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Existing System Improvement and Expected Configuration based on Risk Control Options for Implementation of e-Navigation

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Abstract : *Common Maritime Data Structure (CMDS) is commonly used by shore and ship users in e-Navigation data domain. In the overarching of e-Navigation architecture, IHO uses S-1XX, a digital exchange standard for next-generation marine information, as data exchange standard. The current CMDS has the advantage of intuitively recognizing the overall structure of e-Navigation. However, it has disadvantage in that it does not allow stakeholders to easily understand benefits that e-Navigation can provide when implementing e-Navigation. In this study, the direction of improving existing system for effective e-Navigation implementation was proposed considering RCOs (Risk Control Options) with expected composition of ship/ shore/ communication system by sector.*

Key words : *The Overarching e-Navigation Architecture, CMDS (Common Maritime Data Structure), e-Navigation Solutions, RCOs (Risk Control Options), e-Navigation System Functional Requirements*

1. Introduction

The IMO agreed to the need for the development of the CMDS (Common Maritime Data Structure) at the 57th NAV meeting, determining the overarching e-Navigation architecture (IMO, 2011b; Shim, 2013). The overarching e-Navigation architecture is divided into data domain and information domain in the vertical direction and divided into the ship and the shore sector in the horizontal direction. System connections are made up of physical connections and functional connections, ship and shore users communicate with each other through the system. In addition, WWRNS (World Wide Radionavigation System) of IMO including GNSS, GNSS augmentation and terretrial backup system is applied to both ship and shore systems for accurate ship location identification for information exchange (Oh, 2007).

CMDS is commonly used by ship and shore users in the data domain of the overarching e-Navigation architecture, and it serves as a data pool for e-Navigation data exchange. CMDS also uses S-1XX, a standard for data exchange, which the IHO has established as a digital exchange standard for next-generation marine information (IMO, 2010; IMO, 2011a; Oh, 2012).

Although the CMDS determined so far has the advantage of intuitively recognizing the overall structure of e-Navigation based on the common marine data system. However, it has a drawback in that e-Navigation core participants are not able to easily understand the benefits that e-Navigation can provide because it is concentrated on the linkage between ship and shore. For this reason, e-Navigation for some participants is misunderstood as simple equipment improvement or system integration.

The IMO 59th NAV included FSA (Formal Safety Assessment) results for the e-Navigation system, and the FSA group presented the preliminary e-Navigation solutions through gap analysis from ship user needs and the existing system, and derived RCOs (Risk Control Options) on risks when applying the e-Navigation solutions (IMO, 2012; IMO, 2013).

In this paper, we identify functional requirements based on RCOs (Risk Control Options) in terms of future e-Navigation system, and suggest directions for integration and performance improvement of existing systems. In addition, the expected change in ship/ shore/ communication system composition were specified by sectors.

2. Current system improvement based on RCOs

The preliminary e-Navigation solutions for implementing

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e-Navigation were presented at the IMO 58th NAV meeting through gap analysis of existing system and ship user needs (Jang, 2015; Jeong, 2008; Jeong, 2016; IMO, 2012; Shim, 2013), and the results of e-Navigation FSA were included in the IMO 59th report (IMO, 2013). The FSA group analyzed the risk improvement effects of e-Navigation solutions for common marine accidents and verified the effectiveness of e-Navigation solutions for risk control through questionnaires from various countries. As a result, nine existing solutions were compressed to five. The five main e-Navigation solutions are (IMO, 2012; IMO, 2013):

- S1: improved, harmonized and user-friendly bridge design;
- S2: means for standardized and automated reporting;
- S3: improved reliability, resilience and integrity of bridge equipment and navigation information;
- S4: integration and presentation of available information in graphical displays received via communication equipment; and
- S5: improved Communication of VTS Service Portfolio.

