## Abstract

This paper explores the current state of automated systems in the Royal Navy (RN), as well as exploring where personnel view systems would have the most benefit to their operations in the future. Additionally, personnel’s views on the current consultation process for new systems are presented. Currently serving RN personnel (*N* = 46) completed a questionnaire distributed at the Maritime Warfare School. Thematic analysis was conducted on the 5125 words that were generated by personnel. Results show that RN personnel understand the requirement to utilise automated systems to maintain capability in the increasingly complex environments they face. This requirement will increase as future warfare continues to change and increasingly sophisticated threats are faced. However, it was highlighted that current consultation and procurement procedures often result in new automated systems that are not fit for purpose at time of release. This has negative consequences on operator tasks, for example by increasing workload and reducing appropriate system use, as well as increasing financial costs associated with the new systems. It is recommended that an increase in communication and collaboration between currently serving personnel and system designers may result in preventing the release of systems that are not fit for purpose.

## On the bridges – insight into the current and future use of automated systems as seen by Royal Navy personnel.

## Introduction

An increase in use of automated systems within the RN has been seen recently (RN, n.d.). This is due to increasing operational complexity across all military environments (Benaskeur, Irandoust, Kabanza, & Beaudry, 2011), combined with a decrease in available manpower. A wealth of literature exists exploring the ways in which automated systems can increase operational capabilities (for example, Röttger, Bali, & Manzey, 2009; St John et al., 2005; Dzindolet et al., 2001). However, in their review on the social, cognitive and motivational factors that influence automation reliance, Dzindolet, Pierce and Beck (2010) found that highly reliable automation does not always lead to performance improvements. This suggests that socio-technical systems, where humans and machines work collaboratively (Hoffman & Militello, 2008), are highly complex and require researchers to continue to explore multiple factors that underpin the efficiency of such systems.

The US Department of Defence (2012) Task Force Report has argued that automated systems are not designed to replace human operators but to extend and complement human capability. Similarly, one vital aspect of RN Rules of Engagements (ROEs) is that a human remains in the decision-making loop. Therefore, personnel across all military platforms are having to adapt their roles to include operating with highly sophisticated automated systems as well as learning how to supervise these systems. Research has shown the derailments that can occur with this type of job role transition, such as loss of situational awareness, ‘out-of-the-loop’ phenomena (Endsley & Kinishi, 1995) and loss of manual skill (Casner, Graven, & Recker, 2014). The introduction of adaptive automated systems is posited to prevent these derailments from occurring (Parasuraman & Wickens, 2008). It is of vital importance to fully understand the job role and decision process that the automated system will become a part of in order to develop appropriate adaptive automated systems. The Tactical Decision Making Under Stress (TADMUS) programme is one example of a comprehensive research project that aimed to develop decision making aids for low-intensity conflict (Riffenburgh, 1991; Cohen, Freeman, & Thompson, 1997; Cannon-Bowers & Salas, 1998). Decision centered design has also provided researchers with a repository of methods that can be used to elicit knowledge and domain understanding from expert practitioners (Crandall et al., 2006). This knowledge can then be leveraged to develop adaptive and effective automated systems that operate alongside their human counterparts. As Militello and Klein (2013) argue “design approaches that are insensitive to expertise run the risk of creating designs that interfere with the development and application of skills” (p. 261).

Good decision making is required to succeed in combat which can be achieved by having timely and accurate information (MOD, 2011), appropriate strategy development and prosecution, well-trained and calibrated teams and facilities that are fit for purpose (Larkin, 2002). Automated systems are now inherently part of the facilities that support good decision making. However, a recent review highlighted that current automated systems can provide more capabilities than operators can understand or use (Strauch, 2017). This can result in increasing operator workload and if the automated system performs unexpectedly (Kaber et al., 2006) can cause “automation surprises” (Sarter et al., 1997). These factors have been associated with decreasing acceptance of automated systems (Woods, 2016; Ghazizadeh, Lee, & Boyle, 2012). Therefore, one way to improve the functioning of automated systems so they are more easily understood by users would be to include users in the design and development process. The Athena project in the US is a forum designed to facilitate US Navy sailors in sharing their ideas on ways to improve Navy operations and Command and Control (C2). This form of open communication between Navy personnel, academics and industrial partners is argued to create forward thinking sailors for the “Fleet of tomorrow” (“The Athena Project”, nd). However, this organisational support for open communication is not common globally (Elgafoss, Skramstad, & Dalberg 2009). Therefore, to facilitate the development of new systems and to promote their appropriate use it continues to be important to explore the current state of automated systems and how they are used in operations. Additionally, it is important to understand where personnel view systems would have the most benefit to their day-to-day operations in the future. This can provide system designers with the understanding of where future automated systems will be required and to what capacity.

Thus, this paper presents unique insights from currently serving Royal Navy (RN) personnel through exploring where automated systems are currently in use when at sea and where personnel view future developments to progress. Additionally, an understanding of the level of involvement between system designers and current personnel is presented. To the best of our knowledge this is the first article to explore United Kingdom (UK) RN personnel’s own opinions towards the present model of system procurement.

## Method

### Participants

Data was collected from *N* = 46 RN Warfare Officers during their training course at the Maritime Warfare School (MWS). MWS operates at HMS Collingwood[[1]](#footnote-1), the Royal Navy’s largest training establishment where a range of training courses for personnel at various stages of their careers are held throughout the year. Fifty personnel were invited to take part in this study who were attending courses to further their professional development and prepare them for higher level Warfare Command roles. Due to the complex nature of the environment, Warfare Officers have experienced a rise in the use of automated and semi-automated systems to support their day to day working. They are therefore well placed to provide practitioner insights into current technology. Additionally, as these officers will be taking command of current and future warships they are uniquely placed to provide insightful answers to where technology could support their operations in the future.

It is customary practice for research with Subject Matter Experts (SME) to gain the support of individuals within the same organisation who act as gatekeepers and facilitate access to the SME. To achieve this support and gain access to this unique sample of experts several meetings were held with personnel at HMS Collingwood to present the planned research as well as to make sure all appropriate channels were observed. For instance, the study received ethical approval from the University of Liverpool and MoDREC (Protocol No: 785/MoDREC/16). Approval from the appropriate persons at MWS was also sought to ensure that the questionnaire was passed out to relevant SME.

