Considerations on the common regulatory issues among the IMO instruments for realization of maritime autonomous surface ships

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Abstract. The Maritime Safety Committee (MSC) of the International Maritime Organization (IMO) included an agenda item “Regulatory Scoping Exercise (RSE) for the use of Maritime Autonomous Surface Ships (MASS)” in order to determine how the safe, secure and environmentally sound operation of MASS may be introduced in the regulations. The results of the RSE have been reported to the MSC, and they will be discussed in the 102th session. The purpose of this study is to provide suggestions for making decisions on the necessary future work at the MSC. The authors have reviewed all the results of the RSE under the purview of the MSC and made discussions on the ways of addressing some important common issues. The suitability of the specific ways of addressing these issues may be turned out in the actual works for amendments. On the other hand, regarding the priority of the discussions, the authors consider that it is appropriate to give priority to the discussions on the partial automation and remote operation with seafarers on board over the fully autonomous or remote operations without seafarers on board. Also, it seems appropriate to give priority to the discussions on the navigation systems and tasks.

1. Introduction

1.1. Background
The Maritime Safety Committee (MSC) of the International Maritime Organization (IMO), at its 98th session (MSC 98) held on June 2017, agreed to include a new agenda item “Regulatory Scoping Exercise (RSE) for the use of Maritime Autonomous Surface Ships (MASS)” in order to determine how the safe, secure and environmentally sound operation of MASS may be introduced in the regulations considered by IMO. The MSC, at its 100th session (MSC 100) held on December 2018, finalized the framework for the RSE and agreed that, as a first step, the review of the IMO instruments, i.e. conventions and regulations under the purview of IMO, would be conducted to identify the provisions which prevent MASS operations or which may need amendments or clarifications and, as a second step, the analysis would be conducted to determine the most appropriate way of addressing MASS operations (See chapter 2). It was also agreed that the initial review and initial analysis should be conducted by volunteering Member State(s) in these two steps.
The authors, as representatives of Japan, undertook the initial review and initial analysis of Chapters II-2, VI, VII, XII and XIII of the annex to the International Convention for the Safety of Life at Sea (SOLAS Convention) and associated codes and standards which were made mandatory by these chapters of the annex to the SOLAS Convention.

The results of the review in the first step of the RSE were reported to the MSC Intersessional Working Group on MASS held on September 2019, and the group agreed on the completion of the first step and commencement of the second step. Subsequently, the results of the analysis in the second step of the RSE have been reported to the MSC, and they will be discussed in the next session (MSC 102). Table 1 is the list of documents reporting the results of the first step of the RSE and these documents are not open to the public. Table 2 is the list of documents reporting the results of the second step of the RSE and these documents are accessible through IMO document website (https://webaccounts.imo.org). After discussion on the results of the second step of the RSE, the MSC will decide the future work to realize MASS, e.g. amending regulations, developing new instruments, etc.

1.2. Previous study
The authors indicated the results of the initial review of the first step of the RSE for Chapters II-2, VI and VII of the annex to the SOLAS Convention and the associated codes in detail, in the previous paper for ICMASS 2019 [1].

1.3. Purpose
The purpose of this study is to provide suggestions for making decisions on the necessary future work at the MSC, by considering the results of the RSE for all the IMO instruments, in respect of safety. As mentioned above, the authors undertook a lot of the chapters of the annex to the SOLAS Convention. Also, the authors have reviewed all the results of the first and second steps of the RSE under the purview of the MSC. Through these experiences, we found some important issues which are common among a lot of the IMO instruments. In this paper, we introduce these important common issues and provide suggestions for making decisions on the necessary future work at the MSC, only from technical viewpoints.

2. Outline of the RSE

2.1. Definitions of MASS and degrees of autonomy
In the framework for the RSE for the use of MASS, the definition of MASS is mentioned as the following text: “For the purpose of the regulatory scoping exercise, ‘Maritime Autonomous Surface Ship (MASS)’ is defined as a ship which, to a varying degree, can operate independent of human interaction.” [2].

Also, the degrees of autonomy are organized as shown in Table 3, which does not represent a hierarchic order [2]. It should be noted that MASS could be operating at one or more degrees of autonomy for the duration of a single voyage [2].

