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Exploring Bridge-Engine Control Room Collaborative Team Communication

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ABSTRACT: The EC funded CyClaDes research project is designed to promote the increased impact of the human element in shipping across the design and operational lifecycle of ships. It addresses the design and operation of ships and ship systems. One of the CyClaDes' tasks is to create a crew-centered design case-study examination of the information that is shared between the Bridge and Engine Control Room (ECR) that helps the crew coordinate to ensure understanding and complete interconnected tasks. This information can be provided in various ways, including communication devices or obtained from a common database, display, or even the ship environment (e.g., the roll of the ship). A series of semi-structured interviews were conducted with seafarers of diverse ranks to get a better idea of what communication does, or should, take place and any problems or challenges existing in current operations and interdepartmental communications, as seen from both the bridge and ECR operators' perspectives. Included in the interview were both the standard communications and information shared during planning and executing a voyage, as well as special situations such as safety/casualty tasks or encountering heavy weather. The results were analyzed in terms of the goals of the communication, the primary situations of interest for communication and collaboration, the communication media used, the information shared, and the problems experienced. The seafarer interviews helped to explore on-board interdepartmental communication and the results are presented in the paper.

1 INTRODUCTION

1.1 CyClaDes Project Overview

The CyClaDeS project (http://www.cyclades-project.eu) is designed to promote the increased impact of the human element in shipping across the design and operational lifecycle of ships. The project brings together a multi-disciplinary team to focus on all the key steps in the lifecycle; the stakeholders; where the barriers to human element integration occur; and how to best locate, produce, disseminate, and apply human element knowledge within the overall context of shipping.

The advantage of the research project is realized by supporting the integration of the human element in the design and operational life-cycle from appreciation, to concept, to design, to application, to evaluation and approval, to maintenance. The project seeks to identify human element guidance and material from within the maritime and other domains and "translate" this information in a way that can be utilized by the diverse stakeholders involved at various stages in the ship's life-cycle.

1.2 Case Studies

The project plan includes the conduct of a series of case studies to demonstrate the application of crew-centered design information and methodologies

collected from the maritime and other domains. Four primary focal areas were chosen for case studies to address a variety of shipboard areas, work types and work environments and the different methods that could be applied to these. These included: Control room environments, Control panel design, design for accessibility, and novel applications. Novel applications included adaptive automation to mitigate fatigue and communication and collaboration processes.

Communication and collaboration between the bridge and ECR, the two control centers of the ship, was selected as the focus for this particular case study. Problems and misunderstandings were reported by seafarer members of the project consortium and anecdotal evidence collected by project members in prior research. The goal of the case study was to objectively examine coordination between the two control centers to describe the communication and coordination that takes place, verify existing problems and to identify potential solution concepts in order to demonstrate a crew-centered design methodology.

The first step in this process was to conduct a series of semi-structured interviews with seafarers of different ranks to get a better idea of what communication does, or should, take place and any problems or challenges existing in current operations, as seen from both the bridge and ECR operators' perspectives. These results are reported in the following sections. A second goal of the case study interview was to evaluate the methodology for applicability to the maritime context and determine if an interview template or other guidance could be provided for future work concerning maritime communication and collaboration.

2 THEORECTICAL UNDERPINNINGS

2.1 *Select Literature*

Coordination of activities is largely achieved through communication in large socio-technical systems such as ocean going ships (Flin, O'Connor, & Crichton, 2008). The environment onboard can be classified as a complex environment, characterized by task distribution across ship's personnel and availability of technology as permissible and embedded in the organizational structure (Hetherington, Flin, & Mearns, 2006). Technology mediated communication therefore plays a pivotal role in coordinating work between participants.

