National Marine Facilities Capability Training Needs Analysis

Project Report

Contents

Abbreviations

AI	Artificial Intelligence
ATSB	Australian Transport Safety Bureau
AUV	Autonomous Underwater Vehicle
DMAIB	Danish Maritime Accident Investigation Board
ECDIS	Electronic Chart Display and Information System
IMO	International Maritime Organisation
IMAREST	The Institute of Marine Engineering, Science and Technology
MAIB	Marine Accident Investigation Branch *[UK]*
MASS	Maritime Autonomous Surface Systems
MCA	The Maritime & Coastguard Agency *[UK]*
MET	Maritime Education & Training
OCIMF	Oil Companies International Marine Forum
SOLAS	International Convention for the Safety of Life at Sea
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
USV	Uncrewed/Unmanned Surface Vessel

Executive Summary

This report was commissioned to provide an understanding and focus for future capability in the operational aspects of the National Oceanographic Centre's (NOC) Sea-based capability with specific relevance as to how advances in technology will affect the National Marine Facilities (NMF) workforce capability over the next 10 - 15 years.

The key to each of the work strands that this report will address will be to focus the research on areas that are likely to affect the workforce. This will provide NOC with the ability to target training activities in the future based on these future trends and developments.

Past technology assessment

Technological advancements are not new within the maritime industry. The first part of this report takes an analytical look back at the implementation of new technology historically and what the impact of this technology was. The significant finding of this look back was that; though the technology improved some aspects of the operations, it opened up new routes for errors to occur. The weak link was found to lie within the operator's competence and ability to identify when problems were emerging and then their ability to respond or take over when the autonomous elements failed.

Future technology 2035 overview

A documentary approach was used with open-source material to conduct a systematic literature survey. The study team used the NMF Technology Roadmap 2020/21 to capture the expected high-level technology roadmap and combined the learnings from this with the predicted developments within the industry to extend the Roadmap out to 2035. This part highlights the significant expected changes that will impact directly upon operations.

Workforce Skills Gap Analysis, Collective Analysis and Measuring Impact

The research draws attention to the impact on core NOC maritime operational streams. To that end, an assessment was made on how the role of the human will change as a result of the implementation of autonomous technologies in the areas of:

- Vessel operations
- Vessel engineering
- Scientific Systems Management
- Scientific System Operations

Investigations revealed that the most significant advancements expected within the next 10-15 years will focus on artificial intelligence advancements. This will be implemented throughout the equipment pool operated by the NOC, which will fundamentally change the way that humans interact with these systems.

As with the advances in AI, there will also be considerable advances in communications systems that will enable personnel to be removed from vessels and transition ashore into a remote operating centre environment. This will require a fundamental evaluation of current operating methodologies to allow operations to continue safely and efficiently whilst being conducted from a remote location.

Coupled with these technological advancements and the shift into a remote operation centre environment, soft skills will become even more essential. The cooperation between different project teams will increase as all elements of offshore operations become interlinked.

General advancements will be made in the equipment available, which will require personnel to be trained in the specific operation of this new equipment; however, the impact of this will be minimal when compared to the transition to remote operations.

Project Conclusions

There is no doubt that this is an exciting time to be working within the field of Marine Research as it is clear that there will be substantial technological advances that revolutionises the way the work is completed by 2035. As this study has found, however, the introduction of new technology creates new gaps in competence. To be a safe and effective Operator and prevent incidents, these gaps must be identified early, and the workforce's transition needs to start as early as possible.

With the possibilities that these new technological solutions will offer, there is a potential that the impact of an accident could be much more significant than that of a conventional operation. This will require higher competence levels than ever before. Whilst current MET institutions are well versed in training traditional skills. They have proved slow to react to emerging technologies and operational practices. Training is expected to become a more specialised area, with new specialist training providers emerging through private enterprise as well as focus on Company and Equipment Operators specific training coming more to the fore.

1. Past Technology Assessment

The past four decades have seen numerous technological advancements in the shipping industry that have sought to enhance the efficiency of vessel operations, improve seafarer safety, and reduce the number of accidents. While there have been many advancements made, ECDIS and Automated Equipment monitoring systems are two with particular relevance to the context of this report. A review of open-source literature was conducted, looking at the introduction of these systems and assessing the training provided to seafarers.

1.1 ECDIS

1.1.1 Background

The introduction of ECDIS was one of the most significant advancements in navigational technology since the installation of RADAR or GPS and brought with it the requirement for a seafarer who was not only conversant in traditional navigational skills but one who was also proficient in the operation of computer systems. The step-change in knowledge demand required that a seafarer be properly trained on these new systems and that this training provide sufficient understanding for an OOW to take full advantage of this new capability for it to have an overall positive rather than detrimental impact on navigational watchkeeping standards.

1.1.2 Training Requirements

Carriage requirements for ECDIS were laid out in SOLAS, alongside which STCW outlined the updated training standards for this new system. STCW required that masters and officers serving on a ship fitted with ECDIS should undertake generic ECDIS training. This should then be enhanced with familiarisation of the equipment actually in use onboard. A requirement echoed in the ISM Code, which requires not only effective training but familiarisation of new equipment and regulations concerning safety and emergency-related duties.

It was intended that the generic training should be delivered such that the navigator could learn to use ECDIS and apply it in all aspects of navigation, including the knowledge, understanding, and proficiency to transfer that skill to the particular ECDIS system(s) actually encountered on board, prior to taking over navigational duties (NI 2012). To formalise this generic training, the IMO produced and then updated in 2012, Model Course 1.27 *The Operational Use of ECDIS,* which could then be developed further by individual training providers. It should, however, be noted that IMO Model Courses are flexible in application. As in all training endeavours, the instructor's knowledge, skills, and dedication are the key components in transferring knowledge and skills to those being trained. (IMO 2011, Brčić et al. 2017).

However, whilst the IMO outlines the basic level of generic ECDIS training, it is left to the Flag States and owners to decide how specific equipment familiarisation should be delivered, leading to inevitable differences in the delivery of system familiarisation between institutions and companies. An issue that is further compounded by the number of discrete ECDIS providers and variations in systems.

1.1.3 Research into Training Delivery

Research conducted into generic training in 2017 by the University of Rijeka, Croatia (Brčić et al. 2017) focused on the 40-hour duration stipulated by the IMO Model Course. Of the 235 respondents covering a range of ranks and roles, it was noted that 88% found the 40 hours sufficient; however, it was caveated that this only provided sufficient time for system introduction and a basic level of knowledge. The view of the majority of the respondents was that it did not offer the required practical skills, and whilst it may meet the legislative requirements, it takes a lot more exposure to use the system correctly. Where opposing views were proffered, it was that the 40 hours would only be sufficient depending on the previous experience of the individual; if they have had no previous ECDIS, navigation or IT experience, this may have to be increased to up to 80 hours, and the course simplified.

