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Relationship between GMDSS modernization and e-navigation strategy

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RELATIONSHIP BETWEEN GMDSS MODERNIZATION AND E-NAVIGATION STRATEGY

By

LIU YIJUN
The People’s Republic of China

A dissertation submitted to the World Maritime University in partial fulfillment of the requirements for the award of the degree of

MASTER OF SCIENCE
In
MARITIME AFFAIRS

(MARITIME SAFETY AND ENVIRONMENT MANAGEMENT)
2021

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DECLARATION

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

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

Signature: ..............................
Date: ..............................

Supervised by: ..............................
Supervisor’s affiliation: ..............................
ACKNOWLEDGEMENT

I was such a lucky person that could spend these short but priceless months at Dalian Maritime University. As a member of MSEM2021, I have gained valuable professional knowledge, as well as friendship, applause and mutual help that are as valuable as knowledge.

After working for 5 years, I returned to campus again, and the excitement at that time is still vivid. Now that the graduation thesis is about to be completed, I can't help feeling that time flies.

First of all, I would like to express my gratitude to everyone who helped me during the writing of this article. I want to give special thanks to Professor YANG Jiaxuan for giving me kind encouragement and helpful guidance in my writing process.

I am thankful to the teachers of the MSEM project team-Zhao Lu, Zhao Jian-for their hard work. I hope MSEM can be more prosperous.

I would also like to express my heartfelt thanks to all the professors and enthusiastic students who have helped me a lot in my academic and social life.

I am also thankful to Mr. SUN Yanze, who, as my off-campus mentor, has given me selfless help and guidance since I first stepped into the work position.

I would also like to thank my friends and family for their great encouragement and support.

Limited for the capacity and time, there must be some errors in the dissertation, I sincerely hope to get support and criticism. I will give careful consideration to every suggestion.

Thanks again to YOU for taking precious time to read and guide my work.
ABSTRACT

Title of Dissertation: RELATIONSHIP BETWEEN GMDSS MODERNIZATION AND E-NAVIGATION STRATEGY

Degree: Master of Science

At present, in order to better enable ships to navigate safely, IMO, IHO and IALA are vigorously advancing the E-Navigation strategy, providing timely, complete and comprehensive maritime safety and navigation information services for ships, ports and other related users, and improving ship transportation effectiveness.

E-Navigation is one of IMO’s important development strategies, with putting forward higher requirements for the collection, interaction, integration, and display of navigational safety information, among which information interaction is the key.

The Global Maritime Distress and Safety System (GMDSS) provides an integrated solution for distress, emergency, safety and conventional communications, and is the main platform for ship-shore, ship-to-ship information interaction. In order to coordinate development with the E-Navigation strategy, IMO proposed a GMDSS review and modernization plan in April 2008.

This paper will first review the current research status of E-Navigation Strategy and GMDSS modernization in China and foreign countries, combine relevant documents issued by various international organizations and the actual situation of member states, clearly point out the development needs of E-Navigation Strategy, and clarify the bottlenecks that restrict strategic development, combining the opportunities and challenges of E-Navigation Strategy, explore the direction of modernization of GMDSS.

KEYWORDS: E-Navigation strategy, GMDSS modernization, maritime communication technology, safety requirement, ethical consideration
# TABLE OF CONTENTS

DECLARATION .................................................................................................................. 1  
ACKNOWLEDGEMENT ...................................................................................................... 2  
ABSTRACT .......................................................................................................................... 3  
TABLE OF CONTENTS ..................................................................................................... 4  
LIST OF FIGURES .............................................................................................................. 4  
LIST OF TABLES ............................................................................................................... 6  
LIST OF ABBREVIATIONS ................................................................................................. 6  

Chapter 1 INTRODUCTION ................................................................................................. 8  
1.1 Background and Significance ....................................................................................... 8  
1.2 Literature Review ......................................................................................................... 11  
  1.2.1 Research Status about the Relationship between GMDSS Modernization and E-Navigation Strategy ................................................................. 11  
  1.2.2 Development Status about Technology and Device of GMDSS Modernization and E-Navigation .................................................................................. 13  
1.3 Structure of Dissertation .............................................................................................. 17  

Chapter 2 REQUIREMENTS OF E-NAVIGATION STRATEGY ........................................ 19  
2.1 Goals of the E-Navigation Project ............................................................................... 19  
  2.1.1 Expectations (MSC) ............................................................................................... 19  
  2.1.2 Implementation Process ....................................................................................... 20  
2.2 Basic Requirements of E-Navigation Strategy ............................................................. 21  
2.3 Users Needs of E-Navigation Strategy ........................................................................ 22  
2.4 Communication requirements of E-navigation Strategy ............................................. 24  

Chapter 3 RELATIONSHIP BETWEEN GMDSS MODERNIZATION AND E-NAVIGATION STRATEGY .......................................................... 27  
3.1 IMO's Implementation Plan for GMDSS Modernization ............................................. 27  
3.2 IMO's Description of the Relationship between GMDSS Modernization and E-Navigation Strategy ........................................................................... 29  
3.3 Current Status of GMDSS Modernization's Support for E-navigation Strategy .......... 33  
3.4 Modern communication technology may provide technical support for E-navigation strategy .......................................................................................... 33  
  3.4.1 Short-range Ship Communication ......................................................................... 34  
  3.4.2 Long-distance Ship Communication ..................................................................... 35
# Chapter 4: The Future of GMDSS Modernization & Ethical Consideration

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 GMDSS Primary Modernization</td>
<td>41</td>
</tr>
<tr>
<td>4.2 GMDSS quasi-modernization</td>
<td>42</td>
</tr>
<tr>
<td>4.3 GMDSS fully modernized</td>
<td>43</td>
</tr>
<tr>
<td>4.4 Ethical Consideration</td>
<td>45</td>
</tr>
</tbody>
</table>

## Conclusion

## Reference
LIST OF FIGURES

Figure 1-E-navigation implementation process (MSC, 2008) .................................. 20
Figure 2-Structure Diagram of Maritime Communication Network under E-
   Navigation .................................................................................................................................. 25
Figure 3-Inmarsat satellite coverage areas before (above) and after (below) the
   migration process ..................................................................................................................... 36
Figure 4- Iridium satellite constellation ................................................................................. 37
Figure 5 – Resources Onboard and Onshore ......................................................................... 40
Figure 6– Resources Onboard and Onshore in GMDSS Primary Modernization
   .................................................................................................................................................. 42
Figure 7– Resources Onboard and Onshore in GMDSS quasi-Modernization... 43
Figure 8– Resources Onboard and Onshore in GMDSS Ultimate Modernization
   .................................................................................................................................................. 43
Figure 9- Frequency of use of the MF/HF radiotelephone ...................................................... 46
Figure 10- Frequency of use of the INMARSAT-C ship Earth station (SES) ... 46
Figure 11- Respondents’ compliance with space reduction and integration of
   GMDSS equipment ................................................................................................................... 47
Figure 12- Relationship between GMDSS Modernization and E-navigation
   Strategy ....................................................................................................................................... 50

LIST OF TABLES

Table 1-Examples of e-navigation users .................................................................................. 23
Table 2 Relationship between GMDSS Modernization and E-Navigation
   Strategy ....................................................................................................................................... 29
LIST OF ABBREVIATIONS