The concept of *joint activity* put forth by Clark (1996) is useful in inter departmental communication onboard. *Joint activity* is defined by Clark as an *activity carried out by an ensemble of people acting in coordination with each other*.
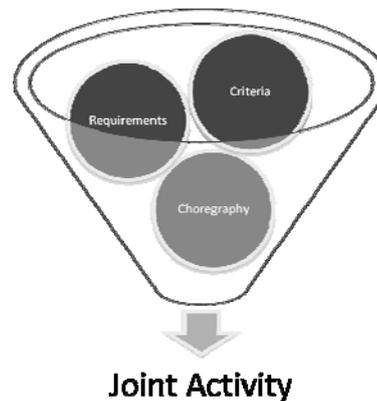
Figure 1. Adapted from Joint Activity (Klein et al., 2005)

Joint activity is facilitated and realized with the help of three basic components, namely – *criteria, requirements* and *choreography* (Klein, Feltovich, Bradshaw, & Woods, 2005). *Intention* and *interdependence* are the two main *criteria* of a joint activity. Participants should have the intention and commitment to participate in the activity and interdependence requires participants to coordinate and align their individual goals for profitable outcomes for the participants.

Interpredictability of actions and *common ground* between participants are the prerequisite *requirements* of a joint activity. Adaptability to the ongoing process requires interpredictability i.e. the ability to predict and/or foresee the actions and reactions of other participants in the joint activity. Common ground refers to the common knowledge, beliefs and assumptions of the participants in the activity. It facilitates communication and coordination between the participants. Common ground accords communicative competence to the participants and therefore eases the communicative burden due to the common stock of knowledge. Task/work/industry-specific technical jargon which enables participants to understand each other while working together in the joint activity is an example of common ground.

The final component of a *joint activity* is *choreography* of the activity which comprises – *joint actions, signaling, and coordination* and can come with accompanying *costs* for one or more of the participants. Participants need to signal their intention and coordinate their joint actions to ensure success of the joint activity. At times one or more participants may have to postpone their individual personal goals in order to achieve the joint goals. This implies that choreography of joint actions may come with attendant costs wherein common goals are prioritized over individual ones.

Joint activity is essential with regards to training in inter-departmental communication. It is only when its prerequisites, namely *requirements*, *criteria* and *choreography* are met that we have the ground ready for a successful joint activity between the participants. Noteworthy is that *joint actions* do not imply *joint activity* as they are but a part of *choreography* within the overall activity. For a successful joint activity to take place, participants need to be aware of its components and their role in the overall scheme of things to ensure a successful outcome. In this respect,

the authors argue that connecting *joint activity* to training is beneficial.

Literature on communication in shipping has hitherto not focused on inter-departmental communication between the bridge and the engine room on-board and this paper makes good this need. Communication in shipping has been studied in the context of the Vessel Traffic Service (VTS) (Froholdt, 2010; Kataria, 2012; Kataria & Praetorius, 2014). Communication as a key issue in multilingual crews emerged in the ethnographic research undertaken onboard by researchers as part of the larger research project on transnational seafarer communities (see Sampson & Zhao, 2003).

Most literature on interdepartmental communication and collaboration is in the discipline of Management with a focus on product development and the bottom line. Interdepartmental integration was found to have positive implications for product development performance (Kahn, 1996). The author differentiates between interaction and collaboration and goes on to identify that while both interaction and collaboration have a positive effect on product development performance, collaboration has a greater impact and it facilitates interdepartmental integration while interaction could be limited to meetings and documentation of information exchange.

Interdepartmental interactions have been found to have an impact on product quality (Menon, Jaworski, & Kohli, 1997). Interdepartmental conflict and connectedness affect product quality and interdepartmental connectedness has been identified as more important for product quality in turbulent market and technological conditions. The study results also indicated that leadership characteristics, reward system and organization structure influence interdepartmental interactions.

In one study, pro-social value orientation in employees was identified as having an impact on concerns for the goals of the organization and other departments and led to the increased likelihood in problem solving behavior during interdepartmental negotiations (Nauta & De-Dreu, 2002).

Collaboration capability has been defined as *the actor's capability to build and manage network relationships based on mutual trust, communication and commitment* and has been identified as a prerequisite for the creation of a sustainable competitive advantage and can be considered as an integrative concept (Blomqvist & Levy, 2006).

