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Study on the applicability of STCW Convention to MASS and updating ETO's standard of competence

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STUDY ON THE APPLICABILITY OF STCW CONVENTION TO MASS AND UPDATING ETO'S STANDARD OF COMPETENCE

by

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DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

(Signature):

(Date): June 27, 2020

Supervised by: Professor Bao Junzhong
Supervisor's affiliation: Dalian Maritime University

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ABSTRACT

Title of Dissertation: **Study on The Applicability of STCW Convention to MASS and Updating ETO'S Standard of Competence**

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In recent years, MASS have received more and more attention, and various countries and organizations are rapidly advancing the process of ship autonomy, carrying out research and practice in technology and supervision. The MASS working group has carried out research on the regulatory scoping exercise and applicability of maritime instruments too. With the digital development of ships, the reduction of the manning level is the general trend of the shipping industry. Although MASS can reduce the risk of human factors, at the same time, the technical problems of intelligent sensors and operating systems may bring more unknown risks to ships. In this case, the supervision and intervention of seafarers or remote operators are particularly important. The STCW Convention and relevant national regulations should regulate and guide the training and management of seafarers so that they can adapt to the development of MASS and master the required knowledge and skills.

This paper will comprehensively sort out the STCW Code, analyze the gaps in knowledge and skills that may be required from the development of MASS technology; and combined with the development trend of green ships and ships' typical defects, the existing problems and new requirements in technology, operation and regulation are analyzed, and the unsuitable or blank parts of knowledge and skills in STCW Code are sorted out.

The innovation of this paper is to draw conclusions on the applicability of the STCW Convention to MASS from the perspective of knowledge and skills. STCW Convention can basically adapt to the degree one and two of autonomy, and only needs to revise the STCW Code, including new training and certification requirements for remote operators. To the degree three and four of autonomy, may require new instruments to address. Finally, the KUP Table for Electro-Technical Officers is used as an example to list specific amendments, and several suggestions for maritime education and training are put forward.

KEYWORDS: Autonomous Ship, STCW, Knowledge and Skills, Applicability, Green Ship, Maritime Education and Training

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AAWA	Advanced Autonomous Waterborne Applications
AI	Artificial Intelligence
AIS	Automatic Identification System
CCS	China Classification Society
CoC	Certificate of Competency
DOC	Document of Compliance
DP	Dynamic Positioning
ECDIS	Electronic Chart Display and Information System
EEOI	Energy efficiency Operational Indicator
GMDSS	Global Maritime Distress and safety System
HSMS	Hull Stress Monitoring System
IBS	Integrated Bridge System
IMO	International Maritime Organization
IOPP	International Oil Pollution Prevention
IoT	Internet of Things
ITF	International Federation of Transport Workers
KUP	Knowledge, understanding and proficiency
MARPOL	International Convention for the Prevention of Pollution from Ships
MASS	Maritime Autonomous Surface Ships
MET	Maritime Education and Training
MSC	Maritime Safety Committee
MUNIN	Maritime Unmanned Navigation through Intelligence in Network
NFAS	Norwegian Forum for MASS
PMS	Power Management System
PSC	Port State Control
SAR	International Convention on Maritime Search and Rescue
SEEMP	Ship Energy Efficiency Management Plan
SOLAS	International Convention for the Safety of Life at Sea
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
UAV	Unmanned Aerial Vehicle
VHF	Very High Frequency

VTS	Vessel Traffic Service
WMU	World Maritime University

1 INTRODUCTION

1.1 Background

Maritime Autonomous Surface Ship (MASS) is an important direction for the future development of ships, and will have a profound impact on the development of the shipping industry. The world's major shipbuilding countries are rapidly advancing the process of ship autonomy. In 2017, on the proposal of some member states, the Maritime Safety Committee (MSC) of the International Maritime Organization (IMO) included the issue of MASS on its agenda. The IMO Strategic Plan (2018-2023) list the “integrate new and advancing technologies in the regulatory framework.” as a strategic direction. IMO is currently working on a regulatory scoping exercise on MASS, to determine how the existing maritime instruments apply to ships of varying degrees of autonomy (Chircop, 2019). The first step is to identify the applicability of the instruments to MASS, and sort out the relevant provisions that are not applicable to MASS, and for those provisions that are applicable but with gaps, revision and clarification is needed. The second step will consider human factors, technology support and relevant operations to determine the most suitable way for MASS operations.

Despite the rapid development of MASS, there are still many factors restricting its development, such as technology, safety, and regulations. Some scholars at home and abroad hold a pessimistic attitude towards the development of MASS , believing that this is a concept advocated by high-tech companies for the promotion of technology and products, or it is an excuse for the container shipping company to reduce the manning level because of the high crew cost caused by slow steaming (Rødseth, 2018). However, the shipping industry is indeed facing the problem of continuous improvement in technology and automation. On January 15, 2019, the report "Transport 2040: Automation, Technology and Employment-The Future of Work" was officially released. The report was jointly developed by the International Federation of Transport Workers (ITF) and the World Maritime University (WMU). This report is the first independent and comprehensive evaluation the impact of automation on the transportation industry. The report pointed out that the automation of the global transportation industry was a gradual evolution process, rather than a revolutionary mutation. Figure 1 shows that the economic benefits are the main driver, regulation and governance could be a deterrent to the development of MASS (Schröder-Hinrichs, et al., 2017). The findings of a survey of what maritime professionals think about autonomous shipping had shown that the biggest obstacles to the development of MASS may be cyber security, which is shown in Figure 2 (Federation, 2018).

Despite the realization of a high degree of automation, high-quality human resources with appropriate skills would still be required in the future. The IMO's Secretary-General Mr. Kitack Lim also emphasized that, as shipping was facing increasing levels of technology and automation, it was necessary to focus on the issues of seafarers' training and competency standards.

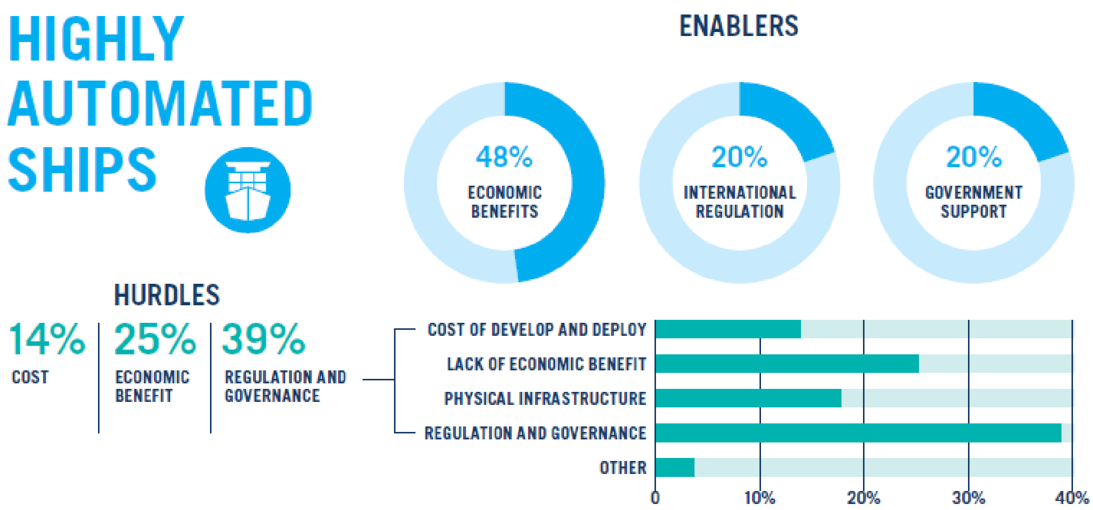

Figure 1 – Factors that enable or delay highly autonomous ship deployment

Source: Schröder-Hinrichs, et al., 2017

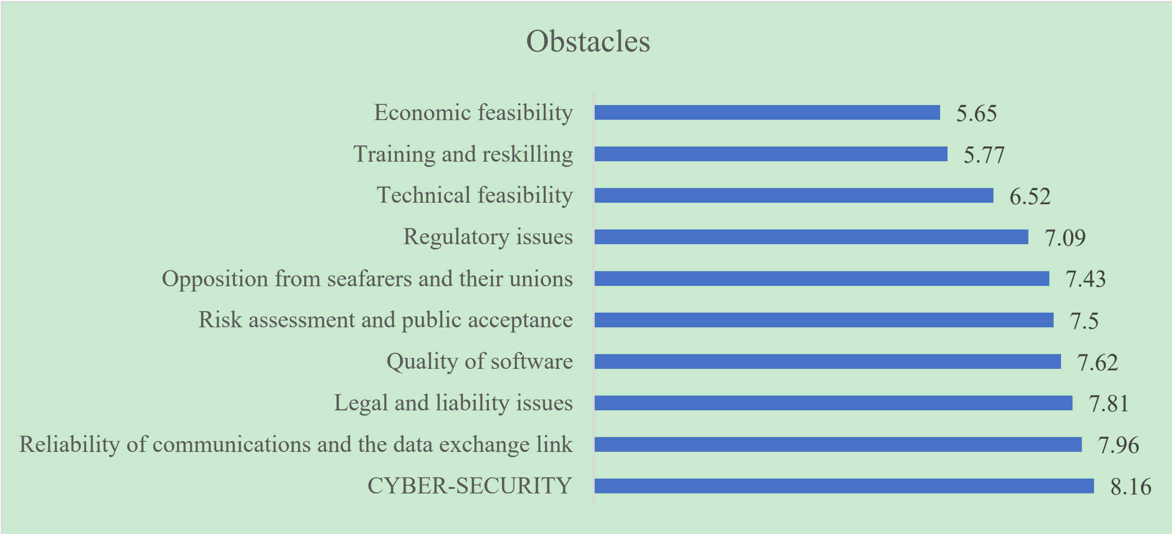

Figure 2 – Obstacles to the adoption of MASS

Source: Data Retrieved from Federation, 2018

The general purpose of the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) is to establish minimum standards for seafarers training, certification and duty that are globally applicable and compliant, and to protect the safety of people, property and the environment at sea through the supervision of human resources and human factors. Conventions and regulations should not be the main factors hindering the development of MASS. MASS require highly skilled crew members, and this involves Maritime Education and Training (MET). Based on the STCW Convention, each seafarer exporting countries will establish seafarers training standards that are applicable to its own country and closely follow the technology and rules of the shipping industry. These questions are in desperate need of answers: How will future seafarers cope with the challenges of increasing levels of automation; what standards seafarers need in terms of education, training and certification to qualify them for future work; and how to conduct effective training to adapt to the development of MASS technology and incorporate it into the regulatory framework. Therefore, at all stages of the development of MASS, it is necessary to comprehensively sort out the requirements of the seafarer's knowledge and skills. This paper will study the applicability of the

STCW Convention to MASS in the context of the MASS' development.

