CONCEPTUALIZATION OF THE ERA OF AUTONOMOUS SHIPPING WITHIN MARITIME EDUCATION AND TRAINING FRAMEWORK

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Abstract

The new developments on telecommunications, computing and sensors are triggering the ships to become more autonomous every day. The new projects leading to a fully autonomous way of transport are already building the fleets of the future, involving more efficient, sustainable and safer shipping operations. Against the expectations of the seafarer's replacement by Artificial Intelligence and the Autonomous Systems, this technological emergence will be the opportunity for new businesses and job creation, which will require highly skilled crews and operators. Maritime Education and Training (MET) should progress towards updating subjects, incorporating new topics and upgrading teaching methodologies in order to develop highly skilled crews and on-shore operators while maintaining compliance with the STCW Convention standards. Previous research has already identified that technology related to autonomy is rarely addressed in the maritime curricula, and that the main gap in the preparation of new training lies in the updated STCW Code. Although some technological and research centres have incorporated concepts related to autonomy in their agenda, its integration has not been widespread across all Maritime Education and Training Institutions. The main objective of this article is to analyse this emerging content in relation to autonomous navigation, machinery systems, cybersecurity and remote-control systems, inter alia. These emerging contents will contribute to the development of a training course designed to establish new educational and proficiency standards to address the implications of this technology. The aim is to achieve a comprehensive conceptualization of the new era of Maritime Autonomous Surface Ships (MASS) within the MET framework, facilitating the development and incorporation of MASS into maritime curricula.

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1 INTRODUCTION

The latest developments on telecommunications, computing, sensors and maritime technology in general, are allowing nowadays different levels of autonomy moving forward to the fleet of the next generation with partially and fully autonomous ships. This technological emergence will upgrade as well all jobs related to maritime infrastructures, terminals, VTS, shipyards, thus in general, highly skilled crews and operators will be required on different maritime workplaces covering several maritime professions.

There are a significant number of projects related to the operation and construction of autonomous ships; some still under design, some other ones with different degrees of development. Among these projects we can outline the YARA BIRKELAND (Yara International ASA, 2021) by Konsberg, which is already undergoing gradual implementation and testing of all its autonomous functional capabilities on its "Zero emission, Autonomous Container Feeder"; the Japanese MV MIKAGE (Ocean insight, 2022), that completed already a full trip with no crew on board; other ones like Hyundai, which has developed an Intelligent Navigation Assistant System (HiNAS 2.0) that gathers data from sensors attached to vessel and its equipment, integrating them all using Artificial Intelligence (AI) (Marine Industry News, 2022). Several large research projects are ongoing worldwide, e.g., the EU projects like Autonomous Shipping Initiative for European Waters (AUTOSHIP, 2022) and the Advanced, Efficient and Green Intermodal Systems (AEGIS, 2022), as well as the Korean Autonomous Surface Ship project (KASS, 2022) or the Norwegian SFI AutoShip (NTNU, 2022).

All technological innovations require new higher education and training to cover the demands of new job creation (Abilio Ramos et al., 2019). Nevertheless, the existing International Convention on Standards of Training, Certification and Watchkeeping (STCW) does not encompass regulations for autonomous ships yet. Keeping in mind that the main purpose of the Maritime Education and Training (MET) institutions is to prepare the professionals of the future, they should be updating their programs to prepare a specialised and qualified staff capable of handling all new technologies and developments, both on-board and ashore.

The direct application of artificial intelligence (AI) (Smith, 2020), the development of new communication and data transmission systems, the optimization of sensors and the control of ship routing are leading to the design of the Remote Operations Center (ROC), the operative base of the autonomous vessels. The IMO MSC-LEG-FAL Working Group on Maritime Autonomous Surface Ships (MASS-JWG) has agreed upon the definition of a ROC as follows: "A location remote from the MASS that can operate some or all aspects of the functions of the MASS". Additionally, it was determined that "There should be a human master responsible for a MASS, regardless of mode of operation or degree or level of autonomy" (IMO, 2023). In consequence, new professional management positions with significant responsibilities will emerge, accompanied by corresponding training requirements.

As it was pointed out in the literature review (Campos et al., 2022), there was and still there is much work to do regarding the Maritime Education and Training in the context of unmanned ships. Nasur & Bogusławski (2020) identified the autonomous merchant ships as a topic that is rarely addressed in the maritime curricula and emphasised the importance of including comprehensive coverage of MASS in MET Institutions (METIs).