The concept of *joint activity* and literature from management can help contextualize and unpack interdepartmental collaborative team communication on-board oceangoing vessels.

3 METHODOLOGY

3.1 *Interview*

A total of 20 semi-structured qualitative research interviews were conducted exploring the information exchange between the bridge and the Engine Control Room. An interview guide was developed that helped

to explore, not only the the standard communications and information shared during planning and executing a voyage between the departments, but also, special situations such as safety/casualty tasks etc. The goal of the interviews were to get a better idea of what communication does, or should, take place and any problems or challenges existing in current operations, as seen from both the bridge and ECR operators' perspectives.

The interviewees were deck and engine officers of management rank with the exception of one Cadet who was somewhat limited in providing informed opinions by virtue of a lack of experience.

Table 1. Interview Participants

Interviewee number	Seafaring Rank
1	Chief Officer
2	Captain
3	1st Officer
4	Naval officer
5	Chief Officer
6	Chief Officer
7	Chief Officer
8	2nd Officer
9	2nd Officer
10	Captain
11	2nd Officer
12	Chief Officer
13	2nd Officer
14	Deck Cadet
15	3rd Officer
16	2nd Engineer
17	2nd Engineer
18	Chief Engineer
19	Naval Commander
20	Master Mariner-Pilot

3.2 *Data Coding in CAQDAS*

Emergent themes in the interview data have informed the thematic in-vivo coding of the interview transcripts. The data was coded and themes and patterns in the data were identified. The primary purpose of exploring interdepartmental communication on-board was to explore the goals of communication between the two departments, the purpose of communication, the situation/scenario necessitating the communication, the media used in the interaction, the information shared during the communication and the problems, if any, experienced during the communication process.

The data was thematically grouped and further micro coded into 27 codes as appropriate. The results revealed the diverse purposes of bridge-engine room communication according to the interviewees; they further identified key inter-departmental communicative acts; the various safety and time critical situations and events in a voyage requiring interdepartmental communication; the tools and strategies that support communication; they also gave their input on the design of communication tools and on-board systems; their opinions of interdepartmental communication; perceived interdepartmental culture; suggestions and solutions for improving communication. The interviewees also reflected upon whether a common language was required for bridge-ECR communication; they further mentioned the

organizational/ on-board policy for interdepartmental communication; the interviewees identified the information required by the bridge from the engine control room and vice versa in their daily work interactions; the interviewees provided their perception on the presence of the Chief Engineer on the bridge as well as on the installation of CCTVs in the engine control room and on the bridge for joint and shared awareness. The interviewees also gave their opinions regarding the installation of the engine control room panel on the bridge. The interviewees perceived a fissure between the two departments; they reflected on the miscommunication between the two departments that can sometimes take place. The role of leadership was identified in improving interdepartmental communication, which is in line with management literature on the subject. The importance of empathy and an appreciation for the work of the other department was noted by the interviewees in improving bridge-engine room communication on-board which has parallels with pro-social values in management literature. Direct face to face meetings between the Chief Engineer and the Captain were considered beneficial for promoting collaborative team communication on-board as it would set an example for the personnel to follow suit. The interviewees also reflected on multinational, multilingual crews and the impact on inter-departmental communication, if any. The following section discusses the results of the research in greater detail.

4 RESULTS AND DISCUSSION

The results were divided into 6 main sections to highlight the core types of information that should be sought out in most communication and collaboration situations. It was thought that if novice designers were not able to adapt the detailed template, then at least the categories could focus the interview on the key information required and provide examples of content for guidance. The results are discussed in the following sub-sections.

4.1 *Goals of the communication*

There were three main goals of the bridge-ECR communications. The first was to prepare the vessel to be ready or available, for example to maneuver, respond to orders, bunker, or allocate power. The second was to be prepared and to respond effectively to accidents, incidents, and failures. The third was to alert the other control center concerning situational variables, such as weather, maintenance, delays, pilot onboard, etc. The goals of the interdepartmental interaction inform the communication scenarios that can be further explored by the concept of *joint activity* (Klein et al., 2005) to inform interdepartmental communication training.