1.2 Current Situation

1.2.1 Definition and classification of MASS

The use of automation and technology on ships has been gradual and increasing. Electronic navigation instruments and electronic charts are fitted on Commercial ships to display ship's position, the distance to other ships, their course and speed as well as the predicted trajectory (from GPS, ARPA, Radar and AIS). For ships, a manned navigation bridge is required and, in certain situations, also a person to monitor surrounding waters. Large ships are steered by plotting a route on the electronic chart. An autopilot keeps the ship on this predefined track. Manual control of the rudder and main engine is used for manoeuvring or for handling emergent. The terminology related to automatic steering, remote operation, remote monitoring and autonomy frequently appear in marine publications (Blanke, Henriques, & Bang, 2017). As early as 2006, IMO adopted the following definition of e-Navigation:
e-Navigation is the harmonized collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth to berth navigation and related services, for safety and security at sea and protection of the marine environment (Amato, et al., 2011).

Based on differences between the technique used as well as the operators' role, Lloyd's Register has developed a definition of ships' autonomy levels for unmanned, remotely operated, remotely monitored and unmanned systems from AL0 to AL6 (Register, 2016).

The company DNV GL has specified five levels of navigational autonomy, as shown in Table 1. The main idea is that navigation is based on a high degree of human observation, analysis, and decision-making, while mechanical functions are largely entirely self-controlled and operate under the supervision of the crew (Senčila, &

Kalvaitienė, 2019).

Table 1 – DNV GL defined levels of navigational autonomy

Autonomy level	Description
M	Manually operated function
DS	System decision supported function
DSE	System decision supported function with conditional system execution capabilities (human in the loop, required acknowledgement by human before execution)
SC	Self-controlled function (the system will execute the operation, but the human is able to override the action. Sometimes referred to as “human on the loop”)
A	Autonomous function (the system will execute the function, normally without the possibility for a human to intervene on the functional level)

Source: Senčila, & Kalvaitienė, 2019

The degrees of autonomy identified for the purpose of the scoping exercise during the Maritime Safety Committee (MSC) 100th session is as follows:

- Degree one: Ship with automated processes and decision support: Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised but with seafarers on board ready to take control.
- Degree two: Remotely controlled ship with seafarers on board: The ship is controlled and operated from another location. Seafarers are available on board to take control and to operate the shipboard systems and functions.
- Degree three: Remotely controlled ship without seafarers on board: The ship is controlled and operated from another location. There are no seafarers on board.
- Degree four: Fully autonomous ship: The operating system of the ship is able to make decisions and determine actions by itself.

In a legal context, the regulatory barriers are convergent for several of the technical autonomy levels. Therefore, we have, in this analysis, chosen to systematize our approach to regulatory barriers on the basis of the above mentioned four degrees of autonomy. And the new regulation will be required in relation to the educational and qualification requirements for the remote operator (Authority, 2017).

Code for intelligent ships (2015) released by China Classification Society (CCS) in March 2016 gives a clearer definition of intelligent ship, which refers to the use of sensors, communications, the Internet of Things (IoT), Internet technology, to automatic perception and acquisition of the information and data about the ship itself, the marine environment, logistics, port; and based on computer technology, automatic control technology and big data processing and analysis technology, to realize intelligent operation in the navigation, management, maintenance, cargo transport of the ship, for the purpose of making shipping safer, more environmentally friendly, more economical and more reliable (Fan, 2015).

1.2.2 The practice of MASS at domestic and abroad

Among projects and initiatives involving MASS, these deserve particular attention: The Advanced Autonomous Waterborne Applications (AAWA) Initiative combines members from academia and the maritime industry to produce specification and preliminary designs for the next generation of ships (Jokioinen, et al., 2016). The Norwegian Forum for MASS (NFAS) reunites individuals and organizations that are interested in the theme of autonomous ship; it was established in the Spring of 2016 by the Norwegian Maritime Directorate, Norwegian Coastal Industry Norsk Industri and SINTEF Ocean (Norwegian, 2017). The Maritime Unmanned Navigation through Intelligence in Network (MUNIN) was a collaborative research project consisting of partners with both scientific and industrial backgrounds, and co-funded by the European Commissions. It aimed to develop and verify a concept for an autonomous ship (Kretschmann, & Jahn, 2017).

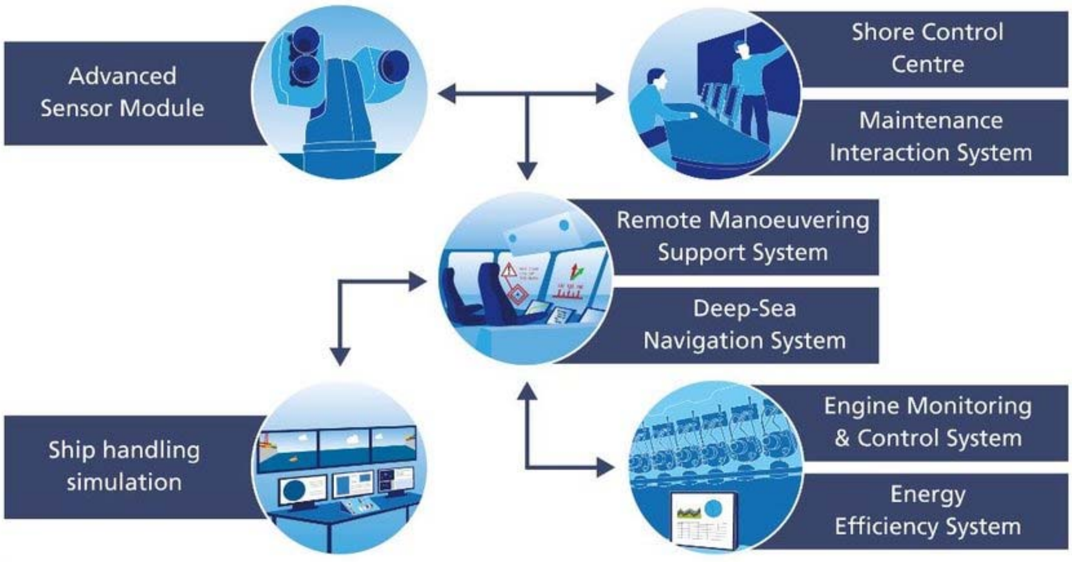

Figure 3 – MUNIN project in Maritime Unmanned Navigation

Source: Emad, Khabir, & Shahbakhsh, 2020

DNV GL is currently developing the ReVolt, which is a concept of battery powered, unmanned, zero-emission ship designed for short voyage. A 1:20 scaled model has been built for testing in collaboration with the Norwegian University of Science and Technology (NTNU) (Alfheim, et al., 2018). Yara and Kongsberg have partnered to build an autonomous and fully electric container vessel called Yara Birkeland, and is expected to conduct fully autonomous operations by 2020 (Maritime, 2017). Recently, China's first self-developed "Jin Dou Cloud 0" cargo ship has completed its first cargo transportation in Zhuhai. The autonomous navigation of ships has a crucial strategic significance. By reducing the number of crews until unmanned navigation is achieved, a revolutionary breakthrough in ship design and construction can be achieved. At the same load capacity, more than 20% of construction costs and 20% of operating costs can be saved, fuel consumption can be reduced by 15% and emissions can also be significantly cut down.

1.3 Objectives of Research

The purpose of this study is to analyze the key technologies and challenges of MASS, combined with the development trends of ships and equipment, such as LNG dual fuel engines, emissions reduction (GHG and sulfur), wind assistance, ballast water treatment equipment, waste heat recovering system, electric power propulsion system, etc. At the same time, typical defects related to human factors found during PSC inspection help to form a more comprehensive new requirement for seafarers' knowledge and skills for future MASS. Then the standards of competency of seafarers in the STCW convention are reviewed. Finally, the differences between the current STCW convention and the new knowledge and skill requirements brought by the technological development of MASS are compared, the adaptability is analyzed, and suggestions for the updating of ETO's standard of competence are proposed.

The research in this paper is expected to have certain guiding significance for the amendments of the STCW Convention, the formulation of standards for MASS, and the development of technology.

1.4 Methodology

The research of the dissertation is carried out through analysis, investigation and comparison.

- Systematically review the STCW Convention and extract the standards and requirements for seafarers' knowledge and skills in the Convention.
- Conduct extensive research on what knowledge and skill should be strengthened in order to skillfully maintain and manage the increasingly digital systems and equipment on board.
- Research and analyze the development of MASS, and summarize the new requirements for seafarers' professional quality and professional skills in new technologies and intelligent equipment.

- Propose recommendations for amendment of KUP Table for Electro-Technical Officers and gives some suggestions for maritime education.

This paper only analyzes the specific seafarer's knowledge and skills requirements. The research is feasible by consulting relevant literatures, reports and questionnaires.

1.5 Structure of Dissertation

This paper mainly studies the challenges faced by the development of MASS and the key technical problems to be solved; specifically analyzes the functional and technical problems that ship equipment and port infrastructure need to achieve in order to adapt to the development of MASS; at the same time, it summarizes the technical and regulatory trends of the shipping industry to form the requirements for the knowledge and skills of seafarers. Then investigate the views of various stakeholders on the STCW Convention and the development of MASS, and learn more about the requirements for seafarer’s knowledge and skills as well as suggestions for seafarer’s education and training. Finally, it summarizes the STCW Convention training standards that are not suitable for the development of MASS and the knowledge and skills need to be added, and amendments to the STCW Convention training standards are proposed.

Chapter 2 looks at the challenges faced by the development of MASS and the key technical problems to be solved. In accordance with the seven functions of STCW Convention, it puts forward the possible technical solutions, including the functions of ship equipment and port infrastructure to adapt to its development and the technologies that may be applied. Finally, the applicability of STCW Convention to MASS and the appropriate ways to address MASS operation are analyzed and summarized.

Chapter 3 analyzes the technology and regulatory trends of the shipping industry, sorts out the typical defects of the ships in the report of Port State Control (PSC) and the human factors behind the defects, so as to analyze the deficiencies in MET, company training, maritime supervision and other aspects.

