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Study on the development of MASS based on safety

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STUDY ON THE DEVELOPMENT OF MASS BASED ON SAFETY

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.

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Date: June 28, 2019

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ABSTRACT

Title of Dissertation: **Study on the development of MASS based on safety**

With the emergence of new ideas such as artificial intelligence, cloud computing, big data, and the Internet of Things, and the rapid development of new technologies. The Maritime Autonomous Surface Ship (MASS) has become a focus in the shipping industry, and many countries have launched technical research on the MASS. Under the current research results, the development of The Maritime Autonomous Surface Ship has been technically feasible, and its emergence is also the trend of the times. The International Maritime Organization (IMO) has also defined and graded MASS. However, as a product of the intelligent age, the large data and intelligent revolution contained in the Maritime Autonomous Surface Ship will inevitably break the existing rules of the shipping industry and affect the interests of shipowners, crew members and even the global economy and the whole water environment. As a typical traditional manufacturing industry, on the one hand, AI will bring it higher production efficiency and lower cost; on the other hand, AI will reduce or even replace the traditional manual operation and subvert the traditional ship technology, which has a huge impact on the relevant practitioners and relevant laws. Its reliability and safety have aroused many doubts.

The existing concerns and doubts in the industry have raised the development of MASS to an ethical perspective. In general, the emergence of MASS will bring huge benefits to people, and even the benefits outweigh the risks, but we still need to reduce the risk brought by MASS to lowest. This paper discusses with the DRAFT ETHICS GUIDELINES FOR TRUSTWORTHY AI issued by the European Union (EU), and proposes that the development of MASS should be based on safety. This

paper will discuss the development of the MASS based on safety in three parts. Firstly, the development of the MASS in different countries will be analyzed. Then explore the impact of the MASS on existing conventions, and how to ensure the safe operation by improving and proposing conventions. Finally, how to develop the technology under the guidance of relevant conventions and regulations to ensure the safe development and operation of the Maritime Autonomous Surface Ship.

KEY WORDS: MASS, shipping industry, AI, safety, Ethics, conventions and regulations, technology

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LIST OF ABBREVIATIONS

ADAS	Advanced Driving Assistance System
AI	Artificial Intelligence
BIMCO	The Baltic and International Maritime Council
EEDI	Energy Efficiency Management Index
GHG	Greenhouse Gas
IACS	The International Association of Classification Societies
IMO	International Maritime Organization
MASS	The Maritime Autonomous Surface Ship
MLC	Maritime Labour Convention
MOU	Memorandum Of Understanding
MSC	Maritime Safety Committee
MUNIN	Maritime Unmanned Navigation through Intelligence in Networks
PSC	Port State Control
SOLAS	International Convention for Safety of Life at Sea
STCW	Standards of Training,Certification and Watch keeping for Seafarers

CHAPTER 1

INTRODUCTION

1.1 Background

In June 2019, China's autonomous navigation test ship ZHITENG successfully demonstrated autonomous navigation and autonomous collision avoidance, which is also the first autonomous navigation ship collision avoidance test in China. This demonstration marks a remarkable progress in the development of the highest-degree autonomous navigation ships in China. On the other hand, ZHITENG is the first autonomous navigation test ship in China that meets the requirements of the International Maritime Organization (IMO) for The Maritime Autonomous Surface Ship (MASS). The ZHITENG is 21 meters long and 5.4 meters wide and has a design speed of 14 knots. It is equipped with the intelligent situation awareness system, autonomous navigation decision-making system and autonomous driving control system which are necessary for autonomous ocean-going ship. At the same time, it also built a ship-to-shore communication system and a big data system, and built a shore-based control center simultaneously. These technical conditions enable the ZHITENG to have the functions of autonomous navigation, automatic collision avoidance, underwater collision avoidance, autonomous berthing or departure, and remote control. ZHITENG has reached the degree 3 of MASS “no seafarers on board”.(Liu, 2019) In the future, it will further meet the degree 4 “fully autonomous”. After that, the related technologies will be applied to 300TEU, 500 TEU and 800TEU autonomous navigation container ships.

With the rapid advancement of new science and technology, the degree of ship automation is constantly improving. The idea of replacing seafarers with high-tech intelligent systems, improving shipping safety and reducing shipping costs has been support by science and technology at present. The Maritime Autonomous Surface Ship (MASS) is a new darling of the shipping industry. It is moving towards the shipping market step by step, and it has brought about a revolutionary storm in the shipping industry. But the emergence of new things is bound to accompany the destruction of old things. The emergence of MASS will inevitably have a huge impact on the traditional shipping industry. For example, it has hit the labor market, causing many laid-off workers to be laid off, and will also break the original regulations. It will be difficult to judge the attribution of responsibility once an accident occurs and so on. Faced with such a change, many questions about the ethical issues of MASS have begun to appear. The Artificial Intelligence (AI) of MASS is only based on the intelligence of big data. Compared with the manual control of traditional shipping, it lacks rational judgment and emergency handling. Can it become "intelligent" when it encounters a situation outside the program?

1.2 Objectives of the paper

While the Maritime Autonomous Surface Ship (MASS) promotes the development of the shipping industry, the uncertainty in its emergence and use will bring new challenges to ethics. There is even a new round of ethics and morality crisis. In the face of this dilemma, while vigorously developing MASS research, we need to consider a series of problems it may bring: impact on social employment, inaccurate judgment of social responsibility, violation of personal privacy and property, and most importantly, the safety of ships in the shipping process. The ethical concerns

caused by MASS have also been raised in other AI products, such as unmanned vehicles and unmanned aircraft. On April 8, 2019, the EU proposed DRAFT ETHICS GUIDELINES FOR TRUSTWORTHY AI. (Zhong, 2019) The newly released ETHICS GUIDELINES lists some key conditions and two essential components for TRUSTWORTHY AI. This paper attempt to combine the DRAFT ETHICS GUIDELINES FOR TRUSTWORTHY AI to discuss the security development of the Maritime Autonomous Surface Ship (MASS) in both regulatory and technical aspects. On the one hand, to explore the impact of the emergence of MASS on existing conventions, whether it is necessary to improve the regulations that are currently not applicable, and whether it is necessary to establish new regulations to ensure the safe navigation of MASS. On the other hand, how to develop MASS technology under the guidance of relevant regulatory conventions to ensure safe navigation. Through these two aspects to break the ethical doubts generated by MASS and reduce the possible security problems. In the end, point out how to develop the Maritime Autonomous Surface Ship based on safety.

CHAPTER 2

THE DEVELOPMENT STATUS OF MASS

2.1 The Concept of MASS

In the era of Industry 4.0, all things are connected to each other through the Internet, and Intelligence develops rapidly. A series of unmanned transportation such as unmanned aircraft and vehicles. have entered people's field of vision. In terms of shipping, an automation revolution is rapidly developing. It is The Maritime Autonomous Surface Ship (MASS). As an intelligent product, MASS is different from traditional ships. It uses computer's Artificial Intelligence (AI), big data and cloud computing to reasoning, calculate and data analysis to realize the application of decision-making system and remote control system, so that ships can still sail on the water without boarding crew. Here is a brief introduction to AI, big data and cloud computing:

In the current development, intelligent technology is also known as "ABC". A stands for artificial intelligence (AI), B stands for Big Data, and C stands for Cloud Computing. They also represent the reasoning ability, data analysis ability and computing ability of computers.