Of the 50 personnel invited to take part a total of 46 RN SME completed the questionnaire (92% response rate). One SME requested to withdraw from the study, leaving *N* = 45. Most participants were aged between 25-34 years, ranging from 24 to 54 years. Most of the sample were males (*n* = 38) and two SME declined to provide their age or gender. Number of years of service ranged from 4 years 5 months to 32 years, on average SME had 11 years of experience. Time spent at sea also ranged between SME, from 480 days to 17 years. Time since last at sea ranged from 2 days to 15 years (two SME only recently returned 2 days and 10 days prior to completing the questionnaire). The average time since last at sea was 19 months. Table 1 provides categorised participant demographics and Table 2 presents a selection of SME current and previous job roles. A full breakdown of time spent at sea and all the previous and current job roles participants recorded is not provided due to the number, sensitivity and specificity of answers.

[Insert Tables 1 & 2 here]

### Materials

Prospective participants were given the questionnaire pack which contained the information sheet explaining the purpose of the study, the consent form and all sections of the questionnaire. This method of distribution allowed each participant to take 24 hours before deciding to take part in the study. To acknowledge their consent, each participant was asked to sign the consent form before completing the questionnaire in the classroom. Participants completed the questionnaire packs individually but were together in their classes whilst completing. Participants were allowed up to 1 hour to complete the questionnaire pack; all participants took between 30-40 minutes to complete. Section A asked participants to provide basic descriptive details on age, gender, current job role, previous job roles and time spent at each, length of time spent at sea during their career and how long it had been since they were last at sea. Section B consisted of 6 open-ended questions designed to identify where automated or semi-automated systems are currently used in service (questions 3 & 4), where current personnel see automated systems being used in future operations (questions 1 & 2), and their level of involvement in the procurement of new systems (questions 5 & 6). Table 3 displays each of the questionnaire questions in full.

[Insert Table 3 here]

### Analysis

Questionnaires collected from participants were completed by hand, therefore the first stage of analysis was to transfer the questionnaire responses into Word documents. These were then inputted into a qualitative analysis tool, QSR International’s NVivo 11 software, which is a commonly used computer-assisted qualitative data-analysis tool (Hoover & Koerber, 2011) that facilitates the management and analysis of qualitative data (Bandara, 2006; Bazeley & Jackson, 2013).

Thematic analysis was used to analyse the data and has been defined as “a method for identifying, analysing and reporting patterns (themes) within data” (Braun & Clarke, 2006, p. 79). If rigorously applied, this analysis technique can provide an insightful method of analysis for research questions as themes emerge inductively from the data. This forms a holistic picture of the collective experience of people, groups or organisations (Aronson, 1995), and as themes are formed from the words of practitioners promotes the ecological validity of the research. Thematic analysis was chosen over other qualitative methods (for example, content analysis) and methodologies (for example, grounded theory) as it is a flexible analysis method that has been found to be useful for producing analyses suited to informing policy development (Braun & Clarke, 2006).

A crucial consideration for conducting thematic analysis is the transparency of the approach taken, which can impact upon the validity of the findings. Guidelines produced by Braun and Clarke (2006) were followed to ensure a robust approach to thematic analysis occurred. Firstly, all the RN SME questionnaire responses were typed into word documents which were then imported into NVivo 11 which has several features designed to support qualitative data analysis. For example, with the identification of themes, which have been defined as “units derived from patterns” (Aronson, 1995, p.4), NVivo enables the researcher to highlight text, and ‘click and drag’ codes (sections of the data) to labelled folders that the researcher creates and refines as they progress through the analysis. The initial folders created by the researcher were labelled to correspond to the topics of the questionnaire questions; current automation use, future automation use and procurement. Through the analysis process these initial folders were refined into the themes identified from the data. With thematic analysis codes are built and develop by grouping recurring statements, conversation topics, expressions of feelings or opinions. Alone these codes may seem meaningless however when combined within a theme it is possible to view a comprehensive picture of the area under exploration. Following the initial generation of themes, the data was re-read to review each theme against the coded items and the entire data set, making the analysis iterative in nature. Once the themes were generated from the data and reviewed, existing literature and documentation available to the author were interwoven into the findings to facilitate comprehension of the results. NVivo 11 facilitated all stages of analysis, from generation of initial codes to report creation. The interface is designed to support inductive qualitative research by making the process of coding, theme creation and revision of themes more intuitive.

## Results

A total of 5125 words were generated by SME for the six questions contained in Section B of the questionnaire pack (Table 4 provides the breakdown of the word count for each question). Initial line by line coding created 272 nodes. These nodes were then analysed using thematic analysis in NVivo11 to identify emerging themes. Themes are presented articulated around four research questions: 1) What are the current areas of operation that utilise automation systems (questions 3 & 4 in the questionnaire pack); 2) Where do RN personnel view automated systems being used in future operational environments (questions 1 & 2 in the questionnaire pack); 3) to explore the level of engagement between practitioners and system developers (question 5 in the questionnaire pack), and 4) to explore current RN personnel opinions of the consultation process (question 6 in the questionnaire pack). Quotes presented throughout the results and in Tables 7-10 are taken directly from SME responses to allow the reader to judge the veracity of the themes that emerged. Where words are underlined this reflects the emphasis placed by the SME on certain words or phrases. Where text was illegible […] will symbolise the omitted words.

[Insert Table 4 here]

**Inter-Rater Reliability**. A commonly used statistical method to analyse inter-rater reliability is Cohen’s K which determines the level of agreement between the primary and secondary coder. The secondary coder was blind to all research questions and was given 10% of the coded references to categorise. There were eight categories that the coder could classify a quote into and a single quote could belong to multiple categories. Therefore, kappa statistics were run for each category providing a range of inter-rater reliability scores. It is commonly cited that kappa statistics of 0.00-0.20 indicate slight agreement, 0.21-0.40 indicate fair agreement, 0.41-0.60 indicate moderate agreement, 0.61-0.80 indicate substantial agreement and 0.81-1.00 indicate almost perfect agreement (Landis & Koch, 1977). Table 5 presents the inter-rater reliability for each identified theme. The sub-themes of sensor and personnel had only slight agreement compared to the other themes that all had substantial agreement between coders. This may be due to a difference in domain knowledge between the primary and secondary coder, as although the secondary coder has expertise in the military domain they are less familiar of the maritime environment compared to the primary coder.