Several European Maritime Educational Institutions have already incorporated autonomous shipping concepts in their curricula. For example, Novia University of Applied Sciences in Finland and Nikola Vaptsarov Naval Academy in Varna have taken steps in this direction. Other ones are research partners on different European projects, such as the Aalborg University (AAU) on AEGIS or The Glasgow's University of Strathclyde on AUTOSHIP. In this last case, it should be pointed out that they are already preparing crew for the ROCs.

Clearly, Maritime Institutions should move forward and focus their efforts in upgrading the future seafarers' curricula. In this respect, during the last year, our research has entailed the acquisition of insights from various stakeholders within the maritime domain. This approach has included not only seafarers on board ships, but also with agents in different roles across the maritime industry such as those in ports, ship operators and surveyors, as well as the point of view of the current maritime teachers and trainers. The perceptions collected from stakeholders cover simulators, competences and topics related to MASS.

It is obvious that the new training and education will still rely on issues such as navigation, safety, planning, navigational equipment, positioning, meteorology and emergency procedures, among others, but also adding knowledge on artificial intelligence, remote operations, cybersecurity, data transmission and communications, inter alia, as we introduce on this paper.

The main objective of this contribution is to achieve a comprehensive conceptualization of the Maritime Autonomous Surface Ships within the MET framework. This seeks to facilitate the systematic development and incorporation of MASS-related content into existing maritime education programs, thereby addressing the needs and challenges of the maritime industry in light of new technological advancements.

Following the introduction and background section (Section 1), this paper continues with the description of the methodology followed to conduct the research (Section 2). Afterwards, the presentation and description of emerging topics in autonomous navigation are presented in Section 3. Then a proposal of a new subject "An introduction to MASS: principles and technological concepts" can be found in Section 4. Finally, the conclusions and the synthesis of the findings are presented in the last section (Section 5) as a precursor to the development of a training course focused on establishing synergies between MET and MASS.

2 RESEARCH METHOD

In this section, the methodology followed to identify suitable and relevant topics will be introduced, with the aim of establishing the base for a comprehensive conceptualization of the new era of Maritime Autonomous Surface Ships (MASS) within the Maritime Education and Training (MET) framework.

The methodology has been divided in the subsequent stages (see Figure 1):

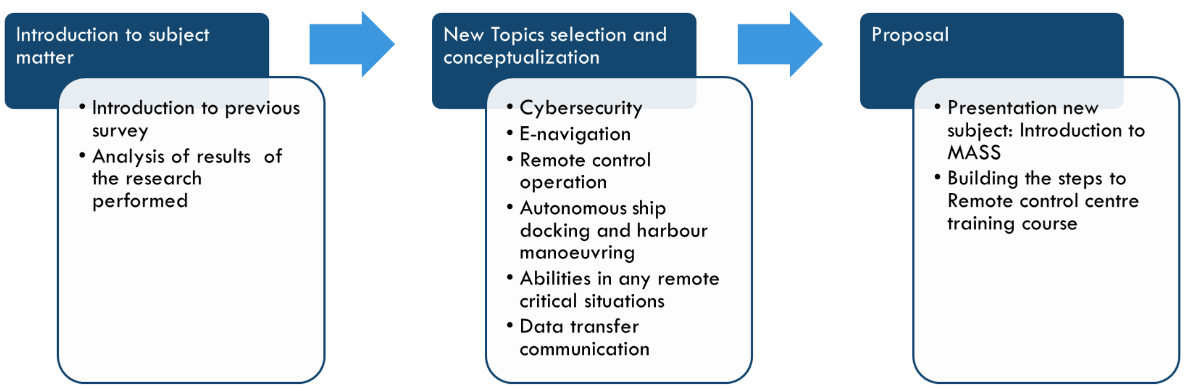

Fig. 1. Chart Flow research methodology

In the first stage (section 3), a short overview about the survey developed during last year has been introduced. In between all questions, the main one related to the key point of this study is introduced. The analysis of results hereunder is provided to guide us towards the selection of the new possible topics.

In the next stage (section 4), the list of main topics has been picked up and outlined in order to clear up the relevance of those subjects as the primary ones to be added to the future MET programs. A basic introduction to those new terms and concepts are provided to emphasise on their meaning and significance in relation to MASS developments.