Artificial Intelligence (AI). In 2016, an artificial intelligence robot (AlphaGo) defeated Korean Go player 이세돌 in a Go game. It is also the first time that AI has shown the world its ability to crush human thinking patterns. At present, AI technology can be divided into two branches: one is the deep learning technology represented by AlphaGo, which is the artificial neural network generated by imitating

the thinking structure of human brain with brain science and technology; the other is the intelligent learning technology which advocates "learning" instead of "building the brain". There are essential differences in the understanding of AI between the two groups of researchers. They are also called "Structuralism" and "Functionalism" by the industry. The current development of MASS focuses on the former, that is, the use of neural networks to judge and analyze the surrounding conditions of ships, but the ability to learn and judge abnormal emergencies is relatively weak, which also makes the safety of MASS questioned. (Buntz, 2018)

Big data. Big data is the huge amount of data generated and recorded by human beings through the Internet and the Internet of Things. IDC Digital Universe report shows that by 2020, the global per capita will produce 5,000 GB of new data, but the distribution of these data is very uneven. The more developed areas of the Internet and the Internet of Things generate more data, the more likely China and the United States will monopolize half of the world's data. This phenomenon will inevitably lead to imbalances in the development of MASS in different countries. Countries with more data will have more advanced ship technology and gain more benefits from it. Such imbalances will also bury hidden dangers for economic and political contradictions, which is also one of the ethical issues to be considered. On the other hand, the advantage of more data is that when the amount of data exceeds a certain level, it presents another aspect of the world for human beings. With more data, people can see information that they could not see before. But there is another characteristic of big data, which is difficult to deal with. When the data is large enough to exceed the storage and processing capacity of a computer, it is likely that "crash" will occur. This problem will cause devastating consequences if it occurs on a ship that is on the voyage. At the same time, the security of huge data is also worth considering. Perhaps we need to rely on such big data analysis technologies as

distributed computing to better deal with excessive data. On the other hand, we also need effective anti-hacker and data protection technology.

Cloud computing. Cloud computing solves the huge computing needs of every industry and even everyone in the future. Cloud computing platform is not so much a new technology as a new infrastructure. Cloud computing is a deep integration of many traditional technologies, such as distributed computing, parallel computing, utility computing, grid storage, hot standby redundancy, load balancing and so on. These traditional technologies work together to manage computing problems in a way similar to company operations, so that computing can be upgraded from manual workshops to assembly line production, and the cost of computing can be greatly reduced. (China Shipping News, 2018)

Promoted by these advanced technologies, the Maritime Autonomous Surface Ship (MASS) has gradually taken shape. It will gradually get rid of the dependence on crew, greatly reduce human costs, be able to carry out transportation tasks independently, and even break through the limits of traditional ships, develop higher performance, play a greater potential value and engage in more dangerous maritime activities. However, the specific description and definition of the have not yet been unified. In the document CMI INTERNATIONAL WORKING GROUP POSITION PAPER ON UNMANNED INTELLIGENT SHIPS AND THE INTERNATIONNAL REGULATORY FRAMEWOEK, the "Unmanned intelligent ship" is used to define it; Norwegian classification society uses "Connected Ship"[1] to name it. While Korea uses the "Connected Ship"[2] to name it. Although they all have the concept of

[1] In 2014, DNV' s GL Group released a "The Future Shipping Industry", proposing the new concept of "The Connected Ship".

[2] In 2013, the “Hyundaiheavy” of Korea launched the "Intelligent Ship 2.0" program and proposed the new concept of "Connected Ship".

"unmanned", there is no uniform naming. In addition, in the classification of ship's autonomy, each country has its own standards: China Classification Society (CCS) divides the functions of intelligent ships into six parts: intelligent navigation, intelligent hull, intelligent cabin, intelligent energy efficiency management, intelligent cargo management and intelligent integrated platform. The American Bureau of Shipping (ABS) is based on sensors, automatic navigation systems, propulsion and auxiliary systems. In its guidance document for entry-level intelligent ships, Lloyd 's Register of Shipping (LR) in England mentions the degree of ship automation, which is divided into six degrees from AL1 to AL6, and precisely stipulates the characteristics of each grade from design to operation. As for the Nippon kaiji kyokai (NK) in Japan, they clarify the operation and responsibilities of intellectualized and unmanned ships, and divide the difference between crew operation and intellectualized operation.(Guo, Xu, Peng, 2019)

Until the MSC98 session, MASS became a new topic. This is the first time that the concept of MASS was put forward and extended to two sessions in the MSC99 and MSC100. IMO indicates that MASS is a ship that can operate independently of human-computer interaction to varying degrees. From this moment on, IMO defined and standardized the development standard of MASS. At the same time, four degrees of MASS were announced in MSC99 (see Figure 1): 1. Automation of partial operation, 2. Remote control and partial crew control, 3. Full remote control, 4. Full autonomous control by operating system.[3]

[3] Cut out from IMO MSC 99 Meeting Summary

Figure 1- The four degrees of the MASS

As mentioned above, China has completed the collision avoidance experiment of autonomous navigation ships, which meets the requirements of IMO for MASS in the degree 3 "periodically unmanned ship". This shows that the era of MASS is coming faster than expected. Not only China, but also many countries and enterprises all over the world are enthusiastic about the research and development of The Maritime Autonomous Surface Ship (MASS), and each has its own characteristics. The following will introduce the development of some countries at this stage.

2.2 The Current status of MASS development in various countries

The Danish shipping giant Maersk Group signed a contract with Boston-based Sae Machines Robotics in 2018. The Maersk will install computer vision, LIDAR and

sensing software on its newly built Winter Palace ice container ship. As a result, the Maersk Group became the first company in the world to test artificial intelligence (AI), dynamic perception and situation awareness technology on container ships. AI is used to improve the ability of situation awareness, target recognition and tracking at sea, similar to the advanced driving assistance system (ADAS) commonly used in automobiles, in order to warn drivers of channel hazards and prevent accidents. The dynamic perception and situation awareness system[4] will use sensors to collect environmental information around ships, identify and track potential conflicts, and display collected information in the steering room. Although the Maersk Group has repeatedly stressed that situation awareness technology is not used to achieve unmanned, in fact, this collaborative Artificial Intelligence (AI) dynamic perception and situation awareness technology is exactly the core technology required in MASS. And earlier, Sea Machines Robotics released its first product, SeaMachines 300, which enables ships to navigate automatically, avoid obstacles and other ships in the process of arriving at their destination, and avoid collisions at sea through common ship equipment and proprietary algorithms.

Norwegian shipping giants Wilhelmsen and Kongsberg joined forces to build the world's first "unmanned ship" shipping company, based in Lysaker, Oslo, Norway, which was called Massterly, . The new company aims to provide complete services for the ship, including design and development, control systems and logistics services. The company was fully operational in August 2018. It is reported that the new company will set up a shore-based Control Center to monitor and operate unmanned ships not only Norway but also come from other countries.. It also receives and operates several unmanned ships, including the Yara Birkeland. (see Figure 2) The Yara Birkeland is 80 meters long and 15 meters wide. It can carry 120

[4] Situation awareness system is an environment-based, dynamic and holistic insight into security risks.

20-foot standard containers at a normal speed of 6 knots and a total speed of 13 knots. In addition to not equipped with crew, the ship also uses batteries as power and does not require ballast tanks for design. The Yara Birkeland was designed in full accordance with the unmanned ship model, the ship does not have the traditional cockpit and bridge building. With its own installed GPS, radar, camera and sensor, it has the ability to avoid collision with other ships during the voyage. In addition, the ship does not need human's intervention in berthing and sailing with its automatic mooring system, and can achieve self-berthing at the terminal point. The ship is scheduled to go into operation this year and may become the first fully autonomous ship in the world.

Figure 2- The Yara Birkeland

In the research and development process of MASS, Norway has benefited from the close cooperation between Norwegian Maritime Corporation and the Norwegian Government, and Norway has taken the lead in this aspect. In recent years, driven by the rapid growth of demand, unmanned transportation and remote operation have developed rapidly. Once MASS is operational, the Massterly will play a vital role in both infrastructure and operational digitization. (Zhang, 2018)

The Daewoo Shipbuilding comes from South Korea announced that it would sign a memorandum of understanding (MOU) with Naver Business Platform (NBP) and Intel Korea to jointly build Smart Ship 4.0 Service Infrastructure. The Intelligent Ship 4.0, which is planned by the three parties, will no longer focus on equipment management and control, but will build technologies based on cloud computing and Internet of Things to collect data in real time. And based on data analysis to manage the ship's architecture. Based on this framework, shipowners and shipping companies can ensure that the ship is in the best state during the navigation through data, and at the same time, they can effectively diagnose and maintain the ship. According to the agreement, the Daewoo Shipbuilding will build a basic environment for the infrastructure of intelligent ship 4.0 service on NBP's Navier cloud platform, and introduce Intel's Internet of Things (IOT) solution into the On-Ship IOT system. Intel will also participate in the development of IOT Hub and IOT Gateway. Through this agreement, we can find that the Daewoo Shipbuilding aims to connect the relevant equipment industry. And in the future, it has the chance to become the leader of the infrastructure service market for the MASS.