[Insert Table 5 here]

### Operational use of automated systems

A total of 223 codes (consisting of approximately 4,120 words) emerged from the data when exploring research questions one and two. Current use accounted for 25.6% of the total quotes identified, future use accounted for 54.3%. From the two questions discussing current tool use two themes emerged, capability (16.6% of total quotes, cited by 31 SME) and safety (8.5%, cited by 17 SME). Within future use four themes emerged from the data, capability (32.3%, cited by 39 SME), safety (11.2%, cited by 21 SME), financial (6.3%, cited by 11 SME) and system design (4.5%, cited by 5 SME). Table 6 provides definitions for each identified theme.

[Insert Table 6 here]

SME identified currently used operational tools that increase RN capability across the domains covered by RN operations; above water, underwater/mine countermeasures and land and littoral manoeuvre. Table 7 displays examples of the systems identified.

[insert Table 7 here]

Automated systems were identified to support the speed at which tactical decisions can be made by facilitating the fusion of sensor data and providing the operator with quick access to the information required to make informed decisions (see examples 1-3 in Table 8). Additionally, automated systems were identified by SME to provide support to personnel that reduces their workload (see examples 4-5 in Table 8).

Associated to the theme of increasing capability is the identified theme of safety. Experts highlighted that several automated systems increase the safety of operating on and around the ship. For example, the use of UUVs has removed the requirement for human divers to search for underwater mines, instead the UUV can be used to perform an initial sweep of an area to identify the mines prior to sending in a diver. Identifying what mines the diver will be dealing with prior to entering the water reduces the risk to operating in a difficult underwater environment as the diver is aware of what to expect and has time to prepare for how to safely remove the mine(s). As one expert wrote, “offboard systems enable commanders to de-risk operations by reducing the hazard to human force elements”. Another identified way in which automated systems support safety on board vessels is via hazard warning systems. These warning systems are designed to prevent the collision of vessels via supporting navigation, as well as aiding with ship maintenance (Table 8 examples 6-7 provide supporting quotes from participants).

However, personnel also highlighted an awareness of the caution that must be applied when utilising automated systems primarily due to ROE concerns. ROEs are the legal frameworks that govern the circumstances and conditions in which military personnel can use force. There is a growing body of literature that is exploring the ethics of the application of automated systems (Royal Society for the encouragement of Arts, Manufactures and Commerce, RSA, 2018) to direct policy development and guidance. Participants responses highlight that service personnel are also aware of the tough questions the ethics of using automated systems pose and therefore remain reticent to hand over complete control of decision making to automated systems (see examples 10-12 in Table 8).

Additionally, several of the systems currently available are not used to their full capacity either due to lack of trust in the system, from not understanding the full capabilities offered by the system or as the system does not function as expected or required (see examples 13-14 in Table 8). This suggests that the current approach to designing and deploying systems is not functioning effectively. This also brings into consideration how systems are designed and the training that personnel receive prior to their deployment. Additionally, and perhaps more importantly, continued training whilst on deployments should also be considered, especially if a new system has been brought into service and is expected to be used operationally at sea.

An increasingly common issue faced by Naval forces worldwide is the requirement to operate with decreased personnel numbers. SME are highly aware of the current reduction in manpowerand the impact this has on the requirement to employ automated systems to maintain operational capability. However, end-users have raised concerns with the reliability of systems available to them, citing that future systems will need to be proven to be robust if they are to be used and provide operational support to the end-users (see examples 15-16 in Table 8)*.*

[Insert Table 8 here]

### Exploration of the level of engagement between practitioners and system designers in the development of new automated systems

Of the total number of SME included in this study (*N* = 45), only eight had been consulted in the development of a new system during their career. Table 9 presents the eight SME experiences in the consultation process. Responses highlight the range of systems SME were consulted on to improve the capability of RN operations, for example, communication systems, mine countermeasures and navigational systems.

All personnel who took part in this study were in the process of completing training for Warfare Command roles and therefore will likely be taking command of current and future warships. With these roles, they will oversee making critical decisions that could have serious ethical and legal consequences. It has been argued that to design automated systems that people understand and therefore use effectively it is important to include as many as possible in the design process (RSA, 2018). Therefore, although 18% of the sample had been consulted in some way, 82% had not and all personnel who took part in this study will one day be making critical command decisions supported by automated systems. Thus, these systems must be designed to integrate into the socio-technical system of an RN ship to ensure effective use.

Responses highlight that is it often support branches within the RN that are consulted in the development of new systems. However, although these individuals will provide a level of domain knowledge to the designers they will not be using the systems in their day-to-day operations; as one SME wrote:

Most systems are not focused around the operator because they are precured by support branches (ME[[2]](#footnote-2)/WE[[3]](#footnote-3)). When I have been consulted the translation of this feedback into changes have often been selective and greater reflect the opinion of those procuring them.

The quotes also highlight that experiences of poor communication between end-users and system designers have occurred, for example with personnel receiving limited feedback from the designers. Clear and consistent communication is important when working as a multi-disciplinary team, as would be the case when end-users are consulted by system designers. Ineffective communication has been argued to result in disparities in communication which can affect how messages are interpreted (Waring et al., 2018). Thereby, the mis-communication caused by this disparity could be considered a key factor that results in systems that do not provide the end-users with the required support to increase operational capability.

[Insert Table 9 here]

### Exploration of the opinions of RN personnel of the current consultation process

Three themes emerged through exploring SME views on the consultation of current and future personnel during the design and development stages of new automated systems (consisting of 49 nodes and approximately 1,189 words); Collaboration (36.7% of total nodes, cited by 18 SME), Knowledge transfer (28.6%, cited by 17 SME) and Fit for purpose (34.7%, cited by 14 SME).

[insert Table 10 here]

Emerging from the data is a clear desire from current personnel to be consulted in the design and development stages of new automated systems. The concept of collaboration between personnel and software engineers is being promoted by the academic community, and the data presented in Table 10, examples 1-4, highlights that end-users are also aware of the value of a collaborative approach. Collaboration and the transfer of knowledge that results from this communication can ensure that systems are built fit for purpose and that personnel understand the capabilities of the systems brought into service, and therefore, can use these systems to their full extent.