While it would appear that people were generally content with a course that lasts 40 hours to provide a base level of understanding, one of the challenges experienced by seafarers is receiving an acceptable level of training. A survey conducted by the NI in 2017 (Gale, 2017) found an issue with the delivery of the generic course, with 50% of the 200+ respondents stating that their course lasted less than 36 hours and 7% comprising of 24 hours or less. Furthermore, 29% did not undergo any form of formal assessment as required by the IMO Model Course. When asked for their view, some of the comments stated that the course was a waste of time and money with little generic information given, the model course syllabus not followed at all, easy questions or questions based on a type of ECDIS not covered in the course. When asked how they viewed their colleague's ability to use ECDIS, 30% stated that they thought their fellow officers were less than competent or not competent at all. In a final comment, one Master stated that the competence of his officers had only improved through ongoing shipboard supervision and instruction. "It is my firm opinion that neither generic nor type-specific training prepared officers for a safe navigational use of the equipment".

1.1.4 Evidence of ineffective training

Unfortunately, the inadequate training and lack of understanding manifests itself in groundings, as witnessed by the sheer weight of evidence that that can be gleaned from the large volume of accident reports. In studying reports focusing on ECDIS-related accidents, it is apparent that these have largely occurred not from technical problems within the ECDIS system but either from user error or improper duties of the bridge crew. The most common errors are (UKP&I 2021, Turna et al. 2019):

- Failure to use the alarms.

- Failure to use the guard cursor.
- Failure to use the automatic navigation check route function.
- Insufficient chart scale and safety contours.
- **Insufficient knowledge and training of crew**.

By way of example, the following is a snapshot of some of the incidents where ECDIS training has been a causal factor:

a. **CSL Thames:** On 9th August 2011, the Malta registered self-discharging bulk carrier, CSL Thames, grounded in the Sound of Mull, Scotland (MAIB report 02/2012). It was identified that the ECDIS safety contour was set to 10m, which was inappropriate with respect to the vessel's draught, and that the master's and other watchkeepers' knowledge of the ECDIS system was insufficient (MAIB 2012).
b. **Ovit:** On 18th September 2013, the Malta registered chemical tanker Ovit ran aground on the Varne Bank in the Dover Strait (MAIB report 24/2014). The investigation identified that although training in the use of the ECDIS fitted to the vessel had been provided, the master and deck officers were unable to use the system effectively. (MAIB 2014).
c. **CMA CGM Vasco de Gama:** In the early hours of the morning on 22nd August 2016, the 399m long ultra-large container vessel CMA CGM Vasco de Gama grounded on the western side of the Thorn Channel (MAIB report 23/2017). The investigation found that the deck officers had all received generic and equipment specific ECDIS training, and all were experienced navigators. Despite this, the vessel's primary means of navigation was not being utilised effectively or in accordance with company policy (MAIB 2017b).
d. **ABFC Roebuck Bay:** On 30th September 2017, shortly after midnight, the Australian Border Force cutter Roebuck Bay grounded on Henry Reef in the Great Barrier Reef, Queensland (ATSB report 335-MO-2017-009). It was identified that the type-specific ECDIS familiarisation training, as undertaken by ABF deck officers, was not effective in preparing the cutter's officers for the operational use of the ECDIS (ATSB 2017).
e. **Seatruck Performance:** On 8th May 2019, the Isle of Man registered roll-on/roll-off (ro-ro) freight ferry Seatruck Performance grounded while transiting the Greenore Channel in Carlingford Lough, Northern Ireland (MAIB report 04/2020). The chief officer and 3/O had all completed the training required to use ECDIS as a primary means of navigation, but for the outbound passage from Warrenpoint, many of the system's safety features were not utilised (MAIB 2020).

During an investigation into ECDIS as a causal factor in accidents on tankers, OCIMF looked at 11 published reports and 7 company investigations for the short period 2016 – 2018. The result of this investigation identified that gaps in ECDIS-related knowledge and practical application by Navigating Officers and Masters remains a reoccurring theme when analysing incidents as well as SIRE observations (OCIMF 2020).

1.1.5 Conclusion

There is no doubt that the introduction of ECDIS has contributed to improving the safety of navigation. However, what seems to be apparent is that the efficacy and safety of ECDIS depend largely on its user's ability. In other words, how the user interacts with this system is key to its success in ensuring safe navigation (UK P&I 2021). Even the most advanced equipment, whether that be ECDIS or any other requiring manual inputs, must be operated by a fully competent operator, as it will not forgive erroneous entry of data or poor configuration.

1.2 Automated Equipment Monitoring Systems

1.2.1 Introduction

Over the course of the past 40 years, there has been a marked change in the operation of engine rooms as increasingly complex systems with automated monitoring were introduced, ultimately leading to Unmanned Machinery Space's (UMSs). The changes have been brought in with the aim of making systems more efficient, with many engineers trying to "design out" human operators, reduce the possibility of human error and increase productivity and safety. Unfortunately, the poor integration of new systems, together with seafarers taking an ever more passive monitoring role, is problematic and has led to an increased risk of human error being the causal factor in incidents at sea.

Indeed, this drive for automation has brought with it two problems, one concerning the inadequacy of existing seafarers' education and training; that if any aspects of automation were to fail, the crew often are not trained to use alternative systems and hence respond to it effectively. The second problem has arisen from the review of the arguments from the IMO Maritime Safety Committee, namely that human operators rarely understand all the characteristics of automatic systems, and these systems' weaknesses and limitations have now been found to be the leading causes of accidents. (IMO MSC 82/15/2 and MSC 82/15/3, cited in Ziarati et al, 2010)

1.2.2 Training

In the past, training programmes focused on developing an engineer with hands-on skills that suited the requirements of the time and was indeed reflected in STCW 78. STCW 95 further enhanced the workshop requirement under the function "repairs and maintenance", with additional theoretical aspects also included. However, the code does not adequately focus Maritime Education and Training (MET) institutions towards the required theoretical concepts essential to prepare engineers with the required knowledge and skills to deal with future trends and advanced technology (Lokuketagoda, 2018). The training requirements in the STCW convention almost certainly require amplification to meet the demands of many sectors of the shipping industry and undoubtedly lag behind the technology.

1.2.3 Research into training delivery

A 2016 study for IMAREST (Maxwell 2016) looked at skills and training shortage at the time, reaching out to 350+ organisations to assess the competency of newly qualified engineering officers. Cumulatively, only 23.5% of survey respondents agreed that newly qualified ship engineers were competent to manage plant onboard; however, this appeared not necessarily to be based on the quality of the individual, but instead the training that they had received. It was suggested that the inadequate training was due to the lack of development of regulations, with nearly 83% of those surveyed agreeing that the industry needs to review modern requirements of the skills of ships staff and modernise training to suit.