Finally, in section 5, the new subject to introduce MASS to our actual program has been set out as a way to update the competences and upgrade the skills of the future professionals.

3 ANALYSIS OF PREVIOUS SURVEY

3.1 Previous research

A study through a survey has been conducted from January to June 2023 among a wide range of professionals from the maritime sector, not only seafarers but also personnel whose job is in the maritime area as port and VTS operators, inspectors, lawyers, Maritime Authorities, teachers and trainers, among other parties. The survey compiled different inquiries all related to Maritime Education and Training in the era of Autonomous Shipping. The questions have been divided into three parts: the first one collects the participants' profiles; the second part focuses on their educational background, training and professional experience and, the final part explores the aim of this study and seeks the point of view of each contestant about those skills and competences that future seafarers need to achieve with reference to unmanned ships.

3.2 Analysis of results

Focusing on the key question based on "Which of the following NEW TOPICS do you think is necessary and should be added to acquire in the new MET education", Figure 2 shows that e-navigation followed by cyber-security, remote-control operation and autonomous ship docking and harbour manoeuvring are the main new topics to be added based on the perceptions of maritime stakeholders.

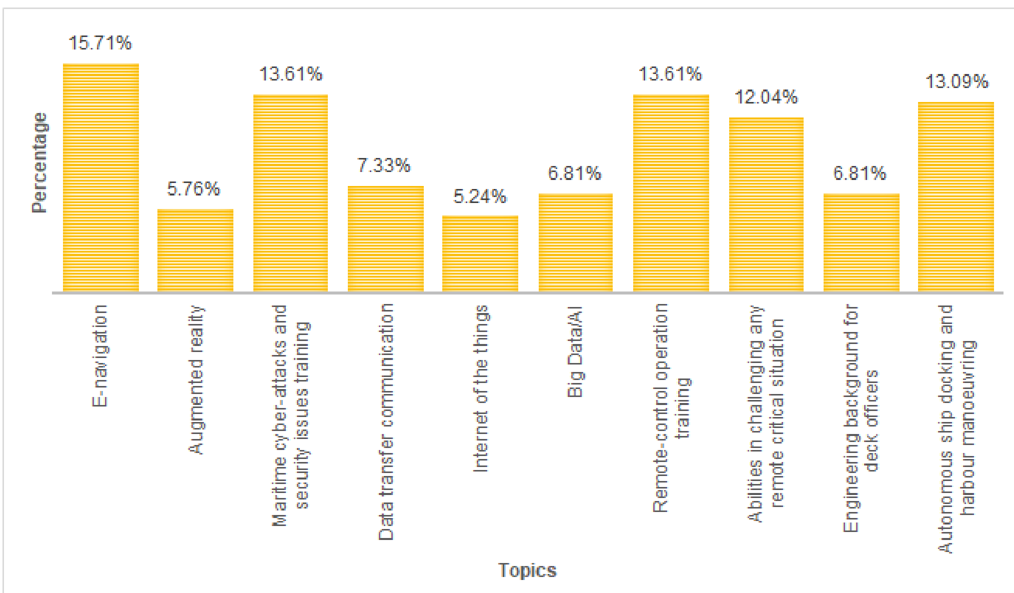

Fig. 2. Result list of possible new topics to be added (surveyed participants answers)

Considering these results, it is important to investigate the background of each concept individually and analyse its influence within the context of autonomous shipping. This ensures that they are the precise contents to be incorporated into future MET. A final double check with the studies already undertaken by other MET institutions (METIs) will give us a better approach to that forthcoming action plan.

4 NEW TOPICS SELECTION

This section will describe the definition and advancements of topics selection: E-navigation, Cybersecurity, Remote control operation, including ship docking and harbour manoeuvring, Abilities in any remote critical situation and Data transfer communication.

Considering that the different concepts are deeply related, each topic will be defined, explained and linked to autonomous shipping separately. This approach will clarify the importance of each term individually, aiding in the challenge of building and developing a new training course related to MASS.

4.1 Cybersecurity

Cybersecurity is the practice of protecting critical systems and sensitive information from digital attacks. As defined by Priyadarshini in the Introduction on Cybersecurity (Priyadarshini, 2019), it is the ability to defend against and recover from cyberattacks.

