ISSN (e): 2250 – 3005 || Volume, 15 ||Issue, 11||November-2025 ||
International Journal of Computational Engineering Research (IJCER)

Systemic Assessment of Remote Operator Governance in Maritime Autonomous Surface Ships (MASS)

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ABSTRACT
Maritime Autonomous Surface Ships (MASS) integrate artificial intelligence, advanced sensors, and satellite-based communication networks into complex control architectures that enable high-level autonomy and remote supervision. Within this system, Remote Operators (ROs) located in land-based Remote Operation Centers (ROCs) function as critical human nodes responsible for monitoring, decision-making, and system recovery in degraded operational states. However, the current international legal and institutional frameworks—particularly the STCW Convention—do not adequately recognize their roles, competencies, or command authority.
This study conducts a systemic assessment of RO governance in MASS operations by analyzing the interaction between human oversight, AI-driven control systems, and regulatory compliance mechanisms. Drawing on computational perspectives in risk management and human–machine integration, it identifies key operational vulnerabilities such as communication latency, cognitive overload, and multi-vessel control complexity. The paper proposes an integrated framework for the certification, training, and legal recognition of ROs, aligning technological reliability with institutional readiness. The findings emphasize that the safe and effective deployment of MASS requires both algorithmic resilience and a robust governance structure defining human accountability within autonomous maritime systems..
KEYWORDS: *MASS; Remote Operator; Remote Operation Center; Artificial Intelligence; Human–Machine Integration; Systemic Governance; Risk Management; STCW Convention; IMO; MASS Code*

Date of Submission: 03-11-2025 Date of acceptance: 13-11-2025

I. INTRODUCTION

Maritime Autonomous Surface Ships (MASS) are remaining unfamiliar to the maritime industry, yet they are regarded as a 4th generation's technologies that can usher in major innovation and change [1]. These vessels aim to achieve more safe and efficient operation with minimum human intervention. They are made possible through the integration of technologies such as artificial intelligence, sensor-based operation, satellite communication and real-time data processing [1]. Especially, Finland has operated a remote control's car ferry since 2018, and Norway conducted the first sea trials of a fully autonomous electric container ship in 2021 [1]. These cases demonstrate that MASS technologies can no longer be applied to illogical theories but to real-world industry. Eastern Asian countries like South Korea, Japan, and China are also actively developing related programs, intensifying global competition. [1]

In response, the International Maritime Organization (IMO) is working to establish international rules by drafting a new regulatory framework called the MASS Code [2]. This code is scheduled to enter into force in 2032 [2]. However, most discussions remain centered on technological advancement currently. Legal and administrative frameworks for operating these vessels safely have not kept pace with the rapid technical development of MASSs.

In this context, special attention must be paid to the role and legal status of the Remote Operator (RO) who is located at a shore-based Remote Operation Center (ROC) and is responsible for monitoring and controlling the MASS under remote operation. Their responsibility is not free if the accidents that occur in remote operational situations. This responsibility requires the RO to ensure the safe operation from a physically separate location. The RO must quickly analyze complex situations and respond effectively in environments with limited condition,

not in the actual ship. That is why the RO need to a high level of situational awareness and decision-making ability.

Nevertheless, it is not clearly defined the legal status of ROs as currently discussed in IMO. The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) of 1978, applies only to personnel physically on board. As a current definition, ROs are excluded from its scope. This legal gap presents an urgent issue as MASS begins to move from experimentation to commercial deployment.

This paper addresses the international legal status of ROs in MASS operations. It explores existing regulatory limitations and offers policy suggestions to establish clear institutional frameworks. Legal clarity and administrative preparedness, along with technological reliability, are essential factors for ensuring the safe and effective adoption of MASS.

II. CURRENT DEVELOPMENT OF THE MASS CODE AND THE POSITION OF REMOTE OPERATORS

The introduction and operation of MASS cannot be accomplished by technological advancement alone. Safe navigation at sea requires more than technical reliability. It also demands immediate response to unpredictable maritime conditions and a clear redistribution of roles among all relevant actors involved in the navigation process. In this regard, the IMO is currently engaged in discussions on the necessary operational concepts and standards for MASS. The results of these discussions are expected to be reflected in the MASS Code, which is under development [3].