In Chapter 4, the specific views of various stakeholders, including shipping companies, maritime bureaus, seafarers, ports, cargo owners on the STCW Convention and the development of MASS had been investigated, the key point is to sort out what knowledge and skills need to be effectively improved by the seafarers. Then the requirements for seafarers' knowledge and skills will be specifically analyzed according to the seven functions of STCW Convention, aiming at the four levels of MASS. Finally, take KUP Table for Electro-Technical Officer as an example to provide specific amendment recommendations to adapt to the development of new maritime technology and regulation rules as well as MASS.

Chapter 5 is the conclusion and suggestion of this paper.

2 APPLICABILITY ANALYSIS OF STCW CONVENTION

2.1 Discussion on the Technological Development

2.1.1 Technological Development in the Seven Functions of STCW Code

The key technologies of MASS are information sensing technology, information and communication technology, energy efficiency management technology, condition monitoring and fault diagnosis technology and autonomous navigation technology. In autonomous navigation technology, automatic collision avoidance, automatic cargo handling and management, and route planning are the main challenges in the development of MASS (Yao, 2019). The following part will take the seven functions of STCW Code as the axis to discuss the technical development of MASS in detail.

(1) Navigation

The seafarers' competency required for navigation functions mainly includes navigation planning, watchkeeping, ship positioning, remote control operation of propulsion, steering gear, bow/stern thrust, fire control system and other devices, ship maneuvering, use of navigation aids and electronic navigation equipment, meteorological information acquisition, understanding and forecasting, search and rescue operations, response to navigation emergencies, etc.

At present, the research on ship autonomous navigation mainly focuses on information perception, communication and navigation, route planning, comprehensive energy efficiency management, automatic collision avoidance and automatic berthing. Use big data analysis, IoT and information and communication technology to achieve comprehensive information processing and independent decision-making, and finally output the decision to the ship's operating system to control the ship's course and speed.

Ship automatic collision avoidance technology is a major challenge in the development of MASS. Convention on the International Regulations for Preventing Collisions at Sea (COLREG), as a ship's navigation operation standard, requires the crew to have strong professional literacy and sailing skills in order to ensure correct decision-making and maneuvering of the ship in the event of an emergency, and reduce ship collisions caused by human factors. In order to achieve automatic collision avoidance, MASS not only needs to comply with the COLREG, but also needs to acquire the navigation signal status, ship speed, bearing, intention of other ships through radar, AIS, camera, VHF, etc. If the visibility is poor, the situation is complicated, or the collision avoidance occurs between the unmanned ship and the manned ship, it is more difficult to achieve automatic collision avoidance. In addition, if one party does not operate the ship in accordance with the COLREG or the autonomous ship makes decision errors due to sensor failures, data errors, program loopholes, etc., the risk of collision is exacerbated. Artificial intelligence technology may not be able to identify ships that display navigation lights incorrectly, are not equipped with AIS, and do not comply with COLRGE, so effective collision avoidance cannot be achieved (Perera, 2018). With the improvement of the ship's automation, seafarers' dependence on navigation instruments is getting more severe. In the case of SANCHI accident, Officers of the Watch have ignored the effective visual look-out and this became the major cause of the accident. Collision avoidance usually uses the information of proper look-out and radar, AIS and ECDIS as a ship collision avoidance assistance. Collision avoidance usually uses the information of proper look-out and radar, AIS and ECDIS as a ship collision avoidance assistance. On the one hand, accidents caused by human errors can be avoided by automation, but on the other hand, accidents that can now be avoided by humans may occur on unmanned ships, and these relationships are described in Figure 4 (Porathe, et al., 2018).

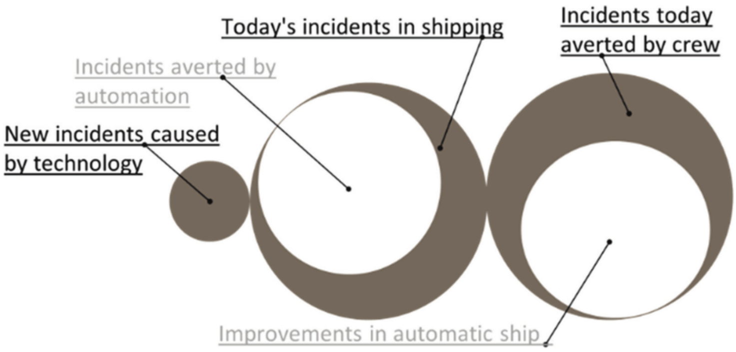

Figure 4 – Incidents in the autonomous ship

Source: Porathe, et al., 2018

In Nautilus Federation report, over 85% of those taking part in the survey hold the view that unmanned, remote-controlled vessels pose a threat to maritime safety, Table 2 lists the main safety risks, and these are also the challenges that autonomous ship needs to overcome, many of which require technology to address.

Table 2 – Safety risks highlighted in Nautilus Federation report

No.	Description
1	routine and corrective maintenance challenges
2	equipment and system failures
3	redundancy and reliability of shipboard equipment
4	software bugs
5	IT and communication problems
6	sensor failures due to heat and vibration
7	piracy and cyber attacks
8	cargo security
9	unpredictable sea conditions
10	on-the-spot decision-making in dynamic environments
11	the relationship between MASS and conventional vessels during the transitional period

Source: Federation, 2018

Collision avoidance systems for ships during navigation should be divided into reef avoidance (ship grounding) and collision avoidance (collision between ships), so underwater target information needs to be collected by sensors, such as sonar. The ship's automatic collision avoidance technology can integrate the COLREG and the data provided by AIS, ECDIS, sonar, cameras and others to realize the collision avoidance autonomous decision-making function in the integrated information system of the bridge. When encountering a manned ship, an alarm can be automatically issued, and the final control can be transferred to the remote-control operator. It can communicate through language to better judge the state and intention of other ships. The ship's automatic collision avoidance technology can reduce the impact of human factors, but at the same time, the reliability of the sensors and the accuracy of the data should be ensured to avoid errors in autonomous decision-making.

(2) Cargo Handling and Stowage

In the cargo handling and stowage functions, seafarers are required to have competency which mainly include knowledge and skills in the safe handling, stowage, securing and transportation of goods; the effects of cargo on ship stability, buoyancy and hull strength; the application of the International Maritime Dangerous Goods (IMDG) Code; anti-corrosion measures and periodic inspection of cargo holds, hatch covers and ballast tanks.

Intelligent cargo management is achieved by installing sensors, electronic tags and other equipment in the cargo hold or cargo handling and securing system to collect the parameters. By using the IoT and big data analysis to analyze and process the collected parameters, the real-time monitoring of the cargo hold and cargo can be achieved, and the alarm and operation suggestions can be given. Meanwhile, the loading configuration of the cargo can be optimized according to the collected hull floating state and strength data. Cargo stowage optimization and automatic loading and unloading are complex engineering problems, which need to consider not only floating state, stability and strength, but also sequence and time of loading and unloading, cargo characteristics, storage conditions, etc. Therefore, it is still difficult to realize. Container ships or ships carrying bulk commodities, such as grain and crude oil, are relatively easy to realize the automation of cargo handling, and they can use port loading and unloading equipment, without having to implement automatic control of the cargo crane on the autonomous ship.

(3) Controlling the Operation of the Ship and Care for Persons on Board

In the ship operation management and personnel management functions, the seafarers' qualification standards mainly include the knowledge and measures of the ship's draft, stability and strength control; supervision and control of compliance with international conventions and regulations, safe and correct operation of deck machinery and equipment, anti-pollution equipment to ensure the safety of human life at sea and the protection of the marine environment; operation, maintenance and inspection of life-saving, fire-fighting and other safety equipment and systems; emergency drills for fire-fighting, life-saving, ship abandonment, plugging, security, etc.; formulating emergency and damage control plans and deal with emergencies; leadership and management, and the use of team work skills; treatment, organization and management of medical on board; occupational health and safety precautions.

MASS can ensure the safety of ships by designing an intelligent hull system. The smart hull includes two aspects. One is to establish a hull database during the design, construction and operation stages, and to provide more reasonable suggestions in terms of hull structural safety and dock repair and maintenance. The other is to collect and monitor hull-related data during navigation and propose ship manipulation. It can collect, store, analyze, and display the data of hull structural stress, motion status, loading, sea state, course, speed, etc. When the change of these data exceeds the preset threshold, it issues a warning and provides guidance for the ship's navigation operation, such as the decision to change course, speed and floating state.

Strainstall Marine Technology has developed the Strass Alert Hull Stress Monitoring System (HSMS), which can monitor the integrity of the hull structure in real time and predict hull conditions and trends, thereby reducing the probability of generating high stress, improving ship safety, while saving fuel and facilitating navigation management. In particular, the ship's stress state is monitored under sailing conditions or during cargo loading and unloading operations, and the captain is reminded to change the course and speed to reduce the hull stress. When micro-cracks appear locally on the hull, early detection and measures can be taken.

(4) Marine Engineering

In the function of marine engineering, the competence standards required of seafarers mainly include the theoretical knowledge of thermodynamics, fluid mechanics, materials science, shipbuilding, etc.; the operation and management of main propulsion device, auxiliary machinery and related control system; the operation and management of fuel oil, lubricating oil, bilge water and ballast water; safety watch; cabin resource management; the operation and emergency procedures of cabin emergency equipment.

The intelligent engine room is based on the engine room automation, using the condition monitoring system to obtain information and data, analyzing the operation status of the main engine, auxiliary engine and other marine equipment and shafting structure in the engine room, and putting forward decision-making and maintenance suggestions on equipment operation. For example, the engine room monitoring and alarm system has the function of real-time online monitoring the operation status of main power equipment in the engine room and generating alarm information. The operation status, parameters and fault alarm status of the equipment can be displayed on the computer and extended alarm screen in the central control room, so that the crew can fully understand the operation status and parameters of all equipment. The development direction of the intelligent ship should be based on the monitoring and alarm system to realize the equipment condition monitoring and fault diagnosis system, which can remind the crew of the devices with fault or performance degradation, the causes of the fault and the development trend of the fault. According to the results of fault diagnosis and health assessment, the detailed maintenance plan of cabin equipment and components can be formulated to optimize the system performance.

Intelligent energy efficiency management is also the development focus of intelligent ships. Marorka from Iceland, one of the leading global provider of data-driven energy management and operational performance solutions for maritime industry, can monitor the performance parameters of machines and ships, regularly check the energy efficiency of ships, optimize the trim of ships, and reduce ship resistance and energy consumption. At the same time, a speed optimization scheme can be formed according to the ship navigation data, combined with the results of voyage planning, route characteristics, ship efficiency, fuel consumption evaluation and navigation cost accounting analysis.