GMDSS  Global Maritime Distress and Safety System
IALA   International Association of Navigation Aids
IMO    International Maritime Organization
MSC    Maritime Safety Committee
MSP    Maritime Service Portfolio
NCSR   Sub-Committee on Safety of Navigation, communication and search and rescue
STW    Sub-Committee on Standards of Training and Watchkeeping
VDES   VHF Data Exchange System
VHF    Very-high Frequency
NAVDAT Navigation Data
WWNWS  Worldwide Navigational Warning Service
LES    Land earth stations
CES    Coast earth station
CRS    Coast radio stations
HMI    Human-machine interface
ENCs   Electronic Navigational Charts
ITU    International Telecommunication Union
IMSO   International Maritime Satellite Organization
AIS    Automatic Identification System
IOR    Inmarsat Indian Ocean Region
EMEA   Inmarsat Europe/Middle East/Africa
MRCC   Maritime Search and Rescue Coordination Center
VDR    Voyage Data Recorder
THD    True Heading
SDME   Speed and Distance Monitoring System
ECDIS  Electronic Chart Display and Information System
VTS    Vessel Traffic Service
AtoNs  aids to navigation
MRIS   Maritime Resources Interconnecting System
Chapter 1 INTRODUCTION

1.1 Background and Significance

With the rapid development of the shipping market, the development of ships also tends to be large-scale, intelligent and specialized, and the capabilities of existing communication equipment on board ships can hardly keep up with navigation safety technology. Technological advances in electronics, radio communications, and information technology have led to new revolutionary proposals to upgrade the equipment and systems used on sea-going vessels. The standards and scope of the equipment on board are playing key role in ensuring these vessels’ safety that strictly monitored by the International Maritime Organization (IMO) and its subsidiary bodies.

On December 19, 2005, the United States, the United Kingdom, the Netherlands and other seven countries jointly submitted a proposal (MSC 81/23/10) to the 81st meeting of the International Maritime Organization (IMO) Maritime Safety Committee (MSC), and proposed to formulate an E-Navigation Development Strategy. to develops a broad strategic vision for incorporating the use of new technologies in a structured way and ensuring that their use is compliant with the various electronic navigational and communication technologies and services that are already available (Japan, Marshall Islands, the Netherlands, Norway, Singapore, the United Kingdom and the United States, 2005). In 2006, the 16th International Association of Navigation Aids (IALA) Conference held in Shanghai officially put e-navigation on the agenda, and the IMO also determined its working definition:

E-navigation is the harmonized collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth-to-berth navigation and related services, for safety and security at sea and protection of the marine environment. (2007)
The international navigation community generally believes that e-navigation is not a hardware device, but the integration of information, which is a safer and more efficient navigation guarantee measure. The e-navigation Strategy has a 16-year history since it was proposed. During these 16 years, the e-navigation strategy has developed rapidly. After the preparations for the E-Navigation initial phase (2005-2009) and the strategic research phase (2010-2014), it has now entered the e-navigation full implementation phase (2015 to present). As a result, another project was also adopted: “Preparation of the E-navigation Strategy Implementation Plan”, and added to the agenda of the IMO NAV and COMSAR sub-committees, as well as the Sub-Committee on Standards of Training and Watchkeeping (STW). It is scheduled to be completed in 2012. In 2013, there were some organizational changes in IMO, including merging the NAV and COMSAR sub-committees to the Sub-Committee on Safety of Navigation, communication and search and rescue (NCSR). Spontaneously, the e-navigation project was entrusted to NCSR. In 2014, the document “E-navigation Strategy Implementation Plan” was accepted by MSC (MSC 94/18/8, 2014).

It is worth mentioning that COMSAR proposed that the development of E-Navigation strategy should not be based on technology, but should focus on users’ needs, that is, to determine the needs first and then carry out technical research (COMSAR 11/WP.4, 2007). The communication requirements of the e-navigation Strategy are determined, and the research and development of maritime communication technology can be more to the point.

The e-navigation strategy is one of the most important strategy of IMO. Its aim is to improve the safety of maritime navigation. E-navigation puts forward higher requirements for collecting, sharing, integrating and displaying data on marine safety. Its key is information technology. The "collection, integration, and interaction" of information is inseparable from communication technology. It can be said that the
development of communication technology is a prerequisite for the development of e-navigation strategy.

On the other hand, the launch of GMDSS modernization is mainly due to the fact that the existing GMDSS system has been launched for too long, and the technology used in many equipment is relatively old and outdated.

The GMDSS, which was fully implemented on 1 February 1999, was expected to represent, at the time, a revolution in maritime communications. Its main purpose is to alert and warn coast centers and surrounding ships in cases of distress, urgency, and safety. It can also be used for routine (commercial) communications. According to the GMDSS requirements, the amount of communication equipment on ships, depends on the area of navigation (A1–A4) and includes terrestrial and satellite devices. GMDSS provides plans in case of distress, emergencies, safety and standard communication. It is the main communication platform used for ship-shore and ship-ship information sharing. The first phase of the GMDSS modernization involved a "High-Level Review", which analyzed the basic elements of GMDSS. In the second phase of 2013-2016, a “Detailed Review” of GMDSS was conducted. The other phase was completed in 2017 and involved preparations for the “GMDSS Modernization Plan”. According to the plan, the GMDSS modernization will be completed in 2021 (NCSR 5/14/7, 2017).

GMDSS is the main component of maritime communications. At the 90th meeting of the MSC conference, it was clearly pointed out that "GMDSS modernization should provide communication support for E-Navigation Strategy" (MSC, 2012), from which we could know that a large part of the heavy burden of E-Navigation's strategic needs will fall on the modernization of GMDSS.

Therefore, it is of far-reaching significance to carry out research on the relationship between GMDSS modernization and E-Navigation strategy in accordance with the requirements of E-Navigation’s safety, technology and communications.
1.2 Literature Review

1.2.1 Research Status about the Relationship between GMDSS Modernization and E-Navigation Strategy

Up to now, there are few domestic researches on the relationship between GMDSS modernization and E-Navigation strategy. Professor WANG and XU (2016) discussed the modernization of GMDSS and the E-Navigation strategy proposed by IMO, and classified the GMDSS and E-Navigation strategy into two parts: communication and navigation (WANG & XU, 2016). LIU, AN, and ZHAO (2015) put forward the ways to develop digital transmission for coast stations by analyzing the new technologies of GMDSS modernization and E-Navigation strategy. The research process fully considers the common influence of GMDSS modernization and E-Navigation strategy, and says that E-Navigation Strategy or GMDSS cannot be considered separately. A method should be sought to ensure the common interests of E-Navigation Strategy and GMDSS (LIU, AN, & ZHAO, 2015). YU and ZHANG (2016) carried out research on maritime communication services under the common background of GMDSS modernization and E-Navigation, and analyzed the possibility of software radio applications in maritime communication services (YU & ZHAO, 2015). In the process of studying maritime radio digital services, SUN and LI (2017) proposed that some evolving basic resources should be properly reserved for future GMDSS modernization and E-Navigation strategies (SUN & LI, 2017).

In foreign countries, there are few studies on the relationship between GMDSS modernization and E-Navigation strategy. KORCZ (2011) studied the future development of GMDSS modernization, and at the same time took into account the requirements of E-Navigation Strategy for GMDSS modernization, and puts forward the viewpoint that the integrity of GMDSS should not be destroyed (KORCZ, 2011). KORCZ also believed that one of the basic elements of E-Navigation will be a data communication network based on maritime radio communication infrastructure, based
on which, they discussed the existing capabilities in GMDSS to achieve these requirements, as well as the key elements of the future development of GMDSS modernization (KROCZ, Problem of Maritime Radio Systems Integration with E-Navigation, 2015). In the other article from KROCZ (2019), he thought that by providing ship-shore and shore-ship data exchange, GMDSS and its new communications technologies will, along with their regular functions, form the foundation of the e-navigation strategy, and the GMDSS modernization plan should provide the framework for developing the communication systems for e-navigation. It should also offer a common shore-based system architecture (CSSA) (KROCZ, 2019).

The current modern technological form of GMDSS can only support the ability of E-Navigation Strategy to a minimum, and the safety, technology and communication requirements of E-Navigation Strategy cannot be met. With the continuous development of high technology, various technologies and equipment are changing with each passing day. The birth of 5G technology means the arrival of the new information age and the improvement of human living standards. Although the communication technology required and used by E-Navigation will eventually be reflected in the terrestrial communication technology, in many cases, maritime communication technology has not kept up with the development of information technology.