A 2006 research paper (Rowley 2006) looking at Mitigation of Human Error in Automated systems, conducted by QinetiQ on behalf of the MCA, investigated Crew Resource Management (CRM) training and found only one course that specifically addresses 'automation awareness', with only a further two encompassing Human Factor topics covering human error. While STCW has been updated to reflect the requirement for greater Human Element training in the form of the HELM Course, there remains little focus on awareness of automation.

1.2.4 Evidence of ineffective training

The lack of adequate training in the operation of mechanical system revisionary modes has manifested itself in accidents, two of which are detailed below;

a. **Savanah Express;** On 19th July 2005, the German flagged Savannah Express made heavy contact with a linkspan at 201 berth, Southampton Docks (MAIB report 08/2006). The investigation found that the chief and electrical engineer's theoretical knowledge, gained from attending standard STCW and Flag State courses (which includes electrical theory and practical training), and the practical knowledge gained over a number of years' experience, appear to have been insufficient to effectively diagnose the cause of the engine shutdowns and deal adequately with the situation that occurred. The present generic training requirements of STCW may be insufficient to cope with the system engineering aspects of complex integrated engine control systems like that of the main engine on the Savannah Express.
b. **Prosperro;** On 10th December 2006, the product tanker Prospero lost control of propulsion on approach to No. 2 Jetty, SemLogistics terminal, Milford Haven and made heavy contact with the jetty's infrastructure (MAIB report 24/2007). It was identified that given the technical complexity of the propulsion system onboard, it was unlikely that the basic elements of STCW training for engineer officers would equip them to operate a plant of this type. Had Prospero's engineer officers received more comprehensive training, they would have been better equipped to operate, test and maintain the drive system on a routine basis. Further, they would have been sufficiently confident in both the drive system and their own abilities to ensure that the reversionary and emergency modes of control were regularly exercised and would have been better able to advise the Master when the control system failed.

1.2.5 Accident root cause analysis

During the course of their research in 2006, QinetiQ looked at a wide range of incidents similar to the above and summarised the issues when ship's crews interacted with automated shipborne maritime systems. As can be seen from the list below (Rowely 2006), it would appear that the root cause of many can be down to inadequate training and a lack of familiarisation with automated systems;

- There is sometimes an over-reliance on the automation by the ship's crew, leading to a false sense of security that the automation will always handle the situation safely.
- Ship's crews are often overconfident in the data presented to them by automated control systems, leading to a lack of crosschecking of data.
- There is often a lack of understanding by the ship's crew of automated control systems and any inherent weaknesses they may possess.
- Automated shipborne maritime systems do not always have the best ergonomic design considerations.
- On some screen-based automatic control systems, the human-computer interface can be very confusing to the user.
- Due to the inherent latency in some control systems, it may not always be possible to recover an error, even if it is very quickly realised.
- Serious consequences can arise if the ship's crew are unaware of the failsafe actions that a control system can take automatically following an operator error.
- Maintenance and calibration errors when setting up automatic control systems can lead to catastrophic consequences.
- Some current automated systems do not adequately augment the situation awareness of the system operators.
- Inconsistencies exist in the display formats of Navigational Information between manufacturers. Greater standardisation is required.
- Human operators rarely understand all the characteristics of automated systems; system weaknesses and limitations can remain hidden from the Operator.
- Designers do not design automated systems with the range of competence of the automation user community in mind.

1.2.6 Conclusion

While there is an irreversible march towards greater automation on vessels, Moray (2001) argued that research and industrial practice have begun to emphasise the virtues rather than the weaknesses of operators. It is now agreed that in automated systems, humans are needed at least for two purposes; as the last line of defence in hazardous operations and to improve productivity. The human intervention or the presence of the remote Operator cannot be underestimated within the operation continuum of the marine engineering functions of both the smart ship and the autonomous ship concept. Irrespective of the degree of automation installed on the vessel, it is essential to enable human intervention if all else fails (Lokuketagoda, 2018).

Where it is utilised, automation changes the nature of the activity it replaced or supports; it creates new error pathways and has the potential for delaying the opportunity for error detection and recovery. It shifts the required focus of knowledge, requiring engineers to have not only a comprehensive working knowledge of the original base system but also the manner in which the automated system functions and what the consequences are when it fails to operate as intended.

2. Future technology 2035 overview

For the purposes of this report, the National Marine Facilities Technology Roadmap 2020/21 was used to provide a baseline for the expected technology advancements to 2025. This has be further projected out to 2035 by reviewing available literature for the areas of focus required from this report. The report is broken down into focus areas as follows:

- Deck Operations
- Vessel Engineering
- Scientific systems
- Sensors & Moorings
- ROV
- AUV
- Long Range

The objective of this section is to provide a high-level overview of the expected advancements and technology available so that a gap analysis can be produced around the training needs of the future workforce.

2.1 Deck Operations

Over the next 5 years, the most significantly anticipated impact on the deck operations of the conventional vessels operated by the NOC will be in the new winch systems being purchased and installed to increase the flexibility for the launching of scientific equipment. A number of these will be fitted with active heave compensation systems; this will require the Operator to understand the impact of the inclusion of this system and how it will affect the safe operation.

Expanding the scope out to 2035, several systems are currently being developed to allow for the autonomous docking of vessels. This would significantly impact the deck operations from a safety point of view. Headcount will be removed from the mooring deck during one of the most dangerous operations any vessel can undertake. The knock-on effect is that with a fundamental change in the way vessels are docked/undocked, those in control of the vessel will need to develop an understanding of how the vessel interacts with these new docking systems whilst piloting the vessel.

Further solutions are also being introduced and will be covered in more detail later in this chapter; however, holistically with new solutions will come new stowage and securing methods, new launch and recovery systems, and new levels of interaction with both the parent vessel and other solutions, which must be understood prior to operation meaning that the back deck of the vessel is likely to also see considerable change.

2.1.1 Key Points

- New winch systems installed, some with active heave compensation
- Autonomous mooring systems

- Changing makeup of the back deck equipment

2.2 Vessel Engineering

Sustainability is a crucial topic over the coming decade, and with this comes a change in how vessels will be powered. An imminent change that is expected to be implemented on NOC operated vessels will be the inclusion of a hybrid battery system to reduce the vessel's carbon footprint. Going forward, it could be expected that the primary fuel source of the vessel will also change to one other than marine diesel or heavy fuel oil. Along with these new power sources will come new challenges in maintenance, charging and refuelling, as well as the requirement to maintain a connection to a national grid when alongside.