From the development of the Maritime Autonomous Surface Ship (MASS) in some countries and companies mentioned above, it can be seen that the technological development of the MASS is accelerating globally. Some countries even regard the MASS as a necessary place in the future shipping field, vigorously promote the implementation of related projects, and strive to take the lead in this market. At the same time, there are differences in the focus and technological advantages of different countries, which make them show great differences in the direction and path of developing the MASS. For most European countries and enterprises, due to the high cost of manpower, more attention will be paid to the shortage of seafarers and the reduction of man-made operational errors. Therefore, remote control,

autonomous route planning, autonomous collision avoidance and other technologies are preferred. Relatively speaking, China, Japan and South Korea focus on the improvement of overall intelligence. For example, China puts more efforts on intelligent research and development on large ocean-going ships. Japan chooses to enhance the overall information level of the MASS, giving priority to information system architecture, data format and communication protocol. South Korea is similar. Despite the different research paths, each country and the shipping industry as a whole are aiming at building a MASS which is closely matching the needs of the shipping industry, which can enhance the shipping ship on the premise of ensuring safety. In the next section, we will elaborate on the advantages of the MASS and the areas needing improvement, which may explain why it is so popular.

CHAPTER 3

ADVANTAGES AND ISSUES TO BE CONSIDERED IN DEVELOPMENT OF THE MASS

3.1 Advantages of the MASS development

As mentioned above, in recent years, many countries and enterprises around the world have increased their development and research efforts on the Maritime Autonomous Surface Ship (MASS). It is generally believed that this research field has broad development potential. Oscar Levander, vice president and head of innovation from the Kongsberg company in Norway, said that shipowners who first embraced autonomous shipping technology would reap considerable returns and gain a clear competitive advantage.

3.1.1 The MASS will improve shipping safety

Safety is the unchanged topic of shipping and the primary prerequisite for ensuring all shipping activities. The "Titanic" incident in 1912 resulted in more than 1500 deaths, prompting the formulation of SOLAS Convention[5]; the “Toli-Canyon” oil spill in 1967 resulted in 120,000 tons of oil spill, causing extensive pollution on the southern coast of Britain, the northern coast of France and the western coast of the Netherlands; and the “SANCHI” incident in the East China Sea in January 2018. Thirty-two Iranian crew members were killed in the ship accident, accompanied by a large oil spill. (Li, Ren, Zhou, Xu, 2018)

[5] SOLAS is a unified principle and relevant rules formulated jointly by the governments of the States Parties, aiming at improving the safety of life at sea.

In the current shipping industry, with the continuous improvement of ship performance, the stability and safety of the ship itself have made great progress than in the past. However, the operational errors caused by fatigue and bad mood of the crew are still the most important factors endangering the safety of the ship. This has been repeatedly mentioned in the class of Professor Baumler, an expert on human factors at the World Maritime University. According to the report issued by Allianz Insurance, 75% to 96% of marine accidents are caused by human errors, such as fatigue during the voyage. Therefore, in the future development of shipping, eliminating the proportion of human factors in the whole shipping link is an important way to improve the safety of shipping. (Hong, 2018)

In the previous introduction of the Maritime Autonomous Surface Ship (MASS), it was mentioned that in the design of the MASS, after the realization of unmanned, the ship's operation is mainly carried out on shore with better working conditions through remote control system and expert decision-making system. As a result, it will fundamentally reduces the impact of human factors on the safety of ship navigation.
For example, according to the requirements of China Classification Society (CCS), in the process of research and development of the MASS, ships need to be equipped with hull monitoring system and navigation aided decision-making system. The hull monitoring system monitors important parameters related to the safety of hull structure and marine environmental. These parameters include not only the total longitudinal strength of hull structure, such as the corner of cargo hatch of large container ships, but also the data of ship motion, acceleration of ship motion, first flat impact, and even the data of sea condition and ship navigation parameters. In order to realize the decision-making function, the ship should equip with different types of sensors are needed for different ship types, and several sensors are required to monitor each key data at the same time. After the corresponding parameters are

measured by sensors, the data will be transmitted to the computer in the background and judged and analyzed by the program. If the parameters exceed the alarm value which was set previously, the aided decision-making system needs to provide decision-making for corresponding operations. The MASS equipped with monitoring system and navigation aided decision-making system can detect potential risks and further improve the safety of navigation. Through the verification results of EU MUNIN project[6], in the future, on the premise of mature and reliable technology, MASS equipped with advanced sensor module expert decision-making system and remote control system can minimize the impact of human factors on shipping safety and the frequency of human errors will eliminate or significantly reduce.

3.1.2 The MASS will increase shipping economic profit

In shipping industry, profit is the main target. All previous innovations and changes in the shipping industry have taken place under the guidance of this target. For example, the rapid development of 4E class container ships, the emergence of super large tankers and the proposal of economic speed are all changes brought by the profit maximization in a specific period of time. Nowadays, the revolution of shipping industry triggered by the Maritime Autonomous Surface Ship (MASS) is also driven by "more profits" to a certain extent.

Professor Ma Shuo, a shipping economics expert from the World Maritime University, pointed out: " Labor costs are the highest expenditures of all costs for most shipping companies." The data displayed by the Drewry Company show that between 2001 and 2005, the labor cost of bulk carriers, container ships and

[6] MUNIN is a cooperative research project of the 7th European Union Science and Technology Framework Program. The MUNIN project aims to develop and validate the concept of an unmanned ship.

supertankers could reach 34%-50% of the average daily operating cost of the ship. Therefore, reducing labor costs can bring huge economic benefits to shipping companies. (Tianjin Navigation, 2018) This is exactly what the MASS can provide. The ultimate goal of the MASS is to achieve no crew on board and intelligent driving. Compared with traditional ships, it has great advantages in saving labor costs. The labor cost mentioned here is not only the cost of crew salary and social security, but also the cost of crew acquisition, training and separation. Nowadays, the employment of shipping industry is declining. The high danger and boredom of long-term drifting on the sea make seafarers lose their attraction gradually. It often takes a lot of time and money to train a seafarer or engineer who can play an important role. Sometimes they face some abrupt situations such as bad weather, pirate attacks, military conflicts, etc. Once a shipwreck and other maritime accidents occur, it will cause huge human losses. The use of the MASS can not only reduce the cost of seafarers training, but also avoid the subsequent losses caused by casualties. At the same time, crew activities on the ship not only need to set up living room, cab and other cabins, but also need to equip with the corresponding pipeline system, water supply and drainage system, using the MASS in degree 4“fully autonomous” can abandon all facilities related to crew, release more space, improve the utilization of space in the ship, enable the ship to carry more cargo or equipment, and save fuel.

When a ship is sailing, the cost of fuel is often the largest of the cost of voyage. According to the oil price and voyage in different periods, fuel expenditure can account for 40-60% of the voyage cost. The fully autonomous MASS abandons a lot of cabins related to crew and has great advantages in reducing the weight of empty ships. The weight of empty vessels has been reduced, and fuel consumption has also been reduced accordingly. On the other hand, the MASS will have the functions of intelligent navigation and intelligent energy efficiency management. Thanks to the

different type of sensors and the computer, the MASS can analyze and process the perceived navigation environment information, and optimize the route and speed. In the aspect of improving energy efficiency management, the MASS will monitor and collect data on the ship's navigation status and energy consumption status in order to evaluate the ship's energy efficiency status, navigation and loading status. Through large data analysis, numerical analysis and optimization technology, they can provide data analysis results and assistant aided decision-making suggestions for ships to improve the ship's energy efficiency management. After that, the cost of fuel consumption can be reduced. (Ding, 2019)

3.1.3 The MASS will be more environmentally friendly

In recent years, IMO and all parties are constantly striving to reduce the pollution caused by carbon emissions and sulfur emissions from ships. Through the introduction of Energy Efficiency Management Index (EEDI)[7] and Energy Efficiency Management Plan, as well as the use of clean alternative energy sources, the CO2 and SO2 emissions of shipping industry have decreased by more than 10%. However, before the emergence of alternative energy sources, it is still difficult to drastically reduce the Greenhouse Gas (GHG) emissions in the shipping sector. The emergence of the MASS has become a new hope for green shipping.