It can be seen from this that although the modernization of GMDSS is related to the E-Navigation Strategy, researchers have not taken this seriously enough to carry out research on maritime communication and navigation. At present, GMDSS modernization and E-Navigation strategy are mostly independent development components. Even if the development of the two is proposed at the same time, they are not well integrated. In view of the current state of development, this paper will try to clarify the relationship between the two and realize the coordinated development of GMDSS modernization and E-Navigation strategy.
1.2.2 Development Status about Technology and Device of GMDSS Modernization and E-Navigation

JIANG (2010) pointed out that the system advantages of the Japanese electronic navigation support system and the Finnish COAST WATCH system should be used to conduct extensive research on the current situation of China's maritime navigation aids based on E-Navigation (JIANG & HAN, 2010). YANG (2012) analyzed the performance and social benefits of traditional maritime radio communication methods, proposed to use 500kHz frequency band NAVDAT instead of traditional NAVTEX communication methods, and analyzed NAVDAT technologies (YANG L., 2012). WANG (2013) proposed a complete radio differential system and an integrated shore-based communication and navigation system based on the Ship Identification System (AIS), which effectively promotes the development and application of E-Navigation technology in China (WANG & HU, 2013). Based on the principles of building smart maritime, LI (2015) designed the port channel of Tianjin Port in accordance with the requirements of maritime informatization and the overall structure of E-Navigation, digital ocean, and smart ports, using new technologies researched in China and other foreign countries (LI S., 2015).

With the research and construction of E-Navigation pilot projects, the concept of Maritime Service Portfolio (MSP) came into being. The definition of MSP for E-Navigation given by IMO is: “the set of operational and technical services and their level of service provided by a stakeholder in a given sea area, waterway, or port, as appropriate” (WEINTRIT, 2011). One of the principles followed in the implementation of E-Navigation is the principle of uniformity/standardization. The principle of unification/standardization is reflected in many aspects, such as the unified data structure S-100. S-100 is a standard in terms of data structure. It is located in the middle and low layers of the E-Navigation system and can realize various E-Navigation services. The passage of standardized interfaces between ships and shores in the E-navigation technology framework relies on the realization of
unified/standardized services. The function of the communication link is to connect the various parts as a whole, so that many E-nautical solutions can be implemented smoothly (ZHU, 2016). Regarding the overall architecture, service requirements and data modeling of MSP, JEONG (2013) pointed out that MSP can provide advanced communication services such as information about anti-congestion mechanism and navigation time window (JEONG & PARK, 2017). JONAS (2013) proposed an information registration model, which is based on the research of general maritime data structure (JONAS & OLTmann, 2013). WANG (2014) introduced the latest achievements of MSP, which was based on the E-Navigation solution and technical framework confirmed by IMO, and discussed the general ideas and technical methods for establishing and developing MSP (WANG Y., 2014). LI (2017) analyzed the connection between MSP and E-Navigation, classified MSP, and explored the establishment process of MSP by analyzing MSP in the port area, and put forward new prospects for its future development (LI R., 2014).

Nowadays, communication and information technology are developing rapidly, and it is urgent to carry out technological innovation to traditional maritime communication methods. VSAT is a satellite communication earth station with a small antenna diameter, and its antenna need to be stabilized by a gyro. Because of its flexible networking, it will not be restricted by various factors of the ground network, and it has low requirements on the users’ environment. It can realize the connection between the maritime communication network and the ground network and provide satellite-based stable broadband communication services for maritime users (YANG & ZHANG, 2014). ZHANG & DAI (2015) pointed out that the use of VSAT equipment can improve the effectiveness of information exchange between ships and shores. Ships can obtain more information services. When the ship is in danger, the device can also transmit voice and video information that is conducive to decision-making, helping shore stations to realize remote command and service rescue of the ship, improving the rescue efficiency (ZHANG & DAI, 2015). XIONG (2016) believes that for the new generation of VHF Data Exchange System (VDES), the satellite and
ground standards have been formulated, the standards have been mature, and the conditions have been met to enter the implementation stage. When the related applications are well developed, the system guarantees the continuous development of maritime communications and the global Navigation Information Resources (XIONG, 2016).

NAVDAT & VDES is listed as a potential replacement equipment by the GMDSS modernization draft issued by IMO. NAVDAT can connect navigation-related safety information and ship information using text, files, broadcast information or images. Its data transmission rate is more than 200 times that of NAVTEX, and it can support the transmission of multiple multimedia types of information. WANG & Peng (2015) pointed out that NAVDAT applies the latest digital transmission technology, which can broadcast relevant safety information at 500kHz to support the modern business of GMDSS and realize the innovation of the shore-based maritime digital communication system (WANG & PENG, 2018). LEI & LIU (2018) pointed out that the NAVDAT system has the characteristics of high digital fidelity, fast transmission rate, easy encryption, and low cost. It can be used as a new digital transmission system to provide stronger maritime communication services for ships at sea (LEI & LIU, 2018).

The development status of related foreign institutions in the United States and Japan also deserve our attention. The Japan Coast Guard has advanced maritime communications technology and has made many innovations in the content and methods of communications services. SHEN (2017) pointed out that, in addition to issuing safety information such as distress communications, navigational warnings, and medical communications in accordance with international conventions, the Japan Coast Guard also innovatively provides a variety of communications services, including: communications related to shipwrecks, aimed at utilizing facilities such as land earth stations (LES), Coast earth station (CES) or coast radio stations (CRS) and maritime mobile platforms to keep a 24-hour watch on the distress communication frequency and improve the emergency response mechanism for distress information;
ship position communication, the Japan Coast Guard has developed a ship position report system, and ships entering the jurisdiction will automatically report its Location information, and ship location data sharing with the US Coast Guard has improved the rescue efficiency (SHEN, 2017). QI (2016) pointed out that the Japan Coast Guard first established a data center to analyze and organize data provided by domestic and foreign maritime research institutions. And aircraft, satellites and other equipment are used to conduct research on offshore production and operation. A large number of first-hand maritime information resources provide comprehensive communication services for maritime users through the development of software information systems and hardware receiving equipment, which greatly meets the needs of maritime users (QI, 2017). WU (2017) pointed out that the U.S. Coast Guard uses differential GPS at sea to provide navigation services for ships at sea, with an accuracy of up to 10 meters (2dRMS), and an availability alert function, which provides security for ships entering and leaving the port (WU F. , 2017). LI (2016) pointed out that all ships entering 1,000 nautical miles off the coast of the United States must report location information to the US Coast Guard data center, which can be obtained in real time by logging into the internal dedicated system (LI P. , 2016).

For the application of technological innovation, WU & YAO (2013) pointed out that based on the needs of maritime distress rescue, the US Coast Guard has independently developed the "Rescue21" system using advanced technology to receive maritime distress alarms. It integrates command and control and is compatible with the GMDSS system. It can cover the Atlantic and Pacific coasts and many rivers. It greatly enhances the US Coast Guard’s maritime distress rescue capabilities. At the same time, the system can also broadcast emergency information to maritime users to improve the crew's safety awareness (WU & YAO, 2017). At present, the United States is still continuing to update and improve the system, and further expand the coverage of distress assistance by improving site construction.
1.3 Structure of Dissertation

Based on the shortage of relevant research around the world, the main contents of this paper are as follow:

(1) Analyze and summarize the research background and the significance, research methods and status.

Explain the background and significance of studying the relationship between the modernization of GMDSS and the E-Navigation strategy, analyzes and combs the research arrangement and ideas of this subject, investigates and summarizes the current research status of this subject, and finds out the main goal and the starting point of studying the relationship between the modernization of GMDSS and the E-Navigation strategy.