2.2. Methodology
The methodology of the RSE consists of the two steps as below.

2.2.1. First step
As a first step, the RSE identifies provisions in the IMO instruments which, as currently drafted: A: apply to MASS and prevent MASS operations; or B: apply to MASS and do not prevent MASS operations and require no actions; or C: apply to MASS and do not prevent MASS operations but may need to be amended or clarified, and/or may contain gaps; or D: have no application to MASS operations [2].
Table 1 Documents reporting the results of the first step of the RSE (Main title of these documents was "Consideration of the result of the first step of the regulatory scoping exercise").

| Document ID | Sub-title of document                                                                 | Submitter                  |
|-------------|---------------------------------------------------------------------------------------|----------------------------|
| ISWG/MASS 1/2 | Results of the first step of the regulatory scoping exercise analysing possible gaps in SOLAS chapter IX and the ISM Code in relation to the safe operation of Maritime Autonomous Surface Ships (MASS) | Norway                     |
| ISWG/MASS 1/2/1 | Summary of results of the first step of the RSE for SOLAS chapter II-1                 | France                     |
| ISWG/MASS 1/2/2 | Summary of results of the first step of the RSE for the International Convention on Maritime Search and Rescue, 1979 | France & Spain             |
| ISWG/MASS 1/2/3 | Summary of results of the first step of the RSE for SOLAS chapter II-2 and associated codes | Japan                      |
| ISWG/MASS 1/2/4 | Summary of results of the first step of the RSE for SOLAS chapter VI and associated codes | Japan                      |
| ISWG/MASS 1/2/5 | Summary of results of the first step of the RSE for SOLAS chapter VII and associated codes | Japan                      |
| ISWG/MASS 1/2/6 | Findings and common issues identified in the initial review of chapters II-2, VI and VII of the annex to SOLAS 1974 and the associated codes | Japan                      |
| ISWG/MASS 1/2/7 | Summary of results of the first step of the RSE for SOLAS chapter XII and associated standards | Japan                      |
| ISWG/MASS 1/2/8 | Summary of results of the first step of the RSE for SOLAS chapter XIII                  | Japan                      |
| ISWG/MASS 1/2/9 | Summary of results of the first step of the RSE for CSC 1972                           | Japan                      |
| ISWG/MASS 1/2/10 | Summary of the results of the first step of the RSE for STCW-F 1995                    | Japan                      |
| ISWG/MASS 1/2/11 | Summary of results of the first step of the RSE for SOLAS chapter III and the LSA Code | Belgium & Netherlands      |
| ISWG/MASS 1/2/12 | Summary of results of the first step of the RSE for SOLAS chapter XI-1 and related codes | Finland                    |
| ISWG/MASS 1/2/13 | Summary of results of the first step of the RSE for SOLAS chapter XI-2 and the ISPS Code | Finland                    |
| ISWG/MASS 1/2/14 | Summary of results of the first step of the RSE for SOLAS chapter XIV and the related Polar Code | Finland                    |
| ISWG/MASS 1/2/15 | Summary of results of the first step of the RSE for SOLAS chapter IV                    | Turkey                     |
| ISWG/MASS 1/2/16 | Summary of results of the first step of the RSE for SOLAS chapter V                      | China & Singapore          |
| ISWG/MASS 1/2/17 | Summary of results of the first step of the RSE for the International Convention on Tonnage Measurement of Ships, 1969 (TONNAGE 1969) | Liberia                    |
| ISWG/MASS 1/2/18 | Summary of results of the first step of the RSE for LL 66, PROT 88, IS Code Part A and III Code | India                      |
| ISWG/MASS 1/2/19 | Summary of results of the first step of the RSE for the International Regulations for Preventing Collisions at Sea 1972 (COLREG) | Marshall Islands           |
| ISWG/MASS 1/2/20 | Summary of results of the first step of the RSE for STCW Convention and Code            | United States              |
### Table 2: Documents reporting the results of the second step of the RSE (Main title of these documents was "Regulatory scoping exercise for the use of Maritime Autonomous Surface Ships (MASS)").

