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Supervision of intelligent ship : analytical review from the perspectives of China maritime administration

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SUPERVISION OF INTELLIGENT SHIP: ANALYTICAL REVIEW FROM THE PERSPECTIVES OF CHINA MARITIME ADMINISTRATION

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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ABSTRACT

Title of Dissertation: **Supervision of intelligent ship: analytical review from the perspectives of China maritime administration**

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With the development of digital technology, the commercialization of the intelligent ships is getting closer day by day. China MSA, as the supervision of the safety navigation of ships, is being impacted by the emergence of the intelligent ships. How to take measures to meet the supervision needs of the intelligent ships is faced by China MSA.

The current maritime supervision system is made based on the traditional ships, which are less digitalized compared with the intelligent ships. As per the definition made by the IMO, the intelligent ships have been categorized into four degrees, and especially in the third and fourth degree there are no crew on board ships. Then the traditional maritime supervision system based on manned ships will be challenged by the intelligent ships.

IMO just started to identify the current conventions whether they are applicable or not to intelligent ships. The international convention is the basis to ensure the safety of shipping, and China, as the class A member state of IMO, also has the domestic law issued on the supervision of the intelligent ships.

This paper, firstly, introduce the current status of the development of intelligent ships, and the measures taken to promote the development of the intelligent ships in some typical countries; secondly, it discusses the status of the supervision in IMO and other leading ROs, including the current status of the supervision measures in China; thirdly, it identifies the impact of the intelligent ships under the maritime supervision through analyzing the characteristics of the intelligent ships. Finally, it proposes the suggestions on measures to deal with the emergence of intelligent ships to China MSA on the aspect of legislation, management of seafarers, infrastructure of construction and digital maritime supervision.

KEYWORDS: Intelligent ship; shore control center; navigation service; supervision on intelligent ships; technology of intelligent ship

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

5G	Fifth generation network
ABS	American Bureau of Shipping
AI	Artificial Intelligence
AIS	Automatic information system
ATC	Air Traffic Control
BV	Bureau Veritas
CCS	China Classification Society
CCTV	Closed Circuit Television
CMI	Maritime International Commission
COLREGS	International Regulations for Preventing Collisions at Sea
DNV-GL	Det Norske Veritas
ENC	Electronic navigational charts
EU	European Union
GEO	Geostationary
GPS	Global Position System
GSM	Global System for Mobile Communications
IALA	the International Association of Marine Aids to Navigation and Lighthouse Authorities
ICT	Information and Communication Technology

IHO	International Hydrographic Organization
ILO	International Labour Organization
IMO	International Maritime Organization
IoT	Internet of Things
IQ	Intelligence Quotient
LR	Lloyd's Register
MASS	Maritime Autonomous Surface Ship
MSC	Maritime Safety Committee
MSA	Maritime Safety Administration
MLC	Maritime Labour Convention
NK	Japan Classification Society
ROs	Recognized Organizations
ROC	Remote Control Operation Center
SCC	Shore Control Center
SOLAS	International Convention on safety of life at sea
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
UNCLOS	United Nations Convention on the Law of the Sea
VDES	VHF Data Exchange System
VTS	Vessel Traffic Service

CHAPTER I: INTRODUCTION

1.1. Background

The shipping industry is one of the oldest industries in the world. And it is the most important mode of transportation for international trade, linking the five continents closely. Up to now, the international shipping industry has undertaken more than 90% of the transportation tasks of global trade. Driven by technologies and concepts such as big data, cyber-physical systems, and the Internet of Things, profound changes are taking place. Intelligent ships were only widely used in the field of national defense and military in the early 21st century. With the transition from a labor-intensive international shipbuilding industry to a high-tech industry with low energy consumption, the wide application of big data and artificial intelligence technology in various industries and fields (Shukai, Zhang, 2015), the application and development of intelligent ships in the civilian field have also made great progress.

At present, the development of intelligent ships is at a turning point during an important period filled with opportunities. On the one hand, with the maturity of typical ship intelligent equipment systems such as autonomous ships, autonomous collision avoidance, automatic berthing, integrated bridge systems, and ship energy efficiency management systems, the first voyage of the zero-emission autonomous container ship "Yara Birkeland" and the system testing of the autonomous sailing ferry "FALCO", the development of intelligent ship technology has reached a new height (Xinping & Shuwu, 2021).

On the other hand, the international rules on intelligent ships are becoming more and more suitable for intelligent ships. At the 98th Maritime Safety Committee (MSC) of

International Maritime Organization (IMO), Denmark, Estonia, Finland, Japan, South Korea, Netherland, the United Kingdom and the United States jointly proposed to the IMO to include Maritime Autonomous Surface Ships (MASS) in the scope of discussion work , and it was the first time that MASS had been known by the world (MSC(IMO), 2017). At the 100^{th} session of IMO-MSC, a framework for a regulatory scoping exercise including preliminary definitions of MASS and also its four degrees was endorsed (MSC(IMO), 2018). The interim guidelines for the trial of IMO MASS Ships were released at the IMO-MSC 101st meeting, and the IMO MASS Regulatory Scoping Exercise was completed at the MSC 103rd meeting. The development of relevant technologies and the improvement of international rules have brought opportunities for intelligent ships to further carry out functional tests on real ships, promote economy and improve reliability assessments well as explore commercial application scenarios.

Shipowners' demand for intelligent ships is also an important driving factor for the development of smart ships, and the demand of shipowners is mainly affected by the ship operation safety and economic improvement. Under the current downturn in the ship market and the reality of long-term excess capacity, the world's mainstream shipping companies have shifted the focus of their future development on improving the operational efficiency and the safety of their fleets, in order to seek development in the face of the downturn (Wei, Liu; Jiafa, 2017). Intelligent ships have outstanding advantages in improving the operational efficiency, safety and decision-making efficiency of ships, and reducing ship fuel consumption, which just meet the needs of current shipowners.

Maritime Administration is playing an important role to make sure the safety of the shipping, especially in a country like China, which has three identities:1) Flag state; 2) Port state; 3) Coastal State. So, within the scope of its functions compelled by law, China Maritime Administration undertakes the important mission of ensuring the safety of maritime traffic and the marine environment protection. However, the essence of maritime supervision is human intervention, the core of which is the process of maritime administration supervising ships and their operations in accordance with relevant laws and regulations (Y. Jin, 2020). Therefore, with the development of intelligent ships, the conflict with the current maritime regulatory model will become more and more intense. The way to promote the development of intelligent ships and even smart shipping by coordinating maritime supervision and the development of intelligent ships will be an opportunity and also a challenge to maritime supervision. As a country that integrates the triple identities of port state, flag state and coastal state, China maritime supervision is particularly important.

1.2. Current status of research

Although the research and development of intelligent ships started late compared with unmanned aerial vehicles, unmanned vehicles and other technologies, it has developed rapidly and has been applied in the fields of military and civilians many countries have paid more attention to the research of intelligent ships, and have listed it as an important direction of the future shipping industry. In this section, the author will start from both domestic and international aspects to systematically sort out the efforts and research results made by domestic and foreign scholars on intelligent ships.

1.2.1. The current status of foreign research on intelligent ships

In the last decade, foreign scholars have conducted in-depth research on technologies, rules and performance standards of the intelligent ships. Lucy Carey's research shows that the development of intelligent ships has made breakthrough achievements in technology, but there are still some legal issues to be solved. She cites some of these obstacles from a common law perspective, such as whether the Hague-Visby Rules, COLREGS and other related provisions apply to intelligent ships, and she believes that unless these problems are solved internationally, the use of intelligent ships as cargo ships will be limited in development (Carey & Carey, 2017).

Aldo Chircop's research argues that international shipping will enter a new era due to the arrival of intelligent ships, but the contemporary international law of the sea and international maritime law regulations on navigation and shipping are premised on the presence of persons on board, so it is necessary to determine how intelligent ships apply the provisions of the 1982 United Nations Convention on the Law of the Sea, and several maritime conventions should be re-examined as Aldo Chircop explored the regulatory system and framework that intelligent ships need to consider. It was also noted that intelligent ships have the potential to provide new research directions for international law and the International Maritime Organization (Chircop, 2017).

Karlis analyses the problems of intelligent ships from the perspective of international maritime law, in particular crew-related articles such as Safety of Life at Sea, STCW and the International Maritime Labor Convention 2006 (MLC), and his main objective is to identify potential operational difficulties that might hinder shipowners' investment or the adoption of new technologies and to make recommendations that could be mitigated in response to these identified difficulties (Karlis, 2018).

Benjie S. Quinisio (2018) proposed a strategy for the coastal state to supervise the MASS ships, and from his point of view, the coastal state should have a MASS ship control center so that it could take over the control of the ship when necessary (Quinisio, 2018).

Wa Nzengu, Jerome Favie, Ann-Safie Pauwelyn, Victor Bolbot, Lars Andreas Lien Wennersberg, Gerasimos Theotokatos (2021) based on the AUTOSHIP project, analyzed the regulatory gaps that exist in the current regulatory framework for supervising the intelligent ships, and proposed a three-phase strategy to overcome the barriers (Nzengu et al., 2021).

1.2.2. The current status of domestic research on unmanned ships

In recent years, domestic scholars have achieved certain results in the research on intelligent ships, such as Zhang Shukai, Liu Zhengjiang and Zhang Xianku. Among them, Liu Yu of Dalian Maritime University reviewed the concept, development status and characteristics of intelligent ships and the technology involved in research and development and its future prospects (Shukai, Zhang; Zhengjiang, 2015); Yunfei Zhang, Deng Pan, Yuliang Cai, Jinhua Liu and others focused on international maritime conventions on ship design and construction issued by international organizations, including SOLAS, MARPOL, 1966 International Convention on Load Lines, COLREGS, 2001 Convention on the Control of Hazardous Anti-fouling Systems for Ships, 2004 Convention on the Control of Ballast Water and Sediments in Ships, 1969 Convention on International Ship Tonnage Measurement, and The International Maritime Labour Convention of 2006 and the main study discussed the design of intelligent ships within the framework of these eight conventions (Yunfei, Zhang; Deng, 2017).

Liu Wei and Shang Jiafa believe the trend of development of the intelligent ships represents the main direction of the development of shipping. They analyzed the situation of the intelligent ships in the world and proposed a strategy for the development of intelligent ships in China (Wei, Liu; Jiafa, 2017).

Zeng Qingshan and Wang Yongjian analyzed the impact on maritime supervision caused by the emergence of intelligent ships from five aspects, and according to the impacts, they proposed relevant countermeasures to China Maritime Administration

(Qingshan, 2018). But the author thinks their analyzation is not deep enough, and the countermeasures are not specific enough.

Li Zhiwei studied the legal issues of the jurisdiction over the intelligent ships. He believed that the emergence of the intelligent ships deeply impacted the foundation of the law enacted on the base of traditional ships. In order to provide a proper and effective jurisdiction on intelligent ships, he analyzed the legal issues from the views of Flag State, Coastal State and Port State in a comprehensive way. Law and regulations are the foundation of the jurisdiction and supervision; therefore it is very important to formulate proper law to ensure the safe navigation and protection to the marine environment (Zhiwei, 2020).

1.3. Significance of the research

The development of intelligent ships will subvert and change the traditional shipping industry as never before. Maritime agencies, as the regulators of shipping safety, should escort the development of intelligent ships. At present, the regulatory model of maritime institutions is still the traditional people-centered supervision, which is obviously inconsistent with the development of intelligent shipping. With the purpose of theoretical orientation, this paper analyzes the characteristics of intelligent ships and its relevant regulatory laws and conventions, finds out the impact of unmanned ships on maritime supervision, and proposes corresponding countermeasures based on the current development status of intelligent ships.

1.4. Research content and methodology

The first Chapter states the background, research status, significance and objectives, research content and methodology of this dissertation.

The second Chapter illustrates the current status of development of the intelligent ships in China and in other countries, such as Japan, Korean, etc.

The third Chapter shows the current intelligent ship-related legal norms and guidelines in China and in other countries through analyzing and comparing those legal norms and guidelines and finds out the deficiencies in our laws and policies related to the development of the intelligent ships.

The fourth Chapter introduces the characteristics of intelligent ships, analyzes the advantage and disadvantage of intelligent ships based on the current technologies, and determines the impact the intelligent ship has on maritime supervision.

The fifth Chapter, based on the chapter four, proposes the suggestions.

The sixth Chapter is the conclusion of this thesis.

CHAPTER II: THE CURRENT DEVELOPMENT OF INTELLIGENT SHIPS

2.1. Overview

In 2006, the International Maritime Organization (IMO) proposed the concept of original e-ship (e-Navigation): which is characterized by electronic information, on board and ashore to collect, integrate and display maritime information, to achieve ship-ship, ship-shore and shore-shore information communication, in order to achieve the ultimate goal of ship safety, economic navigation and environmental protection (IMO, 2006). At present, international and domestic consensus has been reached on intelligent ships within a certain range, but when it comes to technical details, there are still differences in the understanding of various institutions. China Classification Society defines intelligent ships as follows:" with the use of sensors, communications, Internet of Things and other technical means, it can automatically perceive and obtain information and data by the ship itself, such as information of marine environment, logistics, ports, etc., and based on computer technology, automatic control technology and big data processing and analysis technology in the ship navigation, management, maintenance, cargo transportation and other aspects of the ship to achieve intelligent operation so as to make the ship safer, more environmentally friendly, economical and reliable (CCS, 2020). The British Lloyd's Register has defined the classification and characteristics of intelligent ships after research: the first generation should include human agent systems; the second generation should include human monitoring systems to give suggestions about decision support; the third generation will include data analysis (Lloyd’s Register, 2017).