On the one hand, as mentioned above, the MASS has greatly changed the hull structure (abandon crew cabins) and related equipment. Compared with traditional ships, the MASS has great room to improve energy efficiency management. On the

[7] EEDI is the proportion index of the energy consumed by ships converted into CO2 emissions and the effective energy of ships converted into CO2 emissions. The higher the EEDI index, the lower the energy efficiency. EEDI was established to establish a minimum energy efficiency standard for ships.

other hand, the Maritime Autonomous Surface Ship (MASS) integrate green ship technology. Through the comprehensive analysis of the autonomous surface ships being built or tested, we can see that the green ship technologies such as no ballast water, all-electric or battery propulsion technology and drag reduction design are equipped on the Maritime Autonomous Surface Ship (MASS). For example, the Yara Birkeland, instead of burning fossil fuels during its voyage, uses hydroelectric power to charge during loading and unloading, thereby reducing carbon dioxide emissions by 700 tons per year.

On the other hand, the MASS will also play an important role in the maintenance of shipping environment. It can not only monitor and maintain the marine environment, but also rescue in some extreme accidents and conditions. In China, “Unmanned Ships” have been used in some areas of environmental protection, such as high-precision underwater topographic mapping, automatic monitoring of water environment, disaster emergency services, etc. When traditional ships monitor the water environment, they mostly rely on fuel tankers. The hull is large and complex waters are difficult to access. Some rivers are narrower and faster, and people can't reach them, so it's dangerous to work. By contrast, the MASS can make a difference by its characteristics. (Ji, 2018)

3.2 Issues to be considered in the development of the MASS

The Maritime Autonomous Surface Ship (MASS) with artificial intelligence has been gradually applied in environmental monitoring and dealing with some dangerous

situations. In terms of safety and environmental protection, MASS has gradually demonstrated its advantages. At the same time, it has enormous economic and social benefits. These also make its development have broad prospects, and the voice of the shipping industry for MASS is growing. But like a series of other products with Artificial Intelligence (AI), the emergence of MASS has also caused a series of ethical problems, and accompanied by many doubts, which deserve the attention of the industry.

3.2.1 Issues in conventions and regulations

When it comes to the MASS, the first thing to think about is the ethical problems caused by its emergence. For example, human rights ethics, the AI of the MASS is not real intelligence. The MASS is efficient and convenient. But it is only based on a large amount of data. The MASS can not rationally analyze special situations like human beings, but it does impact the labor market. In the highest degree of the MASS, the crew on board will be completely replaced by intelligent machines. In this case, can the procedures and machines contained in the MASS be called "artificial life" and endowed with human rights? When we further study this issue, we need to consider the ethics of responsibility. (Chen, 2018) In the future, intelligent devices and computers will replace human labor, and unemployment rate will continue to rise. When some accidents occur, should the programmer or shipowner be responsible for the accident? Existing regulations for seafarers are totally inappropriate for the MASS liability judgment. The vigorous research and rapid development of the MASS in various countries are arousing people's concern about AI, which also reflects that the relevant conventions and regulations urgently needed by the MASS are far from keeping up with its rapid development. (Ma, 2019)

Taking the International Convention for the Safety of Life at Sea as an example, the SOLAS Convention stipulates that “Each flag State shall equip the ship with qualified crew members in accordance with its Minimum Safe Manning Rules.”, which is obviously not satisfied by the MASS. When the minimum manning is reduced to zero, the following legal issues must be addressed:

How to redefine the crew. Current crew work includes tallying, maintenance, driving, etc. It is not only the main body of operation but also the main body of responsibility. If there is no crew, the driver will use the program to execute, then do these programmers also need to receive corresponding training for crew? In PSC (Port State Control) inspection, the captain signs the problem and confirms it. If there is no crew, at the very least, regulations must be issued to indicate who will replace the captain with the responsibility that should be born.

When an accident occurs in a MASS with the highest degree, who should bear the responsibility? Shipowners, shore-based operators, equipment manufacturers and system maintenance personnel are all likely to be the responsible party. The identification of liability needs to be regulated by new laws.

Similarly, in the United Nations Convention on the Law of the Sea (UNCLOS), the jurisdiction issues and flag State obligations arising from the MASS, and whether STCW conventions need to continue to be applied in the MASS need to be reconsidered. In a word, the existing SOLAS, STCW, MLC conventions all protect or restrict seafarers. If there are no seafarers on board, these conventions need to be abolished or revised, which will take a long time to study and discuss. (Fan, 2018)

3.2.2 Issues in basic technology

Not long ago, Nautilus Internationals surveyed about 1,000 maritime professionals from around the world, and 85% of respondents believed that MASS posed a threat to maritime safety. Only 18% thought that the reduction of seafarers was beneficial to shipping. Many MASS supporters believe that the safety of shipping can be improved by eliminating "human factors", but some respondents stressed that if you carefully analyze every accident on board, you will find that the whole accident causal chain is usually very complex, and every industry can not avoid the quality of equipment. (Sindh Maritime, 2018)When all driving rights are handed over to equipment and procedures, These hardware and technologies are the determinants of security. On the other hand, respondents believed that any emergency of the ship needs immediate intervention and treatment by human. Only in this way can the ship's safety and smooth navigation be guaranteed.

In order to improve the safety of the MASS, the key technical obstacle to break through is the stability of power plant. Sustainable and stable propulsion power is an important guarantee for the safety of the ship. The "unmanned vehicle" can easily get maintenance support in case of accidents, but the unique harsh marine environment makes it difficult to get timely maintenance in case of malfunction of the MASS while navigating on the sea. Therefore, the stability of power plant is particularly important. At present, the low-speed diesel engine power device has been widely used in civil ships. Its motion structure is complex and its stability is not high. In the face of harsh sea conditions, low-speed navigation and other special circumstances, it still needs the crew to operate manually, especially in the case of equipment failure. In this sense, the diesel engine power plant will be difficult to meet the stability requirements.

Secondly, we need to consider the reliability of remote control, which is the key technology of the MASS. The harsh marine environment and the huge resistance of sea water determine that the maneuverability of ships is far less flexible than vehicles and aircraft. Ships are even recognized as the most difficult transportation for humans. At present, the ship with small and flexible hull and high-power propulsion system is relatively easy to achieve remote control. However, due to economic constraints, there is still a certain gap in maneuverability of large vessels, such as ocean-going cargo ships. The operation in navigation is much more difficult and complicated than that of ocean-going ships. Therefore, it is necessary to improve the corresponding equipment and technical conditions for remote control of large vessels. (Shi, 2017)

At the same time, in the development of the MASS, the crew positions will gradually be transferred from the ship to the control center, which also makes the knowledge structure and ability that the crew need to master change. The basic technology described in this part not only refers to equipment and procedures, but also includes the basic technology that the crew themselves need to improve, that is, the learning technology and operation technology of the MASS. Therefore, it is necessary to add the content of "adapting to the MASS" to the training objectives of the existing maritime specialty.