To date, there has already been a large increase in the use of automation within the engine room, with periodically unmanned engine rooms now being commonplace on most vessels. This is only expected to increase with new and more accurate monitoring systems being developed and solutions to introduce an automated monitoring element to conventional analogue systems. The use of digital twins of engine room equipment is also expected to increase drastically. Theoretically, this has changed the role of an engineer from reactive maintenance to preventative data driven maintenance and even further to dynamic maintenance.

With much of the engine room equipment now having a digital overview, the burden can also be shifted from the onboard engineering team to a remote engineering team. Information can be shared from the ship to the shore to allow personnel to assess the information, guide and support the team onboard, and ensure the vessel operates as efficiently as possible without increasing the workload of those onboard.

Whilst ship to shore teaming brings with it many advantages and access to specialist offboard knowledge, remote monitoring and remote intervention brings with it further risks and the potential for new failure modes. One of these is from security breaching through new cyber physical interfaces and vessel networks.

2.2.1 Key Points

- New power solutions
- Increased automation in the Engine room
- Digital twins
- Remote support opportunities
- Switch from reactive maintenance to preventative maintenance
- New potential failure modes through cyber security intrusion

2.3 Scientific systems

Due to the nature of scientific systems, it is difficult to determine what evolution or introduction of new systems there may be over the next 15 years. However, what is apparent in the short term is that the main change will likely be system enhancements of the current solutions, improving redundancy, giving better quality data, and improving launch and recovery systems.

2.3.1 Key Points

- Improved redundancy
- Better quality data
- Improved launch and recovery systems

2.4 Sensors & Moorings

2.4.1 Moorings

Mooring systems are set for several upgrades in the coming years. The mooring itself is expected to be refined to ensure they are better equipped to survive the harsh environment in which they operate. New solutions for identifying the location of the mooring system upon its return to the surface will be available within a short period.

The multi-modal potential of these systems is also expected to advance with the introduction of two-way telemetry systems for real-time data transmissions and the inclusion of charging stations for in-situ AUV's. These multiple-use scenarios may also require a design change to ensure the mooring is situated sufficiently to allow all operations to occur without interference. This will require an effective launching system to ensure the mooring is landed as required.

2.4.2 Ship-based data acquisition systems

Seismic survey solutions are currently advancing to allow for more adaptable systems to be installed onboard vessels. With these adaptable systems, the way of working can be modified to fit the surroundings and increase the depths at which surveys can be completed. Sensing systems will also be able to be utilised on both fixed and mobile platforms.

A significant advancement will be the introduction of USV's to make surveys more environmentally friendly and efficient. The introductions of USV's does not mean the current onboard systems will be outdated but will work together to reduce the amount of time taken to cover a large survey area. This will require effective mission planning and operation of the USV's to ensure the coverage is complete and avoid interference with each other. The pattern used to complete surveys could evolve to maximise the effect and number of the USV(s) involvement. The introduction of swarm technologies where the vessels talk to each other to prevent collisions and pass information about the area of operation will drastically improve safety and efficiency and reduce the burden on operators monitoring the whole operation.

Away from the hardware advances, there are expected software advances with the introduction of automated processing for the data acquisition process. This will, in effect, 'clean' the data before it is delivered to data processors and thus reduce the amount of processing time required before the data is useable.

In keeping with the theme of integration, with the increasing number of sensors available to gather data, it is essential that they all communicate to one another and that the data is centrally located to avoid duplication. Open control systems are being developed to allow users to control a multitude of assets from a central device with a unified user interface across all equipment. Coupled with this, data processing tools will develop to the point where the data can easily be stored, processed, quality checked and delivered to consumers with ease.

With the introduction of these integrated systems for control and data processing, the use of remote operations centres becomes a more relevant use case. With improvements in satellite communications, data can be transferred effectively from the remote locations where the vessel operates to a land site in order to reduce the workload of those offshore. Those located in the land site can access and process data without being exposed to the HSE risk of being onboard a vessel.

2.4.3 Calibration Laboratory

The increased number of vehicles capable of carrying sensors will come with an increased requirement for calibration of these sensors. Along with these advancements, there will be a requirement for the support services to progress in order to support continued operations. Whilst it cannot be fully realised at the moment how far these will progress within the timeframe explored, it is suggested that this will be an essential support service for all activities.

2.4.4 Key Points

- Improved mooring system design for the operational environment and identification system for recovery.
- Refined mooring systems to provide a platform for multi-modal activities such as data gathering, data transmission and AUV charging etc.
- Adaptable seismic solutions to fit the operational environment, reduce background noise and simplify use.
- Collaboration between ship systems and ASV's to improve the efficiency of the data gathering process.
- Software enhancements to allow for automated processing of data.
- Unified control systems to allow operators to manage all the systems available to them from a single location.
- Centralised data storage to avoid duplication.
- Remote assistance from a shore-based location.
- Onboard support services to reduce downtime and improve the efficiency of sensors and equipment.

2.5 ROV

Improved ROV design will make use of a modular setup, smoothly allowing them to be customised for a specific operation. By taking a modular approach, the ROV units can develop over time as new working methods develop. An integral part of this development will be the addition of more autonomy within the control system, simplifying the job of the ROV pilot.

Alongside these autonomous elements to the control system, as with the ship-based systems. A remote element will be realised, allowing ROV's to be piloted from a remote location, not specifically onboard the vessel where the ROV was launched from. Moving the location that the ROV pilot sits will allow them to be more integrated with the mission team and give a greater oversight for all involved. By allowing this oversight, the value of the ROV operations will be significantly enhanced and provide the opportunity for dynamic mission planning.

To ensure that the remote and autonomous elements of the ROV setup are a success, closer integration with the ship's systems will be required in order to maintain close control and a stable data link with the ROV. There is also a potential for the ROV to be integrated into one of the USV's to further expand the remote and autonomous capabilities and remove personnel from exposure offshore. Thus improving the HSSE standards of the operations.

The ROV design will have to be further enhanced to reduce the amount of maintenance required to enable these advancements. Utilising alternate power sources, the shift to fully electric ROV's and the removal of hydraulic systems is envisaged to be critical to this.

2.5.1 Key Points

- Modular design approach to allow quick transition between payload systems. It will also allow for custom payloads to be designed by external users.
- Improved autonomy within the control system.
- The introduction of remote ROV pilotage.
- Enhanced oversight of missions, allowing for dynamic mission planning.
- Improved integration with ships systems to maintain control and a robust data link.
- Potential combination with USV solution to further improve efficiency and increase the safety of personnel.
- Alternate ROV designs to reduce maintenance periods.