2 .2. Current research on intelligent ships

The world's major shipbuilding countries have accelerated the pace of research on intelligent ships, Asia such as Japan and South Korea, focusing on the overall improvement of intelligence. The intelligent system developed by them has been installed on many large ocean-going ships; European enterprises such as Wärtsilä, Rolls-Royce, Kongsberg and others focus on intelligent ships for the current and future research and development, and such technology and systems first are applied to small ships while trying to transit from local intelligence to global intelligence.

2.2.1 Research on intelligent ships in Korea

In 2010, South Korea implemented the Smart Ship 1.0 program, and Hyundai Heavy Industries Group of Korea and the Korea Electronics and Communications Research Institute (ETRI) have jointly developed the ship communication technology, named Ship Area Network (SAN), which has 2 major advantages, one is to use Internet technology to comprehensively manage more than 460 kinds of components including power propulsion systems and navigation systems on board. This technology, firstly makes operating the navigation-related devices on board easier. Secondly, shipping companies can use remote technologies such as satellites to manage and monitor the operating situation of ships in real time on shore, and carry out remote maintenance and repair when general problems and faults occurs (Lee, S.-H., Kim, J.-H., Moon, K.-D., Lee, K., & Park, 2013). Hyundai Heavy Industries Group built an intelligent 4500 TEU container. The technology was applied to the container ship and was delivered to the A.P. Müller-Maersk Group in Denmark for operation in March 2011. Its highly automated performance and scientific, easy-to-operate equipment are well received by shipowners (B. K. Park, 2011). Based on this technology, in May 2011, South Korea led the formulation of IEC61162-450: 2018, which became one of the models for its advantageous technology rising to international standards.

In 2013, Hyundai Heavy Industries launched the Smart Ship 2.0 program with the main purpose of making economical, safe and efficient navigation services. Based on the Smart Ship 2.0, Hyundai Heavy Industry also proposed a new concept of Connected Ship, which combines ships, ports and onshore logistics information with ship operations. In May 2014, South Korea's Daewoo Shipbuilding and Marine Engineering Company joined forces with SK Telecom Corporation (SKT), Korea's largest mobile operator, to develop a new type of intelligent ship based on Information and Communication Technology (ICT). Equipped with a global telecommunications network navigation and monitoring system, the intelligent vessel integrates all services on board into a single, multi-link network for automated and unmanned control to realize efficient and safe operation of the vessel.

In April 2020, the Korea Autonomous Surface Vessel Project (KASS Project) was launched. The four main objectives of the project are to develop intelligent navigation systems, develop automation systems of engine, create autonomous performance centers for ships, and set operational techniques and standardization. It aims to develop an intelligent system with autonomous navigation capabilities for an integrated platform for controlling the nacelle, collision and accident prevention, situational awareness and decision-making (KASS, 2020).

In September 2021, Mokpo Ocean University and Samsung Heavy Industries successfully conducted the tests on collision avoidance with two autonomous ships sailing in head-on courses, and passing by each other with a Distance at Closest Point of Approach (DCPA) one nautical mile. This is the first successful test using ship mutual recognition and automatic collision avoidance technology in the world. Based on this performance test, the two institutions are planning to commercialize their autonomous ship navigation system in this year (Kim byeong seong, 2021).

2.2.2 Research on intelligent Ships in Japan

Since 2014, Japan has launched the Japan Smart Ship Application Platform (SSAP) project, which aimed to build ships and shores standardized methods for obtaining ship equipment data to continuously improve the safety of ships and environmental protection. The project was led by the Japan Shipbuilding Machinery and Equipment Association (JSMEA) and involved 27 units from the field of shipping, such as Mitsubishi Heavy Industries, Kawasaki Heavy Industries, Daihatsu Diesel Corporation, Tokyo Meter Co., Ltd., Japan Post Marine, Mitsui Merchant Marine and Japan Classification Society (NK). The platform was installed on a ferry ship and a crude oil carrier in Japan (Ando, 2014).

In August 2015, two international standards, the Shipboard Offshore Condition Data Server and the Standard Data for Shipboard Machinery and Equipment, proposed by Japan were officially established, relying on the Secretariat of the Navigation and Ship Operation Subcommittee of the International Organization for Standardization's Ship and Ocean Technical Committee (Sijia, 2021). Japan has successively proposed and promoted the development of more than 10 international standards, covering the fields of intelligent ships such as ship navigation, heading control, navigation records, and information transmission.

At the beginning of 2022, Japan carried out and passed a number of autonomous navigation tests shown in Table 2-1. Among them, the ship Mikage used the drone to help with its berthing operation, which was the first time in the world. All of those tests proved the reliability and feasibility of the autonomous navigation system.

Table 2-1 Japan Autonomous ship tests in the beginning of 2022. Source: Author

Date	Ship name	Particular	Content
17 Jan 2022	Soleil	222meters in length	Completed an autonomous high- speed navigation test, lasting for 7 hours.

24 to 25 of Jan 2022	Mikage	Container ship	Completed the independent navigation test in domestic trade.
6 to 7 of Feb 2022	Sunflower Shiretoko	Car ferry ship	Completed autonomous test during day and night.
26 of Feb to 1 of March 2022	Suzaku	Container ship	Completed the test of autonomous navigation system in congested area.

2.2.3 Research on intelligent ships in Europe

In 2017, the Norwegian agricultural company Yara International and Kongsberg Marine had developed the world's first zero-emission unmanned vessel (Yara, 2017). Yara Birkland, delivered in 2020, is purely electric drive and uses unmanned technology to load 120 containers, saving an average of 90% on operating costs per voyage. The vessel is equipped with an automatic mooring and unmooring system and autonomous navigating technology so that it can transmit navigation coordinates to the control center in real time and it can also use its own sensors to make temporary route adjustments to avoid other ships.

In June 2017, Rolls-Royce showed off Svitzer Hermod, the world's first remotely piloted tugboat (Rolls-Royce, 2017). The ship has a length of 28 meters and is equipped with a remote-control system with Rolls-Royce's power positioning system as the key equipment, which can realize intelligent control such as docking, undocking, and 360° rotation. The vessel is also equipped with a variety of sensors, which can collect detailed ship equipment and surrounding environment data after advanced software analysis and transmission to the shore-based remote control operation center (ROC), providing an accurate data reference for the captain.

In 2018, the first port berthing test of the ferry vessel Folgefonn using Wärtsilä's automatic berthing system was successful (Wärtsilä, 2018). This ship is an 83 meters long ferryboat with hybrid propulsion and equipped with a wireless charging system that enables automatic deceleration operation, fully automatic alignment and berthing operation. The automatic berthing system will make the ship safely parked in the berth. The navigation operation of the ship is fully authorized to the autonomous controller, which controls the speed, track and the course of the ship, so as to achieve no intervention throughout the process.

The ship Yara Birkeland was officially put in operation in November 2021(Yara, 2021), and from 2022, the vessel will undergo a two-year technical test period for manned commercial operations, with the ultimate goal of achieving full autonomy.

2.3 Research on intelligent ships in China

The development of the intelligent ships is a little bit late in China. The details will be shown in Table 2-2. China State Shipbuilding Corporation has carried out research on the design and construction of i-Dolphin intelligent ships on the platform of green Dolphin 38 800 t bulk carriers since 2014. In December 2017, China's first self-developed and constructed intelligent ship, the i-Dolphin38 800 t intelligent bulk carrier "Dazhi", was successfully delivered (State Administration of Science, 2017). The vessel is the world's first intelligent vessel certified by the classification society, and has also received the intelligent ship symbol awarded by the China Classification Society and the British Lloyd's Register.

The Mingyuan received the i-ship (N, M, E, I) symbol from the China Classification Society and the Intelligent Ship (OE, PE, CME) symbol from DNVGL Classification Society, and is the first intelligent vessel in the world certified by DNVGL Classification Society (Luyan, 2018).

At the end of 2017, China Classification Society, Wuhan University of Technology, Zhuhai Municipal People's Government and Zhuhai Yunzhou Intelligent Technology Co., Ltd. jointly launched the Small Unmanned Cargo ship project. On December 15, 2019, the independent sailing cargo ship "Jindouyun 0" developed by Chinese enterprises made its maiden voyage on Dong'ao Island in Zhuhai for cargo carrying tests (China GOV, 2019).

On May 15, 2020, the "Zhifei" officially started construction. Launched on June 15, 2021 (CCS, 2021), "Zhifei" is equipped with an intelligent navigation system independently developed by China, which is the first integrated sample of systematic testing carried out by the Qingdao Maritime Ship Intelligent Navigation Test Field. It is of great significance for China to explore and master the autonomous technology of intelligent navigation of ships and to build a comprehensive demonstration area of intelligent shipping in Qingdao.

Table 2-2. Intelligent ships built in China. Source: Author

Year	Ship name	Particular	Technology Content
Dec. 2017	Dazhi	38800t Bulk carrier	Independent development and integrated application of key core systems such as ship intelligent integrated information platform, intelligent operation and maintenance system, intelligent navigation system, etc.
Nov. 2018	Mingyuan	400000-ton Ore ship	Five intelligent plates of auxiliary automatic driving, energy efficiency management, equipment operation and maintenance, ship-shore integrated communication, mineral liquefaction detection; the ability to use a unified network platform and data platform to complete the collection, processing and analysis of the whole ship's data information, which can provide decision-making support for ship navigation, operation and maintenance, and provide information feedback for the continuous improvement of ship design and construction.

Dec. 2019	Jindouyun 0	12.8 meters in length	On August 16, 2021, the official website of the International Maritime Organization (IMO) officially released the Report on MASS trials of unmanned ships studied and completed by the Guangdong Maritime Safety Administration, which is based on the practice of the "Jindouyun 0" unmanned ship trial conducted under the auspices of the Guangdong Maritime Safety Bureau, and comprehensively covered the technical elements of intelligent navigation such as remote control, automatic tracking, and automatic collision avoidance. etc.
June, 2021	Zhifei	Container ship	It integrates and installs an autonomous navigation system and adopts the large-capacity DC integrated electric propulsion system, which made the two major technical leaps of DC and intelligence on the same ship for the first time.

2.4 Conclusion:

At present, the development of intelligent ships is accelerating, and has gradually become the main research direction of various shipbuilding powers in the world, but there are different ways of development. South Korea uses the information technology industry as the traction, including Daewoo Shipbuilding and the other three major shipyards for ship intelligence and intelligent construction technology research and development with the focuses on making full use of shore-based resources. Japan, based on its own leading-edge shipbuilding technology, combined with cutting-edge scientific and technological achievements, takes the environmental protection and intelligence as the main direction of technology and standard research and develops coordinately in the field of scientific research and standardization. Europe focuses on the current research and development of intelligent ships based on the remote-control technology and the feasibility of unmanned autonomous navigation.

The development of intelligent ship technology in China has also started the top-level design and research work of ship intelligence. However, at present, China's intelligent ships are still lack of shipbuilding automation, big data analysis technology, ship safety and security, autonomous navigation under complex conditions of inland waterways and other aspects. Therefore, attention should be paid to the development of intelligent ships at home and abroad and the focus on promoting the technological development of intelligent ship-related supporting industries, with the help of relevant enterprise advantages of independent innovation. China should constantly improve the theoretical and technical level of intelligent ships, with the coordinated development of intelligent ship scientific research and standardization, so as to improve the intelligence technology in the shipping field.

CHAPTER III: THE CURRENT REGULATION OF INTELLIGENT SHIPS

Global research and development of the technology and legal issues of intelligent ships are in full swing. IMO is sorting out the existing international conventions to lay the foundation for the future revision of the convention to adapt to the development of intelligent ships while other major countries in the world have also introduced intelligent ship specifications to guide the development of global intelligent ships. As a shipping country, China actively participates in the research of international legal issues of intelligent ships, grasps the research direction of intelligent ship, formulates and improves domestic policies and relevant laws and regulations to promote the development of intelligent ships, and strives to take the lead in the research and development of intelligent ships and promote the development of China's shipbuilding industry and shipping industry.

3.1 Legal regulations of intelligent ships abroad.

3.1.1 Legal regulations of intelligent ships in IMO.

In 2006, IMO first divided the development stages of intelligent ships into the e-Navigation program and proposing the concept of electronic navigation. With the emergence of the industry 4.0 era, the core technical breakthrough of intelligent ships has been realized one by one, leading to an urgent needs of intelligent ships legal norms. In 2017, the United States and other countries jointly submitted a proposal on the scope of intelligent ship legislation to the IMO, making full preparations for the subsequent formulation of an internationally harmonized legal norm for the intelligent ship industry. On June 16, 2017, IMO hosted the MSC 98th meeting, putting the regulatory scoping exercise of intelligent ships on the agenda for the first time. It mainly summarized the legal issues related to intelligent ships, proposes that

IMO should actively guide the development of intelligent ships, and define intelligent ships in more details at different stages. In 2021, at the 103rd MSC meeting of the IMO, the definition of the regulatory scoping exercise for MASS ships was completed, and the output was approved by IMO.

3.1.1.1 MASS definition and classification (MSC(IMO), 2021)

In order to avoid limiting the practice of MASS, the difficulty of giving an accurate definition of MASS and the classification of the level of autonomy in the current situation should be taken into account. MSC has given a provisional term only for regulatory grooming, that is, MASS refers to a vessel that can operate independently of human intervention to varying degrees.

The MSC divided the MASS into four degrees of ship autonomy to carry out regulatory work (MSC（IMO）, 2021). See Table 3-1:

Table 3-1. Four degrees of MASS ship. Source: Author

Autonomous degree	Description
Degree 1: Ship with automated process and decision support	Seafarers on board 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 2: Remotely controlled ship with seafarers on board.	The ship is controlled and operated form another location. Seafarers are available on board to take control and to operate the shipboard systems and functions.
Degree 3: Remotely controlled ship without seafarers on board	The ship is controlled and operated from another location. There are no seafarers on board.
Degree 4: Fully autonomous ships.	The operating system of the ship is able to make decisions and determine actions by itself.