Although the value of collaboration is recognised by RN personnel, the data also highlights that collaboration seldom occurs and when it does occur it is unclear to personnel how their feedback influenced and/or impacted the system design process. This lack of collaboration is perceived by personnel to result in systems that are not fit for service at time of release which can increase personnel workload and increase the financial costs associated with bringing systems into service (see Table 10 examples 5-10).

The lean manning of current RN operations may be a factor behind the dis-connect between end-user and system designer. If designers are unable to test their systems in ecologically valid environments, for example on the platforms they will eventually be used on, it is easy to see how tools may not be fit for purpose when first released. Although challenges exist for system designers to test their products in ecologically valid environments this should not prevent the engagement of current personnel in the planning and initial concept design phases. Early engagement from end-users may reduce the likelihood of encountering future problems with the system.

An awareness of the limits to their knowledge was shown by several SME see Table 10 (examples 11 & 12), eight of whom omitted to answer this question. Training may provide a route to increase the willingness of personnel to comment on what features of systems would be useful to their job roles. Alternatively, if collaboration becomes commonplace within the organisation, the transfer of knowledge this will allow will result in both operators and engineers developing a common language (Robertson, Martin, & Singer, 2003; Miller, 2017), facilitating an understanding into each other’s domains of expertise.

## Discussion

[Insert Figure 1]

This paper presents a synthesized analysis of end-user perspectives on the current and future use of automated systems. A survey method was used to collect qualitative data from 46 experienced RN personnel, one SME requested to withdraw from the study, leaving *N* = 45. The data was used to generate a thematic map of the idealised intention and the current state of automation use in the field (Figure 1) and revealed limited engagement between personnel and system designers. However, RN SME expressed a desire to be involved in the design and development stages of new systems to facilitate collaboration and knowledge exchange, and therefore to ensure that systems are built fit for purpose. The results of this study highlight the importance of including the end-users in the design process.

SME identified the use of automated systems across all aspects of operations onboard RN vessels; as one expert participant wrote, automated systems are “inherent to operating/living on a ship”*.* This is in line with current literature that posits the increased occurrence of joint human-automation systems within military environments (MOD 2011, 2014). SME also provided a comprehensive picture of the increasing importance of automated systems in future operations. The nature of warfare will change as automated systems and the use of unmanned vehicles increases. It has been argued that as humans may have less front-line involvement with combat this may change public and political opinion towards combat, which could increase the likelihood it occurs (MOD, 2014). It is therefore of paramount importance that all automated systems and unmanned systems are developed fit for purpose. The data presented shows that this is currently not always the case.

Automated systems are required to perform alongside individuals and teams in complex environments. Field research has highlighted how individuals and teams self-organize and continuously adapt to their current situation; at times diverting from standard operating procedures (Bingley & Roberts, 2001). Therefore, as highlighted by Naiker (2017), systems designed according to normative procedures may hinder the ability for socio-technical teams to self-organize when faced with complex, dynamic and time constrained environments. The inability for systems to adapt increases the operators cognitive burden as they will have to adapt not only to the situation but also to the constraints of the system. This requirement was highlighted by experts in this study (see examples 14-18 in Table 8). Therefore, it could be that personnel viewed systems as not fit for purpose as the systems were unable to adapt to the challenging environments the socio-technical team faced.

Increasing the reliability of new automated systems has been a key feature of human factors and ergonomics research. A wealth of literature highlights the importance of operators’ awareness of the reliability of systems to ensure appropriate use and facilitate trust in the system (for example: Hoff & Bashir, 2015; Parasuraman, de Visser, Lin, & Greenwood, 2012; Madhaven, Wiegman, & Lacson, 2006). This body of literature has also shown how trust in automation is influenced by a complex combination of factors, for example individual differences in working memory (Parasuraman, de Visser, Lin, & Greenwood, 2012). Trust is not formed solely based on the features of the system (Hoff & Bashir, 2015); research has shown how reduction in trust due to reliability errors can be mitigated if the operators are provided with information as to why the system may err (Dzindolet et al., 2003). RN personnel could gain this information through being involved in the development process of new systems via communicating with system developers.

The data further showed how current personnel voiced caution towards overly relying on automation. Recent collisions involving US naval vessels and merchant ships have highlighted the dangers of over-relying on automated navigation systems (Forcast International, 2017; Fraher, 2017). Additionally, with the UK’s current ROEs a human will always remain in the decision-making loop. Therefore, personnel are continually adapting to their new roles as fully trained and capable naval officers as well as supervisors to increasingly sophisticated systems.

The Human Factors (HF) community has identified the importance of taking human-centered design approaches (Parasuraman, 2010; Militello & Klein, 2013) and has developed several different Human System Integration techniques to support this approach (for example see, Booher, 2003; Roth & Pew, 2008; Pew 2008; Boehm-Davis, Durso, & Lee, 2015). The results from this paper provide a unique insight into the opinions of end-users and show that they concur with the HF community. Personnel expressed a desire to be part of the development process and to support the robust development of automated systems that will translate easily from controlled environments to operational settings. Adopting more approaches like the Athena project may facilitate improved future collaboration between personnel, industry and academia by providing an open environment where ideas and knowledge can be exchanged.

It is often difficult for academics to engage with military end-users due to restricted access to this population; security concerns depending on the topic that is being researched also present a barrier to engaging with this community. This study was only possible due to the primary author developing strong links to gatekeepers within HMS Collingwood as research in this domain is still partly driven by the opportunities that may arise through working contacts and networks. However, as this study has evidenced that there is a desire from these types of communities to engage more with academia, it is hoped that early engagement with end-users becomes commonplace in the development of new automated systems. This study has also supported the value of the data that can be collected through survey-based designs. The adaptation of more traditional qualitative methods to facilitate access to expert populations can also help to facilitate early collaboration with this population. For example, adapting an interview protocol to an online or paper-based questionnaire that can be administered by a gatekeeper. If practical, it may also be worthwhile utilising online based data collection techniques such as online surveys or applications that personnel can respond to with mobile devices.