4.2 *Situations of interest for coordination and communication*

The purpose of bridge-engine room communication is primarily business-related, focusing on the routine communications and communications required during key events in a voyage. These included examples such as the departure and arrival phases due to the coordinated checklists and constraints such as the significant advance notice required to complete tasks such as switching fuels. This also included communications for events that affect propulsion, such as when the tugs are attaching or towing. Approaches to shallow water or dangerous areas were also important because then maneuvering becomes more time critical as there is a need to be prepared for an accident or incident and the potential need to manually operate the engines. Incidents or maneuvering where more power might be required were also reported as important. These could include for example collision avoidance, anchoring or berthing and any other incident where more power or maneuvering might be required (e.g., crowded areas—fishing, separation zone, port areas). One interviewee noted that immediate anchoring during collision avoidance caught him by surprise as the engines need time to adjust. Another interviewee reported having to coordinate to control the revolutions per minute (RPM)s when slow steaming.

Problems with the machinery, such as blackout or other power/engine failure, were listed as situations where coordination is important but challenging. It was noted that it is also important to know when the engine room is really busy in order to time communications better (i.e., there is no one there to answer the phone). Another example given was trying to start engines, as not all control is in one place (bridge or ECR). Also included was coordination for accident, incidents, or groundings to understand the damage situation, as well as the maneuvering needs and options.

Communication can also be required when coordinating electrical power availability, generator, or pump requirements. Delays to the schedule (e.g., strong current, traffic, pilot delay, etc.) should also be communicated. Bunkering and ballasting operations were also reported to require communication and coordination, especially if under time pressure.

For dredging operations it was reported that it could be helpful to have the chief engineer up on the deck to have a better view and understanding of the situation and to coordinate directly with the engine department. Overall, it was noted that with automated engine rooms the communication is mostly just reporting.

The interdepartmental communication situations on-board fulfill the requirements of *interdependence* and *intention* of a *joint activity* (Klein et al., 2005) as the situations require the participants to commit with intent to cooperating in the activity to have a favourable outcome. *Interpredictability* and *common ground* between the participants can be facilitated with the development of novel solutions, which would also aid the *chorography* of the joint activity through *joint actions, signaling* and *coordination*. The concept of *joint activity* needs to be utilized to inform

training for interdepartmental communication in diverse scenarios facing the personnel onboard.

4.3 Communication media:

The key tool used for bridge-ECR communication is the telephone and other tools like the VHF, walkie-talkie, citophone, a voice tube, telegraph, speakers; paper messages, including instructing a person to run up and down between the departments are used as appropriate in facilitating inter-departmental communication. By far the telephone was reported as the preferred choice of communication, which often included a direct line from the bridge to the ECR and sometimes included various telephone sets mounted around the engine room. The walkie-talkie was reported to be used but that it does not work in the engine room and its use is difficult due to noise and distortion. The chief engineer often also meets in person with the bridge, for example before arrival or when problems happen. The intercom was also noted to have the advantage that everyone can hear the conversation and it can also be used hands-free to allow work to continue. This was only reported by a naval mariner though and not from merchant mariners.

Included in this discussion of how the control centers communicate was the concept of positioning the chief engineer officer on the bridge with an ECR mimic panel as is becoming standard practice on some ships. The mariners interviewed provided mixed opinions on having an engineer directly on, or close to, the bridge in general. Positive factors included: some reported that having the chief/watch engineer on the bridge improves the communication between bridge and engine department (e.g., as an interpreter), a better understanding of the other department's situation and mutual tasks, the ability for the engineers to provide information directly to the bridge and see the non-verbal reactions, and more of a team feeling. Negative factors included: the engineer on the bridge can feel frustrated by not being able to see and interact directly with the other engineers; especially in emergency situations the chief engineer often needs to be back down in ECR quickly and have direct interactions with the personnel there; confusion and distraction by having two concurrent tasks in one room; and increasing the number of alarms experienced in the bridge area which is an already existing problem. It was also noted that the ECR console on the bridge often only gives a restricted view of the operational status of the machinery (e.g., single windows that have to be viewed in isolation) and not the overview that is desired by the engineers. Taking the chief/watch engineer out of the engine room can also leave the rest of the engineers feeling even more isolated.