| Document ID   | Sub-title of document                                                                 | Submitter                          |
|---------------|--------------------------------------------------------------------------------------|------------------------------------|
| MSC 102/5     | Status report – Progress of the regulatory scoping exercise                           | Secretariat                        |
| MSC 102/5/1   | Report of the Intersessional Working Group on Maritime Autonomous Surface Ships       | Secretariat                        |
| MSC 102/5/3   | Summary of results of the second step and conclusion of the RSE for the International Regulations for Preventing Collisions at Sea 1972 (COLREG) | Marshall Islands                   |
| MSC 102/5/4   | Summary of results of the second step of the RSE for SOLAS Chapter III and the LSA Code | Belgium, China & Netherlands        |
| MSC 102/5/5   | Summary of results of the second step of the RSE for LL, LL PROT 1988, IS Code Part A and III Code | India                              |
| MSC 102/5/6   | Summary of results of the second step of the RSE for SOLAS chapter II-1               | France                             |
| MSC 102/5/8   | Summary of results of the second step of the regulatory scoping exercise for the International Convention on Tonnage Measurement of Ships, 1969 (TONNAGE 1969) | Liberia                            |
| MSC 102/5/9   | Summary of results of the second step of the RSE for SOLAS chapter V                   | China                              |
| MSC 102/5/10  | Summary of results of the second step of the RSE for SOLAS chapter XI-1 and related codes | Finland                            |
| MSC 102/5/11  | Summary of results of the second step of the RSE for SOLAS chapter XI-2 and the ISPS code | Finland                            |
| MSC 102/5/12  | Summary of results of the second step of the RSE for SOLAS chapter XIV and the Polar Code | Finland                            |
| MSC 102/5/13  | Summary of results of the second step of the RSE for SAR 1979 Convention              | France & Spain                     |
| MSC 102/5/14  | Development of interim regulatory measures for operation of MASS in the Russian Federation | Russian Federation                |
| MSC 102/5/15  | Summary of the results of the second step of the RSE for SOLAS chapter IV             | Turkey                             |
| MSC 102/5/16  | Summary of results of analysis of IMO instruments under the purview of the Maritime Safety Committee | CMI                               |
| MSC 102/5/17  | Summary of results of the second step of the RSE for STCW Convention and Code         | United States                      |
| MSC 102/5/19  | Summary of results of the second step of the RSE for SOLAS chapter II-2 and associated codes | Japan                              |
| MSC 102/5/20  | Summary of results of the second step of the RSE for SOLAS chapter VI and associated codes | Japan                              |
| MSC 102/5/21  | Summary of results of the second step of the RSE for SOLAS chapter VII and associated codes | Japan                              |
| MSC 102/5/22  | Summary of the results of the second step of the RSE for SOLAS chapter XII and associated standards | Japan                              |
| MSC 102/5/23  | Summary of the results of the second step of the RSE for SOLAS chapter XIII           | Japan                              |
| MSC 102/5/24  | Summary of the results of the second step of the RSE for CSC 1972                    | Japan                              |
| MSC 102/5/25  | Summary of results of the second step of the RSE for SOLAS chapter IX and the ISM Code | Norway                             |
| MSC 102/5/26  | Summary of results of the second step of the RSE for the STCW-F Convention            | Japan                              |
Table 3 Degrees of autonomy [2].

| Degree of autonomy | Definition |
|--------------------|------------|
| One                | Ship with automated processes and decision support: Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised but with seafarers on board ready to take control. |
| Two                | Remotely controlled ship with seafarers on board: The ship is controlled and operated from another location. Seafarers are available on board to take control and to operate the shipboard systems and functions. |
| Three              | Remotely controlled ship without seafarers on board: The ship is controlled and operated from another location. There are no seafarers on board. |
| Four               | Fully autonomous ship: The operating system of the ship is able to make decisions and determine actions by itself. |

In the first step, the initial review should be conducted by volunteering Member States [3], and these instruments should be reviewed on a regulation or rule level [2]. In other words, volunteering Member States should choose an option A, B, C or D for each regulation or rule of the instruments that they undertook.

2.2.2. Second step
After the completion of the first step, a second step is conducted to analyse and determine the most appropriate way of addressing MASS operations, taking into account, inter alia, human element, technology and operational factors by:
   I: equivalences as provided for by the instruments or developing interpretations;
   and/or II: amending existing instruments; and/or
   III: developing new instruments; or
   IV: none of the above as a result of the analysis [2].

The initial analysis should be conducted, preferably, by the volunteering Member State(s) that conducted the initial review [3]. The initial analysis should be high level and should not be conducted regulation by regulation [3].