3.1.1.2 Regulatory Scoping Exercise

The MSC has sorted out the technical conventions to produce legal documents that will affect the operation of MASS and the applicability of these legal documents. The combing results show that the regulations are sorted out in two steps: the first step is to identify the applicability of the provisions of the regulations to MASS; the second step is to determine the best way to dispose mass operations, clarify the priority review of mandatory regulations, and divide the conventions into three levels according to the degree of impact of the convention on MASS, among which the high-priority part covers 12 conventions, pointing out the problems that need to be solved urgently to adapt to the development of MASS ship, and clarified the next step of IMO's work in the field of MASS ships. The Circular also noted that because of the many things that need to be changed in the Conventions, it may cause confusion for traditional ships, recommend developing a specific regulation on the regulation of MASS ships (MSC(IMO), 2021).

3.1.1.3 Interim Guidelines for MASS trail

In other areas of transportation, such as unmanned vehicles, countries have policies and guidelines to provide safety requirements for road testing. If sea trials are to be completed in international waters, international guidelines are also required to ensure that MASS considers safety risks and human factors as well as traditional manned vessels.

To this end, the 100th session of the MSC held in December 2018 decided to prepare the MASS sea trial guidelines and clarified the basic principles of the preparation. To be specific, the guidelines should put forward general requirements for the sea trials of MASS, rather than prescriptive or technical requirements; and should use a goal-based approach. The 101st session of the MSC in June 2019 approved the Interim Guidelines for MASS Trials and issued a Circular (MSC. 1/Circ.1604 on Interim Guidelines for MASS Trials). The guidelines propose that the risks associated with the experiment should be appropriately identified as a threat to safety, security and environmental protection, and measures to minimize risks (IMO, 2019).

3.2.1 Legal regulations of intelligent ships of Recognized Organizations (ROs) abroad

In response to the rapid development and continuous improvement of intelligent technology, the world's major classification societies have made corresponding regulations for intelligent ships. Although it is slightly different, it is the same in terms of the requirements of the main technologies. The ultimate purpose of the certification channels and other specific laws and regulations of the classification societies for intelligent ships is to enable the smooth use of intelligent ships in their own countries.

3.1.2.1 Lloyd’s Register (LR)

Lloyd's Register published the LR Code for Unmanned Marine Systems in February 2017. The rule follows the system of traditional ship specifications. Highly consistent with traditional ship specifications, it divides into different chapters such as structure, stability, control, electrical, navigation, etc. Unmanned systems in this specification mainly refer to unmanned boats and unmanned submersibles. From the perspective of unmanned navigation, the unmanned system is discussed from four levels within the scope of application, purpose, functional objectives, and performance requirements. Based on risk control, British Classification Society discussed nine risk elements including human-computer interaction, data quality, system architecture, hardware, software, etc., (Lloyd’s Register, 2017).

3.1.2.2 Class NK

The Japan Classification Society, NK, published the Guidelines for Concept Design of Autonomous Operation/Autonomous Operation of Ships in 2018, and it was revised in 2020, renamed as Guidelines for Automated/Autonomous Operation on ships (Class NK, 2020). The entire guideline has seven chapters, mainly covering several aspects such as safety design elements, risk assessment, autonomous level grouping, and remote control. The NK Classification Society borrowed from unmanned vehicles to propose a concept of Operational Design Domain. Through this concept, the NK Classification Society divides the autonomous ships into autonomous navigation and autonomous navigation in unlimited scenes. NK Classification Society emphasizes the need to identify risks, postulate risk scenarios, good risk assessments, and finally consider how to mitigate risks. In the aspect of risks, it mainly includes human-computer interaction, ship automation, communication network, reliability of computer systems, sensor failure, network attack, and external physical intrusion.

3.1.2.3 American Bureau of Shipping (ABS)

In May 2019, ABS published guidelines for Smart Functions for Marine Vessels and Offshore Units and updated in 2020 (ABS, 2021), which mainly includes target principles, risk classification, data, hull structural health, turbine health monitoring, system evaluation, etc. This guideline establishes a complete system for the implementation and evaluation of intelligent functions, see Figure 3-1. At the same time, this guideline also proposes the concept of Service Provider, providing new ideas for the establishment of smart shipping formats. There are 11 points in the concept of risk matrix and risk factor proposed by the American Classification Society and the main considerations in the risk, including the role of intelligent functions, the reliability of software and hardware, networks, and data communications, the redundant design of shipboard systems, power failure, etc.

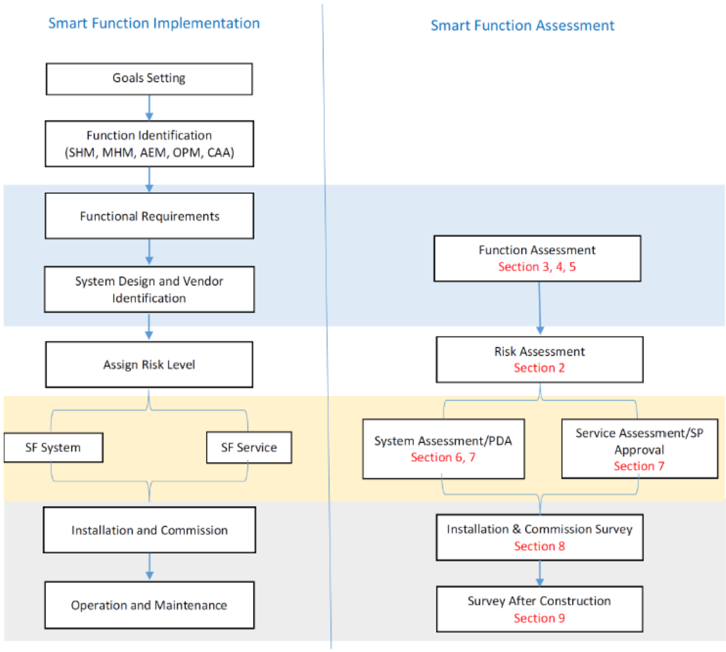

Figure 3-1. Smart Function Implementation and Assessment. Source: Guide for Smart Functions for Marine Vessels and Offshore Units

3.1.2.4 Bureau Veritas (BV)

France Classification Society, in October 2019, released a guideline called Guidelines for Autonomous Shipping, which is the only guideline that aims at intelligent shipping (Bureau Veritas, 2019). The guidelines include chapters on general principles, risk and technical assessment, functionality of automated systems, reliability of automated systems, and others. In the General Provisions, safety and security are explicitly mentioned, while the applicability of the Convention is outlined. BV has a separate technical risk assessment section in which the requirements for hazard identification, risk index, risk assessment and risk control are set out. Moreover, BV considers the risk of voyage, navigation risk, perception risk, communication risk, ship system risk, remote control risk and security risk, and meanwhile subdivides the risks of various aspects, and proposed the risk control options (see Figure 3-2).

Category	Risk Control Option
Unmanned ship and Remote Control Centre	Design of RCC for a proper control and monitor Suitable RCC manning as well as training of operators
	Ship should be directly controlled in heavy or complex traffic
	A ship without accommodation is easier to secure against stowaways
Unmanned mainte-nance and technical operations	Design of aboard systems for easy maintenance and accurate monitoring of maintenance state Must also be fast to repair
	Need redundant power generation, distribution, propulsion and steering
	Automated fire extinguishing systems are required in all relevant areas Note that no crew makes this simpler as areas are smaller and that CO_2 can be used more safely
	Improved cargo monitoring and planning is required.
Heavy weather	Software are to be able to avoid heavy or otherwise dangerous weather – use of weather routing.
	Restricted navigation notation.
Sensors systems	Need good sensor and avoidance systems. Selected systems must also be redundant so that a single failure does not disable critical functions identified during the risk assessment.
Cybersecurity	Cybersecurity measures are important, including alternative position estimation based on non-GPS systems. The RCC may be particularly vulnerable. Data communication links must also have sufficient redundancy.

Figure 3-2. Risk Control Options. Source: BV Guidelines for Autonomous Shipping.

3.1.2.5 DNV-GL classification society

DNV-GL classification society released Autonomous and remotely operated ships in 2018, and it was revised in2021(DNV, 2021), mainly including the safety and risk identification and analysis, operation mode, risk minimization, ship function, degree of automation and human intervention, system function integration, overall design, software function and testing, cyber safety and other elements. According to the relevant ship operation and technical characteristics, the functions involve intelligent navigation, engine room operation and maintenance and management, remote control, ship-to-shore communication and other functions are stipulated.

3.2 Regulations and policies of intelligent ships in China

Since 2015, China has actively introduced a number of legal norms and policies to encourage the development of intelligent ships, with a view to bringing the development of intelligent ships in China into the legal track.

3.2.1 China's intelligent ship related laws and regulations

Before other countries and international organizations made clear legal provisions on intelligent ships, China Classification Society (CCS) promulgated the Rules for Intelligent Ships in 2015 (CCS, 2020), taking the lead in making functional and technical requirements for intelligent ships which filled the gap in the legal norms of intelligent ships.

In 2017, CCS held the Intelligent Ship/Unmanned Ship New Technology forum, and in the same year, it promulgated a series of documents such as the Ship Intelligent Engine Room Inspection Guide and the Ship Network System Requirements and Safety Assessment Guide to support the Rules for Intelligent Ships.

In 2020, on the basis of the original specifications, the CCS added the requirements for remote control technology and autonomous control technology of intelligent ships to publish a new edition. The Rules for Intelligent Ships divide the research of intelligent ships into six major intelligent modules such as intelligent navigation, intelligent hull, intelligent engine room, intelligent energy efficiency management, intelligent cargo management, and intelligent integration platform, It involves information perception technology, communication and navigation technology, energy efficiency control technology, route planning technology, status monitoring and fault diagnosis technology, distress early warning and rescue technology, autonomous navigation technology, and provides technical standards for intelligent ship research and development (CCS, 2020).

At present, the legal norms of China's intelligent ships take the Rules for Intelligent Ships promulgated by the CCS as the core, with support from other technical regulation, which complement each other and organically combine to jointly promote the development of China's intelligent ship technology and ship manufacturing. However, in general, the CCS's legal norms on intelligent ships focus on the technical development and shipping industry norms that serve intelligent ships but lack clear and specific provisions on legal risks, environmental protection, legal responsibilities, safety and security and other issues after operating, compared with the legal issues of developed countries and international organizations in the shipping industry in Europe and the United States. This reveals that China does not attach enough importance to the legislative issues of intelligent ships and the supervision on the intelligent ships as well.

3.2.2 Policy on the development of intelligent ships

Chinese Government has made many policies to push the development of the intelligent ships in China, the main policies shown in Table 3-2. The main purpose of China's intelligent ship development policy is to solve the problem of overcapacity in the shipbuilding industry and the problems brought about by the transformation of the shipbuilding industry, but with, the development of big data, the Internet of Things, the international community's emphasis on environmental protection and green energy development in Industry 4.0 era, the development of intelligent ships is not merely the responsibility of the shipbuilding industry. The relevant Departments of China need to take the concept of a community of human destiny as the guide, timely adjust the development goals of intelligent ships, and direct the development of smart ships consistent with the international development trend from the macro policy level.

Table 3-2. The main intelligent ships policies in China. Source: Author.

Year	Policy Name	Content
2015	Made in China 2025	For the first time, the research and development of intelligent ships is included in the national policy, and it is listed as one of the top ten key development areas of the manufacturing industry in the future.

2017	An outlook for the development prospects of artificial intelligence	Intelligent ships are included.
2018	Smart Ship Development Action Plan (2019-2021)	Put forward the development of intelligent ships separately for the first time.
2018	Guidelines for the Construction of Intelligent Ship Standard System	It made more detailed provisions on the basic principles and guiding ideology of intelligent ship development, the basic content of intelligent ship construction, and the organization and implementation.
2019	Intelligent shipping development guidance	It pointed out the direction for the future development of intelligent ships and smart shipping.

3.3 Summary

The regulations of intelligent ships are on the way to developing. IMO, as the organization of the world for instrument making in the shipping field, has completed the regulatory scoping exercise for MASS ships, which provides a guidance to the MASS and also its member states on their own local law to facilitate the development of the MASS ships in their own countries. The Interim Guidelines for MASS Trial provides the guidance while carrying out the sea trial of MASS ships in international waters.

As of now, there are six classification societies developed specifications on intelligent ships. As can be seen from the above analysis, classification societies in various countries have formulated corresponding specifications related to intelligent ships according to their own technology and industrial development, but these classification societies have different understandings of intelligent ships. At present, the specifications of national classification societies mainly stipulate intelligent ships in terms of objectives, functions and performance, and involve less in terms of solutions and inspection guidelines. The risk of intelligent ships should be the focus of national classification societies, but each classification society has different views on risk perception, risk identification and how to reduce risk.

With the support and guidance from governments, the intelligent ships are developing pretty fast worldwide, but the legislation on supervision of intelligent ships is lacking behind, it's just a start-up from IMO by scoping the regulations Maritime administration needs the legal basis to support their supervisions on the MASS ships. In order to facilitate the development of MASS ships and the operation, it is urgent to develop the specific regulations on MASS ships as the legal basis for the maritime administration to carry out supervisions.