Table 1 e-Navigation system functional requirements by ship/ shore/ communication sector based on RCOs

Area	RCOs	Functional requirements
Ship	RCO 1: integration of navigation information and equipment including improved software quality assurance	• Develop integrated display system of navigation information • Develop navigation information processing system • Develop navigation system (equipment) following Software Quality Assurance (SQA)
	RCO 2: bridge alert management	• Develop bridge early-warning system • Develop integrated ship alert system (Personnel/ equipment)
	RCO 3: standardized mode(s) for navigation equipment	• Establish/ amend navigation equipment performance standard • Establish/ amend linkage standard • Draw up/ revise list of required navigation equipment
	RCO 4: automated and standardized ship-shore reporting	• Develop auto-reporting system • Define report contents/ standard format
	RCO 5: improved reliability and resilience of onboard PNT* systems	• Develop complex PNT system
	RCO 7: bridge and workstation layout standardization	• Establish/ amend standard on bridge equipment layout • Establish/ amend standard on integrated display of navigation information
Shore	RCO 1: integration of navigation information and equipment including improved software quality assurance	• Develop integrated display/ transmission system of navigation information • Define contents/ display standard of required navigation information • Develop VTS system following SQA
	RCO 4: automated and standardized ship-shore reporting	• Develop auto-reporting system • Define contents/ standard format of transmitting information
	RCO 6: improved shore-based services	• Shore Single-Window service (government) • Develop MSPs (Maritime Service Portfolio)
Communication	RCO 4: automated and standardized ship-shore reporting	• Develop digital auto-reporting system • Develop communication system by MSP service waters
Common requirements	Apply SQA, HCD (Human-Centered Design) and U-TEA (Usability-Test, Evaluation, Assessment)	

PNT* (Positioning, Navigation and Timing)

In addition, the IMO 59th NAV working group has identified seven risk control options (RCOs) based on five solutions. The seven RCOs approved by the FSA are as follows (IMO, 2013).

- RCO 1: integration of navigation information and equipment including improved software quality assurance
- RCO 2: bridge alert management
- RCO 3: standardized mode(s) for navigation equipment
- RCO 4: automated and standardized ship-shore reporting
- RCO 5: improved reliability and resilience of onboard PNT systems
- RCO 6: improved shore-based services; and
- RCO 7: bridge and workstation layout standardization

The seven approved RCOs as a result of the FSA are applied to the ship/ shore/ communication sectors as follows.

- Ship - RCO 1 ~ 5, RCO 7
- Shore - RCO 1, RCO 4, RCO 6
- Communications - RCO 4

The five compressed solutions are applicable to the conceptual design phase of the e-Navigation system, and the seven RCOs based on them are appliable to the basic design stage of the e-Navigation. IMO identified the technical requirements T1 ~ T18 required to implement e-Navigation solutions and established a yearly implementation plan for 2019 (IMO, 2014).

In order to implement effective e-Navigation, the functional requirements of the e-Navigation system for each RCOs by ship/ shore/ communication sector are summarized in Table 1 on the basis of technical requirements T1 ~ T18.

The functional requirements of the e-Navigation system based on RCOs (RCO 1 ~ 5 and RCO 7) applicable to ships are summarized as follows.

Firstly, ship systems are designed and deployed based on the usability including SQA (Software Quality Assurance), HCD (Human-Centered Design) guidelines. Navigation information such as sensor information/ alarm/ navigational support information can be transmitted through an onboard network to an integrated alarm management system (collision/ grounding/ engine and equipment malfunction alarms), automatic reporting system (maritime service portfolio information received from the shore), an improved PNT system, and it is displayed in the integrated exhibition system and provides navigational support service to users of the ship.

In addition, the information in the integrated alarm management system, automatic reporting system, and enhanced PNT system is transmitted to the shore and other vessels through the automatic reporting system.

Secondly, the shore-based service core of the e-Navigation system based on RCOs (RCO 1, RCO 4 and RCO 6) applicable to the onshore is to construct an automatic reporting system on the ship to automatically transmit necessary information on the land and to simplify the procedures required for port services. In other words, if the existing computerization was to computerize the physical document, e-Navigation is a concept that goes from here to working on data instead of document.

Thirdly, the key to implementing e-Navigation is to build a communication system for the shore to ship, ship to ship. The services (MSPs) that are provided to vessels through e-Navigation are limited without seamless network construction.

Finally, it should also be designed and developed based on the usability, HCD guidelines, which include SQA as a common functional requirement of the ship/ shore/ communication system.