3. Review of the results of the RSE
As mentioned in chapter 1, all the results of the first and second steps of the RSE were reported to the MSC (Tables 1 and 2). The authors have reviewed all the results and found the following important issues which are common among a lot of the IMO instruments. The list below shows only the especially important and common issues among a lot of the IMO instruments. The other issues and findings can be found in the documents in Tables 1 and 2.

   (1) The definitions of master, crew, etc. should be defined clearly for remotely or autonomously controlled ships.
   (2) The requirements for outboard personnel in remote control centers, etc. should be developed for remotely or autonomously controlled ships.
   (3) The relation between seafarers on board ships and outboard personnel in remote control centers, etc. should be defined clearly for remotely controlled ships with seafarers on board the ships.
(4) The requirements for remote control centers, etc. should be developed for remotely or autonomously controlled ships.
(5) The requirements for onboard systems and equipment should be reconsidered for remotely or autonomously controlled ships, especially for the systems and equipment which need manual operations in the existing provisions, in relation to firefighting, life-saving, cargo handling, etc.

3.1. Definitions of master, crew, etc.
The definitions of master, crew, etc. are related to almost all the IMO instruments. The definitions of these people should be clarified for degrees of autonomy two, three and four. In section 6.2 of the ISM Code [4], it is required that “each ship is manned with qualified, certificated and medically fit seafarers”. For degree of autonomy two, there are personnel both on board and outboard (i.e. remote control centers, etc.). Although onboard personnel are obviously seafarers, it will be needed to clarify whether outboard personnel are seafarers or not. For example, in Part 7 of the IMDG Code [5] “Provisions concerning transport operations”, paragraph 7.5.2.13 requires regular inspections of ro-ro cargo spaces during the voyage by an authorized crew member or responsible person for early detection of any hazard. Also, chapter 7.8 refers to the judgment by the master in the event of incident. Regarding these provisions, if the regular inspections can be conducted remotely, it will be needed to clarify whether such personnel who conduct the regular inspections at a remote control center, etc. are crew or not. Also, if the judgement by the responsible person, on behalf of the master, can be made at a remote control center, etc. and communicated to ships in the event of incidents, it will be needed to clarify whether such person who make judgement is the master or not. The same things can be said to the other provisions referring to the actions by seafarers (master, crew, etc.).

Similarly, for degree of autonomy three, since there are no seafarers on board and there are personnel only in remote control centers, etc., it will also be needed to clarify whether such personnel are seafarers or not. On the other hand, for degree of autonomy four, although it is clear that there are no seafarers on board, it is not clear whether there are personnel outboard or not. The authors consider that there are personnel for supervision of a fully autonomous ship in a remote location, but it is not clearly determined at the MSC. Therefore, it will be needed to clarify whether personnel exist outboard for supervision at first, then, clarify whether such personnel are seafarers or not.

Regarding this issue, there are various opinions among the IMO Members: developing interpretations (option I in the second step of the RSE), amending each provision one by one (option II), and developing new instruments (option III). Although the possible means for addressing this issue are various, the aim is identical: to apply the consistent and unified approach over all the IMO instruments. Indeed, it may not be turned out that which means would be best for addressing this issue since it may only be determined during the actual works for amending instruments. However, the authors consider that it may be more appropriate to prescribe clearly in the regulations (amending each provision one by one or developing new instruments) than to make interpretations because these provisions impose obligations on a person.

3.2. Requirements for outboard personnel in remote control centers, etc.
As mentioned in the previous section, it will be needed to clarify whether outboard personnel are seafarers or not for degrees of autonomy two and three, and for degree of autonomy four if there are outboard personnel for supervision. In addition, it will be needed to clarify the required abilities of such outboard personnel, for example as mentioned in the previous section, personnel at a remote control center, etc. who conduct the regular inspections of ro-ro cargo spaces carrying dangerous goods according to paragraph 7.5.2.13 of the IMDG Code, or who make judgement on behalf of the master according to chapter 7.8 of the IMDG Code. Therefore, no matter whether outboard personnel are determined as seafarers or not, the requirements for such personnel should be developed.
The ways of developing the requirements for outboard personnel will depend on the result of the clarification. One way is to consider such personnel as a kind of seafarers, who are not on board but acting as seafarers in practice. In that case, it will be needed to amend the definitions of seafarers for adding such personnel (e.g. “remote operator” as a kind of seafarers) to the existing definitions and to prescribe the roles and responsibilities of such personnel in the respective provisions if they are different from the existing ones for the seafarers on board.