Creating an environment that fosters collaboration and knowledge exchange between practitioner and designer is vital. This could be achieved through combining training of personnel with the testing of new systems. The value of training personnel within immersive environments has been shown in several fields for example, the military (Jean, 2008), emergency services (Alison & Crego, 2008), and medical practice (Kirkman et al., 2014). Further, by providing personnel with safe-to-fail environments (Rouse, 1991) cognitive learning can be facilitated (Klein & Baxter, 2006). There are of course challenges associated with the development of immersive realistic test-beds for military operations, for example security concerns. Industrial partners hold the capabilities to test new systems in highly secure immersive environments with high-fidelity scenarios. However, such test-beds are currently not easily accessible to academia or other industries who may be researching and developing new systems. One way in which academia could provide support for this problem is through the continued development of immersive and ecologically valid test-beds that generate domain specific challenges (Jenvald & Morin, 2004). Additionally, there is little ability to quickly bolt on new systems or amendments to current systems to perform quick tests of their functionality and how operators interact with them. Personnel are also restricted on their availability to take part in test research due to the reduced manpower that naval services are operating with. Therefore, it would be beneficial for military organisations to build stronger links with academic partners who currently have test-bed capabilities, for example The Command Teamwork Experimental Test-bed (ComTET). ComTET was designed to explore how information flows within socio-technical command and control teams (Roberts, Stanton, & Fay, 2015). These high-fidelity environments could provide an alternative route to system development within academia. Immersive simulations can elicit how systems are interacted with during operations, showing their flaws and strengths. Personnel will also develop a flexible and dynamic understanding of how systems function, their capacity and reliability through taking part in training. This understanding can facilitate more accurate system use (Hawley, 2005) and mitigate against misuse, disuse or abuse (Parasuraman & Riley, 1997). The data generated by SME who took part in this study suggests that an innovative approach to system procurement is needed to ensure that capability is maintained across RN operations.

**Limitations.** A potential weakness of using a questionnaire-based method is that it was not possible to probe upon answers provided by participants. However, the findings from this study can be used to formulate topics to cover if researchers have greater access to SME to conduct comprehensive interviews with. It is also acknowledged the shortcomings of qualitative research to provide generalizable conclusions, however, the uniqueness and size of the sample arguably mitigates this. Of the 50 available SME on courses at the MWS when this study was conducted, 45 responded, suggesting that there is a desire from this expert population to be involved in research that will directly impact their operations. Additionally, the 45 RN personnel who completed the questionnaire demonstrated a range of expertise. It is acknowledged that organisational cultural norms may have influenced the responses provided, however it is beyond the scope of this paper to explore this. It would be of great interest and worth for future work to explore the influence cultural frames can have upon responses (Klein, 2004). Additionally, research that draws upon eliciting knowledge from experts is often considered vulnerable to bias in interpretation of the data (McAndrew & Gore, 2013). However, the use of inductive data analysis techniques, such as thematic analysis, that are applied using a transparent framework can reduce this vulnerability.

**Implications for findings.** This paper presents unique insight into currently serving RN personnel’s views of the existing and future state of automated systems and the present situation surrounding the procurement of new systems. The privileged access to this sample population is a rarity and combined with the range of experience provided by each SME and the size of the sample (*N*=45) provides a singularly exclusive window into a hotly discussed research topic. Uniquely, the findings presented highlight that end-users concur with the academic community. Alison et al., (2015) argued for the importance of credibility and transferability of conclusions gained from naturalistic research as a way to judge research. The quotes provided by experts provide strong grounds for highlighting the credibility of this research. Although looking specifically at RN operations, the recommendations provided by SME arguably provide transferable conclusions. Globally the decisions made within naval operations are similar, with additional factors of fleet capacity, manpower and available technology influencing standard operating procedures. Research into human-machine interaction has also highlighted the facilitators and barriers to appropriate automation usage; these often transcend operational environments and cultures. Therefore, the results presented in this article can provide avenues for future research to explore with naval organisations globally.

### Conclusions

A disconnect currently exists between RN personnel and system designers. This results in new systems not always being fit for purpose which can negatively impact upon RN operations across all domains. For example, by increasing the workload of personnel who are already balancing time pressures, uncertain information and the criticality of the environment. To overcome this, greater communication and knowledge exchange should be promoted between currently serving RN system end-users and system designers throughout the lifecycle of the system design. One way in which this could be achieved is through open forums where personnel could suggest new systems that would support and improve their operations. For example, a forum similar to the Athena project could be considered. Additionally, to ensure personnel understand current and emerging technology, system designers could also present their ideas at this open forum. A collaborative environment such as this would enable knowledge exchange and promote the development of systems that are fit for purpose at time of release. It is worth remembering that “war is ultimately a human endeavour. It will be humans who choose to go to war, it will be humans who can stop wars and it will be humans who suffer the consequences of war” (MOD, 2014 p. 96). Therefore, the humans on the front line should be consulted in the way developments of new automated systems are made.

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Table 1.

*Participant demographics.*

|  |  |
| --- | --- |
|  | **Number of Participants** |
| **Gender** |  |
| Male | 38 |
| Female | 5 |
| Prefer not to say | 2 |
| **Age** |  |
| 18-24 years | 1 |
| 25-34 years | 30 |
| 35-44 years | 11 |
| 45-54 years | 1 |
| Prefer not to say | 2 |
| **Number of years of service** |  |
| 0-5 years | 3 |
| 5-10 years | 17 |
| 10-15 years | 17 |
| 15-20 years | 5 |
| +20 years | 3 |
| **Time since last at sea** |  |
| Less than 1 month | 3 |
| 1-6 months | 11 |
| 6-12 months | 15 |
| 1-2 years | 9 |
| 2-3 years | 2 |
| 3-4 years | 3 |
| 4-5 years | 0 |
| +5 years | 2 |

Table 2.

*Examples of SME current job roles and previously held roles within the RN.*

|  |  |
| --- | --- |
| Examples of Current Job Roles | Examples of Previous Job Roles |
| Officer in charge of Advanced Warfare Training | Engineering Officer |
| Warfare Officer | Officer of the Watch |
| Principle Warfare Officer Training Student | Navigator |
| Electronic Warfare Specialist | Gunnery Officer |
| Fighter Controller | Commanding Officer |

N.B to preserve anonymity of participants the current job roles presented do not match to the previous roles presented.