A rank of the RCO 7 by PLL (Potential Loss of Lives) reduction per ship year was 14%, which is the highest rank, then RCO 1 and RCO 2 were 11% and 10%, respectively (IMO, 2013). As ships are able to apply RCO 7 and RCO 1 ~ 2 having high PLL reduction rate, it is necessary to implement e-Navigation system function considering RCOs PLL reduction ranking as priority.

3. Expected system configuration by sector

There are three major ways to improve existing systems according to application of the functional requirements of e-Navigation system. The first is system integration that minimizes the distraction of sailors, and the second is the automation of information acquisition and reporting tasks. Finally, system standardization to improve the operational convenience of the system should be done.

It describes the existing system improvement directions

for effective e-Navigation implementation by sectors of ship/ shore/ communication.

3.1 Ship system configuration

Ship-based e-Navigation core is not a concept of introducing independent and disconnected system of equipment but it is the basic concept to integrate, which is harmonization, existing system. Therefore, the equipment configuration as shown in Fig. 1 can be expected.

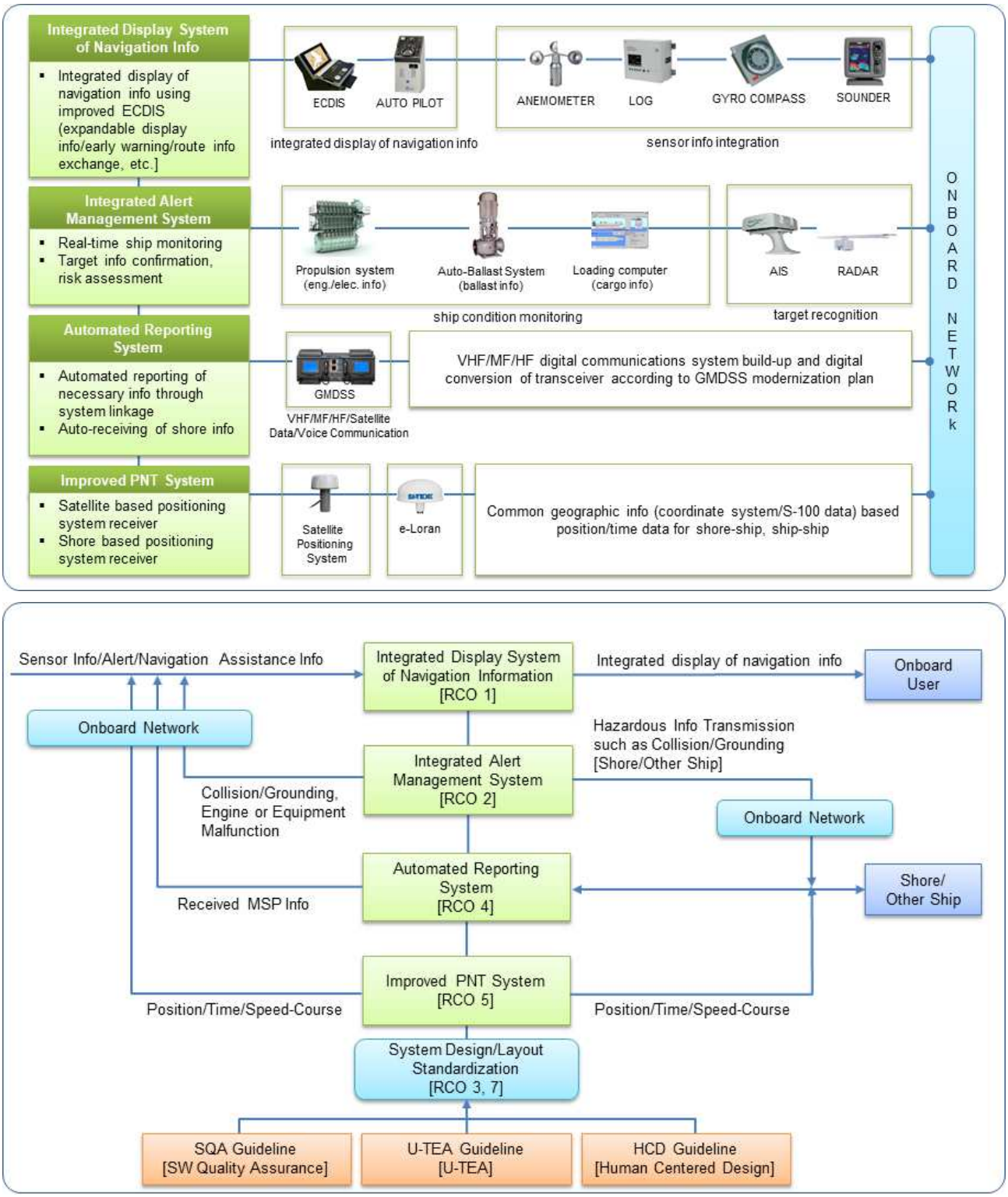

Fig. 1 Expected composition of ship-based e-Navigation system

In order to realize integrated exhibition system, various sensor information and other information from the onboard network can be integrated and displayed through the enhancement of the S-100 based next generation ECDIS function enabling the digital exchange standard of ship information and marine information. Collision/ grounding/ engine and equipment malfunction alarms can also be transferred to the integrated alarm management system through the onboard network and integrated and managed.

The automatic reporting system can be realized by digital conversion of transmitting/ receiving terminal and VHF/ MF/ HF digital data communication system according to GMDSS modernization plan. The enhanced PNT system can be implemented via satellite and position measurement system via e-Loran. RCO 5 describes the improved resilience of onboard PNT system, which includes the concept of using the e-Loran system as a backup system in the event of a satellite-based positioning system failure.

3.2 Shore system configuration

Shore-based e-Navigation system configuration is expected as shown in Fig. 2. Based on this, IMO MSP proposes to provide a single window service on the land. Documents required for work are automatically generated by the system. To do so, it is first necessary to standardize the entry and leaving procedures related to port operations, which are not standardized at present, and the standards for reporting port-related procedures or at least the information to be transmitted from the ship to the shore.

Improved traffic control means that the VTS center and the ship show the same screen. A typical example is a service that sends a recommended route on land, rather than calling a ship by voice and designating a route.

At the core of the shore service is to reduce the workload of the ship, reduce the fatigue of the crew, and provide a service that allows the crew to concentrate more on the sailing work by providing a comprehensive understanding of the sailing situation.