3.2.3 Issues in Network and Security

The Maritime Autonomous Surface Ship (MASS) combines artificial intelligence, big data and cloud computing. Based on these technologies, a series of applications

for remote ship controlling are developed. These applications usually include assessment, diagnosis, prediction and decision-making of ship and surrounding environment. To achieve "fully autonomous", the MASS needs three parts: intelligent perception center, intelligent decision center and executive agency. The network system is the bridge between autonomous navigation system and shore-based support system. If accurate operation is to be achieved, the efficiency and security of network communication must be realized. (Weng, Liu, Gui, 2019)

First of all, the high bandwidth and low latency requirements for the network system are needed. Because of the need to transmit a large number of sensor information and device status information between ship and shore control center, as well as radar images, sea video and so on, the data traffic needs to be very large. At the same time, we should also face the interference of different weather and sea conditions. Under such circumstances, it is particularly important for the safe navigation of the MASS to ensure smooth and stable communication between ships and shores. (Weng, Liu, Gui, 2019)

At the same time, improving the security of information transmission is a serious problem that must be solved before the MASS is put into operation. The AI, data transmission and remote control technology used in the MASS not only bring convenience to ship driving, but also provide more choices for pirate robbery. In 2016, the Verizon RISK security team revealed a very interesting case. After hijacking a cargo ship, a group of Pirates did not ask for ransom for the people on board and the ship, but quickly found the target container and took away the valuable cargo in the container. Verizon RISK security team found in the investigation that the pirates had successfully invaded the company's Bill of Lading Management System before the robbery was carried out. They knew the situation of the cargo well and

locked the robbery target accurately in advance. In this case, pirates in the future may no longer have to take the risk of being swept into the seabed by big waves to boarding and robbing. They only need to employ hackers to successfully control the ship by attacking the control system, so as to achieve robbery. With the increase of ship and shore traffic, the Maritime Autonomous Surface Ship (MASS) are more exposed to network communication. Therefore, the security of communication system and data is becoming more and more important. How to avoid hacker attacks, key information leakage and create the emergency plan in case of network attacks need further study. (Sokratis K. Katsikas, 2017)

3.3 Draft Ethics Guidelines for Trustworthy AI

The legal problems, basic technical problems and network communication and security problems that the MASS needs to face are fundamentally rooted in the impact of Artificial Intelligence (AI) and information technology on human labor. The impact of the MASS on society, shipping industry and all maritime-related personnel is in line with the ethical issues that must be experienced in the age of science and technology, which have been discussed in similar ways in vehicles and aircraft. In order to make advanced technology serve people better, it is necessary to make guidelines to regulate. In view of this series of ethical problems, the EU issued Draft Ethics Guidelines for Trustworthy AI, which put forward relevant conditions and norms for all intelligent products using AI technology. (Chen, Jingru. 2018)

In Ethics Guidelines, “Artificial Intelligence” is defined as “a system showing intelligent behavior”. It can analyze the environment and exercise certain autonomy to perform tasks, which is also the ultimate goal of the MASS. In CHAPTER 2, "A FRAMEWORK FOR TRUSTWORTHY AI" of the Ethics Guideline, some key

requirements for TRUSTWORTHY AI are put forward, including human initiative and supervisory ability, security, privacy data management, transparency, inclusiveness, social well-being and accountability mechanism, in order to ensure that AI is safe and reliable enough. (Zhong, 2019) These elements also accord with the problems mentioned above in the development of the MASS: the judgment of legal responsibility for ships and human rights, how to use laws and regulations to continue to ensure the safety of ships and maritime personnel, the requirements of equipment and intelligent technology, and how to ensure the safety of data in information technology.(see Figure 3)

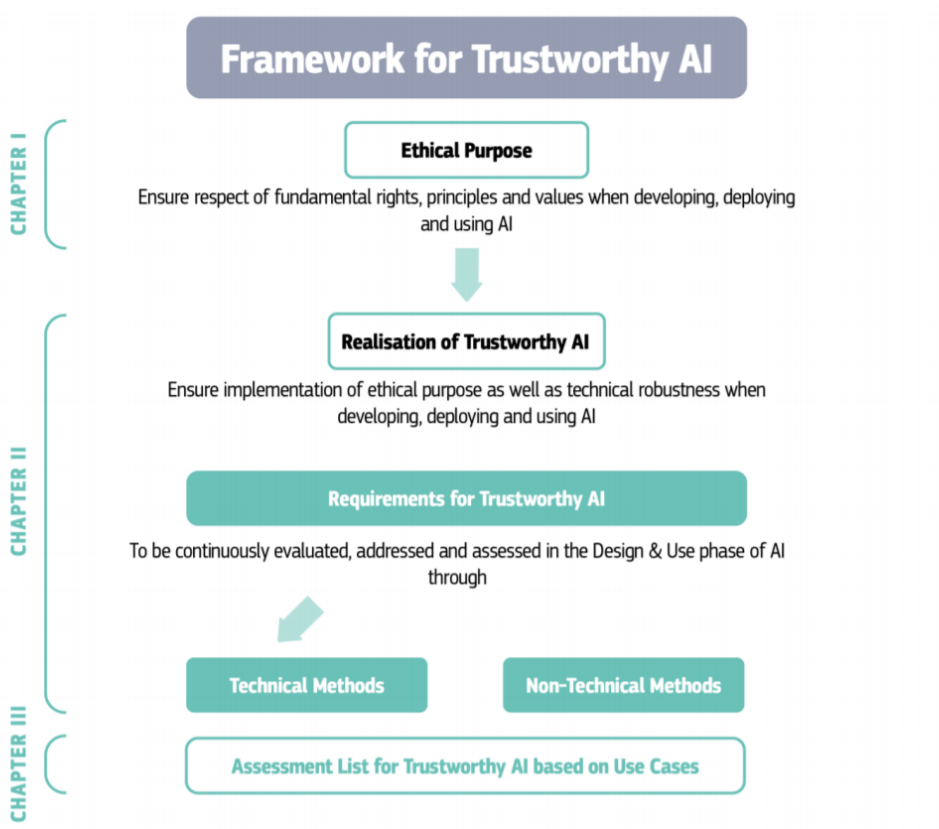

Figure3 - The Guidelines as a framework for Trustworthy AI

In order to reduce doubts about AI ethics and improve the reliability of MASS. Reference can be made to the division of the components of "TRUSTWORTHY AI", which will help to ensure the safe operation of the MASS in the future development:

First, non-technical, requiring respect for basic human rights, rules and regulations, core principles and values;
Second, it should be technically safe and reliable to avoid unintentional harm caused by lack of technology.

For example, if AI is applied to ships, the Guidelines is to restrain ships from designing technical systems that are harmful or potentially harmful to maritime practitioners. Considering these two concepts further, when we develop the MASS on the premise of security, we can also consider non-technical and technical aspects. Traditional ships achieve this goal through the constraints of legal conventions and technical equipment support. The MASS also needs these two guarantees, but due to its particularity, there are still many areas to be improved. The first is the impact on the existing legal conventions. Because the MASS will greatly reduce the crew and give more driving rights to the computers, some traditional conventions will no longer apply to the MASS. Therefore, it is necessary to amend and develop new legal conventions for the MASS to ensure the safe navigation. Then there should be technical support, including power, driving, crew training, and how to ensure information security in the whole shipping process. These two aspects will be explained in the CHAPTER 4 and CHAPTER 5. (Cao, 2019)

CHAPTER 4

HOW TO GUARANTEE THE SAFE DEVELOPMENT OF MASS FROM THE NON-TECHNICAL LEVEL

When we consider how to ensure the safe development of the Maritime Autonomous Surface Ship (MASS) from the non-technical aspect, most of the methods are to regulate the MASS through international conventions and regulations. The traditional maritime law regards people as the core, restricts and regulates ships and related maritime acts with laws and regulations, so as to ensure the safety of life and property of maritime practitioners. When AI, big data and cloud computing are widely used on ships, the MASS will have environmental awareness technology, navigation technology and remote control technology, which are gradually replacing the traditional seafarer position. When the crew gradually moved from deck and cabin to shore control center, the original conventions and regulations were also greatly impacted. Many rules related to traditional ships and crew would no longer apply to the MASS. It also forces IMO and other countries make large-scale amendments and supplements to related conventions and regulations for the Maritime Autonomous Surface Ship (MASS)，It mainly includes the following four categories:

(1). Jurisdiction conventions, such as the United Nations Convention on the Law Of the Sea (UNCLOS)

(2). Technical conventions and rules, including two aspects:

A. Relevant categories of seafarer management, such as the International Convention on Standards of Training,Certification and Watch keeping for Seafarers (STCW 78/10), the Maritime Labour Convention (MLC 2006), etc., which include relevant

requirements for seafarer definition, safety crew assignment, crew operation, training and so on.

B. Regarding ship safety and pollution prevention, including the SOLAS convention and the MARPOL73/78 on life-saving fire-fighting equipment, anti-pollution structures and equipment, ship manning, signal and alarm requirements, as well as related requirements in the Convention on the International Regulation for the preventing Collision at Sea (COLREG).