(2) Detailed analysis of the requirements of the E-Navigation Strategy IMO's Implementation Plan for GMDSS Modernization.

Starting from the following four aspects, a comprehensive analysis of the needs of E-Navigation: the goal of the E-Navigation Project, basic requirements of E-Navigation strategy, the users’ needs of E-Navigation Strategy, and the communications requirement of E-Navigation Strategy. Pave the way for the following theories.

(3) Explain the relationship between the modernization of GMDSS and the E-Navigation strategy.

According to the needs of the previous analysis, analyze the relationship between the two item by item. This chapter comprehensively analyzes the relationship between the two from the following three perspectives: IMO's implementation plan for GMDSS Modernization; IMO's description of the relationship between GMDSS Modernization and E-Navigation Strategy; Current status of GMDSS Modernization's support for E-Navigation Strategy; Analyze the communication capabilities that can be achieved by
the current modernization of GMDSS, and propose the degree of support that can be provided for the maritime E-navigation strategy at the emergence stage.

(4) Conceiving the future development of GMDSS modernization under the framework of E-Navigation Strategy

Combining the research results previously, study the technical form that should be presented in the modernization of GMDSS under the framework of the E-Navigation Strategy. Analyze the development format of maritime communication modernization, and propose the future development of GMDSS modernization, and combined with the current situation, conduct ethical consideration and reflection on the future development of GMDSS.

(5) Conclusions and prospects: Summarize the completion of this research, research conclusions, condensed innovation points, and put forward the concept of further improving the model and the next research direction.
Chapter 2 REQUIREMENTS OF E-NAVIGATION STRATEGY

2.1 Goals of the E-Navigation Project

As mentioned above, in the development process of E-Navigation strategy, the first thing to accomplish is to determine the strategic needs and carry out technological research and development according to the strategic needs.

There is a clear and urgent need to equip ship users and shore personnel responsible for the safety of shipping with modern, proven tools that are optimized for good decision making to make maritime navigation and communication more reliable and user-friendly. The main goal of this method is to improve the safety of navigation and reduce errors. According to the definition of E-Navigation, it aims to meet current and future needs of users by coordinating maritime navigation systems and supporting shore-based services.

2.1.1 Expectations (MSC)

**On board** – Navigation systems that benefit from the integration of own ship sensors, supporting information, a standard user interface, and a comprehensive system for managing guard zones and alerts;

**Ashore** – The management of vessel traffic and related services from ashore enhanced through better provision, coordination, and exchange of comprehensive data in formats that will be more easily understood and utilized by shore-based operators in support of vessel safety and efficiency;

**Communications** – An infrastructure providing authorized seamless information transfer on board ship, between ships, between ship and shore and between shore authorities and other parties with many related benefits. (MSC, 2008)
2.1.2 Implementation Process

Implementation of E-Navigation should be a phased iterative process of continuous development, including, but not necessarily limited to, the steps shown in Fig. 1 (MSC, 2008) (KROcz, Problem of Maritime Radio Systems Integration with E-Navigation, 2015).

![Figure 1-E-navigation implementation process (MSC, 2008)](source)

User needs: The first step of the plan is to identify users and their needs. The next step should be to link functions with tangible operational benefits based on a structured, systematic and traceable method, and determine the functions or service groups required to meet these major navigation needs.

Architecture and analysis: The definition of the integrated E-Navigation system architecture and operating philosophy should be based on integrating user needs across the entire user range and taking into account all possible economies of scale.
The architecture should include the hardware, data, information, communications, and software required to meet user needs.

Cost-benefit and risk analysis should be an integral part of the plan. It should be used to provide information for strategic decisions, and it should also be used to support decisions about when and where certain features need to be enhanced.

The training requirements should be analyzed based on the system architecture and operating concepts, and training specifications should be clarified.

The analysis of system and regulatory requirements should be carried out according to the system architecture and operating concept.

Gap analysis:

– Analyze regulatory gaps, in particular to identify gaps that need to be filled in the current framework;

– Operational gap analysis to define simplified operational concepts that can be used based on existing technology and system integration;

– Identify and describe existing systems that can be integrated into the E-Navigation concept, covering functions, reliability, operational management responsibilities, supervision/standardization, assembly and usage supervision status;

– Technology gap analysis, which compares the capabilities and attributes of the existing system with the architectural requirements to determine any technology or system development that may be required, based solely on user needs.

2.2 Basic Requirements of E-Navigation Strategy

In order to obtain the benefits of E-Navigation, as a driving factor for the implementation and operation of E-Navigation, some basic requirements should be met in particular:
1) The implementation of E-Navigation Strategy should be user-oriented rather than technology-driven, and avoid excessive reliance on technology;

2) Operational procedures should be developed and continuously reviewed, especially those related to human-machine interface, training and development of seafarers, and the roles, responsibilities and responsibilities of users on board and ashore;

3) As the supporting role of shore-based users increases, seafarers should continue to play a central role in decision-making;

4) Human factors and ergonomics should be the CORE of the system design to ensure the best integration of the system, including the human-machine interface (HMI), the presentation and scope of information, avoiding overload, integrity assurance, and adequate training;

5) Sufficient resources should be provided and guaranteed for E-Navigation itself and necessary facilitating factors (such as training and radio frequency spectrum);

6) The implementation must be carried out in a planned way;

7) The cost should not be too high.

2.3 Users Needs of E-Navigation Strategy

There are a huge number of potential ships and shore-based users of E-Navigation. Examples of e-navigation users are given in the Tab. 1.
Furthermore, the key strategic elements of electronic navigation based on users’ needs include: Architecture, Human Elements, Convention and Standards, Positioning, Communication Technology and Information Systems, Electronic Navigational Charts (ENCs), Equipment and Standardization Scalability. These keys are detailed below in order:

It is needed to develop and maintain the overall concept, functional and technical architecture, especially process description, data structure, information system, communication technology and regulations.

Training, competence, language skills, workload and motivation are considered essential. Alarm management, information overload and ergonomics are prominent issues. According to IMO's human factors work, these aspects of E-Navigation must be considered.

The provision and development of E-Navigation should consider relevant international conventions, regulations and guidelines, national legislation and standards. The development and implementation of electronic navigation should be based on the work of IMO.

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<th>Shipborne users</th>
<th>Shore-based users</th>
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<tbody>
<tr>
<td><strong>Generic SOLAS ships</strong></td>
<td>Ship owners and operators, safety managers</td>
<td></td>
</tr>
<tr>
<td><strong>Commercial tourism craft</strong></td>
<td>Pilot organizations</td>
<td></td>
</tr>
<tr>
<td><strong>High-speed craft</strong></td>
<td>VTS centres</td>
<td></td>
</tr>
<tr>
<td><strong>SAR vessels</strong></td>
<td>National administrations</td>
<td></td>
</tr>
<tr>
<td><strong>Law enforcement vessels (police, customs, border control, immigration)</strong></td>
<td>Coastal administrations, Port authorities</td>
<td></td>
</tr>
<tr>
<td><strong>Nautical assistance vessels (tugs, salvage vessels, tenders, firefighting, etc.)</strong></td>
<td>Security organizations</td>
<td></td>
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<tr>
<td><strong>Fishing vessels</strong></td>
<td>Counter pollution organizations</td>
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<tr>
<td><strong>Leisure craft</strong></td>
<td>Military organizations</td>
<td></td>
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<tr>
<td><strong>Ferries</strong></td>
<td>Meteorological organizations</td>
<td></td>
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<tr>
<td><strong>Ice patrol/breakers</strong></td>
<td>Hydrographic Offices/Agencies</td>
<td></td>
</tr>
<tr>
<td><strong>Offshore energy vessels (rigs, supply vessels, lay barges, survey vessels,</strong></td>
<td>Ship owners and operators, logistics managers</td>
<td></td>
</tr>
</tbody>
</table>
It is necessary to provide a **positioning** system to meet the requirements of users in terms of accuracy, completeness, reliability and system redundancy, as well as to meet the requirements of risk level and traffic volume.

