Current Status of MASS and Initiatives of ClassNK

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1. INTRODUCTION

Nearly a decade has passed since the International Maritime Organisation (IMO) formally began its examination of Maritime Autonomous Surface Ships (MASS). During this period, international discussions have progressed, and various countries initiated demonstration trials and commercial operation of MASS, resulting in gradual progress towards social implementation. For example, the Nippon Foundation's MEGURI2040 project successfully completed its Phase 1 demonstration trials in 2022, and is currently proceeding with Phase 2 trials.

The background of interest in MASS is the need to reduce human error, which accounts for about 70 % of accidents involving ships [1)], and to cope with an aging population of seafarers and shortages of human resources [2)]. Automation and remote control of seafarers' tasks are expected to reduce their workload and improve the working environment, thereby improving safety and maintaining sustainable logistics. In light of this situation, various scenarios for the use of MASS are being considered in a number of countries.

Use cases for MASS are organized along two axes, the Mode of Operation (MoO) and the environments under which automation and remote control are used [3)]. For MoO, there are cases in which the operation of the vessel is entrusted to an Autonomous Navigation System (ANS), and seafarers are in charge of monitoring and emergency response on board the vessel. There are also cases that involve remote human control of the vessel from a Remote Operation Centre (ROC). Since uniformity of the MoO across all phases of ship navigation is not necessary, there are examples where an ANS controls the vessel in the open sea and remote control is used in coastal areas where communication between the vessel and an ROC is stable.

Since these use cases will only be acceptable to all stakeholders if they are consistent with laws and regulations, each country is improving its legal and regulatory framework based on the progress of technological development and the results of demonstration experiments. For example, the MASS Code, which is an international regulation being developed by the IMO, is being finalised first as a non-mandatory code, and this work is now in its final stage. However, since the MASS Code only specifies functional requirements, it is essential to establish more detailed technical requirements to ensure social implementation.

The Society has responded to these trends from an early stage. In addition to conducting safety assessments in demonstration projects from the standpoint of a third-party organization, the Society is also actively working to establish technical requirements by compiling and publishing the knowledge obtained through those projects in ClassNK Guidelines. From the standpoint of a classification society, we believe that these efforts will contribute to ensuring the safety of technological development and the establishment of laws and regulations for MASS.

This paper first reviews the trends in the development of MASS and the establishment of laws and regulations in each country, and then introduces the initiatives of the Society and their results.

2. DEVELOPMENTS OF MASS

Development and actual operation of MASS are progressing rapidly in various countries. Although the efforts of each country differ according to the circumstances and objectives of their respective regions, they all aim to establish MoOs and system configurations for practical use while gradually verifying the technology.

In Norway, development is progressing on the assumption that MASS will navigate the country's coastal fjord areas and operate from berth to berth with unmanned operation on board (automation of navigation) and remote human participation (monitoring and emergency response). One example is the electric propulsion RO-RO ship ASKO Marit (Fig. 1), which is

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operating on a route of approximately 10.5 km between Moss and Horten ports. Verification is being carried out in a step-by-step manner. At present, ASKO Marit is operating with remote monitoring and crew members on board in case an emergency occurs while the system is operating. Another feature of ASKO Marit is automation of port side operations. The infrastructure necessary for unmanned operation on board is being developed, including a hull fixing device for automatic berthing and an automatic power supply system.

Fig. 1　Automatic berthing of ASKO Marit (going astern)

In Belgium, remote navigation in inland waters by Seafar is a distinctive feature. The company operates and manages MASS from its own ROC, and commercial operation is already underway at the ROC in Antwerp (Belgium) shown in Fig. 2. With the aim of commercial operation outside Belgium, demonstration tests in Amsterdam Port (Netherlands) and Duisburg (Germany) are also underway with operation from the ROCs. In the future, Seafar aims to operate vessels that are unmanned on board, but the current commercial operation uses manned vessels with a reduced crew to cope with situations such as communication interruptions. At the ROC, one Remote Operator is in charge of each vessel, and the Supervisor, who has higher authority, monitors the entire fleet and responds to emergencies.