2.6 AUV

It is expected that the capability of use of AUV's will increase vastly over the coming period. Before the AUV even enters the water, the introduction of synthetic environments will allow simulations to be run and software bugs to be identified prior to the commencement of the mission. As with other systems mentioned in this report, the integration and advancements of autonomous elements within the control system will significantly improve the safe navigation capabilities of the AUV, with specific steps being taken to enhance the under-ice operation, integrate reference systems and improve the navigation systems by introducing new abilities such as a hover or hibernation mode. This, combined with improved power systems, should greatly improve the endurance and reliability of the equipment, whilst at the same time reduce the risk of loss. Subsea charging stations will also start to be integrated into other fixed solutions, which will remove the requirement for launch and recovery.

Tighter integration of the communications system with that of the parent vessel will increase the quality of control and monitoring for the AUV. The introduction of onboard data processing will improve the data storage onboard the AUV and reduce the bandwidth required to transmit the data back to the parent vessel remotely. Improved communications can also be extended to the vessel-tracking systems and enhance the position monitoring of the AUV.

With advancements in interconnected networks, this could create a connected field where the parent vessel communicates with USV's, AUV's, gliders and fixed sensors at all times, giving a full oversight of all operations simultaneously. With enhanced control and greater oversight comes the ability for dynamic mission planning, making operations safe and efficient as conditions change or a new objective is identified. Increasingly within control software, the front seat/back seat setup is being utilised to allow for different systems to operate within the vessel simultaneously. This can be used to run mission-specific software on top of the generic navigation software. With the changing environments the AUV will operate in, this could be capitalised upon to alter how the AUV will react to situations depending on the current circumstances.

2.6.1 Key Points

- Development of synthetic environments will allow for simulation of mission environments and fault finding within the control software.
- Introduction of autonomous elements to control system will improve safe navigation.
- Introduction of new abilities will enhance the capabilities of the equipment and allow for greater control.
- Improved power systems and installation of subsea charging stations will increase the range and reduce the number of launch and recovery operations. Further integration of comms systems will improve oversight and give greater operational control.
- Onboard data processing will improve storage capacity and reduce bandwidth requirements for remote data transfer.
- Interconnected network developments will allow for a connected field and reduce the risk for loss of equipment.
- Enhanced control systems allow for dynamic mission planning for the AUV.
- Front seat/back seat system architecture allows for more specific software to be introduced to improve operational effectiveness based on operating conditions.

2.7 Long Range

2.7.1 Gliders

From a power source point of view, gliders are already operating on battery power. Developments in battery technology may improve the duration or ability to utilise higher-powered sensors for missions. Advances in the design will also allow for greater depth ratings and improved reliability.

New sensor technology will improve the navigational awareness of the glider, and with the introduction of autonomy into the control system, the obstacle avoidance should be improved all around; advances in under-ice navigation will also allow the gliders to work in more challenging terrains. The introduction of the unified user interface will improve the users' operational awareness and speed up the pre-mission processes.

With advancements in interconnected networks, this could create a connected field where the parent vessel communicates with USV's, AUV's, gliders and fixed sensors at all times, giving a complete oversight of all operations simultaneously. Allowing all equipment in the field to communicate will increase the ability of the individual equipment to better locate itself within the field, again improving situational awareness and obstacle avoidance.

2.7.2 Key Points

- Improved power systems.
- Improved navigational awareness.
- Introduction of under-ice operations.
- Introduction of autonomous elements to control system will improve safe navigation.
- Interconnected network developments will allow for a connected field and reduce the risk for loss of equipment.
- Improved power systems.
- Introduction of unified control systems.

2.7.3 MASS

Perhaps the most significant change in the field over the next 15 years will be the introduction and adoption of MASS technologies. This could range from a small vessel designed to assist in the overall operations by supporting an AUV and acting as an acoustic gateway. To a large vessel that can act independently, capable of launching AUV's and ROV's remotely and being controlled from the shore. These vessels could carry similar scientific equipment to that of a conventional vessel and remotely transmit the data to a shore location.

As with other solutions, software advances will introduce automated processing for the data acquisition process. Delivering 'clean' data to data processors and thus reduce the amount of processing time required before the data is useable. Increased use of satellite communications for command and control; the data transfer process will be able to easily tap into the readily available communications systems for transfer to the shore.

With the move to the shore, the shore-based location can be designed to allow the multiple actors in the projects to sit together and form a cohesive operational unit, improving communications amongst the team and the overall efficiency of the operation. The adoption of a unified control system will allow users to control the multitude of different vehicles in the field seamlessly.

Again with an interconnected network, there will be one connected field where all equipment interacts simultaneously, giving complete oversight of all operations simultaneously. The MASS could act as the gateway to all other elements within the field and be the focal point from which all other operations are planned.

2.7.4 Key Points

- Revolutionise the way work is carried out in the field.
- Will assist in current operations, tracking and communicating with assets in the field.
- Could remove the need to have a crewed vessel on location.
- Remote/autonomous launch and recovery of other scientific systems.
- Autonomation within the control system to aid safe navigation.
- Interconnected network developments will allow for a connected field and reduce the risk for loss of equipment.
- Introduction of unified control systems.
- Remote data transfer.

3. Workforce Skills Gap Analysis, Collective Analysis and Measuring Impact.

In reviewing the training and workforce upskilling challenges associated with the introduction of previous ‘new technologies’, it is evident that a better approach, beyond minimum regulatory standard courses is needed. This is to ensure that an individual is appropriately trained to operate the equipment currently in use. It is also clear that given the evolving nature of the industry, the scope of training will have to be adjusted to ensure it covers the technological developments projected within the Shipping industry and specifically the Marine Science environment by 2035. For these technologies to be utilised to the fullest potential, the personnel charged with the setting to work, operation and oversight of these systems need to be fully conversant with their operation. To that end, the following is an initial assessment of how the role of the human will change as a result of the implementation of autonomous technologies in the areas of;

- Vessel operations
- Vessel engineering
- Scientific Systems Management
- Scientific System Operations

3.1 Methodology

The methodology used for knowledge elicitation was based upon and guided using the following questions:

- Currently what do each of the groups need to do to deliver the current capability operationally?
- How will new technology change the way they deliver new high-level operational functions?
- What broad new skill requirements are required to deliver on any operational gaps?

In attempting to answer these questions, in our approach we began by identifying the high-level macro view capability requirements of both assets - the vessel and the cyber-physical vessel interaction. As such we sought to amalgamate the macro duties of the workforce onboard on the basis of human reliance going forward, combined with the rate of technological advancement 'assured' by Moore's Law and the age of acceleration. We start from today’s assured basis of knowledge and oriented towards the future, rather than normative technology forecasting where we first assess future goals, needs, desires, mission, etc., and work backwards to the present.

From this we were able to tentatively predict some potential timelines, based on technological rate of change and combine this with Lloyds register’s, categories of autonomy.