4.4 Examples provided of information shared

Each mariner provided examples of the types of information shared and just the trends and not the detailed list are included here. The communication mostly focusses on rpm, speed, pressure, air, valves and the information required to make the engine ready for ensuing maneuvers or prepare for upcoming demands (e.g., auxiliary engines, bow thrusters). The purpose of bridge-ECR communications is largely linked to the requirements of the bridge and to safety and time critical situations at sea. Additional items included examples such as pre-departure discussion, stability and trim calculations, delays and changes to the schedule, critical maintenance that impacts the other department, power and pressure demands throughout the ship, and administrative issues such as drills and meetings. There can be a difference depending on if the engine room is manned or unmanned as well, and notice must be provided if the status changes or someone is in the machinery spaces.

4.5 Problems with communication and coordination

The mariners also reported the problems that they had experienced with communication and coordination. A lack of advanced warning and updates was one type of problem experienced and was seen to include misunderstandings and miscommunications (e.g., forgotten communications). An example given was with the 1 hour notice required to slow down the engines for maneuvering and to pick up the pilot. In the example given the pick-up time got changed but was not communicated well with the engine room resulting in being unprepared and having to repeat the maneuver. This forgetting can take place, both across departments and within the departments.

One group of problems involved a lack of understanding of the other group's job and context, such as how the engines work, what engineers do, and the concerns the bridge has. Bridge officers noted that they do not always know the difficulties and concerns for engineers related to a maneuver such as when they want to go from full ahead to full astern. Another example was given where after a maneuver the engineers might ask as to why so many engine orders were required. There can also be a difference in priorities in the two departments, namely concern for the engines vs. optimal speed or ship handling. The engineers noted that sometimes there may be some problems with the engines that the bridge does not completely understand and think the maneuver requests have higher priority.

Another group of problems was related to not knowing what was going on in the other department (e.g., are actions in process, is the other department really busy). One part of this is knowing when the other department is occupied in work and when to time the communications that are non-urgent. One example was the bridge needing to coordinate the pre-departure checklist with the engineer at the same time that the engineers are very busy getting the engines ready for departure. The ECR officers reported not being able to see what happened on the bridge and often the upcoming situation (e.g., harbor and traffic) that might require maneuvers. The bridge reporting not knowing what is going on when they give an order and after a time see no change and get no call. It was also noted by the engineers that the situation can be even more exaggerated when there is a pilot onboard as the pilots have an even less understanding of the ship and the onboard situation.

A related problem was the engineers being unreachable, for example at times when all of the engineers are outside of the ECR, especially during unmanned periods where a single engineer has a lot of room to cover. It was further noted that the alert to a phone call is not distinct from other alerts and this can cause it to be ignored. Alarm and alert presentation was listed as a general problem as well.

There were also reports of inter-departmental culture clashes that can inhibit good coordination. The general issue appears to be that of a rivalry or status conflict where there are perceptions of the bridge officers in their nice white suits that are seen to get all the credit and blame the problems on the "blue collar" engineers. The control of the engines is seen as a way that the engineers can take back some of the status and power. One interviewee even referred to the division between the two as a 'huge Berlin wall'.