Fig. 2　ROC of Seafar

In Korea, seafarer support systems utilizing automation of navigation have been developed. For example, Samsung Heavy Industries (SHI) has developed an ANS called SAS (Samsung Autonomous Ship) and received AiP (Approval in Principles) and a Technology Qualification statement from the Society. Avikus, a subsidiary of Hyundai Heavy Industries (HHI), has also developed an ANS, HiNAS Control, and is already deploying it as a commercial product. As remote operation technologies, the smart ship demonstration vessel Ulsan Taehwa was constructed, and a new ROC called the Ship Integrated Data Centre was established at UIPA (Ulsan ICT Promotion Agency), as shown in Fig. 3, enabling remote monitoring of the operational status of the vessel.

Fig. 3 Ship Integrated Data Centre at UIPA

In Japan, the second phase of the MEGURI2040 project by The Nippon Foundation is underway. As shown in Fig. 4, demonstration tests are being conducted with a total of four vessels: one remote island passenger ferry, one container ship, one RO-RO ship and one newly-built container ship. For example, the MoO of the new container ship is assumed to be automation of navigation from berth to berth and remote monitoring of the engine. Various elemental technologies are being developed to realize these functions. The Society is also conducting safety assessments from a classification society perspective, advancing the survey of NK-classed ships and the evaluation of elemental technologies.

Fig. 4 Second phase of MEGURI2040 project [4)]

In this manner, each country is carrying out step-by-step verifications tailored to regional conditions and objectives with the aim of social implementation of MASS, and the transition from demonstration to commercial operation is now entering a realistic phase.

3. DEVELOPMENT OF LAWS AND REGULATIONS

In line with advances in technological development, each country is also progressing with the establishment of supporting laws and regulations. Since MASS involve operations not contemplated in the framework for conventional vessels, mechanisms are required to underpin safety and operational systems from an institutional perspective, based on the insights gained from technological demonstrations. With this background, each country is advancing the development of its regulatory framework by various approaches, such as utilising existing legal systems or enacting new legislation.

Norway issued guidance RSV12-2020 (Guidance in connection with the construction or installation of automated functionality aimed at performing unmanned or partially unmanned operations) concerning MASS in 2020. This document stipulates that assessments should be conducted based on existing regulations, whilst requiring that MASS demonstrate equivalent safety to conventional vessels using the risk-based assessment methodology outlined in IMO MSC.1/Circ.1455

(Guidelines for the Approval of Alternatives and Equivalents as Provided for in Various IMO Instruments).

A notable feature in Belgium is that legislative amendments were enacted in June 2021 based on the outcomes of demonstration experiments. This legislation (Royal Decree on unmanned navigation in Belgian maritime zones) includes the definition that “An unmanned ship is a seagoing ship that can sail partially without human intervention for all or part of its voyage or that can sail with remote control.” It also states that “remote control centres are considered an integral part of the unmanned ship,” thereby legally permitting use scenarios involving remote operation from land without human intervention on board.

In Korea, the Enactment of the Enforcement Decree of the Act on the Promotion of Development and Commercialization of Autonomous Ships came into force in January 2025. Its section on “Test Operation and Special Provisions for Autonomous Ships” stipulates that authorisation is required for test operations and demonstration trials. It further specifies that upon receiving such authorisation, the vessel is exempt from certain legal regulations within designated navigation zones. This is positioned as part of the country’s efforts to foster an enabling environment to encourage the demonstration of development technologies and accumulation of operational track records.

In Japan, the relevant ministerial ordinances were amended and came into force in June 2025. MASS (vessels equipped with ANS) were positioned within the framework of the Ship Safety Act as subject to inspection as special vessels. The main amendments are outlined below.

- ■ The Ship Safety Act Enforcement Regulations classify vessels equipped with ANS as special vessels.
- ■ The Special Regulations for Automated Equipment on Ships prescribe the functional requirements for ANS.
- ■ Instructions and procedures for ship inspection prescribe the flow of specific inspections of vessels with ANS and the timing of issuance of ship inspection certificates.

Discussions are expected to be held regarding manning and responsibilities, based on the results of demonstration tests.

The IMO agreed that, rather than amending individual conventions to address the issues identified in the Regulatory Scoping Exercise (RSE) for the use of MASS, a new Goal-Based Standard (GBS) code, the MASS Code, should be developed. The MASS Code is divided into the three Parts outlined below. PART 2 contains requirements applicable to all MASS, irrespective of whether tasks are autonomous or remotely controlled. PART 3 contains task-specific requirements, the applicability of which is determined by the flag States.