(3). Civil liability and compensation laws and regulations, such as pollution, collision, cargo damage, salvage and general average, involve the captain's liability, legal subject and insurance liability.

(4). Operational supervision, such as flag state, port state, customs and other institutions need to change from traditional boarding inspection to remote enforcement by automatic access to information. It is necessary to adjust the relevant management mechanism and formulate operational supervision policies of the MASS. (Ding, 2019)

4.1 The IMO' s research on the MASS conventions

IMO has formulated more than 50 effective conventions and regulations for the use of the global contracting parties. With the development of the MASS, these conventions and regulations need to be adjusted and revised accordingly. The IMO' s current research on the MASS conventions is mainly reflected in the sorting out of laws. IMO aims to clear the legal barriers to the MASS development through the Maritime Safety Committee (MSC) sessions. The IMO said that the first step would be to assess the relevant provisions of the current IMO conventions and regulations

in order to confirm whether they apply to ships with varying degrees of autonomy and how they apply to MASS with different degrees. In the second step, the IMO will take into account human factors, technology and operation factors, and make a correlation analysis of the most appropriate methods to carry out MASS ship operation. Let's take a look at how did IMO sort out the regulations of the MASS in various MSC sessions. (Wang, 2018, pp27-29)

MSC98:

In MSC98 session, the United Kingdom, Denmark, Finland, the Netherlands, Japan, Norway, Korea, the United States, Estonia and other countries proposed for the first time that IMO should increase its research on the MASS, and proposed to carry out the Regulatory Scoping Exercise For The Use Of The MASS, with a target date of 2020. At present, the scale of commercial research and development and application of MASS is increasing, but how to apply it to such ships is not covered by existing regulations. Therefore, countries think that the scope of legislation of MASS should be defined. After the session, the Member States agreed to the new proposal, decided to carry out the work of sorting out regulations, collating the provisions related to safety and operation of MASS under the IMO framework, and specify the completion time from MSC99 to MSC102.[8]

MSC99:

In MSC99 session, 17 proposals on MASS were submitted, including 6 information proposals. The proposals were discussed around the objectives, definitions, scope, methods and work plans of the MASS regulation, and the above contents were clarified after the session. As for the definition of the MASS, it is the first time that the Maritime Autonomous Surface Ship (MASS) has been defined as a new topic in

[8] The IMO MSC 98 Meeting Summary gives further information on courses

the MSC session. In order to avoid restricting the development of the MASS, and considering the difficulty of defining the MASS accurately under the current situation, In MSC99 session, it was gave a temporary term only for combing laws and regulations: the MASS refers to ships that can operate independently of human intervention in various degrees. At the same time, the MASS is divided into four degrees, which are mentioned above. It was also pointed out in the session that this regulation review focuses on identifying the legal documents that affect the MASS operation and their applicability to the MASS operation.[9]

At the end of the session, countries reached agreement on the scope of sorting out laws and regulations, forming a list of legal documents that need to be sorted out. In addition, it is pointed out that it should be sorted out in two steps. Based on the discussion and consensus at the session, a communication working group was set up after the session. The working group is led by Finland with the participation of 134 other member countries or organizations; its purpose is to provide guidance for the regulation work.

MSC100:[10]

In the second part of the MSC 100 session, the MASS was discussed. This is the third time since MSC98 that the MASS has been the topic for discussion. It shows that IMO attaches great importance to it.

On the one hand, this session reviewed the experimental results of sorting out the relevant regulations of the MASS after MSC99 session, and agreed with the four degrees of the ship autonomy that determined in MSC99 session. The working

[9] The IMO MSC 99 Meeting Summary gives further information on courses
[10] The IMO MSC 100 Meeting Summary gives further information on courses

framework of relevant conventions and regulations was established, including the method of sorting out laws and regulations, the revision of template and the formulation of follow-up work plan. IMO emphasizes in its working methods that the mandatory IMO documents should be sorted out first, and that priority should be given to the documents related to the degree 2 and 3 of autonomy. It is clear that the work of sorting out laws and regulations should be carried out at the level of clauses. At the same time, the previous template was modified.

On the other hand, the session has clearly defined the task allocation of legislation sorting, which is voluntarily led by member countries and can be attended by other interested countries. After the session, the work of MASS regulation sorting will be officially launched and planned to be completed by 2020. In addition, the formulation principle of guidelines on MASS trials was discussed in MSC100 session, and the formulation of the guidelines was determined. The reporting mechanism of the MASS trials should be formed to ensure the transmission of test information in relevant test areas. The scope of each MASS trial should be clearly defined. It can be seen that the development planning of IMO for the MASS is to clarify the relevant conventions and regulations before carrying out technical specifications. This article will also discuss how to develop the MASS based on safety from legal and technical aspects.

MSC101:

In the MS100 session just ended on June 14, 2019, IMO discussed the progress of the MASS regulation sorting and approved interim guidelines for the MASS trials, which pointed out the principles and objectives of the trials.

4.2 New regulations based on traditional conventions (take China as an example)

With the increasing enthusiasm of the MASS research, not only IMO is stepping up the sorting out of relevant conventions and regulations, but also governments and major classification societies from different countries have issued normative documents related to the MASS. Taking China as an example to analyze the guidance and norms of the government and classification societies on the development of the MASS security at the non-technical level.

4.2.1 CCS Rules for Intelligent Ships (2015)

On December 1, 2015, during the 18th China International Maritime Exhibition held in Shanghai, China Classification Society (CCS) issued the "Rules for Intelligent Ships (2015)". It came into force on March 1, 2016 and is the first MASS-related rules in the world. To a certain extent, it filled the gaps that there was no standard for intelligent ships at that time in the international maritime industry, and began to lead the development of the MASS towards standardization in the non-technical direction. The "Rules for Intelligent Ships (2015)" covers the whole life cycle of intelligent ships from design, construction to operation. The system consists of six functional modules: intelligent navigation, intelligent hull, intelligent cabin, intelligent energy efficiency management, intelligent cargo management and intelligent integrated platform. In the degree of Intelligence, different intelligent functions are required from the aspects of ship data perception, analysis, evaluation, diagnosis, prediction, decision support and implementation of autonomous response. The main contents of the rules include: 1. Intelligent Ship's Purpose and Application Range; 2. Intelligent

Ship's Definition, Objectives and Functional Requirements; 3. Application Principles of New Technologies; 4. Computer System and Software Development Requirements; 5. Additional and Functional Signs of Intelligent Ships: i-Ship (Nx, Hx, Mx, Ex, Cx, Ix).

When a ship has a certain intelligent function, the relevant intelligent function signs can be awarded separately. 6. General requirements and functional requirements of intelligent ship functional modules. Here are three examples of intelligent navigation, intelligent hull and intelligent cabin to introduce specific functional requirements:

Intelligent navigation

It requires intelligent navigation to analyze and process meteorological, economic and logistics information, and to design and optimize ship routes and speeds based on the analysis results. In addition, intelligent navigation can also have the function of autonomous navigation in open waters, or the advanced autonomous navigation ability in complex environments such as automatic docking and narrow waterways.

Intelligent hull

Intelligent hull is required to establish and maintain hull database, and to provide assistant decision-making for safety and structural maintenance in the whole life cycle of hull based on hull database data. In addition, the intelligent hull can also automatically collect and monitor the relevant data of the hull, and provide auxiliary decision-making for ship maneuvering as a supplementary intelligent function of the intelligent hull.

Intelligent cabin

Intelligent cabin needs to monitor the operation status of main engine, auxiliary

engine and shafting in the room. At the same time, according to the data collected by condition monitoring system, the operation status and health status of machinery and equipment are analyzed and evaluated. Based on the analysis and evaluation results, corrective suggestions are put forward to provide auxiliary decision-making suggestions for ship operation. According to the analysis and evaluation results of the running status and health status of the mechanical equipment, the room can also formulate the corresponding condition-based maintenance plan as a supplementary function of the intelligent cabin.