China Classification Society (CCS) and COSCO have developed the energy efficiency service product of "ship energy efficiency online intelligent management system". It has the function modules of energy efficiency management, energy management, energy consumption equipment condition monitoring, navigation state information monitoring, navigation state analysis, Ship Energy Efficiency Management Plan (SEEMP) management, report management, etc. Based on the analysis of navigation environment, cargo status, draft, engine power (rotation speed) and other factors such as meteorology and hydrology, and on the premise of ensuring the safety and operation efficiency of the ship, the energy efficiency management system should optimize and control the ship's speed, cargo loading, draft, route, etc., as well as the power system, such as the paralleling and splitting of main generator, the switching of main generator and shaft generator, etc. to minimize Energy efficiency Operational Indicator (EEOI).

(5) Electrical, Electronic and Control Engineering

In the functions of electrical, electronic and control engineering, the competency standards for seafarers mainly include the knowledge of basic theory and application technology such as circuit principle, electronic technology, power electronic technology, electric machinery, electric drive, automatic control, as well as the operation principle of main propulsion device, engine room auxiliary machinery, deck machinery, etc.; the condition monitoring and emergency test of propulsion device and auxiliary machinery control system; operation of generator and distribution system; operation and maintenance of high-voltage power station; operation and maintenance of ship computer and local area network; operation and maintenance of internal communication system on board; safe use and operation procedures of electrical equipment; inspection, maintenance and repair of electrical faults.

Electric propulsion has become the development direction of ship propulsion. The conventional electric propulsion system of diesel engine is usually composed of diesel generator sets, main switching board, propulsion transformer, frequency converter and propulsion motor. At the same time, it also includes the Power Management System (PMS), which distributes, monitors, controls, manages and protects the power from all levels of power generation, distribution and consumption. Its main functions include power distribution; optimal control; state monitoring; fault diagnosis, and fault-tolerant control. The core technologies to realize the above functions are as follows: computer technology, such as database, network communication, fieldbus, etc.; automatic control technology, such as process monitoring, optimization algorithm, fault-tolerant control, etc.; artificial intelligence, such as pattern recognition, expert system, fuzzy logic, neural network, genetic algorithm, etc. The use of electric propulsion system in ships can improve the efficiency of diesel engines and reduce fuel consumption. Because the design will calculate the load of the ship under various working conditions, and determine the capacity and quantity of the generator. In actual operation, these units will operate at loads close to their "best efficiency point" (usually 80-90%), so as to reduce emissions. The technology of electric propulsion system is based on the development of many items, including high-power fuel cell, solar cell, wind power generation, high-power inverter, soft switch technology, harmonic suppression, super capacitor, medium and high voltage power system, etc. Propulsion motor technology includes high-power permanent magnet synchronous motor, polyphase motor and fault-tolerant control. In addition to the protection of over-current, short circuit, under voltage, over-voltage, reverse power, there are also ground fault monitoring and protection, differential protection, zero sequence protection and so on.

(6) Maintenance and Repair

In the maintenance and repair function, seafarers are required to comply with such competence standards mainly including engineering practice theory, maintenance and repair planning and program management, fault diagnosis and maintenance of mechanical equipment, electrical and electronic equipment, maintenance and repair of main propulsion system and auxiliary machinery, maintenance and repair of navigation equipment of bridge and ship communication system, maintenance and repair of deck machinery; maintenance and repair of living equipment and safety system, safety and emergency procedures, and use of tools.

In the course of intelligent ship development, the maintenance and repair function focus on condition monitoring and fault diagnosis. It needs information fusion technology, big data analysis technology, intelligent diagnosis technology such as deep learning, neural network, blind source separation, support vector machine and so on. Nowadays, smart sensors have been developed rapidly, such as ABB Ability^{TM}, which can monitor the temperature, vibration and other signals of low-voltage motor in real time, and regularly measure the key parameters accurately. Data can be transmitted to smart phones or security cloud-based servers to help users view the running status of the motor at any time, realize intelligent maintenance of the motor, optimize the energy consumption of the motor, etc. The intelligent sensor can monitor the vibration parameters of the motor, help to find the motor foot screw loose, unbalanced, misaligned, abnormal load and other faults; it can monitor the motor operation parameters, including temperature, output power, operation time, startup times, speed, power frequency, etc.; it can also give maintenance suggestions, such as adding grease, replacing bearings, etc.

(7) Radiocommunications

In the radio communication function, the competency standards that seafarers need to have mainly include the ability for the use of Global Maritime Distress and safety System (GMDSS) subsystem and equipment to send and receive information, and to meet the functional requirements of GMDSS; the use of radio equipment in emergency situations. MASS requires high communication quality regarding distance, speed, capacity and reliability, and communication technology will have a huge and rapid development. Maybe quantum satellite and 5G will be the solution. The ship radio communication system will develop towards integration and intelligence, and will continue to expand and optimize network functions in combination with IoT technology, big data, cloud computing, etc. Therefore, the competency standard of radio communication function will be greatly changed, and the importance of the function will be increased. When seafarers perform this function, the task volume may be reduced due to the high reliability of communication technology, but once there is a communication failure, the complexity of their work will be significantly increased.

2.1.2 Impact of MASS on VTS and Port Operation

In order to attract more shipping activities to improve trade and economy, coastal state has taken the initiative to provide better infrastructure and navigation services. Infrastructure includes beacons and buoys that help ships navigate safely in coastal waters and ports. In order to maintain the order of navigation in the coastal waters, the vessel traffic separation scheme, warning area, coastal navigation area and deep-water channel are established. The development of MASS brings opportunities and challenges to ports and Vessel Traffic Service (VTS). It is expected that manned ships will operate together with unmanned autonomous or remote-controlled ships (Baldauf, et al., 2018), so whether it is necessary to digitize the existing lighthouses and buoys and whether it is necessary to establish a dedicated channel for MASS are questions to be considered by the maritime authorities. In order to adapt to the development of MASS, the operation, technology, training and regulation to strengthen the infrastructure construction of ports and waterways should be improved. The information interaction between MASS and VTS will differ from that of manned ships. There will no crews aboard to evaluate the state of the ship, and then report to VTS through Very High Frequency (VHF) radio telephone, or show intention to other ships with signal light and radio telephone. All information interaction is digital, so it is necessary to establish advanced and reliable communication facilities and management system in technology to support large capacity data transmission between VTS and MASS. For the benefit of life safety and environmental protection at sea, VTS may take over the control of MASS. In this case, new regulations need to be formulated to establish the legal relationship between MASS and VTS, and VTSOs need accept special training in this regard. In addition to mastering the necessary knowledge and skills to complete the operation of MASS, VTSOs should also be able to respond to emergencies, such as fire accidents on board, mechanical failure, cyber security threats, etc.

The challenges faced by the port lie in the communication with MASS, the operation mode of pilots and tugs, automatic or semi-automatic mooring facilities, shore power equipment, etc. The construction of smart ports focusing on automated container port needs to be accelerated in order to improve the port's intelligent technology, system integration capabilities, operational efficiency, and significantly reduce personnel costs. At the same time, it is the future development direction for ships to use shore power to reduce air pollution emissions. In 2020, Shenzhen Haixing container port will realize the combination of high technology with port business such as unmanned container truck, Unmanned Aerial Vehicle (UAV) for real-time monitoring, intelligent security, etc. through 5G application, and upgrade the port to a world-class "smart port" with highly automatic and intelligent operation management capability.

2.2 Applicability Analysis of STCW Convention

In recent years, the development of information communication, computers, new energy, IoT, big data, machine learning, artificial intelligence (AI) and other technologies has accelerated the process of ship autonomy. Superficially at least, the application of various intelligent systems can simplify the operation and management of the ship, and it has played a prominent role in reducing some dirty and dangerous tasks, reducing paperwork and bureaucracy, and significantly increasing productivity. But it cannot be denied that it may bring new challenges, such as the seafarers' failure to understand the operating mechanism of the intelligent system due to lack of knowledge, resulting in judgment errors or will lead to the degradation of seamanship and situational awareness.

But what is more challenging is the supervision of MASS, and the applicability of current international conventions and domestic laws to MASS, which needs to be systematically examined. When the ship autonomy is at the first and second degrees, the framework and rules of the current STCW can still be applied, but it may be necessary to provide flexible transitional rules for training and certification, and relevant knowledge and skills should be strengthened in the competency standards to adapt to the development of ship autonomy. For example, in the Manila amendments to STCW, such knowledge and skills such as Electronic Chart Display and Information System (ECDIS), Dynamic Positioning (DP), high-voltage power station above 1000V, management skills and leadership of senior officer are added. However, it is not true that by simply adding new knowledge and skills into the competency standard of STCW seafarers' competency for the work on MASS can be guaranteed. In the implementation and management of seafarers' education and training, there must be mandatory provisions to ensure the implementation effect of training and certification, or recommended guidelines for countries to establish their own seafarer training and management mechanism.

The intelligent ship or MASS discussed in the industry is basically based on "Big Data analysis", and uses advanced information technology, machine learning, AI and other technologies to realize the ship's information perception, autonomous decision-making and intelligent control. Ship "big data" comes from the application of information perception technology, that is, through various types of sensors, AIS, radar, ECDIS and weather instrument. It should also include underwater robots, drones, cameras, etc. to obtain information about the ship itself and the surrounding environment. The processing and transmission of data requires computers and communication networks, so the next revision of STCW may consider strengthening the training and evaluation of knowledge and skills related to sensor technology, computer technology, and network communication technology. Because automation may also have a negative impact on ship safety, such as reduced seafarers' practical ability, ineffective monitoring, wrong situational awareness, and over-reliance on technology. Therefore, it is necessary to strengthen trend analysis, critical thinking and emergency response capabilities. Seafarers' mental health also needs to be focused on, as they need to adapt to increasingly stringent monitoring from shore-based remote-control centers. Certainly, when revising the STCW Convention, we cannot just add new competence standards regardless of whether seafarers have sufficient time and energy to truly master them, but also need to eliminate outdated and redundant knowledge, preventing the traditional navigation and collision avoidance skills from being dangerously diluted, such as positioning with a nautical sextant.