- ■ PART 1 (Introduction)
  The scope of application is defined. The non-mandatory Code is intended to apply to cargo ships.
- ■ PART 2 (Main Principles)
  Common requirements for all MASS are prescribed. An approval process based on the ConOps is described.
- ■ PART 3 (Goal, Functional Requirements and Expected Performance)
  Functional requirements for each task to be autonomous or remotely controlled are specified. The applicability of these requirements should be determined by the flag States in accordance with the ConOps.

It was deemed appropriate for the MASS Code to establish a non-mandatory Code as provisional guidance in order to indicate the direction at an early stage. Consequently, the roadmap is to first adopt the non-mandatory Code in 2026, gather feedback through an Experience Building Phase (EBP), and then aim for the mandatory Code to enter into force in 2032.

While legislative and regulatory frameworks aligned with use case implementation are being advanced by individual nations and the IMO as described above, it is also essential to concurrently establish specific technical requirements to ensure the safe implementation of MASS technologies. For example, the MASS Code comprises Tier I (goal(s)) and Tier II (functional requirements) in the GBS framework shown in Fig. 5, and ensuring its effectiveness will require the development of more detailed technical requirements, namely Tier IV (class rules, etc.) and Tier V (industry practices and standards). Tier IV, in particular, is expected to be developed primarily by classification societies, including the Society.

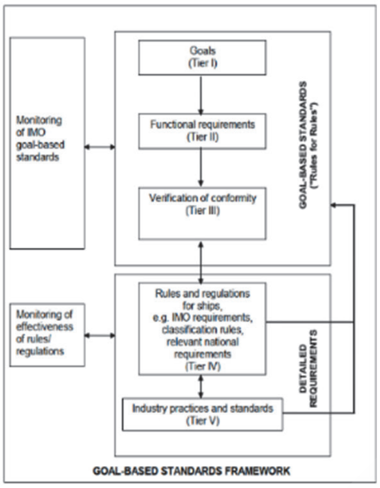

Fig. 5 Goal-Based Standards framework (MSC. 1/Circ. 1394)

4. INITIATIVES OF THE SOCIETY

4.1 Overview

The Society has proactively advanced safety assessments and regulatory development by establishing a cross-functional project team, MASS PT, in response to trends concerning MASS. For safety assessments, the Society reviews and evaluates demonstration projects from a third-party perspective to confirm compliance with guidelines and requirements prescribed by the Society. Based on these findings, the Society revises its guidelines, contributing to the establishment of technical requirements. To support these efforts, the Society also conducts research on improving evaluation methodologies and utilising simulation technology with domestic and international leaders in the field. The following sections describe these initiatives in more detail.

4.2 Safety Assessment

Since issuing "Guidelines for Automated/Autonomous Operation on Ships (hereinafter, the Guidelines) [5)]" in 2020, the Society has conducted safety assessments of MASS and their onboard systems both domestically and internationally.

For ANS, the Society has issued AiPs for APExS-auto by NYK, MTI, and Japan Marine Science; Advanced Maneuvering Assistant System by Kawasaki Kisen Kaisha, Kawasaki Kinkai Kisen Kaisha, Japan Radio, and YDK Technologies; and overseas, for SHI's SAS. The Society also assesses elemental technologies based on the Guidelines and issues Technology Qualification statements. For instance, statements for collision avoidance functions have been issued for Japan Marine Science's ARS and SHI's SAS-IBS following assessments of results of simulations of multiple collision avoidance scenarios.

For remote operation technology, an AiP has been issued for SHI's ROC, SROC (Samsung Remote Operation Centre). Through these safety assessments, the Society is confirming the safety of key functions of MASS and accumulating knowledge for establishing future technical requirements.

4.3 Rule Development

This section details the key changes introduced in the Guidelines ver. 2.0 published in March 2025, specifically the establishment of new notations and a new annex.

4.3.1 Notations

For vessels equipped with ANS, the notation "Autonomous-XY(Z)" (abbreviated as "AUTO-XY (Z)") is affixed to the classification characters of the vessels in accordance with the Guidelines. The notations "X," "Y" and "Z" indicate the automated function, the level of autonomy and the phase of navigation, respectively.

The automated function "X" explicitly specifies which tasks are to be automated. Its content is chosen from Navigation (Nav), Engineering (Eng), Safety (Saf), or Operation (Ops). The level of autonomy "Y" uses the following numbers to express the degree of human intervention in the functions being automated.