Table 3.

*Qualitative questions included in Section B of RN Personnel questionnaire pack*

|  |  |
| --- | --- |
|  | |
| 1 | In your opinion, do you see automated tools/systems having a role in future naval operations? |
| 2 | If so, where do you see such tools/systems having the most benefit and why? |
| 3 | During your time spent at sea or during training, how often did you interact with and utilise automated tools or systems? (i.e. daily, weekly, monthly, once etc.) |
| 4 | What were the tools you used and how did they aid your operations? |
| 5 | Have you ever been consulted in the development of new tools/systems prior to their release into operational use? |
| 6 | What are your views on the consultation of current and future personnel during the design and development stages of new automated tools/systems? |

Table 4.

*Word count breakdown of question responses provided by participants*

|  |  |  |
| --- | --- | --- |
| Question Number | Word Count | |
|  | Mean | Range |
| 1 | 25 | 1 - 166 |
| 2 | 24 | 1 - 95 |
| 3 | 1 | 1 - 5 |
| 4 | 17 | 1 - 68 |
| 5 | 5 | 1 - 78 |
| 6 | 23 | 1 - 126 |
| N.B. Question 3 only required a one-word response; therefore, the mean was only 1. | | |

Table 5.

*Inter-rater reliability for each theme*

|  |  |  |  |
| --- | --- | --- | --- |
| Theme | Subtheme | Kappa statistic | Level of agreement |
| Capability | Sensor | κ = .052 (95% CI, 0.13 to 0.44), p < .793 | Slight agreement |
| Personnel | κ = .182 (95% CI, -0.14 to 0.49), p < .269 |
| Tactical decision making | κ = .505 (95% CI, 0.14 to 0.87), p < .013 | Moderate agreement |
| Weapons systems | κ = .466 (95% CI, 0.08 to 0.85), p < .021 |
| Safety | Navigation | κ = .582 (95% CI, 0.16 to 1.00), p < .006 |
| Caution | κ = .792 (95% CI, 0.52 to 1.06), p < .000 | Substantial agreement |
| Financial |  | κ = .773 (95% CI, 0.48 to 1.07), p < .000 |
| System Design |  | κ = .645 (95% CI, 0.01 to 1.28), p < .001 |

Table 6.

*Thematic definitions.*

|  |  |
| --- | --- |
| Theme | Definition |
| Capability | In line with the remit of the RN, this theme refers to comments that identify how the application of an automated system impacts (either positively or negatively) upon RN personnel’s ability to perform their job. |
| Safety | This theme refers to how automated systems have increased or decreased the safety of personnel operating on maritime vessels, and/or tasks associated with operations on a ship. |
| Financial | This theme encapsulates the financial implications of designing, developing and deploying new automated systems. |
| System design | In line with human-machine-interaction literature, this theme encompasses the key system features that have been identified to impact upon the use of automated systems, for example, system reliability. |

Table 7.

*Examples of the automated systems identified by personnel*

|  |  |  |
| --- | --- | --- |
| Operational Domain | Types of automated system used | Quotes |
| Above water | Classification tools support the identification of vessels and aircraft within the ship’s area of operations. | * Automated ID of tracks within Command System. Currently increases efficiency |
|  |  | * Combat management systems- reduce operator workload in managing the tactical picture |
|  |  | * ECPINS[[4]](#footnote-4) – massive reduction in time spend fixing the ship, Radar- automated systems to automatically hook & track contacts improves reaction time, especially in the air environment |
| Underwater/ Mine countermeasures | C2 system that controls unmanned underwater vehicles (UUV) and combat systems that enable mine countermeasure missions to be conducted with increased accuracy and reduced risk to RN personnel. Remus 100 is an example of a UUV that is currently used by the RN. | * [One expert described Remus 100 as a] survey system [that] identified bottom contacts for investigation by divers removing requirement to risk ship proceeding through hazard area to conduct mine countermeasures |
| Land and littoral manoeuvre | Navigation systems have been partially automated to provide support to personnel operating on the ships bridge. | * Automated systems for navigation, for example, are of great value to a bridge-watchkeeper- it allows them more time to think, act and surveil |
|  |  | * Autopilot on ship’s helm reduces helmsman steering burden to enhance visual outlook |
|  |  | * WECDIS[[5]](#footnote-5) Navigation system- auto displays ships position and reduces chartwork burden |
|  |  | * In peacetime, for maintaining safety at sea is of paramount importance in my opinion using the example of WECDIS |

Table 8.

*A selection of quotes to support themes on operational use of automated systems. The complete table of quotes is provided in the Appendix.*