In the transition stage from the second degree to the third degree of MASS, the number of seafarers on board will be correspondingly reduced. At this time, the definition and functions of the crew members such as the master, chief engineer and ship security guard may be greatly changed. The concept of a remote operator is new for degrees two and three of autonomy. Changes to establish definitions and provisions to include the "remote operator" can be made through the existing Convention processes and other flexibilities – through authorized equivalencies or amendments to the Codes or regulations. Because the factors of people's living can no longer be considered in the ship design, the structure and equipment of the ship will change fundamentally, and the accommodation for people and its corresponding ventilation, air conditioning and sewage system will also be reduced or eliminated. Therefore, the conventions and rules related to fire protection structure, life-saving facilities, anti-pollution equipment (such as marine sewage treatment system), marine galley equipment, ship safety alarm system will be changed. When MASS enters the third and fourth degrees, there will be no seafarers on board, and the navigation of the ship mainly depends on shore based remote control and autonomous navigation. For the unmanned ship, the "watchkeeping" at this time becomes remote monitoring. Seafarers as an occupation "disappeared" on board, and whether the watchkeeper or remote operator can be defined as "seafarer", these answers cannot be found in the current STCW Convention, maybe determined by MSC (IMO, 2020). If it is established that the remote operator is not a seafarer, it will be necessary to define the remote operator in terms of instruments other than the STCW Convention or in new instruments, as well as to define its functions and standards of competency. If determination that "remote operator is a seafarer", on-board training and function certification system of STCW will have a radical change.

3 NEW TECHNOLOGIES AND REGULATORY RULES

3.1 Marine Environment Protection

The measures of international shipping decarbonization can be discussed from four aspects: fuel, technology, operation and policy. Diesel engine is the main power plant of commercial merchant ship. Gas turbine, which is commonly used in surface warships and high-performance ships, and new energy power sources such as wind power, solar power and fuel cell, have positive development prospects, and cannot replace the dominant position of marine diesel engine at present. Alternative energy sources include LNG, biofuels, methanol and even nuclear fuel. As a measure of energy saving and emission reduction, waste heat recovery of main engine exhaust gas has been widely used in ships for such facilities as exhaust boiler, exhaust turbocharger and exhaust turbine generator. In recent years, wind-assisted propulsion such as Kite, Sail and Flettner Rotor. Flettner Rotor has also begun to attract attention. Flettner Rotor generates forward thrust through the Rotor's Magnus effect to provide power assistance to ship, and it is estimated that the main engine can achieve approximately 14% fuel savings. By means of diesel exhaust post-processing technologies, like Selective Catalytic Reduction (SCR) and Scrubber, and high-pressure common rail electronic-controlled fuel injection technology, emissions can be effectively reduced and fuel can be saved as well.

Reducing carbon and sulfur emissions to meet the convention's requirements may require a combination of measures, including using new fuels, improving technology, optimizing ship propulsion efficiency, and slow steaming. Container ships have experienced the development of large scale and high speed, but now more and more use slow sailing, because fuel consumption depends on the size and cruising speed of the ship (Notteboom & Cariou, 2009), and a 10% reduction in speed will result in a 19% reduction in fuel consumption (and hence CO2 emissions), as shown in Figure 5.

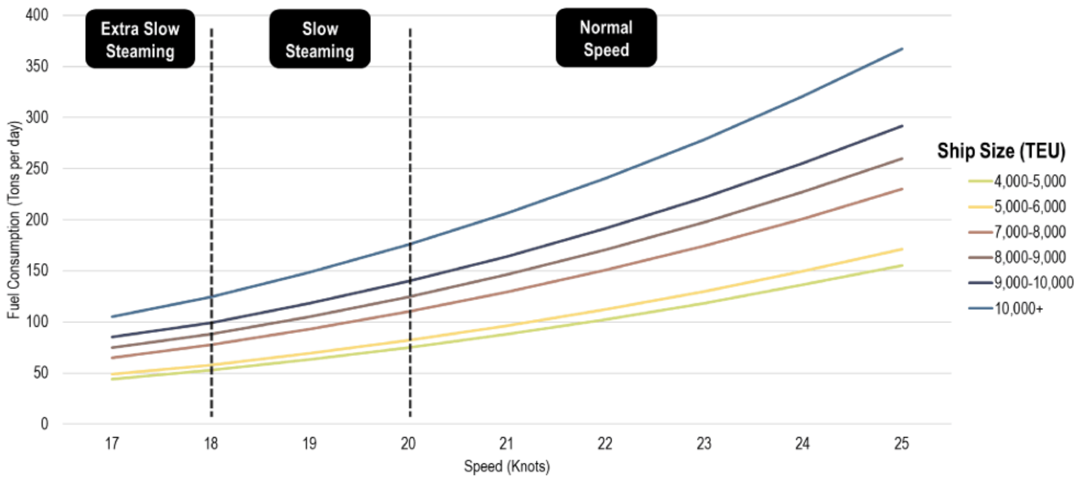

Figure 5 - Fuel Consumption by Containership Size and Speed

Source: Retrieved from https://transportgeography.org/

In addition, the use of shore power by ships is also an effective way to reduce the discharge of pollutants from ships. It is not only related to the construction of port shore power facilities, such as high-voltage shore power system, but also requires ships to have new shore power devices to connect and control.

On September 8, 2017, the Ballast Water Convention officially entered into force. Ships built on or after September 8, 2019 shall meet the ballast water performance standard, namely the D-2 standard, when delivered, and ships built before September 8, 2019 meet the D-2 standard in the first International Oil Pollution Prevention (IOPP) Certificate renewal inspection since that date. BWMS ballast water treatment units will also be gradually installed on sea ships, and the crew will need to master the knowledge and skills of BWMS operation, management and necessary maintenance. Ballast water treatment device and technology have been greatly developed in recent years. MASS installation of BWMS will face the problem of how to go through PSC inspection. The PSCO will board the ship for inspection, and then decide whether to take samples for indicative analysis or detailed analysis; or BWMS can automatically sample and analyze the data and then transmit it to an information system in each MoU, such as the Asia-pacific Port State Surveillance Information System (APCIS).The inspection of certificates and documents may be easy to achieve, but it is difficult for PSCO to check whether ballast water management is effectively conducted, whether BWMS lacks maintenance, and whether the working performance is normal through simple data transmission. Indicative analysis tools may be useful for port state control compliance checks and/or BWMS performance monitoring. A variety of indicative analysis tools have been developed that are highly differentiated in terms of portability, sampling and analysis capabilities, principles of measurement, and types of organism size detected. At present, there is no general method of indicative analysis tool for technical evaluation and verification, so its application to MASS still needs to remedy certain technical and management gaps.

3.2 Cyber Security

In recent years, some typical incidents of cyber security appeared in the shipping industry. Based on the urgent need to enhance the awareness of network risk threat, the IMO's MSC adopted the interim guidelines for maritime network risk management (MSC.1/Circ.1526) at the 96th session of the general assembly, and it was then replaced by the guidelines for maritime network risk Management (MSC-FAL.1/Circ.3) approved by the 98th session of the general assembly, providing guidance for the industry in dealing with ship cyber security. At the same time, according to the resolution MSC.428(98) - maritime network risk management in safety management system was adopted by the 98th Congress, which emphasizes that the company's safety management system should consider network risk management in combination with the objectives and functional requirements of ISM Code, and encourages Governments of all countries to check safety management no later than the first Document of compliance (DOC) initial audit, renewal audit or annual audit after January 1, 2021.

China promulgated the cyber security law on November 7, 2016, and it came into force on June 1, 2017. This is the first basic law in China to comprehensively regulate

Cyberspace Security Management. In addition, the national standard basic requirements for classified protection of cyber security (GB/T 22239-2019) was implemented on December 1, 2019, meeting the requirements of cyber security protection in new technologies and applications such as cloud computing, mobile Internet, IoT, industrial control and big data. In 2017, China Classification Society (CCS) issued the guidelines for ship network system requirements and safety assessment. Through the guidance on software, hardware and risk, it further conducted safety assessment on network status and network products to help the shipping industry prevent network risk. In 2020, it revised the 2017 version of the guidelines to regulate the design, construction and operation of ship network, make relevant management and technical personnel understand the importance of ship cyber security, and provide guidance for ship owner / ship management company, system developer, etc.

Although intelligent ship has great potential in saving energy consumption and reducing ship manning, and in recent years, it has become a hot spot in the shipping industry, but its safety problems cannot be ignored. Intelligent ships are highly dependent on computer, automatic control, network communication, artificial intelligence and other technologies, so hackers can not only attack ships' computer system, but also remotely control the satellite communication and navigation system, causing ships collide and even explode and sink. Intelligent cyber security includes preventing hackers from intruding into onboard system, control system and equipment; impeding interfering with satellite navigation communication and data transmission, preventing viruses from damaging onboard system, equipment and communication network; encrypting data information transmission, preventing key data leakage, etc.

CCS issued the first "ship cyber security compliance certificate" for a 13500 TEU intelligent container ship "COSCO SHIPPING LOTUS" on May 8, 2019. Cyber security can be strengthened from three aspects, one is human factor. No matter how complex the cyber security technology is, people are always the weakest link, in case the crews click the malicious link in the e-mail, or introduce the virus into the onboard equipment or system through USB. In addition, in the face of network attack or illegal intrusion, the professional knowledge and operation skills of security personnel are equally important, hence improving the basic awareness and professional knowledge of cyber security is indispensable. The second aspect is technology. The advanced cyber security technology is very important. The third aspect is management, which includes system maintenance and update, personnel authorization or access restrictions.

It is therefore highly recommended that the responsible crew members receive the training of cyber security capability and have the basic cyber security awareness. This is the focus of attention in the supervision process, and may be included in the list of issues revised by STCW Convention.

3.3 Port State Control and Typical Defects

Tokyo MoU releases their PSC Annual Report for 2019, the top three categories of deficiencies are fire safety measures, safety of navigation and life-saving appliances, basically the same trend as in 2018. The top 5 defects that cause detention in the PSC Annual Report 2018 of the Black Sea MoU are lifeboat, storage battery and switch for emergency lighting, fire detection and alarm system, navigation lights, emergency fire pump and its piping system. Among them, the defects of lifeboat grow year by year. The defects in the test records of batteries such as emergency lighting system and GMDSS equipment are obviously not caused by the equipment construction and technology, nor can they only be attributed to the lack of responsibility and knowledge of the crew.

The improvement measures should be to strengthen the training and management of the crew, some typical defects and recommended practices should be easy for the seafarers to learn and implement, and be effectively supervised; typical accidents and their root causes and barriers should also be easy for the seafarers to learn. The digitalization of knowledge and management (such as multimedia data, simulator, intelligent sensor, ship equipment maintenance management system, etc.) is an effective way to improve the quality of seafarer training and management.