The STCW Convention of 1978 defines its scope of application based on seafarers who are physically present on board. Therefore, ROs who control vessels from ROC are excluded from its regulatory coverage [4]. This regulatory gap is likely to raise serious legal issues concerning the status, responsibility and certification of ROs as MASS enters its commercial phase [5].

A ROC is a land-based facility from which vessels are monitored and controlled remotely. These centers provide real-time navigation information and rely on satellite communication and related technologies to maintain a secure and stable operational environment. Countries such as Norway and Finland have already accumulated operational experience and technical expertise through actual ROC implementation [6]. It is expected that ROs working in ROCs will be assigned ultimate responsibility for any incidents that occur during MASS operations [3].

Because ROs carry out their duties from locations physically distant from the MASS, they must be capable of rapid and accurate situational assessment even with limited environmental feedback. They are required to overcome the constraints of remote information and make high-stakes decisions within short time frames [7]. In addition, they must be able to manage several vessels simultaneously. This responsibility calls for exceptional situational awareness and high-level decision-making abilities [8].

The STCW Convention does not currently provide any concrete provisions for the duties and responsibilities of ROs. As such, the lack of regulatory clarity presents a critical challenge that must be addressed in order to support the practical and safe operation of MASS in the near future [4]. In response, the IMO is considering ways to integrate MASS-specific training and certification systems with the existing STCW framework, while also developing a legal definition of the RO's status [5].

It is essential to clearly define the legal status and role of ROs and to establish an internationally standardized system for their training and certification. This is a fundamental requirement for the safe introduction and effective management of MASS. Continued legal and institutional coordination, led by the IMO, is necessary to achieve these goals.

At present, the MASS Code under development remains non-mandatory in nature and refers to the qualifications of ROs only in broad terms. It suggests that these operators should possess competence equivalent to the standards of the STCW Convention. However, no detailed training or certification procedures have yet been established.

The voluntary status of the MASS Code may evolve into a binding regulatory instrument in the future. Therefore, international consensus on the legal responsibilities and operational role of ROs must be reached through further structured discussion and negotiation.

III. LEGAL RESPONSIBILITY AND COMMAND AUTHORITY OF REMOTE OPERATORS

Legal responsibility and command authority in the context of remote operation of MASS present a range of complex issues. Among these, the allocation of responsibility and the clarification of command authority for ROs have emerged as central and controversial topics. Since the basic principle of MASS operation assigns ultimate responsibility for incidents and accidents to human actors—specifically, ROs—it is essential to clearly define where that responsibility lies [3].

A key point of contention involves the physical presence of the vessel master. At present, there is no international consensus on whether the master must be physically on board. One Sea-ry, for instance, maintains that under certain conditions involving controlled risks, it is acceptable for the master to perform duties from a remote location [9]. This position is based on the growing capability of remote operation systems to provide sufficient information and control to ensure vessel safety, even from a distance.

Nevertheless, the remote operation is subject to several practical limitations. it is included that the limited range of information available at remote sites, the risk of communication delays, etc. That of which may hinder the RO's ability to respond quickly and appropriately in emergency situations. The IMO and other relevant international bodies have noted that these limitations must be taken into full account when discussing the scope of command and responsibility for ROs [5].

It needs to be also considered for a single RO to be responsible for multiple MASS at the same time. If one RO holds responsibility for several vessels, concerns arise regarding whether each situation can be accurately assessed and effectively managed. There is an urgent need to clarify the boundaries of command responsibility and decision-making authority [3]. The IMO is therefore considering regulatory measures to define the scope of authority and responsibility for ROs and to establish a clear command structure for different operational contexts [4].

Addressing these legal and organizational challenges requires a set of structured regulatory responses. First, there must be an international legal standard that clearly defines the roles and responsibilities of both ROs and onboard personnel. These standards should be detailed within the MASS Code and tailored to the various levels of autonomy [3].

Second, procedures and technical support systems must be implemented to reduce the risk of cognitive overload and command confusion when a RO is responsible for multiple vessels. Enhancing the speed and accuracy of decision-making in ROCs requires both organizational planning and technological reinforcement [7].

Third, human factors such as working conditions and fatigue management for ROs must be explicitly addressed in the MASS Code. These considerations are essential to ensure that ROs can perform their duties effectively and fulfill their responsibilities in a sustainable manner [3].