**The communication technology and information system** must be determined to meet the needs of users. This work may involve enhancing existing systems or developing new systems. Any impact that affects the existing system needs to be determined and resolved according to the technical standards and protocols of data structure, technology, bandwidth and frequency allocation.

By the time the IMO may adopt any further mandatory transport requirements, the consistent **ENCs** will be fully covered.

This work will follow the development of **performance standards** and will involve users and manufacturers.

**2.4 Communication requirements of E-navigation Strategy**

The E-Navigation strategy has not progressed smoothly since it was put forward, mainly because the communication problem has not been resolved. The E-Navigation strategy aims to develop the integration of maritime information so that ships can obtain more valuable information at sea. Ships can obtain information from satellites, terrestrial transmissions, and perception information broadcast by nearby ships through the external wide area network. At the same time, ships can get environmental information by using their own equipment, and distribute the information within the ship by a local area network. In order for ships to obtain real-time shipping and hydrometeorological information, it is necessary to start with the method of obtaining information, that is, to increase the speed (bandwidth) of satellite communication, reduce the price of satellite communication, update the communication system of shore-based facilities for marine vessels, and improve the perception of ships. In doing so, the ability to ensure the safety of navigation and protect the marine environment will be improved.
One of the user requirements of the E-Navigation Strategy is: effective and stable communication, automatic and standardized reporting functions, among which "effective and stable communication", it is proposed that "the ship should make full use of sound, image, video and other means when communicating. Crew provide effective information support" specific description.

E-Navigation strategic development requires communication technology to be integrated as shown in Fig. 2.

![Figure 2-Structure Diagram of Maritime Communication Network under E-Navigation](image)

Communication content includes text, voice, and video information, among which video information is generally the most demanding communication bandwidth. Maritime video communication can provide ships with richer navigational safety information and provide more intuitive and effective safety supervision methods for shore-based facilities. Under the background of the low bandwidth of existing maritime communications, to realize maritime mobile video communications, it is particularly important to compress video files to the greatest extent.
As mentioned in the Literature Review, H.265 (High-efficiency Video Coding) is the latest video coding standard adopted by the International Telecommunication Union (ITU), which can transmit higher-quality network video under limited bandwidth (Joint IMO/ITU Experts Group, 2014). H. 265 can realize the transmission of 720P ordinary high-definition audio and video at a transmission speed of 1 ~ 2 Mbit/s, which basically meets the current marine video transmission needs. A special study shows that, in order to meet the requirements of maritime video transmission in the E-Navigation strategy, the fidelity of the video should first be ensured, that is, the accuracy of the information can reach a standard acceptable to the trustee. After analyzing the evaluation results of the video transmission quality of 30 trustees, it can be determined that the accuracy of the video information can only be guaranteed when the channel signal-to-noise ratio is above 19.4dB. (WANG M., 2019)

Therefore, the further goal of E-Navigation lies in a high-speed, seamless network, with a bandwidth that can reach the minimum standard of 1 Mbit/s or more, the channel signal-to-noise ratio is above 19.4dB and ensure low price and reliable access rates.
Chapter 3 RELATIONSHIP BETWEEN GMDSS MODERNIZATION AND E-Navigation Strategy

In order to realize the communication support of the E-Navigation Strategy by the modernization of GMDSS and solve the development bottleneck of the realization of maritime communication in the E-Navigation Strategy, this paper combined the current development status of the modernization of the GMDSS with the application of technology to further analyze the development direction of the future modernization of the GMDSS under the E-Navigation Strategy framework. The relationship between the modernization of GMDSS and the E-Navigation Strategy is determined. As mentioned above, among the few studies conducted by China and other countries in the world on the modernization of GMDSS, the modernization mentioned in the research content is only the initial stage of GMDSS modernization, and it is difficult to fully meet the needs of the E-Navigation strategy and communication. Therefore, it is necessary to optimize the traditional GMDSS framework, incorporate more advanced technologies, realize the modernization of maritime communication technology, and effectively promote the strategic development of E-Navigation.

3.1 IMO's Implementation Plan for GMDSS Modernization

IMO's latest development plan for the modernization of GMDSS has been continuously carried out since the draft of the modernization of GMDSS. The research on new communication technologies includes the following aspects:

1) International Maritime Satellite Organization (IMSO) for the United Kingdom's proposal NCSR4-18-3 and NCSR4/INF. The relevant content of Inmarsat-FBB maritime safety data service in 9 has been evaluated technically and operationally, and the results show that the Inmarsat-FBB maritime safety data service has met all the requirements specified in Resolution 1001 (25). The Inmarsat F ship station was
closed in 2020 and the FBB ship station will be opened at the same time (IMSO, 2017).

2) At the 96th meeting of MSC, the committee reviewed NCSR 3/WP. 5 Regarding the result report of the Iridium system, the sub-committee reviewed the work process of the Iridium satellites joining the GMDSS, and stated that the unfinished review work is still carried out by the IMSO organization. The fifth meeting of the NCSR submitted the second round of technical and operational evaluation of the Iridium satellite system conducted by IMSO, mainly for the NCSR 3/WP. The uncompleted requirements in 5 were evaluated, and the results showed that the remaining requirements meet the standards in A. All the provisions of Resolution 1001 (25) are expected to be incorporated into the GMDSS system to provide communication services for ships in 2020 (IMSO, 2017).

3) The GMDSS modernization draft pointed out that VDES will become one of the important mechanisms for maritime MSI broadcasting in the future, especially for longer-distance MSI broadcasting. In addition, VDES is also the key communication system built in the E-Navigation Strategy. According to the current experimental situation, its ideal data exchange rate can reach 307.2kbps, which is 32 times that of AIS. According to the 95th meeting of the MSC and the development plan formulated by WRC-15, WRC-19 has provided detailed spectrum allocation and complete the development of VDES in 2020 (Chinese Maritime Authority, Japanese Maritime Authority, Sweden Maritime Authority, IALA, 2015).

4) NAVDAT is a digital broadcasting system that uses multi-carrier frequency modulation technology to work in the 495-505kHz frequency band. According to the current test results: Compared with NAVTEX, NAVDAT e has a higher communication rate. According to the actual measurement results of the East China Sea Navigation Support Center of the Ministry of Transport of China, the NAVDAT communication rate is about 360 times that of NAVTEX, and NAVDAT e has better Confidentiality. However, due to the current small coverage of NAVDAT and the
greater impact of the changing marine channel environment, it is not clear how NAVDAT will provide services for the modernization of GMDSS (Donghai Navigation Safety Administration, 2015).

It can be seen that the modernization of GMDSS described by IMO has already possessed elementary digital communications ideas and is gradually adopting digital communication technology. However, the current development and goals of GMDSS modernization are not clear enough, and the characteristics of informatization and networking are not prominent enough. GMDSS modernization is a product of the E-Navigation strategy. The development of GMDSS modernization is subject to the needs of E-Navigation strategy to a certain extent. Therefore, research on the future development of GMDSS modernization should be carried out for the needs of E-Navigation strategy.

3.2 IMO's Description of the Relationship between GMDSS Modernization and E-Navigation Strategy

The development of communications technology is an indispensable and important part of the development of E-Navigation strategy. Only when ships have complete maritime communication capabilities can the implementation of E-Navigation strategy have a fulcrum and operability. GMDSS is an important part of maritime mobile communications at present. The modernization of GMDSS, which IMO vigorously promotes, is developing in the direction of digitization, informatization, and networked communications, laying a solid foundation for the development of maritime communications modernization. IMO's description of the relationship between GMDSS modernization and E-Navigation strategy is shown in Table 2.