1: (Support) Partially automated with decision-making by humans.

2: (Conditional autonomous) System use monitored by humans.

3: (Advanced autonomous) Human intervention is basically not necessary; however, the system can always be overridden based on decision-making by humans.

The phase of navigation “Z” represents sea areas where the ANS is to be used. The content of “Z” is either Limited or All, corresponding to the functions to be automated. In the case of “Nav,” Limited is then chosen from Berth/unberth (Be), Harbor (Ha), Coastal (Co) or Open Sea (Os).

For example, vessels equipped with an ANS that can control the vessel under human supervision only in the open sea would be assigned the notation AUTO-Nav2(Os).

4.3.2 New Annex

As regulations corresponding to Tier IV, the Society decided to concretize the knowledge so far in the form of an annex. The annex can be roughly divided into two parts, requirements for ANS that automate navigation (Annex I) and requirements for remote monitoring and operation of machinery (Annex II).

Annex I specifies common requirements, definitions, approval processes, etc. in “General,” and provides detailed requirements for each of the essential ANS functions, namely situational awareness, collision and grounding avoidance, and route execution and monitoring. In particular, evaluations using simulation techniques involve simulation scenarios and mathematical manoeuvring models, reflecting the results of the research activities described in the following section.

Annex II specifies the scope of application and specific functional requirements as safety requirements for engine monitoring and operation from remote control facilities. For example, this annex describes requirements for monitoring multiple vessels and information requiring warnings and display in remote engine monitoring.

4.4 Research Activities

The Society conducts research that contributes to safety assessment and rule development in cooperation with domestic and international research institutions and companies. This section outlines the research activities that form the basis of the development of the Guidelines.

4.4.1 Research on Manoeuvring Models

In the route execution function of MASS, automation of in-port manoeuvring including automatic berthing and unberthing is regarded as a highly novel technology. For safety assessments, the validity of the manoeuvring model used in simulation evaluations is important. Ideally, it is desirable to standardize the manoeuvring motion model used in simulations, but because port manoeuvring involves complicated motions in the low-speed range, efforts to standardise the model are still in progress.

Given this situation, from the perspective of safety assessment, it is more practical not to prescribe a single standard model, but rather to define the requirements to be satisfied by manoeuvring models, and to require simulations using models that meet those requirements in assessments. In other words, it is necessary to establish the requirements demanded from the motion calculation component of simulators reproducing in-port manoeuvring.

Therefore, in 2023, the Society established a study group to examine the requirements for manoeuvring models, and invited experts in ship manoeuvring and ship control from domestic universities, research institutions, shipyards, and manufacturers to participate. Discussions were held with the aim of examining the requirements for manoeuvring models and their verification methods, and the outcomes were published on the Society’s website [6]. For example, Fig. 6 shows the verification scenarios for thruster manoeuvring. The findings have also been presented at both domestic and international academic conferences [7), 8)].

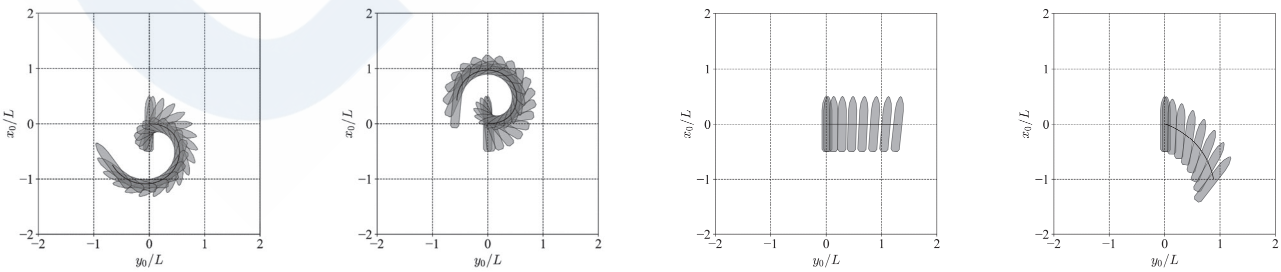

Fig. 6 Scenarios for confirmation of thruster manoeuvring (excerpt)

In automating navigation, the collision and grounding avoidance functions are crucial. Particularly, as the COLREG Convention prescribes manoeuvring according to the encounter situation with other vessels, compliance with that regulation is also required for MASS. Therefore, it is necessary to verify that MASS can appropriately avoid collisions with other vessels and grounding while adhering to COLREG.