CHAPTER IV: THE CHARACTERISTICS OF INTELLIGENT SHIPS AND THEIR IMPACTS ON MARITIME REGULATION

With the rapid development of intelligent ships, many countries have launched the experiment of intelligent ships, and the emergence of intelligent ships has a great impact on existing laws and regulations, as the current regulatory regulations applicable to traditional ships are not applied to intelligent ships. For example, the emergence of unmanned ships makes the crew's workplace shift from ship to shore-based control center, and the existing STCW rules will not be applicable to shore-based operators. The use of modern information technology, artificial intelligence and other advanced intelligent technologies will enable a safer, more environmentally friendly and more economical ship, but the existing regulatory regulations will seriously restrict the development of intelligent ships. Therefore, at the 102nd MSC, the IMO issued the guidelines for the trial voyage of MASS ships. At the 103rd MSC, the output on the regulatory scoping exercise of unmanned ship was approved, and at the 104th MSC, China and other countries submitted proposals to propose the roadmap for the development of the MASS ship regulations. This series of initiatives demonstrated the determination of member countries to actively promote the development of intelligent ships.

Intelligent ship research in various countries has developed rapidly. Among them, Japan's intelligent ship experiment has been carried out at the beginning of this year with the aim to achieve commercial operation of intelligent ships this year. Norway's intelligent ship Yara Birkeland was put into operation, and experiments on China's intelligent ship JinDouyun 0 was carried out, which shows that intelligent ships are getting closer and closer to reality. At present, the IMO has just begun the formulation of intelligent ship regulations for the differences between the supervision of intelligent ships and that of traditional ships, which brings great challenges to maritime supervision. This chapter focuses on the technical characteristics of intelligent ships, and analyzes the impact of intelligent ships on maritime supervision from five aspects.

4.1 Technical characteristics of intelligent ships

Intelligent ship refers to ships that use intelligent perception technology to obtain its real-time status, the marine environment around the ship, traffic environment and other data information, and also involves computer technology, network control technology and big data analysis technology, etc., to achieve intelligent management of ship navigation, maintenance, maintenance and cargo management. IMO divided the intelligent ships into four degrees according to the degree of intelligence of the ship and personnel on board (MSC(IMO), 2021), and the unmanned nature of the ship will be the ultimate goal of intelligent ships. The key to realizing the unmanned of ships is the remote control and autonomous navigation of intelligent ships, which is also the core technology of intelligent ships, including intelligent perception technology, communication technology, control technology, network security, etc., (YuanyuanWang, Jialun Liu, 2021).

4.1.1 Perception technology of intelligent ships

Ship information perception technology refers to the ability of ships to use various sensing equipment, sensing networks and information processing equipment to obtain various data and information of the ship itself and the surrounding environment. The ship's own information includes the ship's speed, course, location, etc., and the surrounding environment refers to the marine environment and traffic conditions. The traditional perception technology equipment commonly used by the ship is Radar, AIS, GPS, Echo sounder, etc., but the perception system on the traditional ship is unable to meet the needs of intelligent ships for safety. For example, the maritime radar has a blind sector, and cannot detect the close object, which requires the crew to perform lookout duty to make up for the deficiency of radar (Juehan Guo, Chengguang Liu, 2020). There is no crew on the intelligent ship that puts forward higher requirements for the intelligent perception system. New types of sensing devices have also been applied to intelligent ships.

Through the analysis of the advantages and disadvantages of the five types of equipment in Table 4-1, it can be seen that any device alone cannot complete the full coverage and accurate perception of the surrounding environment under all weather conditions. Multi-source perception information fusion technology is to use a variety of sensing equipment with fusion technology to integrate the information collected by each sensor at different times and remove redundancy and conflict information, could achieve full coverage of the ship environment and ship movement situation. The technology has been used on real ships, proving the reliability of the technology. In November 2021, the Norwegian Yara Birkeland intelligent ship was launched, an 80-meter-long container ship with autonomous driving, remote control capabilities (Kongsberg, 2020). The ship's perception system adopts multi-source perception information fusion technology, in addition to the AIS system, equipped with 4 different sensing devices: infrared camera, visible light camera, lidar, and maritime radar (Figure 4-1). The ship collects information through various sensors and uses computer algorithms, removing redundant and conflict information, and finally reconstructs the three-dimensional environment around the ship, providing strong support to remote operators to avoid collision hazards.

Table:4-1 Sensory devices. Source: Author.

NAME	Advantage	Disadvantage

Visible Light Camera	Intuitive and efficient with high resolution.	When the light is insufficient, fog, snow and other weather occlusion of the line of sight, the function of the visible light camera will be greatly affected.
Infrared camera	The infrared camera can eliminate the interference of light and can work in any lighting condition with little influence from the weather.	The detection distance is short and it is susceptible to external interference.
Navigation radar	It can achieve long-distance detection and identify obstacles at longer distances.	For obstacles in the vicinity of the ship, the navigation radar cannot identify them, and the navigation radar also has a visual blind spot, and the navigation radar cannot detect the obstacles located in the visual blind zone.
Millimeter wave radar	Millimeter-wave radar can directly detect the distance and speed of obstacles, with less weather interference.	The detection area is fan-shaped. In a blind spot area, the detection distance is short, and its ranging accuracy is not high.
Lidar	It can achieve 360-degree scanning, with high ranging accuracy and resolution, and can accurately detect obstacles within 300 meters.	The influence of weather such as rain, snow and fog will make the laser decay sharply, which will seriously affect the detection range of lidar.

4.1.2 Communication technology of intelligent ships

When intelligent ship is in operation, the operator in the shore-based control center and the shipboard control system exchanges data and information, especially the ship's movement situation and navigation environment information through network link to achieve remote control of intelligent ships. The remote control of intelligent ships requires stable and fast communication to ensure the safety of ships. Due to the less stability of software and hardware equipment in the network, the limitation of network bandwidth, the uncertainty of communication load and transmission mechanism, intelligent ships will inevitably encounter network delay, network packet loss, network disconnection problems in the process of communication. These problems exist objectively and are related to the distance of signal transmission. For example, in terms of real-time transmission of command signals, ships can reach 100% transmission within 15-20 nautical miles from the shore base, 95% within 30 nautical miles, and the transmission speed outside 35 nautical miles will drop rapidly, and the packet loss rate beyond 50 nautical miles will increase significantly (Maritime Bureau, Ministry of Communications of China, 2020). But with the development of communication technology, the impact of these problems will become less and less.

The communication technologies used in the experimental process of current intelligent ships include global mobile communication systems, maritime broadband radio technologies and satellite communications. The advantages of the Global System for Mobile Communications (GSM) are fast speed, large bandwidth and small latency, especially with the support of 5G communication technology, and have become more and more obvious (Ming Yang, 2021). However, GSM transmission is limited by the layout of the base station, and intelligent ships sailing along the coast or inland water can achieve communication between ship and shore through GSM communication technology, and the communication of intelligent ships for ocean voyages must rely on satellite communication (Yuanyuan Wang, Jialun Liu, 2021). The current maritime satellite communication transmission in slow speed, long delay and small bandwidth (Wei et al., 2021), and it cannot meet the data communication needs of intelligent ships during ocean voyages. For the data communication among ships for maritime navigation, the maritime broadband radio technology developed by Kongsberg in Norway can realize inter-ship networking and support high-speed data dissemination (Kongsberg SEATEX, 2019), see Figure 4-1, which provides a solution for intelligent ship to ship communication, and the technology has been applied on the intelligent ship, Yare Birkeland (Kongsberg, 2020).

Figure 4-1. Broadband Radio. Source: Kongsberg.

In summary, the existing communication technology cannot meet the needs of intelligent ship in ocean navigation, but the low earth orbit satellite networks are under construction, such as Starlink plan, VDES communication technology, etc., and can provide stable maritime communications with small latency, large bandwidth and high-speed services (Ge et al., 2022), providing unlimited possibilities for solving the communication issue of intelligent ship in ocean navigation in the future.

4.1.3 Control technology of intelligent ships

According to the IMO's classification of intelligent ships, ships in the third and fourth categories use different control methods the application of remote-control systems, and autonomous navigation respectively, the later on which is the autonomous control of ships. No matter what form of control, the operator can't perform his duty without the shore-based control center. For remotely controlled ships, the shore-based control center implements instructions to control the movement trajectory of the ship. For autonomous ships in the fourth category, the shore-based control center mainly plays a role of monitoring and when the intelligent ship encounters a situation beyond its cognitive range, or is attacked by a network, the shore-based control personnel intervene to ensure the navigation safety of the intelligent ship (MUNIN, 2015).

4.1.3.1 Remote-control mode

Intelligent ship remote-control needs the shore-based control center to send control instructions, shipboard control system to command and feedback the implementation of the information through the constructed ship network control system. According to the definition of remote control from the MUNIN project, intelligent ship remote control mode can be divided into three levels as follows.

Remote follow-up control, the operator in the shore-based control center issues instructions to the intelligent ship in real time to control the ship's engine, rudder, etc., so as to achieve the purpose of remote-control of the ship (MUNIN, 2013).

Remote automatic control, the operator in the shore-based control center issues target instructions to the intelligent ship by the shipboard control system to control the engine, rudder, etc., to achieve remote-control of the ship (MUNIN, 2013).

Remote autonomous driving, the operator in the shore-based control center sends a sailing plan to the intelligent ship, by the ship's intelligent decision-making system through the controller to initiate the engine order, rudder order, etc., to achieve the remote-control of the ship (MUNIN, 2013).

Through the above three remote controlling methods, it can be seen that remote automatic control and remote autonomous control have realized the autonomy of the shipboard control system to varying degrees. The remote-control mode of the ship brings risks and challenges to the safety of the ship, especially the latency of the network, packet loss, network disconnection, the complex environment at sea and the influence of network security; therefore, the ship should obtain a certain degree autonomous decision-making ability to ensure the safety of the ship, cargo, etc. in case of emergency.

Ship control problems can be divided into the following 4 aspects: heading control, track following control, speed and course control and position control. Ship has been widely equipped with autopilot system that can achieve speed and course control and high-speed track following control (Yuanyuan Wang, Jialun Liu, 2021). Dynamic positioning system is more common in marine drilling ships with its accurate and automated positioning ability which can achieve low-speed track following and accurate position control of ships. China's Zhifei intelligent ship is equipped with an autopilot system and a dynamic positioning system. On September 14, 2021, it completed the debugging of the autopilot system and the dynamic positioning system under the automatic control system (Jingang Zhang, 2021), which verified the combination of the autopilot system and the dynamic positioning system that such a combination could ensure the stable control of the ship's movement situation under the autonomous control. How to achieve the fine handling of ships through the integration of the autopilot system and the dynamic positioning system under the control of the autonomous navigation decision system is the future direction.

Intelligent ships only have a stable track control function that cannot meet the requirements of ensuring ship safety when the ship loses contact with the control center, and the ship must also have a certain ability to avoid collisions autonomously.

Navigation and collision avoidance behavior of intelligent ships, especially cargo ships sailing at sea, is subject to the COLREG. Benjamin et al. has applied multi-objective optimization methods to convert collision avoidance rules into behaviors. Huang et al. outlined the existing human-computer interaction mode in the process of collision avoidance of intelligent ships, and proposed a framework for collision avoidance system oriented to human-machine interface, which is conducive to the autonomous collision avoidance of ships (Benjamin et al., 2006). In September 2021, South Korea's Samsung Heavy Industry completed the autonomous collision avoidance test for the head of the real ships; in September 2021, China's Zhifei intelligent ship completed part of the test of the automatic collision avoidance of the real ships. At the beginning of 2022, Japan conducted five consecutive real ship experiments on fully autonomous ships, which verified the effectiveness and reliability of ship autonomous collision avoidance to a certain extent.

In summary, the ship's remote-control mode is shown in Figure 4-2. Shore-based operators send operating instructions to the ship and then intelligent ships determine whether the communication is normal, directly execute the instructions and feedback execution information. When the system determines that the network communication is not smooth or disconnected, the system should automatically switch to the autonomous mode, so as to ensure safety of the ship after lost contact with shore control center. Indeed, current autonomous decision-making techniques are not yet sufficient to meet the needs of ships on the condition of berthing and unberthing and navigating in scenarios with complex traffic situations such as narrow waterways, and this issue will be discussed in this paper when discussing the distribution of shore-based control centers.

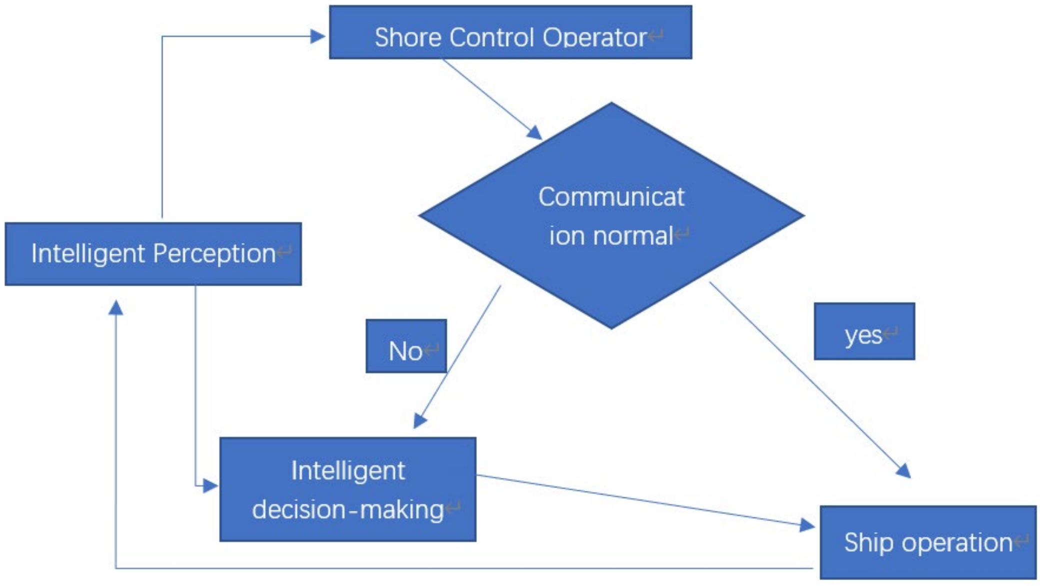

Figure 4-2. The interaction Between SCC and Ship. Source: Author.