For the three or four degree of MASS, the battery test function of GMDSS equipment shall be able to complete independently and synchronize the data into the test record. In order to ensure the safety of ships and protect the marine environment, ships should still be subject to port state supervision and other safety inspections. It is a possible way for MASS to automatically sense the key running parameters of ship equipment and system and transmit the data to PSCO for inspection when necessary. This is a possible way for PSC inspection of MASS. Of course, on-site inspection is also essential. At this time, how to define, what knowledge and skills should be mastered, and what responsibilities should be performed by the personnel receiving PSC inspection also need to be considered.

4 THE STANDARD OF COMPETENCE

This chapter will focus on the development of MASS technology. Automated systems for the possible operation and management of seafarers under each function are discussed. Then the requirements for seafarers' knowledge and skills will be specifically analyzed according to the seven functions of STCW Code, aiming at the four degrees of MASS. Finally, a suggestion for updating the ETO'S standard of competence is proposed.

4.1 Summary of Views on MASS from All Stokeholds

The STCW Convention is an international convention formulated to unify the standards of seafarer training, certification and watchkeeping in various countries to ensure the safety of marine vessels. The revision of the STCW Convention should firstly not restrict the development of technology. At the same time, because the development of MASS still counters many barriers in terms of technology, supervision, and infrastructure construction, its solutions will be at the stage of exploration and verification for an extended time. Therefore, the update of knowledge and skills, including training requirements still essential. The revision of the STCW Convention will most likely not begin until other relevant Conventions and industry standards have been revised for MASS, like International Convention for the Safety of Life at Sea (SOLAS), COLREG, SAR, International Electrotechnical Commission (IEC)'s digital interfaces series standards 61162. However, its applicability research and the updating of seafarers' knowledge and skills requirements are still of great significance, which can become a significant guide for seafarers' education and training and also will constitute the technical standards in many countries. The uneven maritime education resources of the Contracting States, and the nonuniform training standards result in uneven quality of seafarers. One possible solution to this problem is that the STCW Convention formulates mandatory provisions or recommended guidance to ensure the effectiveness of training and certification implementation. IMO should organize the development of digital maritime education resources and shares best practices. The IMO model course is an active exploration. With the development of Virtual Reality (VR) technology, multimedia technology, artificial intelligence technology, etc., training software can be conveniently developed and virtual training centers be established. For example, ship simulators based on VR technology can bring interactive, immersive seafarer knowledge, skills and scenarios awareness training, some dangerous emergency response procedures, such as the safety protection function of the main engine, boilers and other important equipment, wind and oil emergency cutoff, CO_2 release device and other emergency equipment safety tests can be simulated by VR technology too. In addition, accident lessons should be used effectively to improve seafarer training and education.

The STCW Convention is basically applicable to the first level of MASS. It can continue to retain the structure and objectives of the 1995 Amendment, not lower the standards of the 2010 Manila Amendment, on the basis of not modifying the main provisions. Add new competency standards, strengthen modern communication and navigation technology, computer technology, network communication and cyber security, sensors and their interface technology, artificial intelligence technology, ship energy-saving emission reduction and anti-pollution technology and situational awareness, decision-making, mental health, etc in the Part A and Part B of STCW Codes. Because some new automation equipment and systems will be added to the ship, such as ballast water automatic adjustment system, valve remote control system, etc., the company and maritime education and training institutions need to conduct corresponding operation and management training for seafarers.

For degree two of MASS, the following gaps exist in the STCW Convention, includes the definition, functions, qualification standards, training and certification of shore-based remote operators, and the supervision procedures of MASS. Some senior engineers and officers will be transferred to shore for remote monitoring and service support of MASS. The main responsibilities of shore-based operators should be to operate the ship remotely and handle part of the paperwork. The workload of seafarers will be reduced, but the manning level will also decrease. Repetitive, mechanized operations are easiest to be automated, but technologies and automation may generate new jobs. Therefore, some support-level seafarers may become redundant. They need to receive training and assessment of new knowledge and skills in order to adapt to the development of MASS and to meet the demands of the shipping industry. Probably in the shore-based remote control center, three MASS remote operators are needed from three channels: the navigation duty officer, responsible for remote control, condition monitoring and maintenance guidance of bridge navigation equipment; engine duty engineer, responsible for engine room equipment remote control, condition monitoring and maintenance guidance; and the company's duty officer, responsible for some documents, training and management on board. On the ship, seafarers mainly assist the shore-based remote operators to monitor the condition of the ship and equipment and check whether their decision is appropriate. The maintenance of the equipment is carried out according to the ship's repair and maintenance system, and the on-site repair is carried out when the fault occurs.

There are no seafarers on the third and fourth degree of MASS. The standards regarding the duty, supervision procedures, on-board training, health, training certificates and competency are not applicable to ship's remote operators. The STCW Convention needs to be comprehensively revised. At the third degree of MASS, the requirements for the knowledge and skills of the ship’s remote operators will be higher than the second degree of MASS. Good seamanship and situational awareness will be particularly important because they need to be based on various sensors, cameras, drones. A large amount of data collected by navigation instruments, etc. is processed and displayed by the artificial intelligence system, and the output is assisted in decision-making, and the ship is remotely operated to ensure navigation safety, equipment safety, network safety, and pollution prevention.

As for degree four of MASS, the ship's equipment and systems will make autonomous decisions and actions. However, ships still need shore-based service support, and will be under constant human supervision, especially in marine search and rescue operation, war requisition, or in case MASS make wrong decisions that endanger other ships, personnel, port and navigation facilities and the marine environment, or even when the network is hacked. The presence of seafarers on board may still be needed for passenger ships and nuclear fuel carriers, their main responsibility is to protect the safety of passengers and cargo.

4.2 Discussion on Updating of Seafarer's Knowledge and Skills

4.2.1 Navigation

Intelligent navigation refers to the analysis and processing of the sensed and obtained information by using computer technology, control technology to design and optimize the ship's route and speed; with the shore-based support center, ships can achieve automatic collision avoidance and autonomous navigation in open water, narrow waterways and complex environments conditions.

With the development of ship automation technology, the intelligent systems that may be developed and their functions at degree one of MASS are:

(1) Integrated bridge system and integrated energy efficiency management system can realize route design, and optimization of route, speed and trim.
(2) The improved degree of electrical automation of the ship's power plant and various ship's auxiliary machinery, can achieve part of the intelligent condition monitoring. Not only the alarm information and operating status are displayed on the computer, but also simple health assessment and fault diagnosis can be achieved, which provide decision support for operation and maintenance.

At degree two of MASS, subsystems such as intelligent navigation, intelligent hull, and intelligent engine room should be initially developed, and shore-based remote-control centers should be established to achieve remote communication with ships:

(1) The intelligent navigation subsystem uses GPS, AIS, radar, ECDIS and other navigation instruments, automatic route design, automatic collision avoidance and autonomous navigation are realized.
(2) The intelligent hull subsystem can monitor the hull status and navigation performance of the ship through various sensors, including structural stress, anti-fouling and anti-corrosion coating, draught, stability, anti-sinking, rapidity, rolling, maneuverability, etc. It can provide decision support for hull maintenance, cargo loading and unloading, ballast water adjustment, fuel oil/bunkering or fresh water supply and other operations.
(3) Under the intelligent engine room subsystem, the automatic control and status monitoring of other electromechanical equipment such as propulsion control, power station automation, auxiliary boilers, etc. are realized. The shore can remotely operate some equipment and some electromechanical equipment failures can be automatically isolated or repaired, automatically transferred to standby control, and guide the crew to do the repair work.

At degree three of MASS, the ship is combined with shore-based remote control and autonomous navigation:

(1) Automatically perform the course and speed setting, positioning and other operations, with the help of shore-based support center, to achieve ship manipulation and equipment operation under various conditions, such as the automatic retracting and releasing of pilot ladders, automatic docking and undocking, automatic operation of winches and fenders.
(2) Remote operators in shore-based remote-control centers need to master the remote operation of ship-related equipment, and be able to perform safety inspections and

maintenance of ships by controlling intelligent robots, drones, and underwater vehicles.

At degree four of MASS, ships can navigate autonomously. In case of emergency such as fire or collision, an alarm can be sent to the shore-based remote-control center, and emergency response can be completed correctly, safety equipment can automatically operate to control damage.

In summary, in the navigation function, the deck officer needs to adapt to the digital development of the ship, master the skills of system operation and maintenance, and have knowledge of computer operation and maintenance, sensors and their interface technology, database, communication technology and cyber security in case the system may crash or data may lose due to improper operation. Meanwhile, the deck officer should be capable of mastering the operation of drones, robots, and underwater vehicles.

4.2.2 Cargo Handling and Stowage

At degree one of MASS, the possible intelligent systems and functions to be developed include:

(1) Cargo tank condition monitoring, including temperature, humidity, liquid level, pressure and other parameters, and automatic control of cargo tank ventilation, fire extinguishing system, and inert gas system of oil tanker cargo tank.
(2) Through data fusion and simulation calculation of relevant sensors, the information of ship stability and hull strength is given, which helps seafarers to make decisions and carry out appropriate operations, such as ship ballast water regulation, cargo loading optimization, etc.

At degree two of MASS, an intelligent goods management subsystem should be developed, which can realize the following functions:

(1) Condition monitoring, stowage optimization, securing and protection of cargo, including dangerous cargo.
(2) Structural strength monitoring and performance calculation of cargo tank, hatch cover and ballast tank.
(3) Remote control and automatic operation of cargo winch through network communication technology and automation technology.

At degree three of MASS, the functions to be realized include:

(1) Automatic or remote control of cargo to realize handling, stowage optimization and fastening functions.
(2) The shore based remote control center can monitor the cargo hold, cargo, ship stability, ship strength and other conditions in real time.

At degree four of MASS, realized functions include:

(1) Cargo hold and cargo monitoring alarm, automatic handling, cargo stowage, cargo automatic fastening and other functions.
(2) Condition monitoring, defect and damage automatic assessment and independent decision-making of cargo tank, hatch cover and ballast tank.

To sum up, the cargo loading, unloading, transportation and fastening equipment are most likely to be operated automatically, and the development of its condition monitoring and trend prediction technology will be gradually improved. Seafarers need to master the operation and maintenance skills of the intelligent system, and can effectively comprehend the condition monitoring and auxiliary decision-making information output by the system.