Table 2 Relationship between GMDSS Modernization and E-Navigation Strategy

<table>
<thead>
<tr>
<th>DATE (D/M/Y)</th>
<th>CONFERENCE</th>
<th>AGENDA</th>
</tr>
</thead>
<tbody>
<tr>
<td>19/12/2005</td>
<td>MSC 81-23-10</td>
<td>The &quot;Seven-nation Proposal&quot; proposes the development of E-Navigation strategy (Japanese Maritime Authority, Norwegian Maritime Au-</td>
</tr>
<tr>
<td>Date</td>
<td>Meeting</td>
<td>Committee</td>
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<tr>
<td>25/04/2008</td>
<td>COMSAR</td>
<td>12-15</td>
</tr>
<tr>
<td>03/12/2010</td>
<td>COMSAR</td>
<td>15-11</td>
</tr>
<tr>
<td>31/12/2010</td>
<td>COMSAR</td>
<td>15-INF. 4</td>
</tr>
<tr>
<td>23/03/2012</td>
<td>COMSAR</td>
<td>16-17</td>
</tr>
<tr>
<td>31/05/2012</td>
<td>MSC</td>
<td>90-28</td>
</tr>
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<td>28/03/2014</td>
<td>NCSR</td>
<td>1-INF. 7</td>
</tr>
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<td>09/05/2014</td>
<td>NCSR</td>
<td>1-13-4</td>
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<td>16/07/2014</td>
<td>NCSR</td>
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<td>16/10/2014</td>
<td>NCSR</td>
<td>2-13</td>
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<td>02/01/2015</td>
<td>NCSR</td>
<td>2-INF. 7</td>
</tr>
<tr>
<td>26/10/2015</td>
<td>NCSR</td>
<td>3-17</td>
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<tr>
<td>11/12/2015</td>
<td>NCSR</td>
<td>3-14</td>
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strategy, and GMDSS satellite communication can provide a large amount of communication capacity for E-Navigation (US. Maritime Authority, 2015)

<table>
<thead>
<tr>
<th>Date</th>
<th>Document</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>22/03/2016</td>
<td>NCSR 3-29</td>
<td>Proposed: The GMDSS modernization plan should be able to provide a communication framework for the strategic development of E-Navigation (NCSR, 2016)</td>
</tr>
<tr>
<td>24/03/2017</td>
<td>NCSR 4-29</td>
<td>Submit the GMDSS modernization plan to the MSC committee, which pointed out that GMDSS modernization continues to provide communication support for the E-Navigation strategy (NCSR, 2017)</td>
</tr>
<tr>
<td>09/03/2018</td>
<td>NCSR 5-23</td>
<td>The receipt of MSI through direct printing has always been an important part of GMDSS, and in the analysis of E-Navigation strategic user needs, it was pointed out that this information should be displayed in a coordinated manner on an appropriate navigation display (NCSR, 2018)</td>
</tr>
</tbody>
</table>

It can be seen from Tab. 2 that:

The development of E-Navigation is inseparable from the support of GMDSS modernization; E-Navigation and GMDSS modernization have many overlapping components. Generally, they need to remain relatively independent, rather than restrict each other.

1) E-navigation strategy needs support from the modernization of GMDSS

GMDSS was born in the late 1980s and early 1990s, and proposed a package solution to the interconnection of "everyone". Its main business includes wireless telephone, fax and telex. Its main purpose is to provide reliable distress, emergency and safe communications. With the addition of Inmarsat F, data services including ISDN and MPDS have gradually taken up an increasingly important position. With the development of maritime safety assurance technology and the ever-increasing demand for maritime safety, the e-navigation Strategy also has a development goal of keeping pace with the times. The bottleneck of strategic development is the communication problem. This is not only the consensus of the maritime industry three years after the e-navigation Strategy was proposed, but also proposed in the GMDSS review and modernization in 2008. This paper put forward the important reasons for integrating GMDSS modernization into the discussion of E-Navigation Strategy.
2) GMDSS modernization and E-navigation strategy should be developed in a coordinated way.

In the future, it may be necessary to improve the function, efficiency, and quality of GMDSS so as to be consistent with the E-Navigation strategy. The E-Navigation Strategy may make use of the same communication systems as many GMDSS. GMDSS communication is essential for navigational safety, and it plays a key role in the implementation of the E-Navigation Strategy. The modernization of GMDSS provides communication support for the E-Navigation Strategy. The newly developed infrastructure of the E-Navigation Strategy should be considered to fully support the modernization of the maritime communication technology. It is necessary to coordinate the development of the modernization of GMDSS and the E-Navigation Strategy. It is proposed that the E-Navigation Strategy has a wider scope than the GMDSS, and radio communication is a key element of the E-Navigation Strategy. The E-Navigation strategy requires high-speed data, and the GMDSS equipment under the modern communication system should be able to meet these demands. GMDSS and other communication technologies are the core of the E-Navigation Strategy, and GMDSS satellite communications can provide a large amount of communication capacity for the E-Navigation Strategy.

3) The modernization of GMDSS and the E-Navigation strategy should develop independently.

GMDSS focuses on distress, emergency and safety communications. The reliability and timeliness of communications are its key concerns. The development of E-Navigation strategy is information navigation, which puts forward higher requirements for the collection, integration, exchange, display and analysis of maritime information. Therefore, on the basis of reliability, the E-Navigation strategy puts forward the requirements of networking, digitization and low latency for communication, and its requirements for communication are broader than GMDSS. Therefore, the modernization of GMDSS and the development of E-navigation
strategy should not replace each other. The former focuses on the reliability and timeliness of communication, while the latter focuses on networking, digitalization and low latency. In general, the modernization of GMDSS should be able to provide sufficient communication support for the E-Navigation Strategy while completing its own construction.

3.3 Current Status of GMDSS Modernization's Support for E-navigation Strategy

According to the GMDSS modernization plan submitted by the NCSR4-29 Subcommittee to the MSC Committee, GMDSS already possesses basic digital communication capabilities. For example, the NAVDAT system proposed by NAV 58-INF. 17 and the VHF Data Exchange System (VDES) proposed by the ITU WRC-12 meeting are both reflected in the GMDSS modernization draft. Although these new technologies have improved the capabilities of maritime data communication, the bandwidth and services provided by the VHF Data Exchange System (VDES) and Navigational Data for Broadcasting Maritime Safety and Security Related Information from Shore-to-Ship (NAVDAT) are difficult to provide. This can fully meet the above-mentioned E-navigation strategy's demand for communication technology. Although the satellite communication capabilities provided by GMDSS are still developing, it is well known that satellite communication is expensive, and due to factors, such as long transmission distance and limited satellite power, the satellite communication rate is still low.

Therefore, the current GMDSS modernization is only a preliminary modernization, and it is not yet sufficient to fully support the strategic needs of E-navigation.

3.4 Modern communication technology may provide technical support for E-navigation strategy

In order to meet the communication needs of the E-navigation strategy, it is urgent to raise the communication capabilities of GMDSS to a new level.
At present, many advanced mobile communication technologies have been relatively mature in land applications, but they are not widely used at sea. Some technologies are still in their infancy in the field of maritime mobile services. However, whether the new technology can be copied to maritime communication or ship-to-ship communication requires repeated demonstration or discussion. For example, video transmission technology can effectively make up for the lack of maritime communication in the future, while 5G, 4G, etc., are not suitable for long-distance ship-to-ship or ship-to-shore communications due to limitations in their transmission distances. However, historically, the development of navigation has been accompanied by an increase in the demand for maritime communication, which has actually promoted the onshore communication technology.