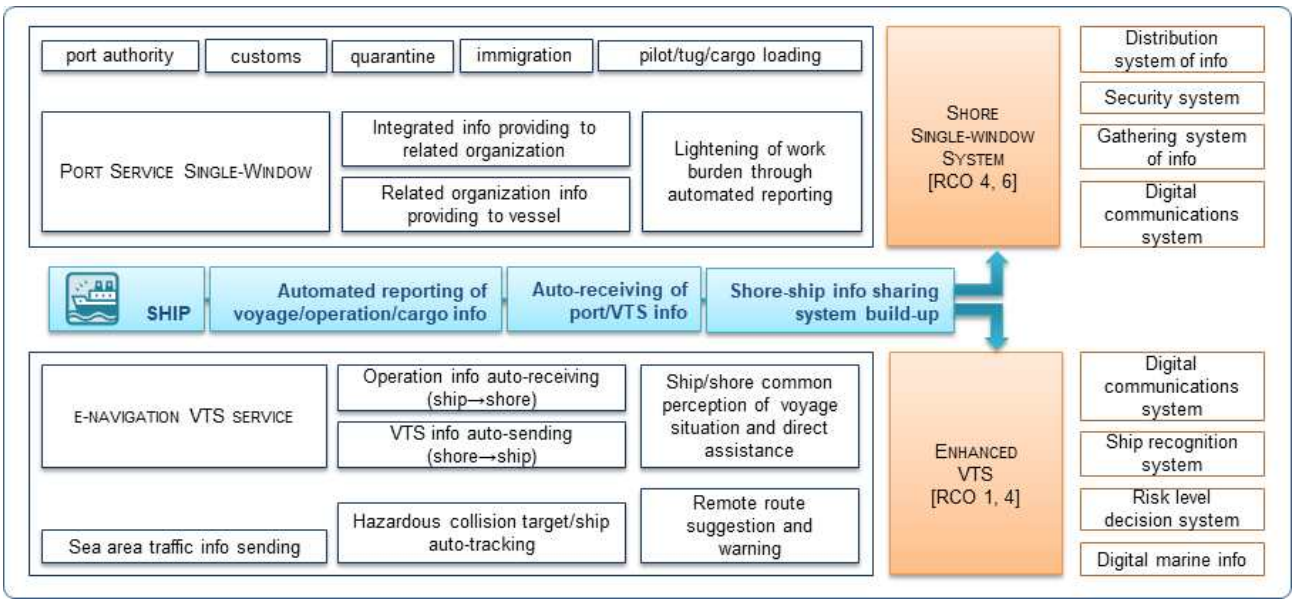

Fig. 2 Expected composition of shore-based e-Navigation system

3.3 Communication system configuration

IMO COMSAR is planning to modernize the existing ship communication system. The completion of IMO e-Navigation is expected to be completed after 2018 considering the completion time of communication system construction (ITU, 2012). The communication system is a key element in implementing e-Navigation.

The ship communication sector is centered on the GMDSS system. Although GMDSS is a distress communication system by name, it actually refers to a possible communication network in the ship. Distress communication is a key requirement of communication system.

The GMDSS modernization plan is to promote digitalization of possible communication networks on the ship. It is to support data communication by converting the communication network of VHF/ MF/ HF band, which is a traditional ship wireless communication, to digital. Through data communication, various services can be provided using ship-to-shore wireless communication network.

As shown in the report of the GMDSS modernization plan and the e-Navigation communication correspondence working group submitted so far, building the digital data communication network between ship to ship and ship to shore is the core of the e-Navigation system communication sector. The communication system configuration of e-Navigation is expected as shown in Fig. 3.

For satellite communication and MF/ HF band communication, a standard for digital data communication has already been established (RSS, 2012). MF/ HF band communication is suitable for one-way broadcasting or intermittent reporting rather than real-time/ high-speed data communication due to its frequency characteristics.