3.2 Definitions of Autonomy

Lloyds Register (LR 2017) has defined seven levels of autonomy, highlighting the changing nature of vessel operations. These have been applied to all aspects of the operations taking place on board these vessels, not merely the vessel operation. These levels are;

AL 0) **Manual:** No autonomous function. All action and decision-making performed manually (n.b. systems may have level of autonomy, with Human in/ on the loop.), i.e. human controls all actions.

AL 1) **Onboard Decision Support:** All actions taken by human Operator, but decision support tool can present options or otherwise influence the actions chosen. Data is provided by systems on board.

AL 2) **On & Off-board Decision Support:** All actions taken by human Operator, but decision support tool can present options or otherwise influence the actions chosen. Data may be provided by systems on or off-board.

AL 3) **'Active' Human in the loop:** Decisions and actions are performed with human supervision. Data may be provided by systems on or off-board.

AL 4) **Human on the loop, Operator/ Supervisory:** Decisions and actions are performed autonomously with human supervision. High impact decisions are implemented in a way to give human Operators the opportunity to intercede and over-ride.

AL 5) **Fully autonomous:** Rarely supervised operation where decisions are entirely made and actioned by the system.

AL 6) **Fully autonomous:** Unsupervised operation where decisions are entirely made and actioned by the system during the mission.

3.3 Vessel Operations

Capability / Timeframe	Passage Planning & Route Execution	Command and Control	Berthing & Mooring Operations	Uncrewed Vessel Operations
PRESENT DAY UNTIL 2025	AL 1	AL 1	A1 / AL 0	AL 3
	SKILLS EXIST IN PRESENT DAY WORK FORCE	SKILLS EXIST IN PRESENT DAY WORK FORCE	SKILLS EXIST IN PRESENT DAY WORK FORCE	NEW SKILLS REQUIRED IN WORK FORCE
2025 - 2030	AL 3	AL 3	A1 / AL 0	AL 4
	NEW SKILLS REQUIRED IN WORK FORCE	NEW SKILLS REQUIRED IN WORK FORCE	SKILLS EXIST IN PRESENT DAY WORK FORCE	NEW SKILLS REQUIRED IN WORK FORCE
2030 - 2035	AL 4	AL 3	AL2 / AL 1	AL 5
	NEW SKILLS REQUIRED IN WORK FORCE	NEW SKILLS REQUIRED IN WORK FORCE	NEW SKILLS REQUIRED IN WORK FORCE	NEW SKILLS REQUIRED IN WORK FORCE

Table 1: Development of autonomy within capability areas related to Vessel Operations

3.3.1 Passage Planning & Route Execution

Current charting technology requires user decisions on which route to take, inputting variables (HoT, Weather, Current) and subsequently choosing whether to run a check to assess the safety of the routes. Implementation of new IHO standards[1] will provide increased levels of data for the Operator to review as well as increasing the complexity of the system. This enhanced charting software will require an operator who is familiar with the core concepts of navigation and can correctly manipulate the software to ascertain the validity of the data received. Subsequent advances (although in some respects already present) will allow for routes to be pre-planned ashore. A remote operator receives the same detailed environmental information, which is then sent to the ship for execution. Regardless of their origin, these routes will also need to be reviewed onboard.

While 'Track Control' systems are already prevalent amongst newer vessels, these will become increasingly integrated within the passage planning & monitoring systems, allowing for real-time updates to planned routes to be suggested for the Operator to then assess. As with the initial planning of the route, its execution will still have to be monitored by a competent individual who will also need to have an awareness of the system to allow for informed decision making and an awareness of a developing failure.

3.3.2 Command & Control (C2)

Further to the advances in passage planning, as outlined above, it is expected that with advances in communications technology, the C2 of certain missions will be based not onboard the vessel but instead in an operations centre elsewhere. In order to facilitate this relocation of function, there will be a requirement for increased connectivity and advances in software development, which will then need to be maintained once installed. Due to the sensitive nature of the information passed between the control room and the Operator on the vessel, a robust maintenance system will need to be established to ensure that any issues are swiftly rectified. While this is easily achieved ashore with on-call staff, it will require personnel trained in 'non-traditional' skill sets to ensure the afloat link is not compromised.

While the C2 function may have been transferred ashore, there will remain a requirement for the Operator to be sufficiently qualified to action the decisions elsewhere after having initially assessed its viability. The training and experience of these individuals will be vital to giving them the gravitas to inform a remote-control centre that a plan cannot be actioned if local conditions are not favourable.

3.3.3 Berthing & Mooring Operations

Technological advancements in berthing are already in development, and range from berthing aids providing distances and aspect relative to a berth, to complete

[1] IHO S-100 Product specifications. https://iho.int/en/s100-project

automated mooring systems. The use of berthing aids is being trialled by numerous harbour authorities to aid vessel handling, and range from shipborne to shore-based systems. Being relatively low cost and simple to install, it is likely that there will be increased use of these systems; however, they will require a level of familiarisation with their operation to ensure they are utilised correctly, and the Operator is ofay with the detail that is being provided at a highly stressful time.

Automated mooring systems are also in development, and have been in use as far back as the '90s. However, they are limited in their deployment, and many require significant investment in port infrastructure, usually being confined to berths with fixed schedules and vessel types. While new systems have been developed to trial automated deployment from the vessel[2], it is expected that even these will require modifications to the berth and will still require human oversight when operated to ensure that any issues are swiftly rectified to minimise risk to the vessel or jetty. Therefore, it is unlikely that these systems will have a role to play in the near future given the nature of the vessels in question and their varied areas of operation; however, as advances are made, a review in mooring procedures will be required with appropriate training delivered.

3.3.4 Uncrewed Vessel Operations

The transition to the use of uncrewed vessels is the most significant transition the maritime industry will go through since perhaps the invention of the diesel engine. This will impact all elements of what is fundamentally understood to form maritime operations, from command and control being moved to a remote location, how situational awareness is achieved, passage planning taking into account limitations of the vessel and interactions with other vessels/equipment in the maritime environment.

This move to uncrewed operations will require a fundamental ground-up approach to identify the necessary skills and competencies for remote operators. There will be a move towards this becoming a more technically aware role as operators will have an awareness of how the system functions in order to be able to identify when it is acting improperly. They may also be required to fault find and work around issues if they arise. Whilst it is envisaged that support will be available for the maintenance and serious IT issues that arise, the primary day to day issues that arise should be within the scope of the Operator. Knowledge of communication systems will also form a fundamental element of operators understanding.

Perhaps the most challenging aspect when projecting the skill requirements for uncrewed vessel operations is just how novel the technology is. The expectations are that the AI level will continue to increase to the point where the human is moved into a monitoring and oversight role, only stepping in when necessary to avoid dangerous situations from developing. With the side-step of the Operator, it is expected that this will expand the role to oversight of multiple vessels at one

[2] Macgregor Automated Mooring System https://www.macgregor.com/intelligent-solutions/automated-mooring-system/

time. This again will require additional skills and competencies which are yet to be defined.