3.4.1 Short-range Ship Communication

For ship-to-ship communication: At present, the data link between merchant ships mainly relies on AIS technology, and the transfer speed provided is only 9.6 Kbit/s. In addition, according to the current research progress report, the theoretical transfer speed of VDES in the research and development stage is only 307.2 Kbit/s, which is difficult to provide sufficient technical support for the E-navigation strategy. At present, the Automatic identification System (AIS) has been relatively mature, which can provide a bandwidth of more than megabytes between ships, and the operating distance can reach more than 6 n mile, which can meet the distance requirements for collision avoidance operations between ships, and can be used for short distance ships and information exchange between ships.

For ship-to-shore communications: current land-based mobile communications technologies include 3G /4G /5G.

Wide range of applications. The communication rate of 3G is generally about 2 Mbit/s, and the transmission rate of 4G/5G is better than that of 3G technology. If 3G/4G/5G mobile communication technology can be applied in ship-to-shore
communication under near-shore conditions, it will greatly increase the data transmission rate and make it possible for near-shore ships to obtain real-time navigational safety information. However, as we all know, with the iteration and update of mobile transmission technology, the transmission distance is gradually reduced, which requires the establishment of a higher density base station, which cannot be achieved at a slightly longer distance from the shore, and only suitable for short distance.

3.4.2 Long-distance Ship Communication

Ocean-going ships can only obtain shore-based support through satellite communication technology. At present, the Inmarsat system is at an advantage, but according to the general requirements of the IMO A. 1001(25) General Assembly Resolution and MSC. 1/Circ. 1414 on the future satellite systems that will join the GMDSS, more and more satellite communication systems will have the opportunity to be included in the GMDSS to provide services for maritime communications. At present, the largest proportion of global satellite communication service network operators are Inmarsat, Iridium and Thuraya. The total revenue of the three of them accounts for 90% of the entire industry chain.

- **Inmarsat system**

  In 2018 Inmarsat announced the transition of its services, including services related to the GMDSS, onto the next generation of satellites. on December 12, 2018, the migration of the Inmarsat Indian Ocean Region (IOR) 3rd generation satellite (at the 64° E) services to the Inmarsat Europe/Middle East/Africa (EMEA) 4th generation satellite (at the 25° E) was successfully completed (Valčić, Žuškin, Brčić, & Šakan, 2019). As it can be seen on the Figure 1, the coverage areas of the AOR-W, AOR-E, IOR and POR are moved to the west after the migration process.
Inmarsat's fourth-generation satellite (I-4) (at the 25° E) can provide FBB (Fleet Broadband terminal) services, among which the fastest FBB 500 ship station has a bandwidth of up to 432 Kbit/s. According to the latest evaluation report NCSR 5-14-1 about Inmarsat FBB joining the GMDSS system, after the technical and operational evaluation of the International Maritime Satellite Organization (IMSO), Inmarsat FBB has fully met the requirements of A. 1001 (25). May 2018 At the 99th IMO MSC meeting held in December; the data service system based on Inmarsat I4-Fleet Broadband (FBB) Maritime Safety Data Service (MSDS) was also officially approved to be included in the GMDSS.

In addition, Inmarsat also announced that it will spend 1.2 billion U.S. dollars to invest in the construction of Inmarsat's fifth-generation star (I-5). Inmarsat I-5 satellite adopts Boeing's mature 702HP satellite platform, with 89 Ka
transponders on board, supporting Inmarsat's upcoming Global Xpress mobile service. Global Xpress will be the first Ka-band system to complete global coverage, providing global coverage and seamless communication services, with a maximum communication speed of 50 Mbit/s, and a user terminal size of only 24.2 cm × 19.0 cm × 1.0 cm. (ZHANG Z., 2013)

- Iridium System

The Iridium satellite system consists of three segments: space or satellite segment; ground segment; and users. The space or satellite segment consists of 66 operational Low Earth Orbit (LEO) satellites and additional 6 spare satellites in each orbit. These satellites are evenly distributed in six orbital planes at an altitude of 780 km with a polar (86.4°) inclination and completely orbit the Earth in a period of approximately 100 minutes (Valčić, Žuškin, Brčić, & Šakan, 2019) (Figure 4).

![Iridium satellite constellation](source: Internet)

The Iridium satellite system can provide voice, data and short message services. Currently, Iridium is developing the second-generation "Iridium-NEXT" constellation (Iridium-NEXT), which was launched in 2015. The new generation
of "Iridium" includes 66 satellites in orbit and 6 to 9 backup satellites, which can provide high-speed services of 1.5Mbit/s in the L-band and 8Mbit/s in the Ka-band. (WIKIPEDIA, 2018)

After 5 years, it was finally officially approved by the IMO to be included in the GMDSS in May 2018, breaking the monopoly of Inmarsat. Due to the positioning and responsibilities of the GMDSS satellite communication system, the Iridium satellite system needs to be interconnected with the Maritime Search and Rescue Coordination Center (MRCC) and MSI providers within its service range to achieve distress alert forwarding and MSI broadcast functions. At present, Iridium has been recognized by IMO and officially provides GMDSS services to global maritime users.

With the development of maritime satellite communication technology, more and more satellite communication systems will be integrated into it, and each satellite system has its own unique advantages. It will also become possible for different satellite service providers to reduce communication tariffs and improve communication technology to seize the market. Similar to the GPS/GLONASS/BDS joint receiving equipment mentioned in the MSC 97-19-6 proposal, various combined satellite communication equipment has been launched, including Iridium-Inmarsat GX and so on. Operators can choose the required services and systems according to different needs, and effectively reduce the operational burden.

- Thuraya System

Document COMSAR 15-3-4 mentions listing the Thuraya satellite system as a regional service satellite for the future GMDSS. The Thuraya system has the ability to cover 2/3 of the world, and the data communication speed it can provide is low, and it cannot fully meet the communication needs of the E-navigation strategy.
However, the price of the Thuraya system is relatively low. According to the calling area, the tariff standard can be lower than 1 USD/min.
CHAPTER 4 THE FUTURE OF GMDSS MODERNIZATION & ETHICAL CONSIDERATION

Professor Li Jianming and others once proposed that the development of GMDSS modernization should be divided into three stages. They are primary modernization, quasi-modernization and ultimate modernization. The basis for the definition is the absorption of new communication technology in the process of modernization of GMDSS and the degree of consistency with modern communication technology (LI, WANG, ZHANG, WANG, & WANG, 2018). This paper will quote Professor Li's naming of the three stages of modern development of GMDSS, but use a new way of defining. Since the relationship between e-navigation and GMDSS modernization is so inseparable, this article will first start with the concept of e-navigation mentioned in the previous article:

E-navigation is the harmonized collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth-to-berth navigation and related services, for safety and security at sea and protection of the marine environment.

Figure 5 – Resources Onboard and Onshore
Source: Teaching Material of IALA International Level 1 AtoN Manager Model Course (LIU T., 2017)
So, according to the development level of harmony and integration (Resource and modules are shown in the figure 5), the efficiency of interconnection and communication, progress and utilization of related equipment and the analysis ability of the system, the three stages are:

4.1 GMDSS Primary Modernization

The primary modernization stage of GMDSS is also the modernization of GMDSS currently being promoted by IMO (LI, WANG, ZHANG, WANG, & WANG, 2018). At this stage, the existing and reliable modern maritime mobile communication technology should be integrated as much as possible on the basis of the original GMDSS framework. The purpose of GMDSS modernization is to provide support for the electronic navigation strategy, and many currently vigorously developed technologies cannot fully meet this demand. In terms of system utilization and integration, each system and module are still relatively independent, not well organized, and stay at the stage of native information and native system, and their help for decision-making is not fully utilized. The figure 6 is a schematic figure of the integration and organization of resources on shore and on board at the primary stage of GMDSS modernization (When this step is almost complete).
4.2 GMDSS quasi-modernization

The modernization process of GMDSS should proceed gradually and progress in a balanced manner. Whether it is the gradual integration of systems and equipment or the development of advanced communication technology, a sudden focus on a certain item will bring unexpected problems. Therefore, GMDSS quasi-modernization is a process of exploration while walking between the primary and the idealized ultimate. Questions about the current development direction can also be answered in the exploration process of the quasi-modernization stage. For example, is the development direction of ship-to-shore communication, VTS, and ship automatic collision avoidance inclined to self-organization or non-self-organization? The endogenous nature of the AIS and VDES systems is the same. Will it be possible to develop another system different from AIS and VDES for identification, decision-making, and data processing in the future? I think we will find the answer in the process of constantly questioning and exploring.