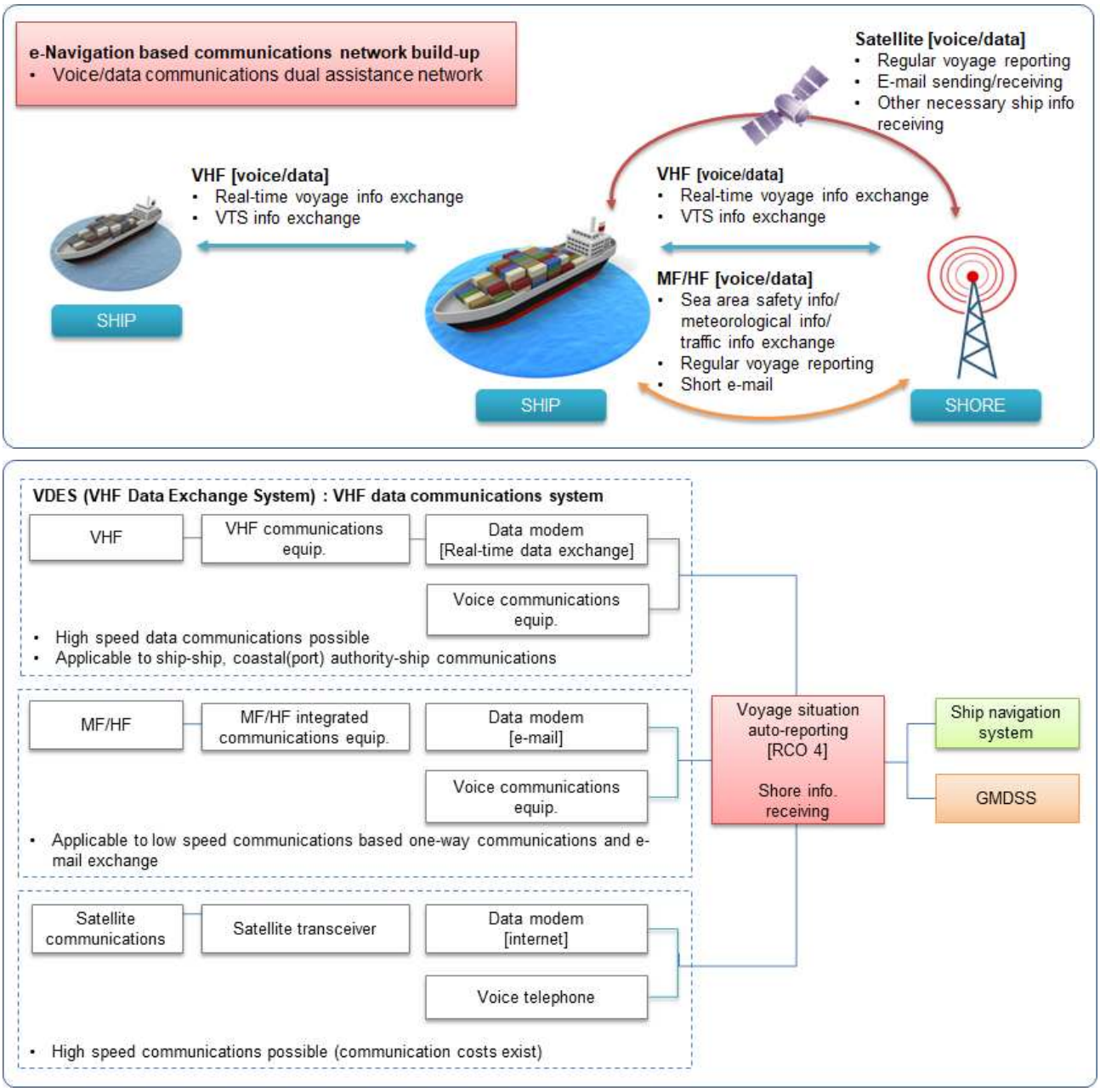

Fig. 3 Expected composition of communication-based e-Navigation system

On the other hand, in the case of VHF, which is the most utilized among the ship's wireless facilities, working on the communication standard is underway.

When the VHF band digital communication standard is completed, it is necessary to develop the communication equipment that has completed the frequency allocation and satisfies the standard. Once the standard and frequency allocation are completed, the development of the related communication equipment is expected to be ready for commercialization with standard completion. IALA expects the completion of technology development for the frequency band to be in 2020 (ITU, 2012).

Existing communication equipment will be replaced when the technology development ends. For digital communication, a different frequency modulation scheme is used, so transceivers and communication modems must be newly installed in ships and onshore base stations.

4. Conclusion

The overarching e-Navigation architecture defined at the IMO 57th NAV meeting is divided vertically into data domains and information domains and horizontally into the ship and shore segments. System connections are made up of physical connections and functional connections. Onshore and ship users can exchange information through system-to-system connections, and global communication systems for information exchange apply to both ship and shore systems. The meeting also agreed to the need to develop CMDS (Common Maritime Data Structure), which is commonly used to shore and ship users, and decided to use S-1XX as a data exchange standard as the next generation marine information digital exchange standard.

The e-Navigation solutions derived from the IMO 58th NAV meeting was determined by the gap analysis between existing system and ship user needs. Seven RCOs (Risk Control Options) based on five e-Navigation solutions were derived from the IMO 59th NAV meeting on the possible risks of applying e-Navigation solutions.

The overarching e-Navigation architecture and CMDS determined so far have the advantage of intuitively understanding the overall structure of e-Navigation. However, it is not easy to understand the benefits that e-Navigation can provide to stakeholders in implementing e-Navigation.

In this research, the functional requirements of the e-Navigation system based on the RCOs are summarized by the ship/ shore/ communication sectors, and the existing system improvement for e-Navigation implementation is suggested. In addition, the expected composition of the ship/ shore/ communication system for implementation of e-Navigation was presented by sector, so that it is easy to understand the benefits that stakeholders would receive when implementing e-Navigation. It is also anticipated that preparation and response according to e-Navigation implementation will be easy for related organizations.

It is necessary to study the improvement direction of e-Navigation system by applying step by step according to priority of RCOs in the future.

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