As autonomous vessels have a system infrastructure composed by digital sensors, controllers, computer systems, telecommunications network and internet on a greater or lesser extent; it is crucial to ensure security on all domains, such as:

- Critical infrastructure, deals with cyber physical systems and real-world introduction.
- Network Security, measures and concerns to protect information systems.
- Cloud Security, technologies and policies to protect information, data applications and any infrastructure within the cloud.
- Application Security, ensured by mitigating security vulnerabilities.
- Internet of Things (IoT) Security, as IoT are those digital devices capable of transferring data without human interference, the stronger security safeguards will be used.

Cybersecurity in crewed ships is a matter to be controlled, but as long as there are protective and updated measures, as well as procedures to follow, recovery should be achieved. In addition, as introduced by Fenton & Chapsos (2023), cybersecurity on uncrewed vessels presents a very complex situation, as the entire ship is linked to cyber; meaning that navigation, power, engine, communications will depend completely on interconnected sensors, cameras, devices, all digitised, capable of being hacked and overridden.

Subsequently, the crew members working on board and the ones controlling on shore should be aware of all possible risks and hazards as well as the detection and corrective measures to be implemented on each case. All stated above, makes this topic the critical one to be incorporated in the new maritime training course.

4.2 E-navigation

The set of algorithms developed for all unmanned operations including berthing, unberthing and the ones detecting obstacles are part of what is called e-navigation. Nevertheless, e-navigation began to appear long before Autonomous shipping. At the 85th meeting of the Maritime Safety Committee (MSC) in December 2008 the strategy to improve and implement e-navigation on all vessels was approved, as a solution to the lack of an effective coordination of non-standard technologies in both ships and coasts. In 2014, at the 94th meeting of the MSC, the first e-navigation strategy implementation plan was carried out. As introduced by Arslan & Nas (2022), e-navigation systems should be flexible, able to compensate for errors, address data reliability and integrity, promote good decision-making, improve performance, and prevent individual errors.

All technological support systems on board and ashore should be congruent and coordinated, to provide harmonised results. The crew members on vessels and RCC as well as other professionals related to vessel operations should be able to understand the benefits of the e-navigation implementation plan and get used to the new standard and reliable information acquired.

4.3. Remote control operation, including ship docking and harbour manoeuvring

Depending on the different levels of autonomy, autonomous navigation will involve remotely controlled operations. In the years to come, conventional ships and autonomous ones will share and operate simultaneously, thus vessel interactions can complicate the decision- making process and compromise safety (Kim et al., 2022) as both humans and systems are making the respective decisions. It is in those situations that the remote control taking over might be the best answer.

In case of harbour manoeuvring and ship docking, this situation will enhance as the navigation is done in closer spaces, with higher vulnerability and communications requirements. Consequently, it will be surely on those moments that the operator on ROC or the crew on board will need to take over the command for a proper and safer navigation. It is known that with the Artificial Intelligence (AI) developments those periods of taking over by humans will be decreasing in the near future, but operators will need to get involved at any time if the manoeuvring situation is not clear.

We could advance that operations under remote control might be linked to Augmented Reality (AR), as all digital information will arrive in real time to the user so, if that data includes the environment, the operator should know how to deal and operate with AR.

4.4 Abilities in any remote critical situation

It is known that the response to any critical situation rely mostly on the personal capability and attitude of each individual, but the knowledge of the different situations that may occur as well as the procedures to follow will be a crucial part of the competences and skills of the future seafarers.

There are several studies to minimise MASS casualty incidents (Berndt & Herczeg, 2019) developing a better software in order to decrease the operator decision-making that, at the end, could cause a major damage or worsen the situation. However, eventually, only the operator will have the choice to overwrite the system, so the preparation on the management of different casualties will be the focal point of this topic.

Team working skills, quick – thinking, confidence, self-discipline, might be some of the attitudes to work on this subject as a part of the abilities to respond to any situation, including any system failures and critical situations.

4.5 Data transfer communication

As highlighted by Martelli et al. (2021), the latest developments on autonomous navigation technology are focused to develop more reliable algorithms for better guidance and control and reduce the human operator's errors (Zaccone et al., 2019). On these emerging technologies, the communication infrastructure is based on the Internet of Things (IoT). The intelligent algorithms can facilitate services such as predictive maintenance, vessel tracking and safety (Plaza-Hernández et al., 2021). As all the information is coming from various sensors controlled by different algorithms, it is important the need for a connectivity manager to satisfy the various communication requirements.