4.2.3 Controlling the Operation of the Ship and Care for Persons on Board

At degree one of MASS, the functions to be realized include:

(1) Collect the ship status data through sensors, such as the draught, stability, sailing attitude, and the use volume of oil tank, ballast tank, water tank. Then through information fusion technology and computer simulation technology to intelligently assess ship status and stability, instruct seafarers to take correct operating procedures.
(2) Develop an intelligent document management system for documents such as ship certificates, crew certificates, and equipment certificates to facilitate reference and reduce paperwork. Develop an intelligent management system for ship materials and spare parts, including medical devices, medicines, and food.
(3) Maintain effective electronic records of anti-pollution equipment and safety equipment working status, operation, maintenance and inspection.
(4) Establish intelligent management system for drills such as fire fighting, life saving, oil spill, plugging, security, and abandon ship, which can clearly show the content of the exercise to the seafarers, so that the seafarers can clarify their responsibilities. The system should also include the formulation of emergency response plans and the handling of emergency situations.
(5) Apply virtual reality technology to simulate the emergency situation of ships and guide seafarers' stop loss and rescue actions; meanwhile, develop an immersive training system for leadership and management skills using virtual reality technology to improve seafarers' leadership and management skills.

At degree two of MASS, functions to be realized may include:

(1) Intelligent ship operation management and crew management. Shore based remote control center can monitor and control effectively.
(2) Realize intelligent management of ship drill, state monitoring and automatic control of life-saving, fire-fighting and other safety systems.

(3) Intelligent management of ship drills, condition monitoring and automatic control of life saving, fire fighting and other safety systems.

At degree three of MASS, the automation of ship operation management, crew management and medical management under the intelligent integrated platform may be realized.

At degree four of MASS, the control of the unmanned ship and cooperate with other rescue units by the shore-based remote-control center when search and rescue and medical services is needed for a manned ship in distress at sea. When the wounded are rescued, the configuration data of the ship's medical resources and remote guidance can also be provided.

To sum up, in ship operation management and personnel management functions, seafarers still need to master the knowledge and skills of operation and personnel management required by STCW Convention. Intelligent equipment and system mainly play the role of assisting decision-making and improving operation and management efficiency. In the third and fourth degree of MASS, the operation and personnel management of the unmanned ship are transferred to the shore based remote control center. Seafarers need to correctly understand the information of state monitoring and auxiliary decision-making output by the intelligent system, and correctly allocate relevant resources to achieve the safety management of the ship.

4.2.4 Marine Engineering

At degree one of MASS, functions to be realized may include:

(1) Application of information sensing technology in engine room equipment, including main propulsion plant and other auxiliary equipment. Sensing equipment status information such as speed, pressure, temperature, viscosity, liquid level,

differential pressure, flow, current, voltage, power, frequency, insulation resistance, etc., to assist seafarers to carry out the management and condition monitoring and fault diagnosis of engine room facilities.

(2) In response to sulfur emission restrictions on ships, new low-sulfur fuel oil supply systems, scrubber, and dual-fuel engines or gas engines fueled by LNG may be added.

(3) Seafarers should master the basic knowledge of sensor technology and automation technology, and complete the judgment of sensor status, maintenance, replacement and calibration, etc.; and master the engine room facilities automatic control, can carry on the fault diagnosis and repair work.

At degree two of MASS, through the information perception technology of the main propulsion power unit and auxiliary equipment, according to the decision input (such as expert system), to achieve equipment failure prediction, evaluation and diagnosis. With the decision support of the intelligent engine room subsystem and the shore-based remote-control center, seafarers complete the necessary maintenance and repair work, such as the disassembly and cleaning of valves, pumps, and motors, and the repair and replacement of defective components.

At degree three of MASS, functions to be realized may include:

(1) The condition monitoring, fault diagnosis, automatic control, remote control, maintenance plan development of the main engine and auxiliary equipment.

(2) Interconnecting with the intelligent energy efficiency management subsystem, through the evaluation of the ship's energy efficiency status, navigation and loading status, to achieve the optimal management of fuel refueling, conversion, main engine power, speed, etc.

At degree four of MASS, functions to be realized may include:

(1) The condition monitoring, fault diagnosis, automatic control and management of

the engine room equipment, including the main propulsion power equipment and auxiliary equipment, for example, it can automatically switch to the backup system, and the dirty and blocking parts can be automatically cleaned.
(2) Through artificial intelligence technology, automatic control technology, etc., simple fault repair and replacement of spare parts are done by the robot autonomously and remotely.

To sum up, seafarers need to acquire knowledge of the principle and operation management of dual-fuel engine, scrubber and ballast water treatment unit as well as skills of maintenance and repair. The automation degree of main power plant, auxiliary machinery, deck machinery and so on will increasing, and with the improvement of technology, its reliability will also be growing. Therefore, the engineer needs to know the alarm information, the actions to be performed and the safety protection when the sensors on the main equipment fail. Seafarers need to have a correct understanding of intelligent equipment and system output condition monitoring and decision support information, be able to operate equipment and systems remotely, and be able to remotely guide and control robots for maintenance work.

4.2.5 Electrical, Electronic and Control Engineering

At degree one of MASS, functions to be realized may include:

(1) The engine room monitoring and alarm system, based on understanding the operation of the mechanical engineering system, applying information perception technology, mainly using sensors, information processors and communication networks to obtain various useful data to assist in decision-making of operation of mechanical equipment and the formulation and implementation of maintenance plan.
(2) Seafarers need to master the maintenance of automatic control equipment and sensors; the setting of alarm and control parameters, the maintenance of databases, etc.
(3) Seafarers need to master the working principle and electrical control of diesel

engines and new equipment for energy saving and emission reduction, such as electronically controlled engines, SCR, Exhaust Gas Recirculation (EGR), Scrubber system, LNG engine, waste heat recovery system.

(4) Maintenance and management skills of valve electric drive unit in valve remote control and liquid level telemetry system. Drones, intelligent robots and Autonomous Underwater Vehicle (AUV) are also expected to be widely used, and seafarers need to master their maintenance and simple fault repair skills.

(5) Ship power management system (PMS), to achieve diesel unit control, monitoring and protection; generator automatic synchronization and parallel operation; standby unit management; load distribution; frequency and voltage control; power limitation; stage unloading and automatic stage start; heavy load inquiry ; The generator set is automatically disengaged; the whole ship loses power control, etc.

(6) For ships with shaft generators and exhaust gas turbine generators, corresponding functions of automatic control, condition monitoring and energy optimization management are added.

(7) For electric propulsion ships, it also includes electrical energy feedback control; for micro-grid ships, it also includes energy storage device management, optimal dispatch, power generation, and load power prediction.

(8) Knowledge base for safe operation and management of high-voltage power stations.

At degree two of MASS, functions to be realized may include:

(1) The intelligent engine room subsystem monitors the state of the main propulsion power unit and auxiliary machinery in the engine room through information perception technology, and transmits it to the shore-based remote control center through network communication technology, through big data technology, expert system, and information fusion technology Etc., to diagnose the operating status and health status of machinery and equipment, assist in decision-making, and conduct remote control operations by shore-based platforms, or guide seafarers to operate, maintain, and repair.

(2) The ship's power management system PMS is intelligent, and the shore-based

remote-control center realizes data transmission and remote control through network communication technology. Operation status monitoring and safety protection function of power supply system above 1kV (high voltage power station).

At degree three of MASS, the functions realized may include:

(1) The intelligent engine room subsystem monitors the state of the machinery equipment and electrical control system of the engine room, assists in decision-making, and is remotely controlled by the shore-based platform to complete the necessary operations and management.
(2) The interconnection and interconnection of the ship's power management system PMS and other intelligent subsystems of the ship, such as the intelligent energy efficiency management subsystem and the intelligent navigation subsystem, optimize fuel consumption, emissions, and economic benefits, and control the increase and decrease of the generator set and load.

At degree four of MASS, the condition monitoring and independent operation of the mechanical equipment and electrical control system of the engine room will be realized, and the necessary control and maintenance management can be completed.

In summary, the digitization and autonomy of ships will have increasingly higher requirements for electrical, electronic and control engineering functions. In addition to knowledge of sensor technology, automatic control technology and artificial intelligence technology, seafarers also need to master databases and network communications, Software maintenance and management skills.

4.2.6 Maintenance and Repair

At degree one of MASS, functions to be realized may include:

(1) Develop an intelligent management system for the maintenance and repair of ship systems and equipment, detect and identify machine faults through the support of equipment status, knowledge base and expert system sensed by sensors, and initially formulate maintenance and repair plans for ship systems and equipment to assist seafarers make decisions, perform actual maintenance and repair work, and make records to form reports.
(2) The status of all emergency and safety equipment, the requirements for use, and the process of automatic control are displayed in the engine room safety system, including the engine room water mist fire extinguishing system, watertight doors, and wind oil emergency cutoff. , Emergency operation of the main engine, oil-water separator, incinerator, lifeboat winch, liferaft crane, etc.

At degree two of MASS, functions to be realized may include:

(1) The intelligent engine room subsystem, intelligent hull subsystem, etc. are interconnected with the shore-based remote-control center to achieve safe and effective management of ship maintenance and repair procedures through big data technology, sensor technology, computer technology, network communication technology, etc. The established maintenance and repair procedures need to integrate the data of ship spare parts and materials inventory, application and consumption.
(2) Simple maintenance and repair work can be performed by the equipment itself, shore-based remote-control center control or intelligent robot.

At degree three of MASS, the intelligent engine room subsystem, intelligent hull subsystem and shore-based remote-control center are interconnected to realize the management and execution of ship maintenance and repair procedures.

At degree four of MASS, the management and execution of ship maintenance and repair procedures will be realized in an intelligent integration platform.

In summary, in the maintenance and repair functions, seafarers mainly add new understanding of the composition and working principles of various smart devices and systems, and master the skills of fault diagnosis and repair. With the development of equipment condition monitoring and fault diagnosis technology, Seafarers need to analyze and implement the status and auxiliary decision information output by the system. During the third and fourth degrees of autonomy, seafarers perform "on duty" at the shore-based remote-control centers, and can analyze the vibration, noise, electromagnetic signals, images, video and other data transmitted from the equipment through professional knowledge and diagnose the fault. It can control the operation of the maintenance robot, complete the repair work, or carry out on-site maintenance by professionals.

4.2.7 Radiocommunications

At degree one of MASS, functions to be realized may include developing electrical and electronic technology, radio communication technology, principles, operation and maintenance of GMDSS communication equipment, maritime mobile business, distress, emergency, safety communication and other knowledge and skill learning software. The exercise system can effectively supervise and form learning feedback.

At degree two of MASS, functions to be realized may include data communication between shore-based and GMDSS equipment is realized. The shore-based remote-control center can guide seafarers or remote-control operations to achieve distress, emergency and safety communications.