At the same time, the quasi-modernization of GMDSS should be based on the premise of meeting the strategic needs of E-Navigation as much as possible, and continue to attract more new technologies that can meet the strategic needs of E-Navigation. For example, it provides different communication strategies for ships' nearshore, coastal and ocean voyages, and uses multiple measures to ensure the access rate of distress alarms.

Figure 7 reflects the integration and data exchange of resources on shore and on ships when the GMDSS quasi-modernization is nearing completion. It can be seen that when the second stage is nearing completion, data can be exchanged freely in each resource module. However, each part of the resources is still an independent module, which has not reached the INTERCONNECTION.
4.3 GMDSS fully modernized

The ultimate modernization stage of GMDSS will be a stage that is fully consistent with modern communication technology, fully integrating modern communication technologies such as digital technology, broadband technology, and mobile terminals. After reaching the goal of quasi-modernization, it does not mean that GMDSS has stagnated, and development is endless. Communication technology is developing, and GMDSS should also keep moving forward (LI, WANG, ZHANG, WANG, & WANG, 2018). At this stage, all parts of the resources must have reached a harmonious integration, and GMDSS modernization has completely absorbed and utilized them.

Boldly imagine that when the E-Navigation Strategy has also been completed at this stage, the efficiency of each communication system and data exchange is extremely
high, and it is reshaped into a new system: **Maritime Resources Interconnection System (MRIS)**. (See in Figure 8)

This kind of progress and vision is full of Zen. After the first two development stages, the communication of resources and data is very smooth, the accuracy of decision-making is very high, and the requirements of GMDSS modernization for accuracy (berth to berth) have been met. In terms of communications, technology can already achieve sufficient bandwidth, transmission speed, and processing capabilities. The communication system has been able to achieve "detection-communication integration". AIS and VDES no longer need to be upgraded, integrated or enhanced, and data comes and goes freely in MRIS. Anyway, although there is still a long way to go, the final modernization of GMDSS is the ultimate goal of maritime communication modernization that fully integrates modern communication technology.
4.4 Ethical Consideration

Judging from the implementation and development of the above GMDSS modernization, now is a key strategic period for the transformation of the maritime communications field into the "maritime Internet era". All major maritime countries and regions around the world are working hard to promote new communications technologies and communications solutions to join GMDSS. Whether it is the mobile satellite communication system or the maritime safety information broadcasting system, many new systems and new equipment that will play a key role in the modernization of GMDSS. Although this is consistent with the hope of the entire shipping industry in recent years to use the development of communication technology and intelligent technology to enhance the existing navigation technology and improve the efficiency of maritime cargo transportation, and it is consistent with the goal of new systems and new equipment in the implementation of GMDSS modernization, it is difficult to be impartial, objective and fair scientific and technologically rational.

A study from Journal of Marine Science and Engineering elaborated that some GMDSS devices are hardly used during the watch on the ship’s bridge (MF/HF radio station and DSC in general), and a qualitative analysis of respondents’ opinions revealed that experienced seafarers want the GMDSS modernization in terms of spatial equipment reduction and integration on a ship’s bridge, as well as in terms of paperwork reduction and process automation, which has not been presented in previous researches (Valčić, Škrobonja, Magić, & Svilić, 2021), part of the questionnaire survey results are shown below:
Figure 9- Frequency of use of the MF/HF radiotelephone.

Figure 10- Frequency of use of the INMARSAT-C ship Earth station (SES).
We should realize that GMDSS modernization should not change the core ethical functions of maritime distress and safe communication guarantee. In the future, the development of technology in GMDSS modernization should use distress and safe communication guarantee as the ethical basis for the implementation of GMDSS modernization. Excessive pursuit of the development of new technologies and products of GMDSS, while ignoring the "ethical function" of the GMDSS system itself.

In addition, the current GMDSS modernization process also shows a trend of blindly pursuing technological development and commercial benefits. For example, the equipment newly added to the mobile satellite communication system generally pursues "high bandwidth". In order to achieve this, the newly developed communication satellite system must use directional antennas. However, directional antennas are difficult to communicate with communication satellites when the ship's attitude is unstable. If a good communication link is obtained, this also greatly reduces the success probability of distress alarm in this case, and thus cannot meet the
basic requirements of the GMDSS system for distress communication functions. (CAI, GUAN, XIAO, LIU, & YANG, 2020)

Therefore, the new systems and new equipment in the modernization of GMDSS must first be technologically advanced, based on demand, and must also be used in professional course teaching and training to inspire students to have a rational cognition and ethical thinking ability on various business issues in the GMDSS system: both As a technology developer, we must carefully evaluate and release new technologies and new equipment, and as a technology user, we must make efficient use of new technologies and new equipment without over-reliance, so that the GMDSS Modernization process will have a rational and efficient pace.

Another very important point is that we must strengthen the awareness of ethical responsibility and ethical ethics of GMDSS operators. This requires the crew administration and relevant training institutions to not only update the GMDSS training content in a timely manner, develop new training methods, but also incorporate ethical thinking into the GMDSS training and teaching process. Let the trainees understand the technical ethical risks in the implementation of GMDSS modernization, and let ship GMDSS operators gradually cultivate the correct ethical orientation and awareness of ethical responsibility in the practice of GMDSS, and always keep in mind the ethical functions of the GMDSS system with distress and safety as the core. In the end, the modernization process of GMDSS will be better developed and improved under the shaping of the correct ethical responsibility concept of GMDSS practice subjects.
CONCLUSION

This article starts with the current deficiencies and defaults of research in the world, combined with the current research status of E-navigation Strategy and the development status of GMDSS, and concludes that the current modernization of GMDSS is not perfect and cannot fully meet the communication needs of E-navigation Strategy. There are few studies on the relationship between navigation strategy and GMDSS modernization.

The main conclusions and achievements are as follows:

In any case, GMDSS modernization is demand-oriented, so when studying the relationship between the development of the two, it is necessary to start with the requirement.

IMO has a relatively clear plan for the requirement, project objectives, and implementation process of e-navigation. Based on this, this paper summarizes the most basic requirements for the implementation of E-navigation strategy, the user needs of E-navigation, and the communications technology requirement.

With the support of the E-navigation Strategy, human navigation activities will be transformed from single-ship behavior with limited shore-based support to ship-ship coordinated behavior supported by the shore-based and massive information of other ships. The modernization of GMDSS will be the most powerful technology in this change. support. The coordinated development of GMDSS modernization and E-navigation strategy is a general trend, and the relationship between the two is shown in Figure 7.
Communications technology is the basis for the development of E-navigation Strategy. Based on the technology and E-navigation Strategy requirements that the current GMDSS modernization can provide, it is proposed that in order to adapt to the development of E-navigation Strategy, the modernization of GMDSS should be divided into three steps: "GMDSS primary modernization", "GMDSS quasi modernization" and "GMDSS full modernization."

The paper also reminds: It is necessary to conduct an ethical review of all kinds of new equipment and new technologies in GMDSS modernization process, carefully evaluate and release them, which enables "sustainable development" of GMDSS modernization and could fully integrate digital technology, broadband technology, mobile terminals and other modern communication technologies while taking into account human nature.
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