Even though there is so much work to do regarding this technology, the future professionals should manage all data arising continuously, they should understand the inputs and outputs and analyse if there is any outcome non secure or any emergency situation that the algorithm is not replying in a proper way. They should be able to overwrite the system at any time and transfer the proper data to the systems.

5 INTRODUCTION TO MASS COURSE

The project of adding new topics to the future bachelors' or masters' degrees is well-founded, yet the process will take some time and will require as well a complete review of all the actual subjects in order to upgrade and keep updated with the new developments as MASS is advancing.

In order to upgrade our actual programs and begin in a short period with some fundamentals related to MASS, an innovative idea will be to develop an optional subject, which will include all the topics introduced and additional ones that might be needed to acquire the knowledge on this matter. Thorough preparation is the key to successful implementation of this course.

"An introduction to MASS: principles and technological concepts" could be a good heading for a six credit (ECTS) new optional subject. This course is structured in four topics, where the knowledge on the different degrees of Autonomy, Cybersecurity, E-navigation, Communication and Remote-control operations in different situations could fulfil most of the subject area as shown in Table 1.

Type	Optional Subject
Competences	Identification, prevention and mitigation of Cyber attacks Remote control general operations of the vessel under navigation Control of sensors and automation systems Knowledge and understanding on robotics and autonomy
Teaching Methodology	Participative lectures Problem based learning / projects Simulator practices
Scope	This course intends to provide a comprehensive guide for all maritime training and education institutions, offering knowledge, skills and understanding of introductory MASS concepts.
Learning Objectives	Those who successfully complete this course should be able to demonstrate sufficient and basic knowledge of MASS concepts
Total learning time	150 hours (Self-study 90; Group Classes: 60)
ECTS	6 credits
Topics	1. Introduction 1.1 Definition of MASS and the different degrees of autonomy 1.2 Overview on different scenarios 1.3 Remote Operation Centres model 2. Remote Control Operations and Communication 2.1 Voyage management 2.2 Manoeuvring of the ship on different scenarios 2.3 Cargo and machinery operations 2.4 Pollution control 2.5 Respond to emergencies and distress signals 3. E-navigation 3.1 Use of Situation Awareness systems 4. Data management and Cybersecurity 4.1 Data protection 4.2 Storage of sensitive data

	4.3 Cyber-attack's introduction and protection 4.4 Virus protection, Firewall 4.5 Software and Hardware Maintenance for better security
References	Arslan, E., & Nas, S. (2022). Conflicts Encountered with Bridge Team from the Perspective of Vessel Traffic Service Operators: A Research Within E-Navigation Concept. Transactions on Maritime Science, 11(1), 247–259. https://doi.org/10.7225/toms.v11.n01.018 Berndt, H., & Herczeg, M. (2019). An Integrated Information and Decision-Support System for the Management of Mass Casualty Incidents. IFAC-Papers OnLine, 52(19), 199–204. https://doi.org/10.1016/J.IFACOL.2019.12.096 Fenton, A. J., & Chapsos, I. (2023). Ships without crews: IMO and UK responses to cybersecurity, technology, law and regulation of maritime autonomous surface ships (MASS). Frontiers in Computer Science, 5. https://doi.org/10.3389/fcomp.2023.1151188 IMO, 2023. Maritime Safety Committee (MSC 107) - amendments adopted, progress on autonomous ships Code. https://imo.org/en/MediaCentre/Pages/WhatsNew-1908.aspx (Last visit on June 23) Kim, T.-E., Perera, L. P., Sollid, M.-P., Batalden, B.-M., & Sydnes, A. K. (2022). Safety challenges related to autonomous ships in mixed navigational environments. WMU Journal of Maritime Affairs, 21(2), 141–159. https://doi.org/10.1007/s13437-022-00277-z Martelli, M., Virdis, A., Gotta, A., Cassara, P., & DI Summa, M. (2021). An Outlook on the Future Marine Traffic Management System for Autonomous Ships. IEEE Access, 9, 157316–157328. https://doi.org/10.1109/ACCESS.2021.3130741 Plaza-Hernández, M., Gil-González, A. B., Rodríguez-González, S., Prieto-Tejedor, J., & Corchado-Rodríguez, J. M. (2021). Integration of IoT technologies in the maritime industry. In Advances in Intelligent Systems and Computing: Vol. 1242 AISC. https://doi.org/10.1007/978-3-030-53829-3_10 Priyadarshini, I. (2019). Introduction on Cybersecurity (pp. 1–37).https://doi.org/10.1002/9781119488330.ch1 Zaccone, R., Martelli, M., & Figari, M. (2019). A colreg-compliant ship collision avoidance algorithm. 2019 18th European Control Conference, ECC 2019, 2530–2535. https://doi.org/10.23919/ECC.2019.8796207