4.1.3.2 Autonomous navigation mode

Ships in the autonomous navigation mode need to have the same capabilities of cognitive, analytical, thinking, decision-making and control as human. Moreover, it is more intelligent than the remote-control mode and can be completely free from manual intervention. Based on the sensing technology, ship communication technology, ship navigation control technology and ship collision avoidance technology mentioned above, this subsection mainly focuses on the intelligent cognition and intelligent decision-making technology of autonomous ships.

1.) Cognitive technology

Cognitive technology is a technique that uses computers to simulate the human brain. Compared with traditional computing techniques, cognitive computing focuses more on studying uncertainty, inaccuracies, and local realities in biological systems to enable computer simulations of human perception, analysis, thinking, and decision-making processes.

In recent years, cognitive computing technologies represented by knowledge graph, digital twins, deep learning, etc. have attracted more and more attention from experts and scholars, and have achieved good results. Among them, digital twin technology is currently one of the hot issues in academia and the industry. In the field of ships, cognitive computing technology is applied to the fields of ship collision accident analysis, shipping intelligence, and meteorological prediction of marine navigation environment (Yongjie et al., 2021).

2.) Collision avoidance decision-making techniques

In recent years, in the decision-making of ship collision avoidance, experts and scholars at home and abroad have proposed the combination of fuzzy reasoning methods, neural network methods, genetic algorithm methods, expert intelligence methods and various intelligent methods.

Li Lina et al. put forward the personified intelligent decision-making theory based on the way of decision-making of human on collision avoidance, and finally realized the ship simulating the way of decision-making of human on collision avoidance through automatic methods such as object cognition, target movement analysis, goal-first judgment, collision avoidance decision generation, and decision optimization and verification (Lina Li, 2011).

Perera et al. proposed an intelligent collision avoidance decision system based on fuzzy logic, which can realize automatic collision avoidance decision-making of ocean-going ships under simulation conditions (Perera et al., 2011). Tsou et al. proposed a ship collision avoidance decision support system on the basis of genetic fuzzy algorithm, which can calculate the optimal safe steering angle, as well as the subsequent return to route time and steering angle by considering the ship safety domain and the relevant parameters of the two ships under the COLREG (Tsou et al., 2010).

Chen Xuejuan proposed a ship collision avoidance theory and method based on BP neural network. This method uses parameters such as the closest point of approach and the time when approaching the closest point, and obtains the collision hazard level through the BP neural network, which provides support for collision avoidance (Chen, 2005). Tang Suixin and Yang Guobin respectively proposed optimization measures for the system (Suixin Tang, 2006;Guobin Yang, 2006).

There is still a lot of room for improvement in the key technology of autonomous ships, especially the cognition and decision-making technology, to meet the requirements of intelligent ships set by IMO at least as safe as manned ships. Hence, a large amount of data support is needed, and the autonomous control technology of unmanned ships needs further development.

4.1.3.3 Shore-based control center

Shore-based control centers are an important factor in ensuring the navigational safety of intelligent ship. Through the shore-based control center, people can monitor the navigation status of intelligent ships and provide manual intervention when necessary to ensure the safety of ships. Whether it is a remote-control vessel or an autonomous vessel, it is inseparable from the shore-based control center. Regarding the setting and layout of shore-based control centers, domestic scholars have relatively little research on control centers, and foreign scholars have started their research on control centers earlier. In 2013, ØJ Rødseth et al. proposed to set up multiple shore-based control centers on the basis of intelligent ship communication security, and the setting of multiple shore-based control centers can ensure that when one of them is unable to work, other control centers can take over and continue to control intelligent ships, thereby ensuring the safety of intelligent ships (Rødseth et al., 2013). The MUNIN project experimented with personnel assignment. The test assumed that the maximum number of vessels that an operator could control at the same time was six (MUNIN, 2015). The experiment verified the possibility of the above hypothesis, but due to the technical limitations of the control center, the result was not satisfactory, and it has not been verified so far. H. Dybvik et al. believe that the MUNIN project assumes that the maximum manning limit is unreasonable, and they believe that when berthing and unberthing, or passing through heavy traffic sections such as canals and narrow waterways, the operator does not have the energy to control more than one ship at the same time. On the other hand, in ocean navigation with less traffic pressure, with the assistance of autonomous navigation function, the operator can control far more than 6 ships (Dybvik et al., 2020).

In order to meet the requirements of unmanned ships as safe as manned ships, the setting of shore-based control centers should be discussed from several aspects:

1.) Human factors

Intelligent ships will reduce human intervention and reduce the risk of accidents due to human factors, but also create new ones because operators are not on board. Mikael Wahlstrom et al. believe that shore-based operators lack the perception of the ship's moving situation, resulting in insufficient understanding of the situation (Wahlström et al., 2015), and personnel need time to understand the situation when responding to emergencies, and shore-based personnel need more time to make decisions than ship personnel (Porathe, 2016). Restrictions based on the transmission of image information can lead to insufficient awareness of the local environment and inability to anticipate the next situation in advance (Man et al., 2015). Reducing human-machine interaction time and providing an immersive working environment for operators with a friendly human-machine interface are key factors in shore-based equipment configuration.

In order to provide the operator with an immersive on-the-spot judgment basis, digital twin technology can be used with complementary use of augmented reality/virtual reality technology. The intelligent perception of the navigation situation data through the data transmission mode sent to the shore-based control center, mapped in the shore-end preset three-dimensional space, and then restore the ship's own movement status and navigating situation (Yuanyuan Wang, Jialun Liu, 2021).

2.) Manning

Manning directly affects the cost of shipping companies and shipping safety. In view of the STCW Convention's requirements for minimum manning of ships and minimum rest hours, the manning of shore-based control centers should also be subject to the corresponding rules to ensure navigation safety. When considering manning, the following should be considered, but are not limited to:

The degree of autonomy of the ship. The more autonomous the ship is, the less human intervention is required and the corresponding manning will be reduced.

Traffic conditions. Ocean-going ships are equipped with autonomous operation mode, the control center is in a state of monitoring, and human intervention is needed when necessary, which will require less man power; when berthing and unberthing, and other complex, refined operations, the operation of a ship requires the full attention of the operator to ensure the safety of the ship.

The capability of the person. Operator’s working experience and work performance should be a measure of the operator’s capability. Experienced operators, proficient with the operating steps, can quickly recognize and perceive the situation and react quickly, while inexperienced operators are not familiar with the control system, situational cognition and response time is longer, therefore, the number of ships controlled by personnel should increase with their working experience.

3.) The influence of communication technology on the distribution of shore-based control centers

The probability of delay, packet loss, and disconnection in existing communication technologies will rise with the increase of communication distance. The uneven economic development will lead to inconsistent construction of communication infrastructure in various countries, which will have an impact on the distribution of shore-based control centers.

The mainly communication between the intelligent ship and the shore-based control center of the ocean voyage is satellite communication. Taking GEO satellite as an example, the ground area covered by one satellite is certain. The farther the signal transmission distance, the greater the delay, and the higher the rate of packet loss and the network disconnection, and the smallest delay is when there is only one satellite involved in transiting the signal. It means if the ground transmitter and the receiving end are in the coverage of the same satellite, the transmission link will be the shortest, and the network signal will be the best (Xianqing Yi,Yang Zhao, 2007). Therefore, the distribution of shore-based control centers should take into account the impact of satellite transmission links. Within the coverage of the same satellite, countries or regions with better communication network infrastructure should be selected to ensure the smooth flow of other types of communication.

The MUNIN project recommends that intelligent ships adopt a manual remote operation mode when sailing near shore (MUNIN, 2015). In this mode, the amount of data exchange between the ship and the shore will increase due to full information data such as video, and the data exchange of multiple ships in the same area will lead to communication congestion. The annual traffic volume in the Strait of Malacca in

2021 is 78,317 vessels, with an average daily traffic volume of more than 210 vessels (Marine Department Malaysia, 2022). As the number of intelligent ships increases, the amount of data traffic in this region will continue to rise, and this, coupled with aviation traffic and other commercial traffic, will put a lot of pressure on the network traffic in the region. This increases the risk of losing contact between the intelligent ship and the remote shore-based control center. Based on the above discussion, the author proposes to set up a shore-based control center in the coastal area with heavy traffic. This remote-control center implements remote control of the intelligent ship with a fast, large bandwidth and small delay local area network using Ethernet technology and GSM communication facilities. This measure will not only reduce the impact of poor networks on the safety of intelligent ships, but also improve the safety of ships because local operators are familiar with the navigational situation in the waters. Of course, the coastal control center is not necessarily owned by the shipowner, but can be a third party who owns the means of providing services to the ship.

4.1.4 Cybersecurity of Intelligent Ships

In a report released in 2017, Lloyd's Register said 44% of shipping companies felt the need to upgrade their information protection systems, most of which had already suffered varying degrees of cyber-attacks (Lloyd’s Register, 2018). A survey released by Allianz in 2020 showed that cybersecurity issues are recognized as the biggest threats to industry (Allianz Global Corporate & Specialty, 2022). The process of controlling intelligent ships relies on technologies such as network communication, artificial intelligence and autonomous control. In the communication link, including intelligent ships, shore-based control centers and communication satellites, network attacks may occur in any parts, which will bring great challenges to the safety of ships, cargo and the marine environment. With the in-depth research of the network security system framework and the advancement of encryption technology, the network security problems of intelligent ships are expected to be solved.

4.1.4.1 Network security system framework

The Framework for Improving Critical Infrastructure Cybersecurity, published by the National Institute of Standards and Technology, includes five core functions, namely identification, protection, detection, response, and recovery, which together form a framework for mapping cybersecurity management standards that can be used to describe the current state or desired goals of specific cyberspace security activities (National Institute of Standards and Technology, 2018). The framework itself is a standard system in the field of cybersecurity, proposing a new model of engagement for critical infrastructure stakeholders that is flexible and scalable. It has guidance and reference significance for the shipping industry to formulate relevant documents on intelligent ship network security.

4.1.4.2 Encryption technology

Blockchain encryption technology is currently the most effective and secure encryption technology (Patil et al., 2021). It adopts a partitioned data management structure that users can independently complete data storage and maintenance with the characteristics of decentralization; the blockchain uses hashing algorithm to ensure that the data cannot be tampered Timestamp technology is used to ensure the traceability of data, and blockchain technology due to its own code particularity, anti-decipherability, can effectively ensure the security of network data.

4.2 The impact of intelligent ships on maritime regulation

Intelligent ship technology is developing rapidly, and the realization of intelligent ships cannot rely solely on the intelligence of the ship; on the contrary, the practice of intelligent ships will trigger the technological evolution of maritime management and supervision as well as the evolution of the technology ecosystem of global shipping. Maritime supervision plays a vital role in the safety of shipping. This subsection will analyze the impact of intelligent ships on maritime supervision from the following aspects according to the operating characteristics of smart ships.

4.2.1 Crew management

4.2.1.1 Legal definition of remote operators

As defined in national laws, the captain is the highest-ranking person on board the ship, responsible for the safe navigation of the ship, and the core of this role lies in the ability to control the ship. In addition to the responsibilities of the ship and the provision of rescue for the shipwrecked at sea, the captain is also the main body who is responsible for collision avoidance and carrying out collision avoidance operations. In jurisprudence, the captain is the representative of the flag State, the shipowner and the ship, indicating that the captain has the right to enforce the laws and regulations of the flag State on board the ship. When inspected by the competent authorities such as port States and coastal States, the captain cooperates with the inspection of the competent authorities on behalf of the shipowner, and the captain is responsible for the illegal acts of the ship (Maritime Safety Committee, 2018). There is no captain on an unmanned ship, and its control is done by shore-based operators. Although the shore-based operator is not on the ship, he performs the duties of a traditional ship captain in practice, and whether his duties can be equated with the captain needs to be legally defined.

4.2.1.2 Training of crew members for competency

From the perspective of human life and property safety at sea and the protection of the marine environment, STCW stipulates the qualification criteria for captains, officers and crew members on duty on the vessel to ensure that seafarers working on vessel can be competent to perform their duties. The STCW explicitly requires seafarers to be "on board", which applies to unmanned ships where there are obstacles. Similarly, the Maritime International Commission's (CMI) Questionnaire on Unmanned Ships sets up the question: " The STCW Convention purports to apply to ‘seafarers serving on board seagoing ship’. Would it therefore find no application to a remotely controlled unmanned ship?” (CMI, 2017). Most countries believe that unmanned ships cannot break through the "seafarers are on board" rule, STCW cannot be applied to unmanned ships, and existing international treaties only recognize the qualifications of crew members of manned ships There are no qualification standards and management methods for unmanned ship operators.

4.2.1.3 Minimum safe manning requirements

The biggest challenge of intelligent ships is how to ensure the safety of the ship when there is no one on board. Article 94 of UNCLOS obliges the flag State to ensure the safety of ships at sea (United Nations, 1994). This more directly and specifically reflected in the minimum manning requirement in SOLAS.

Chapter 5, Regulation 14 of SOLAS provides that States Parties shall, from the perspective of the safety of life at sea, provide vessels with "a sufficient number and competent crew" (IMO, 1974), and the IMO Adopted Principles of Minimum Safe Manning specifically cited in a footnote to the Convention. Through the Principles of Minimum Safe Manning (IMO, 2011), the IMO lists 12 reference elements for determining the minimum level of safe manning of a ship, including the type and size of the vessel, the level of vessel automation, the structure and equipment of the vessel, the maintenance method, the applicable working hours limits and/or rest requirements. The principles require that engine officers and officers on watch should be configured in such a way so as to ensure that the chief engineer and master are not involved in the regular watch. In Annex 3, Article 2.7, it is emphasized that flag State authorities should pay particular attention to cases where there are fewer than three officers on watch. This indicates that the principles take a cautious approach to the reduction of watch keeping officers. Annex 5 of the principles stipulate that the company's application for downsizing must cover the operation function, operation elements, working capacity and workload assessment, to ensure that the minimum manning cannot violate the requirements of rest hours, and to ensure the safety of human, ships, cargo and environment.