In addition to the above main functions, the rules also clearly defined the computer system drawings, operational inspections, and staffing of each intelligent module. At the same time, considering the better development of technology in the future, through the open compilation method, the Rules for Intelligent Ships (2015) can continuously incorporate new functions, refine technical requirements, and gradually improve the rules. In 2017, CCS also issued a series of technical standard documents, such as "Guidelines for Inspection of Intelligent Integrated Platform", "Guidelines for Inspection of Ship Intelligent Engine Room", "Guidelines for Inspection of Ship Intelligent Energy Efficiency Management", "Guidelines for Requirements and Safety Assessment of Ship Network Systems" and so on, which are matched with the Rules for Intelligent Ships (2015). (Yang, 2015)

4.2.2 CCS Guidelines for Autonomous Cargo Ships (2018)

In September 2018, The CCS first published the Guidelines for Autonomous Cargo Ships 2018 at the 28th SMM in Hamburg, Germany. The guidelines aims to provide technical basis for the design and construction of Autonomous cargo transport ships.

The guidelines came into effect on October 1st, 2018.

The CCS indicates that autonomous ships are the advanced stage of the development of intelligent ships. At present, there are many projects related to the autonomous ship being implemented in China, so it is urgent to formulate guidelines for ships to provide support for the safety of autonomous ships. In MSC99 session, IMO discussed the scope of the MASS conventions and regulations and set up a working group to carry out its work. The CCS has completed the compilation of the Guidelines for Autonomous Cargo Ships 2018 combined with the discussion results of IMO MSC99 session.

As described in the guide, autonomous ship will be a highly integrated ship with various intelligent systems compared with traditional ships in terms of the overall structure of the ship. Considering the whole process of autonomous ship operation and the relationship between various systems, at the present stage, cooperative operation between ship and shore is the best way to realize autonomous ship. Therefore, CCS has constructed the basic framework of autonomous ships. The framework is based on autonomous shipping system, communication system and electrical system. It covers safety, fire fighting and pollution prevention systems, and is guaranteed by remote control center. In the compilation of guidelines, the guideline specifies the objectives, functional requirements, inspection and test requirements of hull systems and remote control centers, so as to realize the safety and environmental protection of ships in marine navigation, port entry and exit, berthing and departure, and cargo operation scenarios.

Based on the above objectives and the structure of autonomous ships, the Chinese Classification Society (CCS) takes the safety and environmental protection level of

international conventions such as SOLAS, MARPOL, COLREG72 and STCW as its principle, and takes the risk analysis results as its basis, and takes the combination of remote control and autonomous control as its main technical means to realize the autonomous operation of ships. With the Goal-Based Standards (GBS), the requirements of scene perception, navigation control, marine machinery, mooring and mooring, electrical equipment, communication and signal equipment, hull structure and safety, fire protection, environmental protection, ship security, remote control center, network security, etc, which include 14 chapters, forming the Guidelines for Autonomous Cargo Ships 2018.

The issuance of the guidelines has systematically and comprehensively stipulated the technical requirements of the autonomous ships for the first time in the world, filled the gaps in the technical guidance documents of the autonomous ships, led the development and application of the ships, and provided non-technical guarantee for the safe development of intelligent shipping.

4.2.3 Action Plan for the Development of the Intelligent Ships 2019-2021

On December 29, 2018, the Ministry of Industry and Information Technology, the Ministry of Transport and the State Administration of Science Technology and Industry for National Defense jointly issued “the Action Plan for the Development of the Intelligent Ships 2019-2021”. The Action Plan aims to provide guidance, basic principles, action objectives, nine key tasks and five safeguards for the safe development of the MASS at the non-technical level. It shows the world China's development plan for MASS in the next three years. In the guiding ideology of the plan, it is pointed out that the development of the MASS requires the improvement of

ship safety, economy, environmental protection and efficiency as the core, which is in line with the theme of this paper: the development of the MASS based on safety.

The plan points out that it is important to strengthen the guidance of industry development, highlight key areas and key links of intelligent ship development, make full use of the foundation and scientific research achievements of relevant industries, promote collaborative innovation and form joint development. Its basic principles are as follows:

First, the development of the MASS should be planned systematically to improve the level of ship autonomy.

Second, we should pursue key breakthroughs in technology. Take key projects as traction, strengthen the research and development of key common technologies and key equipment.[11]

Third, different ships should be classified and promoted. According to the characteristics of different ships, we should formulate targeted intelligent development strategies to promote the orderly development of various types of ships.
Fourth, cross-border integration. Not only expand international cooperation, but also cross-border linkages within and outside the industry, because the MASS not only requires ship technology, but also involves all kinds of intelligent products. It requires all countries and industries around the world to jointly explore and practice the MASS.

Through three years' efforts, China aims to form a top-level plan for the development

[11] The Action Plan for the Development of the Intelligent Ships 2019-2021 gives further information on courses

of intelligent ships, establish a preliminary system of regulations and standards, break through the core technologies of navigation situation intelligent perception and automatic berthing and departure. On the other hand, it is necessary to complete the development of relevant key intelligent equipment systems, realize the typical scenario test of remote control, autonomous navigation and other functions, and expand the "one platform + N Intelligence application" mode of typical intelligent ships. It can be seen that China is also developing the MASS from non-technical and technical aspects, and emphasizes the premise of security.

4.3 Conclusion of the conventions and regulations

From the current development point of view, the technology development of the Maritime Autonomous Surface Ship (MASS) has gradually matured, and many functions have been applied in test. However, the development of the MASS has a huge impact on traditional conventions and regulations, which makes many legal treaties concerning the MASS still blank in the non-technical level, and the security development of MASS has not been guaranteed as it should be. This has become an urgent problem for the whole shipping industry. IMO and governments from all over the world have recognized this huge problem, and both believe that the MASS needs to develop from both non-technical and technological aspects. Making use of conventions and regulations at the non-technical level to guide and restrict the technology of MASS so as to ensure the better development of MASS based on safety.

Generally speaking, the combing and revision of the existing maritime conventions

and regulations by IMO is a huge and complicated work, and the whole Maritime Convention System will undergo a landmark change. However, with the gradual improvement of the convention system of the MASS, international shipping will also enter a new historical stage. At the same time, under the framework of international conventions, each country is also formulating relevant regulations and guidelines in line with the development of the domestic MASS, and these provisions are not lower than the minimum standards of international conventions. Through written guidance and rigid regulations, it is conducive to solving the ethical problems existing in MASS, reducing the hidden dangers of insecurity in the process of development, and providing evidence for dealing with accidents, and providing better protection for the interests of all parties

CHAPTER 5

HOW TO GUARANTEE THE SAFE DEVELOPMENT OF MASS FROM THE TECHNICAL LEVEL

5.1 Key technologies of the MASS

In the third chapter, the basic technical problems of the development of MASS mentioned that the safe development of the MASS needs to ensure the stability of power plant and the reliability of remote control.

5.1.1 The stability of the power plant

The first is the stability of the power plant. The power plant of the low-speed diesel engine mentioned above does not meet the requirements of the MASS because of its instability and difficulty in getting rid of crew maneuvering. Compared with conventional cargo ships with single engine and single propeller, ships with two engines and two propellers have obvious advantages in overall stability of power plant and propulsion redundancy. However, the working principle of low-speed diesel engine determines that it is difficult to operate steadily under sudden load changes. In order to maintain the stability of ship propulsion, different types of diesel engine may be a suitable power scheme for the MASS. Ships can use different types of two-stroke diesel engines with better economy under normal sea conditions. When the main propulsion diesel engine fails, a four-stroke diesel engine with higher reliability can be used as emergency power device to ensure that the ship does not lose power in the course of navigation.

