown that there was an imbalance between tasks and resources relating to the technical operation of the frigates. This had led to a gradual and subtle shift from what is considered good safety management to what has turned into an unstable situation.

The Norwegian Safety Investigation Authority recommends that the Norwegian Defence Materiel Agency, in cooperation with the Royal Norwegian Navy, put in place measures in its own organisation to ensure correct prioritisation with respect to balancing tasks and resources relating to the technical operation of the frigates.

Norwegian Safety Investigation Authority

Lillestrøm, 20 April 2021

6 Details of the vessel and the accident

6. DETAILS OF THE VESSEL AND THE ACCIDENT

Vessel	
Name	HNoMS ‘Helge Ingstad’
Flag state	Norwegian
Classification society	DNV GL, class entry 24 November 2014
Call signal	LABI
Type	Frigate
Build year	2009
Owner	Norway,
Operational manager	The Royal Norwegian Navy
Construction material	Steel
Length	133,24 m
Destination port	Dundee, Scotland
Persons on board	137
Information about the accident	
Date and time	8 November 2018, 04:01:15 LT
Type of accident	Collision
Location/position where the accident occurred	The Hjeltefjord, N 60º38,5, E 004º51,9
Place on board where the accident occurred	The hawsepipe of Sola TS tore a large gash along the HNoMS ‘Helge Ingstad’ starboard side.
Injuries/deaths	Minor injuries to 7 persons on board HNoMS ‘Helge Ingstad’
Damage to vessel/the environment	Minor foreship damage on Sola TS. On HNoMS ‘Helge Ingstad’, approximately 46 m of the ship’s starboard side was torn open.
Ship operation	In shore voyage, navigational area 2
At what point in the voyage was the vessel	Under way
Environmental conditions	Southerly breeze, good visibility, night darkness

Appendices

APPENDICES[143]

Appendix A	Abbreviations
Appendix B	Extract from the P-200 manual – Emergency procedures
Appendix C1 (R)	Marking plan
Appendix C2 (R)	Description of flooding and shutdown state
Appendix D	Stability calculations carried out by the NSIA
Appendix D1 (R)	Inclining test report
Appendix D2 (R)	Verification conditions
Appendix D3 (R)	Damage conditions
Appendix D4 (R)	Damage conditions with vessel in maximum shutdown state
Appendix D5 (R)	Other (hypothetical) calculated conditions
Appendix D6	Drawings used by NSIA as basis for stability calculations
Appendix D7 (R)	Hull geometry
Appendix E1 (R)	Report from Navantia: IPMS data – Bilge and sea water fire main systems operation
Appendix E2 (R)	Report from Navantia: IPMS data – Doors, hatches & HVAC valves status
Appendix E3 (R)	Report from Navantia: IPMS data for progressive flooding analysis
Appendix E4 (R)	Report from Navantia: Analysis for the propulsion and steering plant control
Appendix E5	Report from Navantia: Navantia's safety measures and barriers following the HNoMS Helge Ingstad and Sola TS collision
Appendix F	Summary of Aker Solutions observations and assessments on the bilge system functionality and design
Appendix G1	Forsvarsmateriells tekniske undersøkelse etter ulykken med KNM Helge Ingstad (Norwegian only)
Appendix G2 (R)	Vedlegg B: Analyse av teknisk hendelsesforløp med KNM Helge Ingstad (Norwegian only)
Appendix G3 (R)	Vedlegg C: Teknisk undersøkelse av ulykken med KNM Helge Ingstad (Norwegian only)

[143] The appendices marked (R) are classified as Restricted under the Security act by information owner the Norwegian Armed forces and the NDMA