|  |  |  |
| --- | --- | --- |
| Example | Quote | Explanation |
| 1 | The speed of reactions required to combat modern threats (esp missiles) is such that an automated system is likely to have a better chance of defeating them in the future | These examples highlight how personnel are acutely aware of the increasing complexities of the environments they operate in. Automated systems are perceived to provide operators with the support required to make decisions in increasingly complex environments and to increase the likelihood of mission success, i.e. combatting threats faced. |
| 2 | Clausewitz said “A great part of the information obtained in war is contradictory, a greater part is false, and by far the greatest part is uncertain”[[6]](#footnote-6) – automation will allow vast quantities of information to be presented for the average [human] to understand in a rapid time frame |
| 3 | The complexity of modern naval warfare can be made easier to exploit by utilising automated systems to remove time consuming tasks away from individuals and allowing more time for thought & decision making |
| 4 | Machinery controls systems – aided by reducing manpower requirements & safeguarding equipment | These examples highlight how personnel perceive workload to be reduced with the adoption of automated systems. |
| 5 | In any part of the job as help for the operator in order to reduce the workload by using such tools/systems to execute simple & repetitive tasks |
| 6 | Automation is free from crew fatigue, can operate multiple systems from one platform creating cost efficiency and reduce risk to personnel | Personnel perceived that automated systems have benefit in improving the safety of operating on a vessel as they can remove the requirement for the human to operate in a dangerous environment. For example, when performing mine countermeasure actions. Additionally, automation is not constrained in the same way that human teams are in that they can operate for extended periods of time without requiring a break. To provide context, operators work in shift patterns to ensure that all jobs are staffed 24/7, however crew can still suffer from fatigue. Having automated systems that support operations enable the crew to have a ‘team member’ that has been on shift 24/7 without tiring. |
| 7 | The use of automation can reduce human fatigue and involvement which has benefits in terms of crew numbers and in endurance. One of the key attributes of maritime power is ‘poise’ an automated or autonomous platform has the ability to remain ‘poised’ for longer periods of time which is a tangible benefit. |
| 8 | I do not believe that we will remove the ‘human factor’ in any of our lethal/non-lethal strike options until AI is much more advanced | Awareness of ROE and the ethical considerations that are key when designing and using automated systems is highlighted by personnel in these examples. The RN currently operate as human-in-the-loop teams when using automated systems to ensure the UK ROEs are adhered to. |
| 9 | There will always be a requirement for human-interface when judgement is required. i.e. we could kill the enemy but should we? |
| 10 | They can simplify highly complex sets of options to provide a smaller selection. They can process a lot of information quickly & present useful results. They can also remove too much information e.g. genuine contacts on radar not displayed due to automated processing | These examples highlight the hesitancy some personnel have towards adopting automated systems. Example 17 for instance shows that in some cases workload is increased by the automated system as the operator still must complete the task manually as well as using the system. Additionally, SME highlighted that they are having to adapt to using automated systems, suggesting that they may be having to learn on the job due to the lack of opportunity to train prior to deployment and/or the systems are not designed with the operator or environment in which they will be used in mind. |
| 11 | The RN will not trust automated systems [and] we therefore double our workload by continuing to do everything manually as well |
| 12 | The art is knowing when to adjust these systems |
| 13 | Beyond supportive systems, core ICT solutions that generate a units warfighting outputs remain exceptionally clunky and (due to security and system integration issues) well behind civilian environments. Without considerable investment/industrial agreement between defence contractors this issue will continue to impact on progress in this domain. | These examples highlight the awareness from end-users that to support uptake of automated systems system features, such as reliability, need to be improved. Additionally, these examples show how the additional complexities of a military environment, such as security issues, reduce the opportunities available to collaborate with system designers and have stifled system development |
| 14 | The overarching intent in the naval service of automation is to reduce the manpower overhead resulting in shrinking organisational mass. While complex systems continue to display fragility their reliable employment in core roles remains a future necessity but an area of uncertainty. |
| 15 | Given the significant manpower issues being experienced, automated tools and systems provide options for lean manning in the future | End-users display an understanding of the additional pressures that are put on their teams by operating with reduced manpower. Automated systems can alleviate some of this pressure by supporting the operations of remaining personnel. However, to do so effectively, the concerns raised by SME (see examples 20-21) will need to be addressed. |
| 16 | [automated systems] can process large quantities of information & cannot be killed, nevermind, are cheaper than the wage bill |

Table 9.

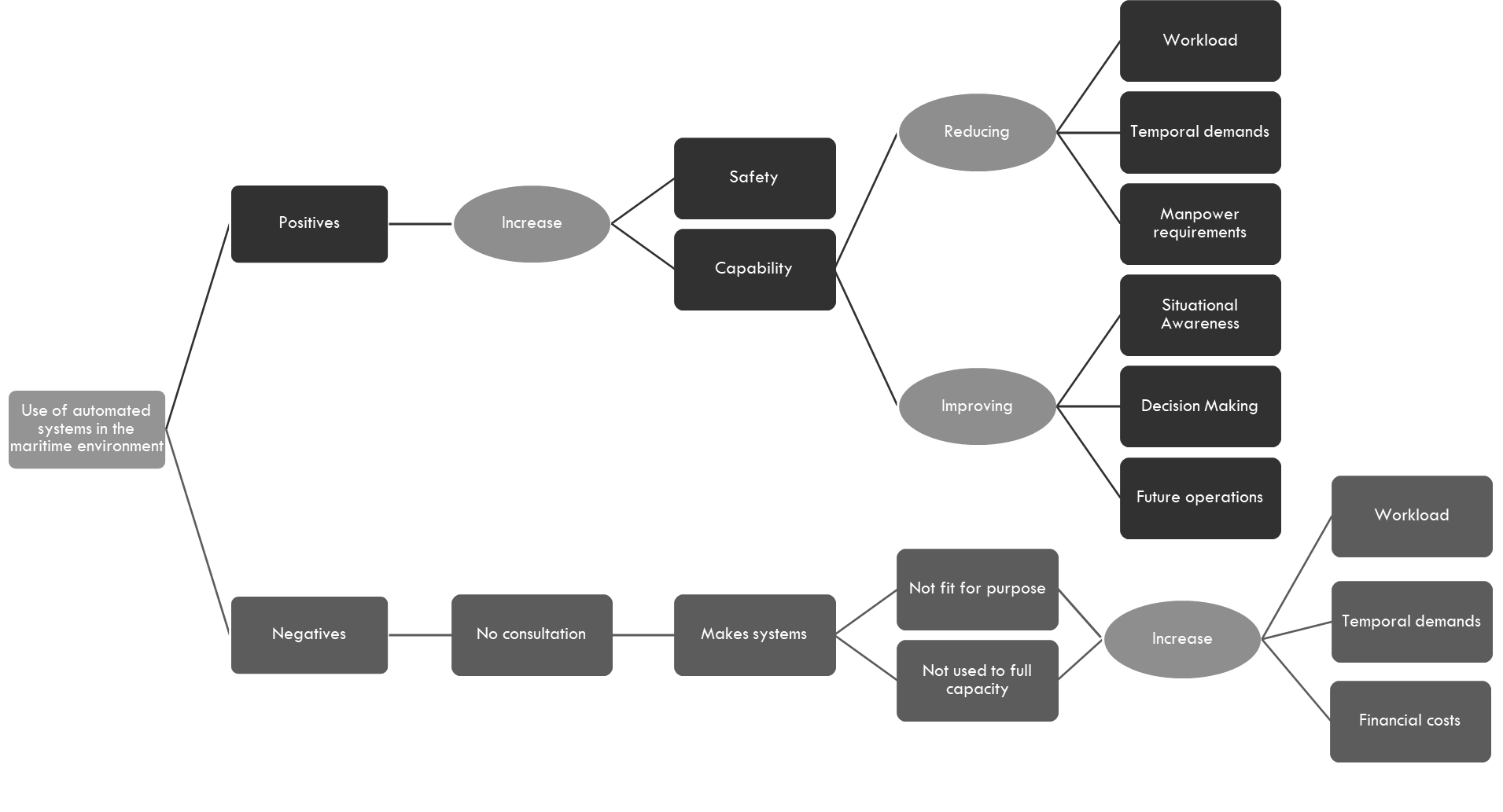
*Comments provided by the eight SME who had experience of being consulted in the development of new systems. […] indicates where text was illegible.*