In addition, electric propulsion is also one of the possible power schemes for the

future MASS. Compared with the diesel direct drive propulsion, the redundancy and stability of the electric propulsion is undoubtedly higher, and it is easier to achieve remote control at the technical level. However, in the current context of acceptable labor costs, shipowners are obviously more inclined to employ crew members to operate than the additional costs of adding a propulsion system or using electric propulsion. In the future, the power plant of the MASS will be further considered in terms of cost performance and stability.(Chen, 2019)

5.1.2 The Reliability of Remote Control

On the other hand, in degree 3 of the MASS, people are still required to operate remotely on the shore, which relies heavily on the stability and efficiency of data transmission. On February 25, 2019, at the Mobil World Congress 2019 held in Spain, Yunzhou Intelligence, together with Ericsson and China Mobile, launched a 5G unmanned ship. The characteristic of 5G is to increase data transmission rate, terminal equipment connection density and ultra-reliable low-delay communication, which makes the interconnection of all things become a reality. Under the 5G communication technology, real-time acquisition of MASS data information, real-time positioning of target individuals and environmental monitoring of waterway will become possible. With the development of the 5G technology, it provides data support for remote control of the MASS and makes it more reliable. Although 5G has been favored by the industry, there are still some problems. 5G is the concept of land mobile communication, which needs the support of land base station. When ships need to sail long distances, how to solve the problem of sea base station is still worth thinking. In addition, the history of the development of maritime communications shows that ships often use non-profit, autonomous communication

network and private maritime communication network, rather than carrier-based communication network. How to reach a reasonable compromise between non-profit and carrier is also a key issue. (Science and Technology Daily, 2019)

5.1.3 More technical equipment support

However, in degree 4 of the MASS: Fully autonomous ship. The ship operating system will make its own decisions and take action, which requires a lot of technical equipment support. First of all, environmental awareness and target recognition are needed. Ships need to be equipped with many accurate and flexible sensing devices, such as electronic chart, navigation radar, underwater sonar and so on, to judge and identify obstacles in short and long distance. The trajectory of the moving target is also need to be tracked, and the next trajectory should be predicted according to the tracking results. Next, data calculation and route planning are needed, and Big data and Cloud computing are used to integrate the data of environment perception and target recognition. The system will reasoning and planning independently, make appropriate decisions, control and modify intelligently in real time, so as to select the best and best route in parallel. Finally, in the face of emergencies, the MASS also needs complete emergency equipment, adjustment programs and rescue measures.

5.2 The crews’ Assignment and Training

With the development of the key technology of MASS, the training of crews also needs to be changed. The traditional maritime education is based on the requirements of the STCW convention to train marine transport ship officers, engineers, electronics technicians and other professionals. During the development of the

MASS, ships will gradually reduce the number of crew members and eventually no longer need crew. In the future, the new type of navigational staff will gradually change from on-board crew to ship followers in the transitional stage of the MASS development, and ultimately completely transform into shore-based crew and port rapid maintenance staff. For the training of crews, we should make full use of the advantages of the traditional professional courses of navigation, and require crews to master the core technology of MASS development, actively carry out the study of computer science, control theory, communication science, artificial intelligence and other information science courses. Train high-quality composite crews who master information technology and navigation science and technology at the same time.

In order to train new seafarers, it is urgent to construct teaching resources, teachers and experimental bases. First of all, teaching resources: the traditional curriculum of nautical education is based on the STCW Convention and the outline of crews' examinations in various countries. With the development of the MASS, it is necessary to develop new courses and textbooks related to ship intelligent control. On the other hand, with the autonomy of ships, traditional training systems such as navigation simulator, marine engine simulator, ship power station and other training projects can no longer adapt to shore-based crew and port rapid maintenance staff. Educational resources need to be built in conjunction with new conventions and guidelines. Then there is the construction of the teachers: teachers with complete theoretical knowledge and high practical skills are the guarantee for the MASS education. Considering that the MASS will be closely related to more technology companies, we can encourage existing teachers to practice in these companies and improve their engineering ability. Finally, the construction of the experimental bases: we can use digital information system to build a virtual laboratory of the MASS through modeling and simulation technology, so as to improve students' cognitive

ability of the MASS. (Ma, 2019)

5.3 Communication and network security

To ensure the safe development of the MASS in technical level, it is necessary not only to provide stable power plant and key technical equipment needed by MASS, but also to ensure the communication and network security during the operation of the MASS. The 5G communication technology mentioned above will provide great convenience for data transmission. However, in the use of 5G, the huge amount of information and the aster transmission speed will make all the information of MASS exposed to the network, which will greatly increase the possibility of accidents or attacks on ships. (Wen, Liu, Gui, 2019)

In view of the network security problem of ship autonomy, the industry has taken some countermeasures. In December 2015, the International Association of Classification Societies (IACS) has set up a professional committee on network systems to formulate unified requirements and standards for ship network security. In 2016, The Baltic and International Maritime Council (BIMCO) proposed and issued The Guidelines for Marine Network Security, aiming at providing clear and comprehensive information on network security risks to the entire shipping industry, so as to take appropriate measures to deal with the network. In addition, the topic of ship network security was also mentioned in the MSC96 session. The IMO approved the Interim Guidelines for Maritime Network Risk Management.

In order to establish a secure MASS network environment, in addition to the requirements and guidelines through relevant documents, the industry also needs to improve its overall awareness and technology in this regard. In the network security

system including human resources, procedures and technology. However, many countries and companies pay too much attention to the development of MASS operation technology at present and ignore the training of crews' network technology and the setting of the network security programs. In the future, in order to enhance the security of the MASS in technical, it is very important to train relevant staff. Countries and companies even need to set up special crews and departments to manage the network security of the MASS. Network security management involves identification, protection, recovery and so on. In network risk identification, relevant staff should have the ability to identify and interrupt the systematic behavior that causes risks to the ship ; In network protection, countries and companies should take risk control measures to formulate emergency plans to ensure the continuity of shipping operation; In network accident response, relevant plans need to be prepared and implemented, and emergency shipping operating systems and repair plans need to be provided.

CHAPTER 6

CONCLUSION

At present, the three core technologies of the era of Industry 4.0：Artificial Intelligence, Big Data and Cloud Computing are closely integrated with the shipping industry. As the product of intelligence, The Maritime Autonomous Surface Ship (MASS). The high enthusiasm of the industry promotes its accelerated development. Like the birth of every new thing, the emergence of MASS is also a double-edged sword. In the current situation, the MASS has both advantages and hidden dangers. Safety is the first prerequisite for the development of shipping industry and the basis of all activities for profit. The emergence of the MASS is accompanied by the voice of reducing crew size and accident rate, as well as the voice of questioning whether it is really safe. When the ship fully meets the IMO standard for the MASS in degree4, the ship will completely get rid of the crew and transfer the crew to a safer working environment on shore. The concept of safer and more efficient brought by the MASS will indeed be realized. However, at the present level of development, the MASS is not mature enough at the non-technical and technical levels. Its impact on the entire shipping industry has caused ethical problems in all aspects. For a new thing, first of all, we need to define and standardize it. In the face of all possible problems in the future, we need to have written treatment methods. Next, we need to ensure that MASS can be used by human beings. When MASS enters the shipping industry, it still needs to take safety as the premise. The plasticity and uncertainty of AI make MASS have many potential safety hazards. Combine with the Draft Ethics Guidelines for Trustworthy AI proposed by the European Union, we can find that EU also considers the non-technical and technical aspects when they discussed the ethical issues of the MASS. The global shipping industry has also made different

development of MASS from these two perspectives, but there is no complete unified plan at present. The research of various organizations, countries and companies is relatively scattered.

This paper proposes that the development of MASS should be studied from the non-technical and technical perspectives to ensure the safe development of MASS. The development progress of the industry in these two aspects has been sorted out. In non-technical aspects, IMO is rebuilding the Convention framework applicable to MASS. Faced with the "unmanned" characteristics of the MASS, the original applicable seafarer regulations and liability regulations need to be reconsidered. When all the regulations are sorted out. The MASS will have a clearer definition and better specifications. At the same time, this Convention framework will also provide minimum standards for each country, and different countries can guide their own MASS development according to their own actual development situation. At the technical level, the MASS still needs to develop the key technology and equipment of ships and reduce the accidents caused by hardware, which is the basic guarantee for the safety development of the MASS. On the other hand, new crew members need to be trained, they need to face the new operations and new shore-based posts and so on. Finally, how to ensure network security under information technology is also the key problem to be solved before MASS came out. It is not only to prevent information leakage, but also to be able to deal with system intrusion. When we use the network to control the ship, we need to firmly grasp the right to manoeuvre, so as to avoid AI becoming a tool for non-legal persons to commit crimes.

The development of the Maritime Autonomous Surface Ship (MASS) is the general trend, and its emergence has become inevitable, but the safe development of the MASS still has great room for improvement. How the non-technical and technical

aspects of the MASS will develop in the future remains to be seen.

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