During the transition period from manned ships to unmanned ships, according to the reference element of the Principles of Minimum Safe Manning, the level of automation of the ship is a factor that determines the minimum manning level of the ship, and according to the regulations, the ship with a higher degree of automation can reduce the man power. How to make a judgment on the degree of intelligence of the ship and prove that the machinery and equipment can replace human is a problem faced by the maritime regulatory authorities.

There are two directions for determining the degree of intelligence of Artificial Intelligence (AI). One is to use the tasks that AI can perform as a rating standard, and the other is to compare it with human intelligence. The first method is relatively simple, dividing human work into specific functions, which are then implemented by intelligent devices. The second method is more complex and is based on human IQ testing to determine the degree of intelligence of mechanical devices (Iantovics et al., 2018). In 2017, the Chinese Academy of Sciences developed a general artificial intelligence testing system that tested both humans and machines (ACM Technews, 2017). Based on the above discussion, in determining the degree of marine artificial intelligence, the author believes that firstly, the daily operations of the crew should be divided into specific functions to test whether the machinery and equipment can achieve these functions; secondly, the human-specific functions such as perception, decision making and analysis of the crew should be used to build a model to test the degree of intelligence of the machine.

4.2.2 Inspection of the competent maritime authority

The on-site supervision of the maritime affairs agency mainly includes the on-site inspection, FSC, PSC, maritime investigation, etc. The development of intelligent ships will have a profound impact on on-site supervision.

First, there is a shift from human communication to intelligent data exchange. Unlike existing crew members who operate and manage ships on board, intelligent ships achieve ship operation management through artificial intelligence algorithms, and the system manages ships according to algorithms and processes, so the traditional on-site supervision methods have become unsuitable. So, it is necessary to formulate specific regulations or specific guidelines for intelligent ship on-site supervision (Ning Gao, 2021).

Second, it is necessary to realize the transformation of on-site supervision to online supervision. Intelligent ships can achieve navigation through remote control and autonomous modes. It allows maritime administration agencies to achieve online supervision through the intelligent data exchange system, and to achieve real-time, full-process supervision of intelligent ships. With the system of intelligent supervision as the mainstay, supplemented with manual intervention, the efficiency of supervision could be improved.

Third, it is necessary to take compulsory measures against ships. Maritime affairs administration agencies can check the operation of ships through online interactive terminals, complete inspections before the berthing of intelligent ships, and take compulsory measures to prohibit entry into ports for ships with major non-conformities. How to ask the ship controller to fulfill the obligations of the law/convention on the compulsory measures of ships, or to realize the transfer of control of the ship from the controlling party to the competent authority requires the corresponding provisions of laws and regulations. At the same time, the requirements for the recording and preservation of statutory documents on ships cannot be realized in on-site supervision, so the legality of system records and electronic data should be stipulated by laws and regulations as statutory documents.

4.2.3 The impact of intelligent ships on navigation service

Navigation service has three basic functions. The first one is to set navigation Aids to help ships navigate safely. The second one is to survey the waterways, update nautical chart data, and provide reliable hydrological data for safe navigation, and the third is safe communication on the water. At present, the navigation service systems of various countries have multi standards, multi systems, which will bring trouble to intelligent ship to acquire and identify the information (Omar Frits Eriksson, 2019). In 2006, IMO proposed the concept of E-Navigation, and all member countries have also carried out the strategic layout of E-Navigation, which promoted the intelligent, digital and informatization development of navigation services (Hailong Huang, 2019), but the data formats and electronic equipment developed by various countries are not uniform, which will hinder the international navigation to obtain shore-based support and identify information . The S-100 is a new generation of marine geographic information data model proposed by IHO in 2005 and updated in 2010 (Jiannan Luo, Xiaoxia Wan, 2019). In 2011, the IMO decided to use the S-100 as the base model for a universal maritime data model. With the development of the series of S-100 standards, the global unified standard specification for all kinds of maritime data is also gradually improving (Park & Park, 2015). The dissemination and data exchange of navigation service information under the unified standard will provide the guarantee for the identification and acquisition of shore-based information for intelligent ships.

Ships need to obtain a large amount of navigational assistance information, including safety information such as navigation warnings, real-time meteorological and sea condition information such as weather, hydrology, and waterway currents in the port area, updates of electronic chart in the port area, real-time status of Aids to Navigation, etc. At present, there are still a large number of navigational assistance information that cannot be provided to ships in time, and navigational assistance information cannot be fully released in the form of data adapted to intelligent ships, so the perception data of intelligent ships is still quite limited (Porathe & Rødseth, 2019). In order to adapt to the identification of intelligent ships, the navigation service department should accelerate the construction of collection systems about offshore and marine environment information of ports, develop marine environmental information related data standards in accordance with the S-100 standard and accelerate the digitization of navigational service information, in order to expand the perception data of intelligent ships.

4.2.4 The impact of intelligent ships on water traffic management

The Vessel Traffic Service (VTS) provides navigation services, ship management services and information services for ships in its waters, and its role mainly relies on the communication and interaction between VTS attendants and seafarers on board the ship. But the unmanned nature of intelligent ships will break this traditional way of information exchange and have a great impact on VTS to perform its duties to ensure navigation safety and protect the marine environment.

4.2.4.1 The communication mode of VTS

The control mode of intelligent ships is divided into two types, remote control and autonomous navigation. VTS needs to use a new communication method to communicate with intelligent ships in each mode, and if necessary, VTS also needs to establish real-time communication with intelligent ship shore-based control centers. The communication technology of intelligent ships determines the communication methods that VTS can adopt, so the information flow between VTS and intelligent ships will increase significantly, which requires higher transmission rates and greater bandwidth communication network support.

4.2.4.2 VTS Regulations

The IALA-led Guidelines For Vessel Traffic Services contain the provision that this guideline does not change the master's ultimate responsibility for all aspects of the operation of the ship, including the responsibility for safe navigation (IMO, 1997). There are many human-related provision in the COLREG, such as Lookout. These international rules and domestic regulations associated with VTS regulation are based on seafarers on board, and once ships are unmanned, VTS regulation will have nothing to rely on.

4.2.4.3 The reference of the VTS regulatory model to Air Traffic Control

The communication requirements and operating modes of intelligent ships are very different from those of traditional ships. The traditional VTS management model will not be suitable for intelligent ships in VTS waters. The regulatory system of aviation developed earlier, and water traffic management can learn from the Air Traffic Control (ATC) system. The ATC consists of three parts, namely terminal control which is responsible for ground management after landing and before take-off, approach control which is responsible for providing traffic control services to aircraft in the entry or exit airport, and area control which is responsible for providing traffic control services for aircraft flying above 6000 meters (Figure 4-3). Each control department monitors the real-time situation in its area, navigation flow, weather conditions and other factors affecting flight safety through radar and other equipment, and shares information with other control departments, works together, takes the initiative to control the take-off and landing of aircraft, provides navigation information for aircraft and other measures to ensure the flight safety, improve flight efficiency, and ensure the smooth flow of air traffic. The ATC realizes the continuous tracking of the entire route of the aircraft through the tower, approach and area control, and the introduction of radar control and other equipment improves the ability of controllers to actively command air traffic (Bing Dong, 2016).

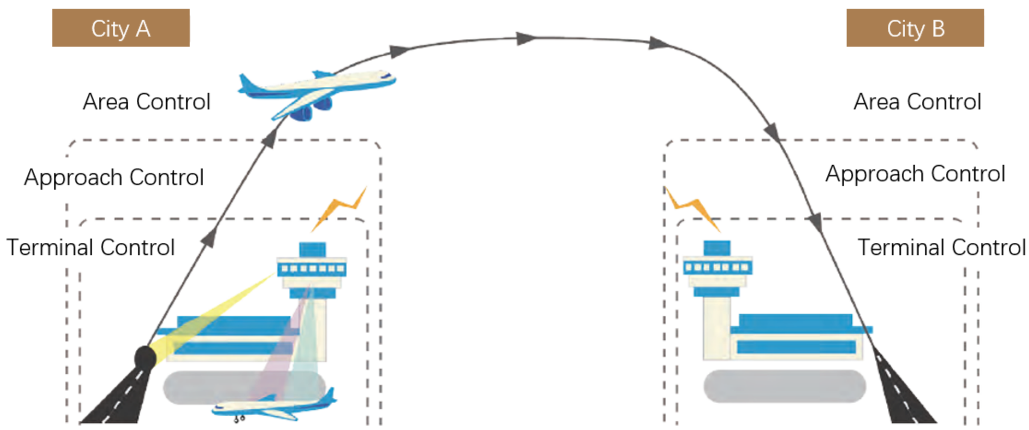

Figure 4-3. The working principles of ATC system. Source: Baidu Baike.

In the current VTS system, each unit has no information sharing but only realizes the supervision within its jurisdiction, and it is not possible to track and monitor the whole route of the ship, real-time situation, continuous tracking, which limits the ability of traffic management personnel to actively and timely determine problems and makes the water traffic management service into a passive situation. The unmanned characteristics of intelligent ships, as well as the possibility of network attacks, network failures and other issues lead to the loss of contact between intelligent ships and the shore-based control center, thus endangering the navigation safety of ships. The above problems are unpredictable, which requires the VTS system to be able to do all-round, all-route, real-time monitoring of intelligent ships, actively discover abnormal behavior of ships, timely discover problems, and provide timely maritime rescue. In 2021, the Maritime Safety Bureau of the Ministry of Communications of China issued the Work Plan for the Construction of Large Traffic Management on All-Factor Water, which proposes information sharing between various departments and the construction of a traffic management system covering the entire water area (Ministry of Transport of the People's Republic of China, 2021). This scheme points out the development direction of the future VTS management model.

4.2.4.4 Intelligent ships and lifesaving at sea

The master of the vessel is obliged to provide assistance to persons in distress at sea in accordance with chapter V, article 33, of the SOLAS and article 98 of the UNCLOS. For intelligent ships, especially those without crew, whether or to what extent the obligation to rescue human in distress can be exempted is a question. Some analysts believe that some artificial intelligence ships do not have good rescue conditions due to their own structural characteristics or their own ship attributes, life-saving equipment and other reasons (Ning Gao, 2021). Measures based on legitimate interests, legislation should reduce or exempt shore-based remote controllers from their obligation of rescue, or develop alternative solutions so that shore-based remote controllers could comply with their notification obligations and transmit information to other vessels or rescue centers. The 100th session of the IMO MSC on intelligent ship rescue obligation combing also believes that unmanned ships as search and rescue facilities, at least to some extent, can play the role of alert stations / ships (Maritime Safety Committee, 2018). In summary, the author believes that intelligent ships cannot completely exempt themselves from the obligation of rescuing human at sea, but they can be appropriately exempted from the obligations stipulated by the Convention and the law according to factors such as whether the ship is equipped with crew, its own structure and functions.

4.2.5 Handling of maritime traffic accidents

In traditional manned ships, the responsible subjects involved in the safety of sea navigation include the captain, crew and ship owner. Intelligent ships include remotely operated unmanned ships and fully autonomous unmanned ships. Even for fully autonomous ships, shore-based control center will be established to monitor the operation of the ships. There is no captain and crew on the intelligent ship, and its manipulation is controlled by the shore-based operator, resulting in unclear subjects of responsibility for intelligent ships and bringing challenges to maritime regulatory authorities in handling accidents (Yan Zhang, 2020).

4.3 Summary

This chapter analyzes the sensing technology, communication technology, control technology and network security of intelligent ships, and analyzes the impact of intelligent ships on maritime supervision from five aspects: crew management, inspection by maritime authorities, navigational services, water traffic management and maritime traffic accident handling according to the characteristics of intelligent ships. Through the analysis, it is found that the current maritime supervision laws for intelligent ships in China are missing, and the infrastructure of supervision is not perfect. At the same time, the training of supervisors is not yet in place, and the existing supervision mode is not adapted to the supervision of intelligent ships.

CHAPTER V: THE SUGGESTIONS ON THE COUNTERMEASURES OF SUPERVISION OF INTELLIGENT SHIPS

The impact and countermeasures of intelligent ships on the shipping industry are still in their infancy, especially in maritime safety supervision. In recent years, with the rapid development and practical application of new technologies such as big data, artificial intelligence and the Internet of Things, the intelligent shipping industry is rapidly developed to the higher level, and intelligent navigation of ships, intelligent health monitoring, intelligent energy efficiency management, etc. have gradually realized commercial applications. In order to better meet the needs of the development of intelligent shipping and promote the modernization of maritime governance capabilities and governance systems, the digitalization and intelligent transformation of maritime management have become an important issue that needs to be solved urgently. In this chapter, the author will focus on the issues faced by the maritime safety regulation of intelligent ships and make recommendations.

5.1. Legislative Recommendations

The law is the foundation and basis for the implementation of regulation. Intelligent ships are new technology products, and the existing laws and regulations on ship regulation are based on the traditional manned ships, and it is doubtful whether they can be applied to intelligent ships, especially the unmanned ships in the third and fourth stages defined by IMO. To solve the problem of whether intelligent ships should be adjusted to the existing international conventions, the legal status of intelligent ships should be determined first. In order to ensure the safe operation of intelligent ships, this subsection will discuss the legal problems encountered by intelligent ships and put forward legislative proposals.

5.1.1 Legal attributes of intelligent ships

Whether an intelligent ship belongs to a ship within the existing legal framework is a prerequisite for deciding whether the relevant ship regulation laws are applicable to intelligent ships.