3.4 Vessel Engineering

Capability / Timeframe	Pre-Departure Engine Configuration	Performance and Efficiency Monitoring	Failure Diagnosis and Correction	Preventative maintenance
PRESENT DAY UNTIL 2025	AL 2	AL 2	AL 2	AL 2
	SKILLS EXIST IN PRESENT DAY WORK FORCE	SKILLS EXIST IN PRESENT DAY WORK FORCE	NEW SKILLS REQUIRED IN WORK FORCE	SKILLS EXIST IN PRESENT DAY WORK FORCE
2025 - 2030	AL 4	AL 4	AL 4	AL 3
	NEW SKILLS REQUIRED IN WORK FORCE	NEW SKILLS REQUIRED IN WORK FORCE	NEW SKILLS REQUIRED IN WORK FORCE	NEW SKILLS REQUIRED IN WORK FORCE
2030 - 2035	AL 4	AL 4	AL 4	AL 3
	NEW SKILLS REQUIRED IN WORK FORCE	NEW SKILLS REQUIRED IN WORK FORCE	NEW SKILLS REQUIRED IN WORK FORCE	NEW SKILLS REQUIRED IN WORK FORCE

Table 2: Development of autonomy within capability areas related to Vessel Engineering

3.4.1 Pre-departure engine configuration

While steps have been made towards increasingly automated engineering systems onboard merchant ships, their highly complex nature means that they still require a significant degree of supervision from onboard engineers. It is expected that whilst ships continue to have a large, complicated plant running on heavy fuel oil or similar, it is unlikely that it will be practicable to remove the human component from the process of getting the ship into a seagoing condition.

However, with an international desire for shipping to become cleaner and with the advancements in future fuel technologies, the design of engine spaces will change with a simplification of systems allowing automated controls to play a more prominent role. It will, however, take some time for confidence to build before the ability of the engineer to interrogate the systems and fix any emergent defects onboard is removed from system design.

3.4.2 Performance and efficiency monitoring

Advances in equipment design have allowed for the placement of thousands of sensors throughout the engine room spaces to monitor the plant. Coupled with advancements in communication connectivity, this information can be passed to shore support teams, who will be able to analyse the data and propose amendments to operating protocols. In order to take full advantage of these systems, both the onboard and shore personnel will need to be adequately supported through training.

3.4.3 Failure diagnosis and correction

While the enhanced monitoring of machinery mentioned above now provides an immediate indication of developing issues, this has brought with it some problems. One such issue is the sheer volume of data that is now presented to the Operator, which is usually accompanied by a list of alarms. To effectively deal with this, operators will need to have an increased awareness of the data streams they will receive in the control room to properly analyse the data and avoid overlooking critical issues. This will require a sound grounding in engineering and training in the operation of the new Platform Monitoring systems.

As these systems develop further, and with the input of manufacturers, it is likely that they will be able to propose corrective action to be taken; however, it will be the Operator who will be required to carry out this work and as such will need to have an understanding of the equipment operation and not just rely on the automated system to provide the answer.

Due to the increased potential of failure modes through cyber security intrusion, the Operator will also be required to ensure the integrity of the overall local and wider area network, maintain security of the system as well as take back control locally as and when required.

3.4.4 Preventative and dynamic maintenance

The data that is being gleaned from the sensors across the plant, as detailed above, will aid the engineering team in planning maintenance routines to avert any major issues. While the requisite skills to fix a 'traditional' engine are taught in marine colleges, the advent of increasingly complex machinery and its control systems will require operators to better understand the whole system. Based on the work undertaken in section 1 of this report, it is anticipated that the level of training is already at an insufficient level to provide operators with the requisite knowledge. Therefore, it is expected that enhanced training packages will need to be introduced in the near term to allow the experience in operation to catch up with the progress made in this area. Furthermore, whilst dynamic maintenance will create opportunities to identify maintenance windows more effectively and increase component performance, as well as provide access to expert knowledge supported from ashore, reliability and capability of new systems will still need to be understood onboard.

3.5 Scientific System Management

Capability / Time Frame	Pre-Launch System Checks	Scientific Sensor Calibration	Launch & Recovery	Maintenance
PRESENT DAY UNTIL 2025	AL 2	AL 1	AL 2	AL 1
	SKILLS EXIST IN PRESENT DAY WORK FORCE	SKILLS EXIST IN PRESENT DAY WORK FORCE	NEW SKILLS REQUIRED IN WORK FORCE	SKILLS EXIST IN PRESENT DAY WORK FORCE
2025 - 2030	AL 2	AL 1	AL 3	AL 1
	SKILLS EXIST IN PRESENT DAY WORK FORCE	SKILLS EXIST IN PRESENT DAY WORK FORCE	NEW SKILLS REQUIRED IN WORK FORCE	SKILLS EXIST IN PRESENT DAY WORK FORCE
2030 - 2035	AL 3	AL 1	AL 4	AL 1
	NEW SKILLS REQUIRED IN WORK FORCE	SKILLS EXIST IN PRESENT DAY WORK FORCE	NEW SKILLS REQUIRED IN WORK FORCE	NEW SKILLS REQUIRED IN WORK FORCE

Table 3: Development of autonomy within capability areas related to Scientific Support Vehicle Operations

3.5.1 Pre-launch System Checks

As systems become more complex, the task of ensuring all systems are operational prior to them going into the water will echo this increase in complexity. With the introduction of synthetic environments, it will become possible to system check the software quickly and efficiently. This will require personnel to be made familiar with the use of synthetic environments to realise the potential use cases fully.

From a hardware point of view, the introduction of improved sensors for pressure testing systems will reduce some of the burdens from human intervention. It is envisaged, though, that most checks will still be performed by a human carrying out visual inspections.

3.5.2 Scientific Sensor Calibration

With the more modular approach taken to the payloads onboard the marine equipment, the frequency with which scientific sensors are changed will increase. To ensure the quality of the data collected is not affected, the responsibility for calibration and testing sensors prior to their use will become more critical than ever. With the advance of technology, there may come the ability for autonomous testing of the sensors after installation; however, with the currently available knowledge, it is envisaged that this task will remain manual and overseen by humans at all stages of the calibration.

3.5.3 Launch/Recovery

The physical act of launching and recovering these scientific systems is set to change drastically both in the short term and long term. Currently, there is a

SeaBotXR

widespread introduction of new L&R systems for all systems. The difference between conventional systems and the novel vary from equipment to equipment. The inclusion of active heave systems is standard across most conventional L&R systems. More novel equipment is developing improved autonomous L&R systems. With the transition of the field to more remote and autonomous technologies, this trend is set to increase. Those personnel in the field will take a step back from the physical activity and take on a monitoring role and only take over in the event of a failure.