There were mixed reports of problems with multi-national crews. A couple of interviewees mentioned differences in nationalities clashing occasionally and some language issues but others noted that even when crews were of the same nationality the regional differences could come up. One interviewee also noted that in multinational crews it is usually for bigger companies and there is more of a system (regulated process) in place so that is better. Management literature on interdepartmental integration and collaboration and potential impact on product quality and competitive advantage is relevant here (see Kahn, 1996; Menon, Jaworski, & Kohli, 1997; Blomqvist & Levy, 2006)

4.6 Potential solutions to identified problems

The interviewees were also asked about their ideas for solutions to the problems they mentioned and ideas on how to improve communication and coordination in general. These will be expanded on as the project proceeds and priority solutions will be evaluated using human centered design techniques. Overall the solution concepts fall into 3 main categories: technologies that aid in communication or provide situational awareness (e.g., shared displays, CCTV, hands-free or portable devices), procedural improvements (more co-planning and joint activities), and training (team resource management training, co-training, cross-training).

Examples provided included providing shared displays (or parts of these displays or information content) to support a better understanding of the situation, as well as of the other department in general. These included displays such as providing ECR panels on the bridge or bridge chart displays in the ECR. The simple solution is to just provide an identical display or mimic but some thought should also be given to how the other department would use this information and if customization (e.g., de-cluttered display, alternative display format, or presentation of additional information) is warranted.

Discussion also included providing CCTV equipment to better see what is going on in the other department and when persons are available, or where they might be contacted outside the ECR. There were privacy issues included in this concept and, if implemented, having cameras in both the bridge and engine department's areas might be better to address both privacy and hierarchy issues. One interviewee suggested that this type of solution might be more appropriate for the chief engineer when he is in his cabin and ECR in unmanned. Another interviewee suggested that this might be helpful if the single person in the engine room (ER) was injured. This might also support another interviewee's problems with interpreting the dead man's alarm in the ER by providing a way to check on the status. This could allow both a quicker reaction and also assist in deciding to reset the alarm before it escalates. Another interviewee noted that in critical situations there would not really be any time to be looking at these monitors. It should be noted that ships have worked out rather sophisticated systems of hand signals for use when communicating via CCTV.

Another set of solutions involved including the engineers more in the planning process as this might address some of the personality/status conflicts and also provide improved shared understanding. Shared planning was reported as effective where the chief engineer signs off on the voyage plan and also has the information of when to expect the pilot or arrival at certain areas or places. It should be further considered if this information could then be provided as a physical reminder, or schedule, and also include any updates or changes. It was suggested that especially when first joining a ship the captain and chief engineer should meet and reach an understanding of responsibilities (what each person does – 2nd engineer, chief officer, etc.).

Communication is an aspect of Maritime Education and Training (MET); and addressing interdepartmental communication in training, has been identified as one of the potential solutions in the study. Communication within the bridge team is addressed in IMO model course 1.22 (2002) on 'Ship Simulation and Bridge Teamwork', however hitherto there is no model course which specifically involves interdepartmental communication per se. The Bridge Team Management (BTM) and Bridge Resource management (BRM) and Engine Room Team Management courses are offered by private players and some public universities, but these exclusively focus within the departments and not between departments and there is no available IMO model course on these subjects.

Shipboard drills involve communication between crew and are conducted to meet the regulations enshrined in Safety of Life at Sea (SOLAS) (IMO, 1974, as amended) convention and competency requirements as laid out in the Standards of Training Certification and Watchkeeping (STCW) (IMO, 1978, as amended) convention, such as Regulation VI/2 on 'mandatory minimum requirements for the issue of certificates of proficiency in survival craft, rescue boats and fast rescue boats' and Regulation VI/3 on '…training in advanced firefighting'. Drills in emergency preparedness do not specifically address the diverse scenarios in which the bridge and engine room communicate as they are largely concerned with competence training for preparing for emergencies. Even though modern simulation facilities are becoming state of the art in MET, combined exercises using linked Ship Engine Simulator (SES) and Ship

Handling Simulator (SHS) is not the standard case yet (see Baldauf et al, 2015). The standard case is the stand-alone use of an SES or SHS for training exercises specifically designed for engineers or navigators. Safety critical exercises belong to standard courses as well as to BRM/BTM courses, however communication problems between bridge and ECR are rarely addressed in such exercises.