5.1.1.1 The definition of ship in international conventions

The major laws and regulations related to the safety of maritime navigation and marine environmental protection are the International Convention for the Safety of Life at Sea (SOLAS), and the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) under the IMO system, the United Nations Convention on the Law of the Sea (UNCLOS) and relevant international customary laws. Among them, UNCLOS provides for the obligations of the flag State and the right of navigation of the ship, but it does not provide a clear definition of the ship (United Nations, 1994), and SOLAS and STCW also do not have a unified definition of ship.

As for the international conventions, according to their different application and legislative purposes, many existing laws and regulations concerning ships and their safety of navigation at sea do not provide a clear definition of ships. The following table 5-1 shows the definition of a ship in accordance with the laws and regulations for the safety of maritime navigation.

Table 5-1 The definition of ship given by some of the conventions. Source: Author.

Convention Name	Article	Definition
Convention for the Suppression of Unlawful Acts Against the Safety of Maritime Navigation	I	“Ship” means a vessel of any type whatsoever not permanently attached to the sea-bed, including dynamically supported craft, submersibles, or any other floating craft.

Hague Rules	I	"Ship" means any vessel used for the carriage of goods by sea.
United Nations Convention on Conditions for Registration of Ships	II	"Ship" means any self-propelled sea-going vessel used in international seaborne trade for the transport of goods, passengers or both with the exception of vessels of less than 500 gross registered tons
International Convention for the Prevention of Pollution from Ships	II	"Ship" means a vessel of any type whatsoever operating in the marine environment and includes hydrofoil boats, air-cushion vehicles, submersibles, floating craft and fixed or floating platforms.
International Convention on Civil Liability for Oil Pollution Damage	I	"Ship" means any sea-going vessel and seaborne craft of any type whatsoever constructed or adapted for the carriage of oil in bulk as cargo
Convention on the International Regulations for Preventing Collisions at Sea	III	The word "vessel" includes every description of water craft, including non-displacement craft, WIG craft and seaplanes, used or capable of being used as a means of transportation on water
International Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances by Sea	I	"Ship" means any seagoing vessel and seaborne craft, of any type whatsoever
Maritime Labour Convention	II	Ship means a ship other than on which navigates exclusively in inland waters or waters within, or closely adjacent to, sheltered waters or areas where port regulations apply.

The concept of ship in the above conventions mainly emphasizes the transport purpose of the ship, and does not involve the maneuvering mode of the ship and the crew that must be on board, indicating that these are not the elements that constitute the ship; therefore, theoretically, intelligent ships should belong to the adjustment scope of the conventions, especially the Convention on the Law of the Sea, and intelligent ships should have various navigational rights that traditional ships have under its provisions.

The second is the sea worthiness conditions that intelligent ships should have before sailing. Article 91 of the International Convention on the Law of the Sea stipulates that the conditions of ship's registry shall be stipulated by the flag state through domestic legislation, and the third paragraph of Article 94 stipulates that the flag state shall take regulatory measures in three aspects: safety equipment of the ship, personnel of the ship and prevention of ship collision to ensure the safety of the ship's navigation. Intelligent ships are able to meet the requirements of this article when they meet the relevant safety standards. Paragraph 4 of Article 94 stipulates the fitness requirements and manning requirements for ships with personnel (United Nations, 1994). The clause sets out the requirements for flag State supervision of ship's personnel but does not make it a necessary condition for a ship to have crew to constitute a ship. The provisions of UNCLOS put the identification and jurisdiction of a ship within the jurisdiction of the domestic law of the flag State. Therefore, author believes that an intelligent ship should be qualified as a ship under UNCLOS, and be given the same right as the traditional ship.

5.1.1.2. Definition of Ship in the relevant laws in China

China's maritime law on the definition of ships refers sea-going ships and other mobile units (Maritime Code of the People's Republic of China, 1993) but does not include ships or craft to be used and provides that the master, as the principal person in charge of the ship, manages and drives the ship, and defines the crew as all persons serving on the ship.

Article 29 of the Regulations on the Inspection of Ships and Marine Installations "defines ship as all kinds of discharging or non-discharging ships, boats, seaplanes, submersibles and mobile platforms. (the People's Republic of China Ship and Marine Facilities Inspection Regulations, 1993). Article 50 of the Maritime Traffic Safety Law and Article 56 of the Ship Registration Regulations also make corresponding provisions for ships. The above definitions of ship do not include the need to carry crew. Therefore, from the perspective of textual interpretation, the maneuvering mode of a ship and whether there are crew on board do not constitute the necessary conditions of a ship, and an intelligent ship meets the requirements of the definition of ship and should be the object of adjustment of the above laws and regulations.

In summary, no matter it is international conventions or domestic laws, intelligent ships meet the definition of ship and should be adjusted by relevant international and domestic regulations. Therefore, author suggests that, in view of the technical characteristics of intelligent ships, experts in intelligent ship technology should be invited to participate in the revision and formulation of relevant laws so as to clarify the legal status of intelligent ships. In the process of revision, the characteristics of intelligent ships and the unity of the law should be taken into account at the same time so that the relevant laws can be adapted to unmanned ships and should not restrict the development of intelligent ship technology.

5.1.2 Legal attributes of shore control center

ISM code is the only convention that extend the maritime safety supervision to shipping company, and the shore control center is located on land. But can it be part of the shipping company or the ship?

According to the research on intelligent ship technology at this stage, shore-based control center is a part of intelligent ship operation; i.e., intelligent ships should be connected to shore-based control center at all times when they are in operation, whether they are remotely controlled ships or autonomous ships. One shore-based control center can control two or more intelligent ships at the same time. The control of a ship is achieved through the operation of the ship by the ship's officer in the ship's bridge, which is the traditional way of navigating a ship. For the unmanned intelligent ships, the above traditional way will no longer be applicable. The intelligent ship is operated by a shore-based operator through the shore-based remote-control center to control and supervise the intelligent ship and realize the normal operation (Nzengu et al., 2021). Compared with the traditional ship, the shore-based control center is equivalent to the cockpit of the traditional ship; i.e., the cockpit of the intelligent ship is transferred to the shore, and the shore-based control center should be regarded as the replacement of the cockpit of the traditional ship (Figure 5-1). The intelligent ship operation is done by the intelligent ship and the shore-based remote-control center together, and the shore-based control center belongs to an extremely important part of the intelligent ship system and equipment. So, to consider the shore control center as a part of the ship is reasonable.

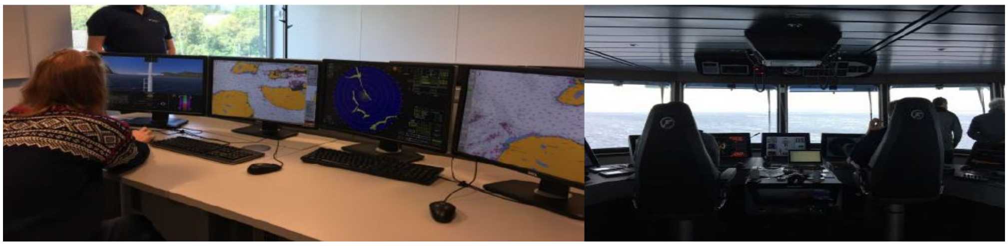

Figure 5-1. The prototype of SCC (left) and Ship bridge (right).

The ship inspection system is a regulatory measure for ships to ensure the ability of the ships and their equipment to navigate safely, and its basic role is mainly to make sure the various systems and equipment of the ships have the technical conditions for safe navigation and operation (Hong Pan, 2020). It is the crucial guarantee for the safe navigation and operation of intelligent ships that the shore-based control center of intelligent ships can meet the requirements of corresponding technical standards.

Therefore, the facilities of the shore-based control center should be regarded as a part of the intelligent ship, and the legal status of the shore-based control center should be clarified through corresponding legislation, and the obligation of the ship inspection agency that conducts statutory inspection on the shore-based control center should be clarified to ensure the operational safety of the intelligent ship.

5.1.3 Intelligent ship technical regulations

Ship technical regulations are the legal basis to supervise the design, construction, inspection and supervision of ships and guarantee the quality and safety of the whole life cycle of ships. Compared with traditional ships, intelligent ships use a lot of artificial intelligence technologies, such as intelligent perception, analysis and decision making, and internet, so the current technical regulations for traditional ships do not fully fulfill the needs of intelligent ships, especially the new applied technology.

In Chapter 3 of this paper, we introduce the current standards of six classification societies for the classification inspection of intelligent ships, in which the classes of intelligent ships are also different according to perception, cognition, decision making and execution. Among them, the Rules for Intelligent Ships (2020) of China Classification Society is the open and principal standard for the classification and inspection of intelligent ships in China. The Code divides the inspection of intelligent ships into six intelligent functions: navigation, engine, hull, energy efficiency management, cargo management and integrated platform (CCS, 2020).

The other factor is that many countries are developing the technologies for intelligent ships, and many are different with each other, so the technical regulation cannot be made including all technologies, but the GBS type Goal-Oriented regulation can be considered when making the regulation, like the Ground-effect wing ship code used.

In order to adapt and promote the development of intelligent ships and unify the technical standards of intelligent ships, the author believes that the technical regulations of intelligent ships should be formulated according to the technical development stages of intelligent ships and the statutory inspection system of intelligent ships should be improved as soon as possible. When formulating the technical regulations of intelligent ships, references should be made to the technical standards of intelligent ships formulated by domestic and foreign classification societies, and the different technologies required by intelligent ships in different stages should be considered so that the regulation could be more practical.

5.1.4 Legal status of the shore-based control operator

In addition to performing responsibilities such as commanding and driving the ship and providing rescue for people in distress at sea, the crew is also the responsible body for performing collision avoidance responsibilities and executing collision avoidance actions. Shore-based control personnel of unmanned vessels are not part of the crew in the laws of many countries but replace the crew in many duties. In most cases, the shore-based manning personnel are in full control of the unmanned vessel's navigation, and they also need to perform the same responsibilities as the crew, such as commanding the vessel and rescue duties in distress (Shahbakhsh et al., 2022). From a job content perspective, there is some basis for defining shore-based personnel as crew members, but there are differences.

The concepts of the seafarer and shore-based control operator are different. Article 1 of the International Maritime Labour Convention stipulates that a crew member is a person employed to work in any capacity on board a ship (ILO, 2006). For the scope of the crew, the provisions of different countries, mainly around whether the captain belongs to the crew is divided into two types. One is represented by Germany and Japan that the captain and other levels and types of seafarers on board collectively are referred to as the crew; the second is represented by the United Kingdom and the United States that the captain and crew on board separate from each other. According to the provisions of Article 31 of China's Maritime Law, crew refer to all personnel serving on board, including the captain (Maritime Code of the People's Republic of China, 1993). The above concept reflects that the current on board is a necessary condition to constitute the crew. Professor Si Yuzhuo believes that the crew in the sense of China's Maritime Law has three conditions: firstly, they are qualified as crew members and have obtained the certificate of competency; secondly, they are employed or hired by the ship owner; thirdly, they serve on board (Yuzhuo Si, 2018). The remote-control operator is a person who works at the remote-control station on land and does not serve on the ship, so conceptually, the remote controller cannot be included in the category of crew.

The two workplaces are different. The traditional crew members need to work on the ship, which have the characteristics of high risk, difficult working environment, high mobility and being far from family, while the telehandlers generally work on land, and thus no longer have the characteristics of the traditional crew members. At the same time, since telehandlers do not have the professional characteristics of crew members, in terms of legal application, those legal systems that provide special protection for crew members based on the professional risks of crew members should not be applied to telehandlers either.

The concept of shore-based operator is not covered in the current relevant laws, but the shore-based operator is the main body of intelligent ship operation and management, and has the same functions as the crew, and affects the operation safety of intelligent ships at all times. Therefore, they should be included in the scope of supervision of relevant laws as crew members. Therefore, author thinks it is necessary to add the definition, fitness standard and equipment standard of shore-based operators of intelligent ships in the crew management system, such as first-class operator, second-class operator, etc., and the competent authority implement should unify supervision and management for them.

5.2. Crew management

With the development of technology, the number of personnel on board of intelligent ships will be gradually reduced until the intelligent ships are unmanned, and the operation requirements of intelligent ships will also change the existing seafarer training mode. The digitalization and informationization of intelligent ships are much better than the existing ships. Another characteristic of intelligent ships is that the safe navigation of ships is done together by the shore-based control personnel and the shipboard personnel or by the shore-based control personnel alone. In addition to the existing navigation knowledge and ship maneuvering skills, seafarers need to master the knowledge to meet the control requirements of intelligent ships; the definition of the intelligent ships will reduce the crew members; how to manage the shore-based control personnel, is the problem faced by maritime supervision.

5.2.1. Manning standards of intelligent ships

During the transition period from manned ships to unmanned ships, according to the reference of the Principles of Minimum Safe Manning, the level of automation of the ship is a factor that determines the minimum manning level of the ship, and according to the regulations, the ship with a higher degree of automation can reduce the man power. The definition of the degree of intelligence of the ship and of the machinery and equipment is a problem faced by the maritime regulatory authorities.

International automotive engineers classify smart vehicles into 6 levels, and the third level is the primary stage of the autonomous driving category. The United Nations has formulated the ECE R157 rules, which define the functions of the L3 smart vehicles, such as system safety and fail-safe, sensing system, network security and software update, data storage system, etc.(UNECE, 2020). The rules become the standard for determining whether a smart vehicle can achieve intelligent driving, and they also provide a basis for regulatory authorities to make a determination.

Author thinks we should refer to the functional standards of intelligent cars and formulate the refined functional standards of intelligent ships at the international level, and set functional standards for automatic sensing, automatic collision avoidance, intelligent cabin, intelligent cargo management, network security, etc. of intelligent ships, and integrate the standards into the minimum safety manning requirements of intelligent ships. For example, when the automatic sensing technology of intelligent ships reaches the technical standards, they can cancel the lookout personnel. This not only provides a basis for flag states to decide intelligent ship manning, but also provides a basis for port state supervision.