This will require personnel to be upskilled with maintenance knowledge for these new L&R systems, be skilled in the distanced monitoring of the process and have the skills necessary to step in if there is a system failure.

3.5.4 Maintenance

The number of condition monitoring sensors is set to increase, which should see a function shift to a preventative maintenance setup similar to that of the vessel engineering team. This will require those monitoring the condition of the equipment to have a comprehensive understanding of the systems and the meaning of the information provided by the condition monitoring sensors.

The practical maintenance of the equipment itself is still expected to require personnel involvement. With the endurance of the equipment improving, however, the management of this equipment will become even more critical. The interaction between the operators of the equipment and the maintenance team will have to be efficient to ensure the maintenance periods do not interfere with operations.

3.6 Scientific System Operations

Capability / Time Frame	Full Field Mission Planning	Remote Monitoring and Intervention	Data Quality Analysis
PRESENT DAY UNTIL 2025	AL 1	AL 2	AL 2
	SKILLS EXIST IN PRESENT DAY WORK FORCE	SKILLS EXIST IN PRESENT DAY WORK FORCE	SKILLS EXIST IN PRESENT DAY WORK FORCE
2025 - 2030	AL 3	AL 4	AL 3
	NEW SKILLS REQUIRED IN WORK FORCE	NEW SKILLS REQUIRED IN WORK FORCE	NEW SKILLS REQUIRED IN WORK FORCE
2030 - 2035	AL 4	AL 5	AL 3
	NEW SKILLS REQUIRED IN WORK FORCE	NEW SKILLS REQUIRED IN WORK FORCE	NEW SKILLS REQUIRED IN WORK FORCE

Table 4: Development of autonomy within capability areas related to Scientific System Operations

3.6.1 Full-field mission planning

This is perhaps where the most significant developments will be seen in the coming years. Connectivity within the field is ever-increasing, both from a ship to shore point of view and more locally within the field itself. The equipment will begin to communicate with each other for collision avoidance, inform each other of navigational hazards and transfer data. The parent ship can be seen as a focal point from which all this equipment will converge around.

The personnel involved in this 'full-field management' will require a fundamental understanding of the operational capabilities of each piece of equipment, the requirements for the field (i.e. what is the expected result from each piece?) and the external forces at play.

3.6.2 Remote monitoring and intervention

As the scientific equipment becomes 'smarter', more autonomous functions will be introduced into the control system. This will allow personnel to take a step back to a monitoring role. Intervention is only taken when necessary to avoid injury, damage to the equipment, damage to the environment, or alterations to the mission plan. Whilst this technically means less operational time for the operators, this does not mean lower skill levels. The opposite in fact, operators will now need to be sufficiently skilled to understand the why and the how of the system's operation. This allows them to monitor what the equipment is doing effectively and if it is reacting as expected. If it is not, they need to understand what has gone wrong with the system to make it act improperly.

It is also expected that operators will take on responsibility for multiple assets as the control systems' intelligence increases. This will again require new skills within operators that previously would not exist within this industry. The ability to work quickly, accurately, calmly and decisively under pressure will be crucial to the success of the operations.

3.6.3 Data quality analysis

The amount of data gathered is set to increase with the expansion of the number of sensors in the field. The data analysis will need to be streamlined to make the best use of the data processors expertise. The introduction of automated processing has already begun, which will continue to be refined in the short-term future. This should remove the burden of monitoring the quality of data constantly; however, it will add a new data control element with the increased volumes. Data processors will need to develop new techniques to incorporate oversight of the automated process to ensure quality is still of a suitable standard and manage all the different data streams efficiently.

3.7 Soft skills

It is expected that the most significant requirement with all of these technological advancements will be soft skills. As remotely operated equipment and AI takes over the dull, dirty and dangerous tasks, the personnel are not removed from the operation but instead move into more of an oversight and coordination role. Communication between different teams will be essential for efficient field management. Whilst the number of people involved may stay the same, it is expected that the number of equipment they are responsible for will increase; this means personnel will have to be adaptable and think dynamically to deal with situations as they arise. The working environment will also change as personnel transfer from an offshore location into an office-based environment; this will mean changing the mindset of personnel to ensure motivation remains high; management skills will play a vital role in this.

4. Report Conclusions

The introduction of new technologies is inevitable in an industry as complex as maritime, and especially within the field of Marine Research, where the incentives of better data allowing for a clearer understanding of the ocean depths will continue to drive the industry to find new ways to work. Whilst this drive is something to be commended and indeed encouraged, it should also be viewed with an element of cautious optimism, for, as shown above, the introduction of new technologies without proper training continues to be a significant causal factor in accidents.

Suppose the impact of these accidents were to be transposed into a maritime research environment, where vessels are likely to operate bleeding edge technologies in remote waters. In that case, the consequences become more acute with potential for serious injury, costly repair bills, time off task (with associated costs) and loss of valuable research.

While there is no doubt that the current crews of NOC vessels are adept at working in inhospitable climates with complex equipment, it would be remiss to expect them to continue to do so without ensuring they are properly trained to operate and maintain new equipment. It is this requirement to train competent and efficient operators that will present a challenge on par with the development of the new technologies they are to operate, for where current MET institutions are able to offer training in traditional skills, they have been shown to be less agile at adapting their training to provide comprehensive training on new systems.

This is not surprising given the number of discrete systems and manufacturers, making it virtually impossible for larger institutions to deliver training tailored to the needs of a particular field or company. An issue that is likely to be exacerbated by the continued development of increasingly complex technologies such as those outlined above. Therefore, the onus will increasingly fall on the company to develop the required training programs to ensure that their operators receive training bespoke to the systems they utilise and tailored to the company-specific ways of working.

4.1 Future Work

In order to avoid repeating mistakes made in developing training syllabuses that are too generic, aimed at providing a 'catch-all' solution, it is recommended that the above work is used as a basis from which to develop specific training pipelines that will both enhance current employees and look to develop new personnel with the correct skill sets.

While this report has provided an overview of the current and forecasted skill gaps, it is suggested that a further piece of work is now needed to identify specific training requirements. Focusing on the current training delivered for NOC, any future work would need to be conducted on a case-by-case basis to provide a tailored scheme of training for each existing role on board to bring their knowledge to a level required to ensure the safety and efficacy of operations. Additionally, it should aim to highlight any potential for new positions that may be required if the skills gap is such that there is an insufficient overlap of existing and future training or if the entry knowledge level does not provide the necessary skillset from which to build on.

The work thus far has been compiled with the intent of bringing to the fore the issues associated with a failure to train operators on new and emergent technologies properly. Technologies that are expected to become increasingly complex and automated in the years ahead requiring a skilled Operator team.

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