In response, the Society has conducted research into simulation-based verification methods through collaborative studies with domestic research institutions. For instance, when simulating collision avoidance manoeuvring, basic scenarios based on the clustering of encounter situation [9] shown in Fig. 7 involving one-to-one or two-vessel encounters were examined, as shown in Fig. 8. As one method for evaluating collision avoidance routes, the Society carried out studies and experiments on the evaluation area diagram shown in Fig. 9 [10), 11)]. Since “good seamanship” as described in COLREG includes elements that are difficult to express numerically, the Society has also examined methods for subjective evaluation by experts such as experienced seafarers, termed expert judgement, and conducted experiments targeting specific collision avoidance algorithms [12].

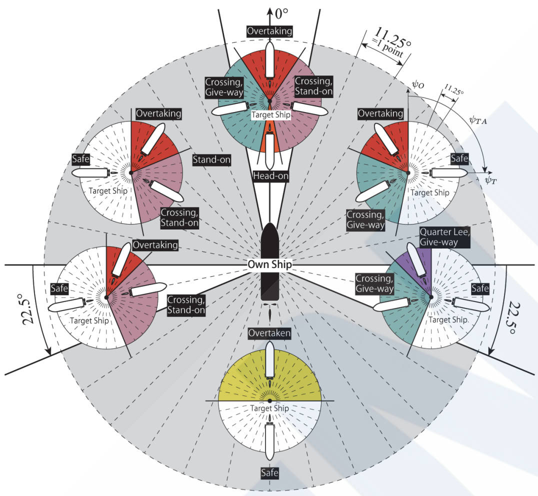

Fig. 7　Clustering of encounter situation

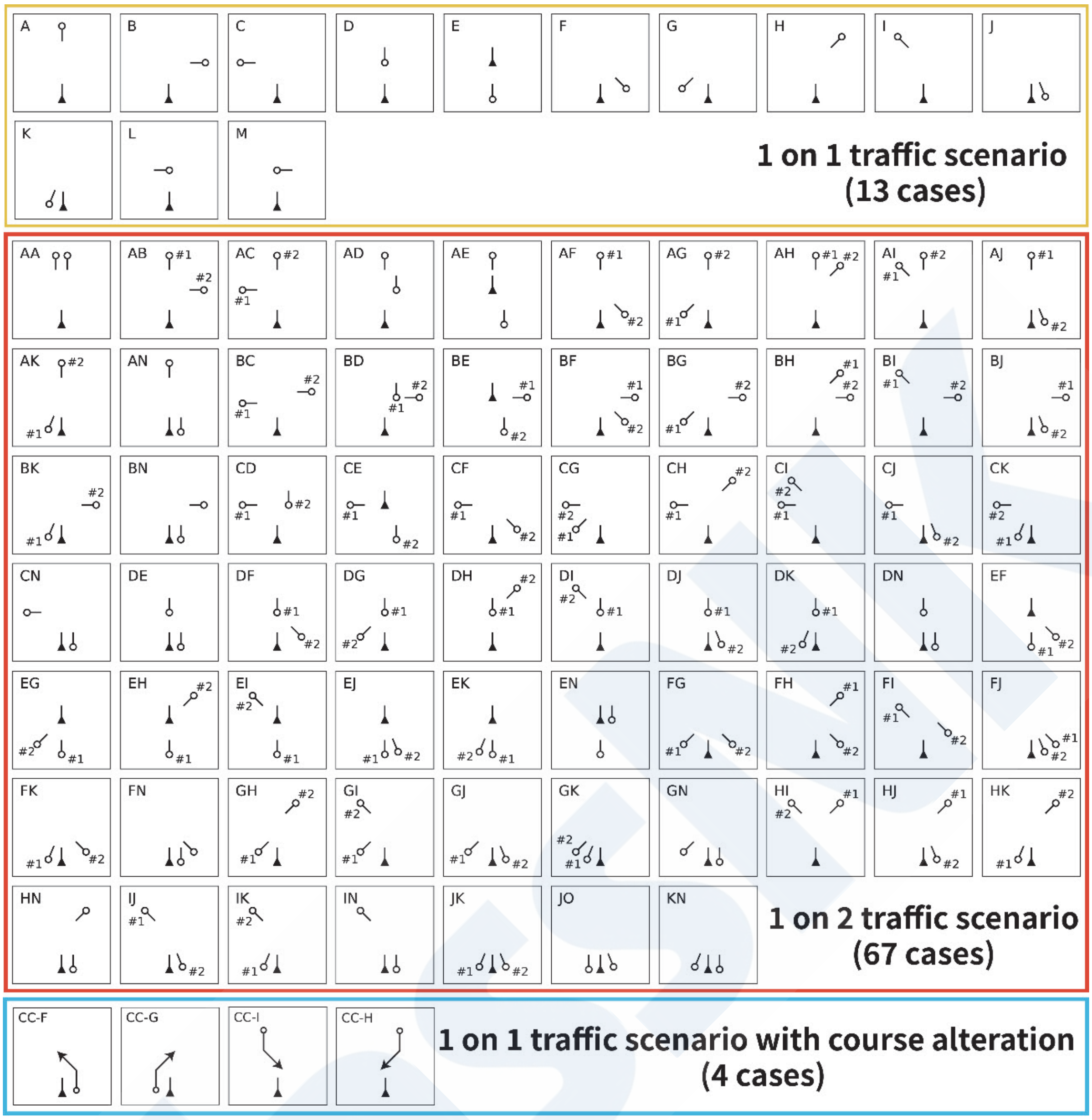

Fig. 8 Basic scenarios

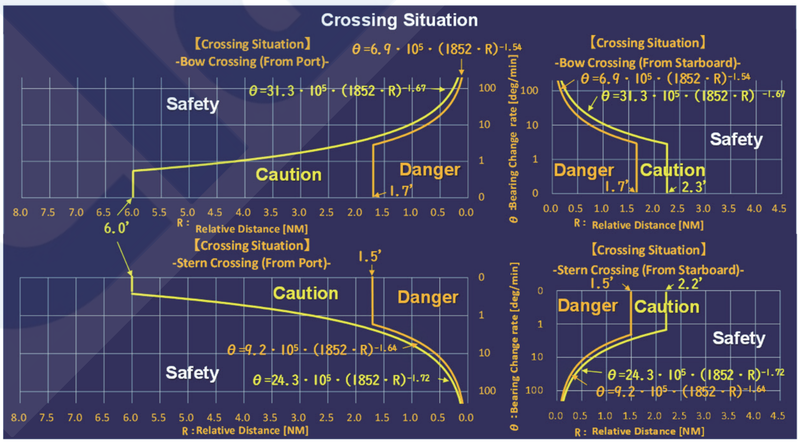

Fig. 9 Evaluation area diagram

4.4.2 Technology Related to Remote Operation

In remote monitoring and control, operations where humans on shore view real-time video are envisioned. In such cases, video transmission is one of the key technologies essential for situational awareness in the ROC [13]. Therefore, the Society is verifying the video transmission requirements necessary for situational awareness in ROCs and the technical feasibility of longdistance, wide-field-of-view video. As part of this effort, a demonstration experiment was conducted to receive and play back live video transmissions from an experimental vessel using Starlink and cellular (LTE) communications. This experiment quantitatively demonstrated the trade-off relationship between latency, image quality, and playback stability, highlighting the necessity for dynamically balancing these factors according to the phase of navigation and the level of remote operation [14).

The Society is also investigating the latest trends in communications technology, which is crucial for achieving remote operations, and publishes the results on its website as they become available. For example, one research report [15) examines the current status of optical wireless communication and its potential applications in the maritime sector, as this technology is attracting attention as a means of supplementing limited radio wave resources. By compiling these recent trends and assessing their technological maturity, the Society is contributing to the formulation of fair and objective requirements.

5. CONCLUSION

This paper summarises the current status of MASS development and regulatory frameworks, and introduces the Society's initiatives in the areas of safety assessment, rule development, and research activities. Regarding MASS development and regulatory frameworks, the paper highlights how each country is advancing development incrementally within their respective regulatory frameworks and the IMO is progressing with the formulation of the MASS Code. As the MASS Code is expected to organise functional requirements based on the GBS framework, the development of more specific Tier IV requirements is anticipated, primarily by classification societies including the Society. In response to the current status, the Society has addressed relevant issues through research activities, guideline development, and safety assessments from an early stage. In the future, the Society intends to continue to provide support for the social implementation of MASS from the perspective of a classification society, drawing upon the expertise accumulated over time.

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