The IMO Standard Marine Communication Phrases (SMCP) (2002) Section AII/2 lists *'Standard Engine Orders'*, however these telegraph orders are given, acted upon and confirmed by members of the bridge team and do not involve the engine room directly in verbal communication. The IMO SMCP (2002) briefly refers to communication phrases regarding *'briefing on operation of main engine and auxiliary equipment; …on pumping of fuel, ballast water etc.'* and *'briefing on special machinery events and repairs'* in sections B1/1.9, B1/1.10 and B1/1.11 respectively. However these phrases are very limited in the communication they cover. Interdepartmental communication is thus found wanting. From the interviews it can be gleaned that the training available currently does not adequately address communication aspects between the ECR and bridge team.

Communication has previously been identified in maritime accidents (see Schröder-Hinrichs et al., 2012) and training in our study was also seen as a way to address some of the personality and communication issues enumerated by participants. This training could take the shape of including the engineers in some Bridge Resource Management (BRM) training or having more inclusive team management training for engineers, possibly combined with bridge officers as well. This training could also be additional co-training, especially on emergency situations. The benefits of this were seconded by the Navy experience which includes co-training for scenarios such as fire, collisions, distress and emergency situations, and engine failure. The last type of training solution was cross-training where bridge officers learn more about engine dynamics and management beyond the minimal training already provided and engineers learn more about ship handling. There was some discussion if the two control center positions might be combined in the future requiring this type of cross-training and expertise. The authors argue for the utilization of the concept of *joint activity* in inter-departmental communication training to support favourable outcomes for the participants in the overall interest of the ship.

It was also suggested to consider further hands-free options for communications as both the bridge and ECR/ER are often busy trying to solve a problem or concentrating and therefore do not call and provide information. Automatic information (i.e., ship cloud) could also help with this and require no action from sender.

Another suggestion was to implement policy restricting engine room calls to business and important items to increase the urgency and tendency to prioritize answering when called.

One bridge officer interviewee suggested displaying a timetable for all the actions that the bridge requests from engine room and with a notification when the action has been seen and completed. This was seen as a way to provide confirmation for both sides.

The ideas for solutions are being further investigated through additional interviews and methods to define scenarios of interest and how these, or other solutions, might support them. A concept for a high-priority solution will be defined as this research task proceeds and further evaluated with end users.

5 CONCLUSIONS AND FUTURE DIRECTIONS

The findings from the interviews with seafarers were used as the basis to inform one of the packages of the CyClaDes research project, which pertained to the *application of innovative ergonomic concepts*. The task in particular concentrated on performing a *crew-centered design case study* of the communication and collaboration processes between the ship's bridge and the ECR. The findings revealed the tasks undertaken by the bridge and engine room personnel in context and revealed the inherent decision making required and the importance of having shared understanding for joint critical tasks. The findings also revealed the problems faced by personnel on-board with respect to interdepartmental communication and gave initial ideas about the development of potential solutions.

The planned activities to follow in the research work, include: onboard observations; detailed discussions between the project team, especially with the seafarers to define pertinent scenarios, roles/tasks, required information, and key sub-divisions; the development of a list of communication/coordination scenarios to focus design efforts on; an online survey to validate for each identified scenario, the information exchanged and to obtain a rating for the need for communication, frequency of problems experienced, and need for improvement that will be used to prioritize where to focus for solution concepts; and the development of solution concepts and potentially prototypes to test those concepts. Future research efforts will continue to iteratively develop and design potential solutions to facilitate inter-departmental communication on-board, while at the same time taking into account the barriers to implementation and ascertaining the viability of the developed solutions and encouraging uptake by undertaking prototype testing.

A secondary focus running concurrently is the evaluation of the applicability of the methods being used in the case study to maritime applications, identifying ways to improve their understandability, applicability and implementation by other maritime designers.

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