SOLAS, STCW and the Maritime Traffic Safety Act all stipulate that the ships must be manned, and in particular the bridge. SOLAS Chapter II-1 Part E defined the requirement for periodically unattended machinery spaces, which means that the engine room could be unmanned. SOLAS Chapter II-1 Part E defines the requirement for periodically unattended machinery spaces, which means that the engine room could be unmanned. To realize the unmanned bridge, the author suggests that the relevant regulations on the manning of the bridge should be amended, so as to provide a legal basis for conventions for unmanned bridges under appropriate conditions.

5.2.2. Training of shore-based operators

The training of traditional crew members is carried out according to the requirements of STCW, and their prescribed ship maneuvering and navigational skills are tailored to the needs of traditional ships. Shore-based operators perform duties such as ship maneuvering and collision avoidance, ship monitoring, ship security, and prevention of ship pollution by remote control, which are not very different from the duties of traditional crew members. The intelligent system on the intelligent ship is linked to the control system of the shore-based control center through the network, and the shore-based controller controls the ship remotely by controlling the shore-based machinery and equipment, which is the difference between the shore-based controller and the crew (Saha, 2021).

Based on the above analysis, the author believes that the training of shore-based personnel should include the following.

5.2.2.1. Navigational Training

According to the scope of application of the STCW Code, it does not apply to shore-based manning personnel, but its training content can be partly referred from the navigational training for shore-based manning personnel. It is a consensus in the industry that the coexistence of intelligent ships and traditional ships will maintain for a long time. In the process of intelligent ship operation, intelligent ships will interact with traditional ships, especially the collision avoidance operation. Shore-based operators are required to master the rules of collision avoidance at sea, radar and electronic chart operation, whether they operate directly and manually or monitor the ship. Ship maneuvering techniques are also required to be mastered by shore-based personnel, such as the influence of wind, waves and currents on the ship's motion, the principle of anchoring the ship, etc.

Of course, there are parts of the training content specified by STCW that are not applicable, such as the use of sextant, survival at sea, etc. The training contents for shore-based maneuvers need to be adjusted according to the technological development of intelligent ships, in order to meet the needs of ship navigation safety while avoiding unnecessary training.

5.2.2.2. System training

According to the handling characteristics of intelligent ships, it is crucial for shore-based control personnel to be familiar with and master the shore-based control system, which directly affects the navigation safety of ships. The training of the control system should include: 1) alarm system that the control personnel should understand the meaning of the alarm system; 2) control system that the control personnel should master the operation of the system and the limitation of the system; 3) emergency measures that the control personnel should be able to react quickly when the system fails to ensure the safety of the ship. In addition to the training of shore-based control system, the shipboard system should also be trained so that the shore-based control personnel can understand the operation of the shipboard system and the collaboration between the shore-based system and the shipboard system.

5.2.2.3. Basic training of intelligent technology

Since intelligent ships use intelligent technologies such as information perception, Internet of Things, digital twin, data management and application, shore-based operators should master certain basic theoretical knowledge of artificial intelligence, Internet of Things, intelligent sensing, control theory and other disciplines to ensure that they can correctly identify the operation of the system and faults prevent. After a fault occurs, the shore-based operator can quickly identify the fault and notify the relevant personnel for repair.

5.2.3. Training of existing crew members

The training of traditional crew is carried out in accordance with the requirements of STCW, and its prescribed ship handling and piloting skills are tailored to traditional ships. Smart ships are characterized by modernization of technology, intelligence of equipment, digitalization of communication and automation of machines, and are the product of integration of various intelligent technologies. The personnel on board must not only know how to drive the ship, but also master the repair technology of the machines and understand the digital technology (Jie Wang, Zhao Sichongyang, 2021). In order to adapt to the development of intelligent ships, the following suggestions are made for the crew training in the primary stage of intelligent ships.

5.2.3.1 Establishing composite crew education and training standards

The development of intelligent ships is in the period of transition to intelligent navigation with crew assistance; meanwhile the duties of personnel on board are relatively reduced, and the original crew subdivision and specialties tend to be integrated. Therefore, it is necessary to redefine the division of crew duties and fitness ability, and further standardize the functional issuance of certificates. For example, multi-functional certificate training should be adopted so that senior crew members with navigational skills can engine management functions at the same time.

5.2.3.2. Establishment of electromechanical positions

The digitalization of intelligent ships needs to be realized through many electronic devices, and the maintenance capability of intelligent electronic devices is not available in the current crew system. At present, the ship's intelligent technology and equipment are still immature and unstable, and the personnel should have the ability to maintain the ship's intelligent equipment in order to deal with the equipment failure that may happen at any time. Therefore, the author suggests to set up electromechanical maintenance posts for the manned intelligent ships and develop training programs and standards according to the technical characteristics and equipment of intelligent ships in order to guarantee the safe operation of intelligent ships.

5.2.3.3 Carry out special training of intelligent ship crew

Add corresponding professional training or special training on the basis of existing training programs. For example, the intelligent sensing system and intelligent navigation system of intelligent ships are included in the training contents, and the professional training as well as special training can be added with reference to Radar and ECDIS system, and the intelligent ships can be included in the ships that need special training, such as basic training of intelligent ship operation and advanced training of intelligent ship operation.

5.3. Infrastructure construction

Infrastructure of navigation assurance can be divided into two kinds according to their functions. One is used to promote safe navigation of intelligent ships, such as navigation aids, navigation warning broadcasts, etc. The other is used to supervise the movement of intelligent ships, such as CCTV, radar, VHF, etc. The traditional visual navigational security means such as visual beacons, paper charts and voice release navigational information will not be applicable to intelligent ships. Instead, digital navigational security services that can be recognized by intelligent ships will be used. At present, there is still insufficient data information for navigation protection, and the information of middle and far sea area is missing; intelligent beacon and monitoring equipment are not enough to cover all waters. Furthermore the data format of each maritime department is not unified and cannot identify each other (Ren, 2021). In order to adapt to the development of intelligent ships, the author makes the following suggestions.

5.3.1 Improve the maritime common information specification under S-100 standard

In order to speed up the development of information sharing in national maritime systems, IMO decided to use S-100 as the base model of common maritime data model. The nautical security information broadcast under the unified standard and data interchange will provide guarantee for identification of intelligent ships and access to shore-based information. Therefore, the information specification of China's maritime security system should be developed according to S-100 standard. Relevant research departments should keep track of the dynamic changes of S-100 standard and make real-time updates. Relevant developers should develop information specifications and make them suitable for China's navigation service system.

5.3.2 Improve the mapping data

Marine surveying and mapping are the basic data source of electronic nautical charts. At present, the domestic mapping data, which will be detrimental to the navigation safety of intelligent ships, is not perfect. It should increase the maritime surveying and mapping efforts to realize the full coverage of inland waters as well as coastal trunk lines, and improve the surveying and mapping capacity of middle and distant waters, and enrich the nautical information of international important waters. Completing mapping data and fining channel measurement are important guarantees for safe ship navigation.

5.3.3 Improve infrastructure construction

Smart ships achieve safe navigation by obtaining information broadcasted through smart beacons, and keep in touch with shore-based control center through maritime communication service, while sensing equipment such as CCTV and radar will provide reliable supervision for maritime supervisors. At present, the coverage of domestic intelligent beacons and perception equipment are limited and cannot achieve the full coverage of intelligent ships. Therefore, the author suggests that from the national level, we should keep an eye on the development progress of intelligent ships, formulate infrastructure improvement plan, promote the improvement of navigation protection infrastructure by waters and zones, and gradually realize the coverage of all waters and all routes.

5.4. Maritime supervision

Maritime supervision includes the static and the dynamic supervision of ships. The former includes ship inspection, ship registration, ship safety inspection, supervision of dangerous goods carried by ships and prevention of environmental pollution, etc. The latter mainly refers to the supervision of ships during navigation and operation, compliant with navigation rules, maintenance of ship navigation order, investigation and treatment of water traffic accidents and disposal of ships in distress, etc. Intelligent ships adopt a large number of cutting-edge technologies, and their digital and unmanned features will challenge the existing human-based maritime supervision mode. Data is the basis for both the implementation of intelligent ships and the main form of communication with the outside world (F. Jin, 2016). Therefore, data will become the basis of maritime supervision of intelligent ships. This will require a shift to digital management in maritime regulation.

5.4.1. The foundation of digital management

The basis of digital management is data. The digital maritime supervision system is mainly used to ensure the safe navigation of intelligent ships. Its main data components are: ship registration information, hydro-graphic data information, port berth information, weather condition information, ship route information, ship berthing plan, ship dynamic information, water safety information, water traffic condition, laws and regulations, emergency procedures, etc. The departments that can provide the above information are: navigation security department, intelligent ships, shipping companies, terminals, VTS center, maritime search and rescue department, meteorological department, maritime supervision department, etc.

Because the decision of digital maritime supervision needs to be integrated by multiple departments and multiple businesses, building a platform is the way to realize the integration. This requires sorting out the maritime supervision business and building a core operation and operation platform oriented by demand. Leading by the government, the functions of various departments involved in maritime supervision are integrated into the platform That can carry out information sharing, comprehensive assessment and centralized decision making are carried out among various departments. The platform should highlight the pivotal role of maritime supervision.

5.4.2 Functions of digital maritime supervision system

5.4.2.1 Realizing remote autonomous inspection of intelligent ships-AI inspection

The intelligent maritime supervision system contains data-based laws and regulations, real-time equipment operation data uploaded by intelligent ships and ship safety equipment, on which the artificial intelligence inspection system is structured to realize the system's autonomous inspection of intelligent ships. AI inspection can improve the efficiency of ship inspection and reduce the workload of inspectors by providing more accurate supervision of intelligent ships.

5.4.2.2. Realize intelligent management of water traffic

By analyzing the navigation dynamic information of all ships in the region, the intelligent decision system predicts the future navigation trajectory of ships, and when there are navigation conflicts, the intelligent decision system will automatically generate instructions and convey them to the intelligent ships. The intelligent decision system can also optimize the sailing speed and sailing route according to the sailing plan of the ships, the efficiency of the destination port and the weather condition, etc. so as to improve the energy efficiency of the ships and the utilization efficiency of the port and the safety of the ships' sailing.

5.4.2.3. Realize the rapid response and treatment of water accidents

Because of the support of complete information data, the digital maritime supervision system can analyze the data, predict the factors affecting navigation safety in advance and evaluate the risk it brings, and take active measures to prevent accidents. In an accident, the decision-making system through the analysis of complete data, quickly make the most scientific and optimal accident disposal plans with high efficiency, and reduce the waste of rescue resources. The digital maritime supervision system realizes the tracking and monitoring the whole route of the ship and records the navigation data of the ship. The system can quickly play back the accident process, effectively reducing the time for supervisors to collect evidence and providing a guarantee for fast handling of accidents.

5.5. Suggestions on improving network and information security protection capability

Intelligent ships mainly rely on the Internet to connect with the outside world, and network security is a very important factor for the security and safety of intelligent ships (Yoo & Park, 2021). Therefore, ensuring network security is a new task of maritime security supervision.

In order to prevent network attacks and ensure network security, the author puts forward three suggestions according to the characteristics of intelligent ships. First, to carry out research on the function, network and information security technology of smart ships and support the development and application of security products. Second, to carry out research on security testing and evaluation system covering intelligent ships, communication networks and shore-based platforms, and to develop security level classification standards. Third, to carry out research on network and information security emergency strategies and propose the technical requirements. Through the establishment and implementation of network security standards, network security risks can be minimized.

The development of intelligent ships not only needs the innovation breakthrough of technology, but also needs the support and guarantee of maritime supervision, especially the research of maritime supervision laws and regulations that should be matched with intelligent ships, instead of lagging behind the constraints or risky leap. Intelligent ship technology research and development cannot be achieved overnight, and the construction of maritime supervision laws and regulations cannot be achieved in one step, which needs to be adjusted in order to adapt and promote the development of intelligent ships and even intelligent shipping.

CHAPTER VI CONCLUSION

The emergence of the intelligent ships is inevitable, and the maritime supervision needs to be adjusted to fit the intelligent ships. In this thesis, through reviewing the development of the intelligent ships and the other countries' regulations as well as IMO regulatory processes, the author discussed the characters of the intelligent ships, determine the gaps between the current maritime supervision and the supervision needed for intelligent ships, then proposed the suggestions based on those findings.

Some limitations exist even when the researcher tried to make this thesis as rigorous as possible, and the limitations must be acknowledged. First, due to the time and scale limit of the research, this research only focuses on China maritime supervision. It is hoped that this research topic about the maritime supervision on intelligent ships could be extended worldwide with consideration of the characters of intelligent ships. Then, the suggestions and countermeasures will be more reliable and reasonable.

Second, this research mainly focuses on the front line of the maritime supervision, but there are still lots of factors, such as the construction, inspection and registration of intelligent ships, which will challenge maritime supervision. Thus, those issues need and are worthy of further study.

Third, this research only studies the maritime supervision on the intelligent ship. The shore control center, which controls and supervises the intelligent ships, is playing an important role for ensuring the safety of intelligent ships. Thus, the shore control center should be supervised by the maritime supervision as well.

All in all, the maritime safety supervision on the intelligent ships, domestic and abroad, faces lots of challenges in the aspects of infrastructures, legislations, supervision model, etc. IMO already started to sort out the barriers on intelligent ships in terms of convention, and many governments have supported projects that are going to study the supervision on intelligent ships. With the cooperation of all interested parties and the development of the technologies, those issues will be settled in the near future. I believe the future of the intelligent ship is bright as well as the intelligent shipping.

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