Table 1. Course Guide Proposal

For the course to run smoothly and to be effective, considerable attention must be paid to the availability and use of:

1. Properly qualified instructors
2. Support staff

3. Classrooms and other spaces
4. Main equipment: simulators
5. Other supporting material
6. Other reference material

The proposed course is a 60-hour course. The topics are organised in 4 general areas. The total number of hours and the duration of each topic is presented in the Course Timetable shown in Table 2.

Topic	**Hours**
1. Introduction	**8 Hours**
1.1 Definition of MASS and the different degrees of autonomy	2 Hours
1.2 Overview on different scenarios	3 Hours
1.3 Remote Control Center model	3 Hours
2. Remote Control Operations and Communication	**22 Hours**
2.1 Voyage management	4 Hours
2.2 Manoeuvring of the ship on different scenarios	5 Hours
2.3 Cargo and machinery operations	3 Hours
2.4 Pollution control	5 Hours
2.5 Respond to emergencies and distress signals	5 Hours
3. E-navigation	**9 Hours**
3.1 Use of Situation Awareness systems	9 Hours
4. Data management and Cybersecurity	**21 Hours**
4.1 Data protection	4 Hours
4.2 Storage of sensitive data	4 Hours
4.3 Cyber-attack's introduction and protection	5 Hours
4.4 Virus protection, Firewall	4 Hours

4.5 Software and Hardware Maintenance for better security	4 Hours

Table 2. Course Timetable Proposal

Large hours of simulation practices and data processing will secure a good leading to the future ROC operator training course that all the METIs should procure in the next years to come.

6 CONCLUSIONS

After gathering the results of our previous study and looking further on the insights of each topic, substantial work is needed regarding Maritime Education and Training with reference to unmanned ships. The STCW code has not changed yet, considering the advancements discussed under the MSC Committee, it may not be longer before some revisions will appear.

Meanwhile, we cannot be passive and stand still until the new competences become mandatory, as this could take too long. We should take appropriate steps to fill out those needs, to build up those new skills and work out on the most probable new competences related to MASS, so that we do not miss the opportunity to step ahead and manage in a better way the advances that will be coming up in the near future.

Arriving at this point, we must turn our attention to the European maritime educational institutions that have already incorporated autonomous shipping concepts into their curricula and try to gradually incorporate similar fundamentals to our training programs. For example Novia University of Applied Sciences in Finland and Nikola Vaptsarov Naval Academy in Varna have taken steps in this direction, while other ones are research partners on different European projects as the Aalborg University (AAU) on AEGIS or The Glasgow's University of Strathclyde on AUTOSHIP, without overlooking the University of South-Eastern Norway with projects in collaboration with DNV, Wilhelmsen and Konsberg regarding ship management of MASS and the most remarkable one building the future training courses for the MASS remote control operators. Most of them are in close contact with the companies developing the technologies applied to the new Autonomous Vessels, they have the access to most advanced simulators and the new emerging remote-control processes. They are already building up the professionals of the future as part of their investigations, researches and projects.

Anyway, all European METI's should be working to arrive closer to the main objective of bringing MASS understanding to our actual programs, try to reach some of the companies involved in autonomous developments and at least grant basic knowledge to the students we are preparing at this moment.

Increasing simulator hours within the undergoing subjects, integrating MASS concepts within existing courses, and introducing new ones, such as those outlined above, either as separate subjects or as a part of a one, will be some of the steps to move forward towards the future of Maritime Education and Training.

We must focus our efforts on updating the actual degree programs and anticipate the preparation of future seafarers and professionals; including those who will continue to sail and those who will operate ships from remote-control centres.

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