At degree three of MASS, functions to be realized may include distress alarm, search and rescue coordination communication, search and rescue on-site communication, positioning, and maritime safety information broadcast by the GMDSS system implemented by the ship and shore-based remote-control center.

At degree four of MASS, functions to be realized may include implementing effective communication of emergency disposal procedures and methods to protect the safety of ships and equipment under the intelligent integrated platform.

In summary, with the development of ship's radio communication technology, GMDSS equipment will implement autonomous or remote-control operation to achieve ship distress alarm. In addition to mastering the operation and management of GMDSS equipment, seafarers may have major changes in other communication and navigation equipment. Their operation, maintenance and management skills also need to be mastered. In addition, knowledge and skills to ensure communication safety need to be strengthened.

4.3 Suggestion for Updating the ETO'S Standard of Competence

New training and certification requirements for electro-technical officers are an important part of the Manila amendments to the STCW Convention and Code. The technological development of MASS is inseparable from computer technology, automatic control technology, big data analysis technology, artificial intelligence technology, etc. Especially electric propulsion may be the key to the realization of MASS, including high-power fuel cells, photovoltaic cells, wind power, and inverter, soft switching technology, super capacitor, high voltage power system, high power permanent magnet synchronous motor and multi-phase motor and their fault-tolerant control. These technologies are closest to the knowledge and skills required in the Knowledge, understanding and proficiency (KUP) Table for electro-technical officers. The electro-technical officers are most likely to meet the operational requirements of MASS by strengthening relevant knowledge and skills training. Therefore, this paper takes the KUP Table for Electro-Technical Officer as an example and puts forward specific revision suggestions.

Function: Electrical, electronic and control engineering at the operational level

Referring to the competence of monitoring the operation of electrical, electronic and control systems, the working principle and electrical fault repair of the valve remote control and liquid level telemetry system, automatic winch, and electric propulsion system. And emphasize the importance of sensor technology, computer technology, and communication technology; master the relevant control system database, operation software maintenance and management skills.

Referring to the competence of operating computers and computer networks on ships, Emphasis should be placed on the operation and maintenance of intelligent sensors, industrial control networks and the IoT, as well as the knowledge and skills to protect cyber security.

Functions: Controlling the operation of the ship and care for persons on board at operational level

Referring to the competence of contributing to the safety of personnel and ship, knowledge of ship structure and navigational performance should be increased, as well as emergency responses such as collision, grounding, loss of control and personnel overboard.

Section B-III/6 Guidance regarding training and certification for electro-technical officers

It is suggested to add the following, that "Parties are encouraged to integrate the components, functions, standards, techniques and maintenance of the Integrated Bridge System (IBS) into their training programmes".

5 SUMMARY AND CONCLUSIONS

The review of international maritime conventions has just started, the application of intelligent systems is still limited, and the global MASS are still in the stage of exploration and initial development. To what extent automation will be applied to the ship's operating system, or which functions are being automated is not yet clear, and may evolve as technology advances. And other conventions must first determine the gap between the current provisions and the operations, cargo handling, and emergency response of MASS before they can determine the extent to which STCW regulations are revised. This does not mean that the articles of STCW Convention must be amended, as bringing any such amendment into force would usually involve a long delay and would not be the most appropriate or practical way to address the potential gaps identified. However, it is still necessary to sort out the knowledge and skills of seafarers, which can provide guidance for the education and training of seafarers to adapt to the development of maritime technology and regulation.

It is recommended to study the definition, functions and competency standards of remote operators of MASS as soon as possible. At the same time, nautical major students are encouraged to actively participate in scientific research projects, academic competitions, open classes, and incorporate multidisciplinary knowledge such as the IoT, sensor technology, and big data analysis into their training programs.

MASS may face the negative effects of automation on ship safety, such as reduced seamanship, ineffective monitoring, wrong situational awareness, and excessive reliance on technology. These cannot be solved simply by revising the STCW Code. And ship accidents have shown that it is no longer convincing to believe that seafarers are capable of performing operations simply because they have a Certificate of Competency (CoC). The government and maritime education institutions should increase investment in policies and resources to provide advanced talent training models, teaching platforms and laboratories. Attention should be paid to training in English communication, marine pollution prevention, situational awareness, and emergency response capabilities. The VR technology should be widely applied to seafarers' education and training to solve the problems of huge cost, high risk and difficulty in repeated training.

The company should also provide adequate training for seafarers and carry out extensive cooperation with educational and training institutions. It is necessary to ensure that seafarers operate and maintain ship equipment safely, especially important navigation equipment and safety systems, rather than just filling in untrue training records. The cost of training is not on the same order as the economic loss of the ship in the event of an accident, seafarers are not cheap labour for companies but key workers to make shipping more competitive.

REFERENCES

Alfheim, H. L., Muggerud, K., Breivik, M., Brekke, E. F., Eide, E., & Engelhardtsen, Ø. (2018). Development of a dynamic positioning system for the revolt model ship. *IFAC-PapersOnLine*, *51*(29), 116-121.

Amato, F., Fiorini, M., Gallone, S., & Golino, G. (2011). e-Navigation and future trend in navigation. *TransNav, International Journal on Marine Navigation and Safety od Sea Transportation*, *5*(1).

Authority, D. M. (2017). Analysis of Regulatory Barriers to the Use of MASS Final Report.

Baldauf, M., Kitada, M., Mehdi, R., & Dalaklis, D. (2018, March). E-Navigation, digitalization and unmanned ships: Challenges for future maritime education and training. In *Proceedings of the 12th International Technology, Education and Development Conference, Valencia, Spain. doi* (Vol. 10).

Blanke, M., Henriques, M., & Bang, J. (2017). A pre-analysis on MASS . *Danish Maritime Authority report*.

Chircop, A. (2019). Maritime Autonomous Surface Ships in International Law: New Challenges for the Regulation of International Navigation and Shipping. In *Cooperation and Engagement in the Asia-Pacific Region* (pp. 18-32). Brill Nijhoff.

Emad, G. R., Khabir, M., & Shahbakhsh, M. (2020). Shipping 4.0 and Training Seafarers for the Future Autonomous and Unmanned Ships.

Fan, Y.Z. (2015). China classification society issues code for intelligent ships. *Guangdong Traffic (6)*.

Federation, N. (2018). Future Proofed? What Maritime Professionals Think about Autonomous Shipping.

IMO. (2020). MSC 102/5/17, *Summary of results of the second step of the RSE for STCW Convention and Code Submitted by the United States*. Maritime Safety Committee on its 102th Session. London.: International Maritime Organization.

Jokioinen, E., Poikonen, J., Jalonen, R., & Saarni, J. (2016). Remote and MASS -the next steps. *AAWA Position Paper, Rolls Royce plc, London*.

Kretschmann, L., Burmeister, H. C., & Jahn, C. (2017). Analyzing the economic benefit of unmanned MASS : An exploratory cost-comparison between an autonomous and a conventional bulk carrier. *Research in transportation business & management*, *25*, 76-86.

Maritime, K. (2017). Autonomous ship project, key facts about YARA Birkeland.

Norwegian, N. F. A. S. (2017). Definitions for Autonomous Merchant Ships.

Perera, L. P. (2018). Autonomous Ship Navigation under Deep Learning and the challenges in COLREGs. In *ASME 2018 37th International Conference on Ocean, Offshore and Arctic Engineering*. American Society of Mechanical Engineers Digital Collection.

Porathe, T., Hoem, Å., Rødseth, Ø. J., Fjørtoft, K., & Johnsen, S. O. (2018). At least as safe as manned shipping? Autonomous shipping, safety and "human error". *Safety and Reliability–Safe Societies in a Changing World. Proceedings of ESREL 2018, June 17-21, 2018, Trondheim, Norway*.

Register, L. (2016). Cyber-enabled ships: Deploying information and communications technology in shipping. *Lloyds Register's approach to assurance*.

Rødseth, Ø. J. (2018). Assessing business cases for autonomous and unmanned ships. *Technology and Science for the Ships of the Future. Proceedings of NAV*, *2018*, 19th.

Schröder-Hinrichs, J. U., Song, D. W., Fonseca, T., Lagdami, K., Shi, X., & Loer, K. (2017). Transport 2040: Automation, Technology, Employment-The Future of Work. *World Maritime University, Malmö, Report*.

Senčila, V., & Kalvaitienė, G. (2019). Industry 4.0: Autonomous Shipping and New Challenges for Maritime Education and Training.

Yao, L. (2019). Research Status and Development Trend of Intelligent Ships. *International Core Journal of Engineering, 5(11),* 49-57.

APPENDICES

Appendix 1 Revision of KUP Table for Electro-Technical Officers

Table A-III/6

Specification of minimum standard of competence for electro-technical officers

Function: Electrical, electronic and control engineering at the operational level

	Column 1	Column 2
	Competence	**Knowledge, understanding and proficiency**
Originals	Monitor the operation of electrical, electronic and control systems	*Knowledge of:* Electro-technology and electrical machines theory Fundamentals of electronics and power electronics Electrical power distribution boards and electrical equipment Fundamentals of automation, automatic control systems and technology Instrumentation, alarm and monitoring systems Electrical drives
Amendments		**Adding:** Sensor principle and technology Fundamentals of Internet of Things and Information and Communication Technology

		Fundamentals of database and software maintenance
Originals	Operate generators and distribution systems	Coupling, load sharing and changing over generators Coupling and breaking connection between switchboards and distribution panels
Amendments		**Adding:** Emergency management of ship power station, including blackout, bus bar short circuit, emergency generator failed to start, etc Control and management of lead acid batteries, fuel cells, photovoltaic, ultracapacitors, all-electric propulsion systems
Originals	Operate computers and computer networks on ships	Understanding of: .1 main features of data processing .2 construction and use of computer networks on ships .3 bridge-based, engine-room-based and commercial computer use
Amendments		**Adding:** .4 sensors, smart sensors and wireless sensor networks, industrial control networks, and the Internet of Things use .5 Knowledge and contingency planning to reduce any potential cyber risks

Function: Controlling the operation of the ship and care for persons on board at operational level

	Column 1	Column 2
	Competence	**Knowledge, understanding and proficiency**
Originals	Contribute to the safety of personnel and ship	Knowledge of personal survival techniques Knowledge of fire prevention and ability to fight and extinguish fires Knowledge of elementary first aid Knowledge of personal safety and social responsibilities
Amendments		**Adding:** Knowledge of ship's structure and navigational performance Knowledge of emergency responses to collision, grounding, loss of control and personnel overboard, etc.