|  |  |
| --- | --- |
| SME 2 | “Most systems are not focused around the operator because they are precured by support branches (ME[[7]](#footnote-7)/WE[[8]](#footnote-8)). When I have been consulted the translation of this feedback into changes have often been selective and greater reflect the opinion of those procuring them.  When I have had the opportunity to procure kit myself to support operations the impact is transient as the tactical development achieved cannot easily be fed back into the organisation. The organisation has considerable change inertia issues.” |
| SME 8 | “Yes. I was a very small contributor to the ECPINS/NAV system for HMS Queen Elizabeth Class in its very early stages of development. Given my currency & previous experience as a navigator” |
| SME 13 | “I tested the comms for the QE[[9]](#footnote-9)” |
| SME 21 | “Development of MCM[[10]](#footnote-10) Expert” |
| SME 31 | “Yes, but not often – as an operator usually hardware is pre-purchased. Occasionally I have had input into software developments based on user feedback” |
| SME 35 | “Yes, NAUTIS replacement” |
| SME 40 | “Once but it received no feedback. It was for the new MCMU[[11]](#footnote-11) […] Indicator” |
| SME 41 | “Yes. I was consulted by EIPT[[12]](#footnote-12) from BAE with regards to the new UK/FR MCM System. Whilst serving as the XO[[13]](#footnote-13) in HMS Catterstock. I was also consulted on the installation of the Remms 600 RUV platform onto Hunt MCMVs[[14]](#footnote-14).” |

Table 10.

*Quotes to support themes on the current consultation process.*

|  |  |  |
| --- | --- | --- |
| Example | Quote | Explanation |
| 1 | It is very important that users are consulted in the design process in order to ensure that the final product is user friendly and fit for purpose | These quotes highlight the awareness from end-users of the importance of designers collaborating and communicating with the individuals who will be utilising the system. Example 4 further highlights the value in communicating with current personnel as they are best placed to provide insight into current operational procedures as opposed to past practices. |
| 2 | How can anyone design an automated system without consulting the people who will use it? |
| 3 | It is essential that those who are going to actually use these tools or systems are consulted as then the system/tool will actually be usable, rather than being overly complicated |
| 4 | You must consult the operator of equipment (at varying levels) to determine gaps in technology that need to be improved and then to put possible amendments of fixes to the system forward for expert, and current, opinions on those improvements |
| 5 | Consultation seems to take place engineer to engineer & not include the operator/end user | Personnel perceive that communication between system designers takes place when developing new software. Additionally, these examples highlight that personnel are aware that software designers often consult in-house experts, who tend to be individual who previously served and therefore understand the operational environment. However, by not consulting with the current end-users’ designers risk developing systems that do not meet the day-to-day requirements of the current or future operational environment. Personnel also perceived how difficult it can be to make changes or upgrades to systems once they have been brought into service. Thereby, highlighting how important it is to get the system design right during the development phases to ensure that once deployed, the system provides the needed support without lengthy and costly, changes. |
| 6 | Only those within teams are consulted and they become an echo chamber of ideas. The only people who should be asked for input at the design stage and in the testing phase are the operators |
| 7 | Whilst people may have had previous experience to contribute, it may have been some time since they had been at sea as an ‘end-user’ with other advances in technology or a full understanding of the needs/requirements |
| 8 | Kit designed and built by engineers having never been employed in a maritime environment always has problems |
| 9 | Many current tools are not fit for purpose as there was no operator input in the design |
| 10 | Too often once we get to use new equipment it quickly becomes clear that one or two main details that if better thought out could have made an enormous difference. Such is the nature of equipment programmes that it is incredibly hard/slow to change such things once in service |
| 11 | Current serving personnel have very little experience beyond their current equipment and rarely have much knowledge of current/emerging technology. Thus, the current community is often not well placed to advise on new automated systems and tools when they have little exposure or experience of them. | Personnel showed an awareness of the limits to their knowledge and areas of expertise. Opportunities to collaborate with system designers will enable a transfer of knowledge between the system designers (i.e. what capabilities an automated system could support) and the end users (i.e. on providing understanding of the context systems may be used in). |
| 12 | This is not my professional field; currently I am of the operator level of tools/systems |



*Figure 1.* Superordinate view of current use of automated systems in RN

1. HMS stands for Her Majesty’s Ship and is the prefix given to all UK Royal Navy vessels and establishments. [↑](#footnote-ref-1)
2. Marine Engineering [↑](#footnote-ref-2)
3. Weapon Engineering [↑](#footnote-ref-3)
4. Electronic Chart Precise Integrated Navigation System (ECPINS) [↑](#footnote-ref-4)
5. Warship Electronic Chart Display Information System (WECDIS) [↑](#footnote-ref-5)
6. It is not possible to provide a reference for this quote as it was provided by one of the participants in their response to the questionnaire. [↑](#footnote-ref-6)
7. Marine Engineering [↑](#footnote-ref-7)
8. Weapon Engineering [↑](#footnote-ref-8)
9. Queen Elizabeth Carrier (QE) [↑](#footnote-ref-9)
10. Mine Countermeasures (MCM) [↑](#footnote-ref-10)
11. Mine Countermeasures Unmanned (MCMU) [↑](#footnote-ref-11)
12. Equipment Integrated Project Team (EIPT) [↑](#footnote-ref-12)
13. Executive Officer (XO) [↑](#footnote-ref-13)
14. Mine Countermeasure Vessels (MUMV) [↑](#footnote-ref-14)