In conclusion, the legal framework surrounding responsibility and command authority in MASS operations must be urgently developed. Achieving safe and effective operation of MASSs depends on a robust and enforceable set of regulatory standards, which can only be established through continued collaboration among the IMO and other international regulatory bodies.

IV. POLICY PROPOSAL

The successful development of MASS depends not only on technological maturity but also on the establishment of a clear and internationally standardized framework for the qualification, responsibilities, training, and certification of ROs. The following problems should be considered.

First, there must be an internationally standardized and independent system for the certification and training of ROs. The current STCW convention of 1978, was originally designed for seafarers working on board. As a result, it does not adequately define the legal status, responsibilities, or required qualifications of ROs [5].

Second, human factors such as working conditions and fatigue management for ROs must be addressed in the MASS Code. Given the high volume of information processing and the complexity of system interaction within the ROC, mental stress and cognitive overload are likely to occur. Furthermore, technical limitations such as latency or communication breakdowns must be managed through clearly defined safety protocols [4].

Third, there must be specific regulations and procedures for situations in which a single RO controls multiple MASS units simultaneously. This operational model has already been demonstrated in trials and is expected to become increasingly common [3]. However, the risk of cognitive overload, limited information processing, and challenges in responding to emergencies must be addressed through comprehensive management and response protocols [4].

The IMO should solve those problems which can be achieved by including explicit qualification and training standards for ROs in the MASS Code or by introducing a new annex to the existing STCW Convention. This would ensure consistent international recognition of ROs and maintain a minimum standard of competence in both routine operations and emergency response situations [7].

Lastly, the Experience-Building Phase (EBP) for MASS must be actively utilized to refine training and certification standards for ROs. MASS operations are still in their early stages, and empirical data remains limited. The IMO should use the EBP to analyze various operational scenarios and evaluate the roles and responsibilities of ROs under realistic conditions [3]. Based on the data and case studies collected during the EBP, detailed training programs and evaluation criteria should be developed. These should include assessments of emergency response, communication failure management, and system malfunction handling. The resulting standards should be formalized in the MASS Code or published as separate guidelines [5]. Continued assessment and revision will enhance the credibility of ROs and ensure the safety and reliability of MASS operations.

In conclusion, the development of an internationally standardized regulatory framework for ROs is essential to the successful deployment of MASS. The policy proposals outlined in this paper provide a foundational direction for building a safe and efficient international MASS regime. Ongoing collaboration between the IMO and national governments will be critical to implementing these measures in practice.

V. CONCLUSION

The MASSs are emerging as key technologies in the shipping and shipbuilding industries. By integrating AI, sensors, and satellite communications, MASS aim to reduce human intervention and improve maritime safety and efficiency. Many countries are actively developing related technologies in anticipation of the era of MASSs.

In response, the IMO is drafting the MASS Code, intended to serve as the global regulatory framework for autonomous vessels. This Code is expected to introduce significant changes to current maritime regulations. However, while technology advances rapidly, legal and institutional frameworks of human element lag behind. One of the most urgent issues is the legal status of ROs, who oversee MASS from ROCs.

This paper examines the limitations of the current legal framework, particularly the STCW Convention of 1978, which applies only to onboard personnel and excludes ROs. As MASS becomes widespread, there is a pressing need to define the legal status and certification standards for ROs. These operators must make rapid decisions with limited information while managing multiple vessels remotely—tasks that differ substantially from conventional seafaring roles.

The simultaneous development of the MASS Code and discussions on revising STCW present an opportunity to integrate ROs into international law. Instead of broad principles, detailed training and certification standards should be included.

This paper proposes:

(1) establishing a dedicated international training and certification system for ROs;

(2) addressing RO working conditions and fatigue in the MASS Code;

(3) developing clear operational boundaries and AI-assisted support for multi-vessel control;

(4) utilizing the Experience-Building Phase (EBP) to test and refine qualification criteria under realistic scenarios.

In conclusion, the effective implementation of MASS requires not only technological advancement but also a robust legal framework recognizing ROs. International guidelines should be developed to regulate work environments and fatigue management and should be explicitly reflected in the MASS Code. These measures are necessary to support a stable and efficient working environment and to reduce the risk of human error during operations.

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