Another way is not to consider such personnel as seafarers, but to develop other definitions for such personnel. In that case, it will be needed to develop new definitions for such personnel separately from the existing definitions, and to prescribe the roles and responsibilities of such personnel in the newly developed definitions (e.g. defining the new terminology of “remote operator” and prescribing the roles and responsibilities of a remote operator in that definition). It needs to be discussed carefully which way is better at the MSC, taking into account merits and demerits for each way of addressing this issue.

3.3. **Relation between seafarers on board ships and outboard personnel in remote control centers, etc.** As mentioned in the previous section, it will be needed to define the roles and responsibilities of personnel in remote control centers, etc. no matter whether they are defined as a kind of seafarers or not. When defining the roles and responsibilities of such personnel, it will also be needed to prescribe the relation between seafarers on board ships and outboard personnel in remote control centers, etc. for degree of autonomy two. It is quite important to clearly and specifically define the relation between them, i.e. assignment of their roles and responsibilities in normal and emergency situations. If there is an ambiguity in the relation between them, it may possibly lead to significant accidents due to human errors such as inconsistency between their assumptions or prejudices.

However, regulations to be developed for addressing this issue might only refer to the necessity of clear and prescriptive definitions for the relation between them, and require that such definitions should be developed by shipping company, etc. prior to operations of remotely controlled ships with seafarers on board. It also needs to be discussed how this issue should be addressed in regulations at the MSC.

3.4. **Requirements for remote control centers, etc.**

In addition to the requirements for outboard personnel in remote control centers, etc., it will also be needed to develop the requirements for systems and equipment in such places for degrees of autonomy two and three, and for degree of autonomy four if necessary.

Especially, the requirements for communication between ships and remote control centers, etc. should be developed for ensuring the safe operations. If communication link would be cut off between ships of degree of autonomy three and remote control center, etc. during a voyage, remote control would become unavailable any more. It will also be needed to develop the requirements for emergency responses to ensure safety even if such a situation occurs. For degree of autonomy two, the requirements for emergency responses should also be developed for onboard seafarers to ensure safety without communication with remote control centers, etc. For degree of autonomy four, the requirements will be needed to ensure safety without supervision in remote locations.

Also, the requirements for alerting systems in remote control centers, etc. should be considered so that the personnel in such places can be notified when any abnormal conditions occur in the remotely or autonomously controlled ships. The requirements for addressing abnormal conditions from remote control centers, etc. should also be considered.

3.5. **Requirements for onboard systems and equipment for remotely or autonomously controlled ships** The requirements for onboard systems and equipment should be reconsidered for remotely or autonomously controlled ships, especially for the systems and equipment which need manual operations in the existing provisions, in relation to firefighting, life-saving, cargo handling, etc.

Among these existing provisions, some provisions clearly require that a human, e.g. a crew or a
master etc., shall conduct the operations regarding firefighting, life-saving, cargo handling, etc. In this case, these provisions should be amended since they will definitely prevent the realization of MASS, especially for degrees of autonomy three and four.

On the other hand, other provisions do not clearly require the operations by a human, but they require that some systems and equipment shall be installed, which need manual operations at present. For these provisions, it may be resolved with novel technologies for automatic or remote operations of systems and equipment which are manually operated at present. However, some of these provisions require that some automatic systems shall also be capable of being manually operated, and other provisions require local manual operations on board. In these cases, it is necessary to understand the intentions of the provisions and consider the alternative means for achieving the intended functionalities.

4. Discussions
Since the issues mentioned in chapter 3 are especially important and cross-cutting issues among a lot of the IMO instruments, consistent approach is necessary to realize MASS. The authors suggest that these issues should be addressed considering all the related provisions in all the related IMO instruments under the purview of the MSC.

When considering the amendments of the related provisions, discussions on partial automation and remote control of the existing onboard functions and tasks with seafarers on board (for ships of degrees of autonomy one and two) should be proceeded at first, taking into account the recent technological developments in the world. Partial automation and remote control will be the first step to realize fully autonomous operation and remote operation without seafarers onboard.

In addition, the priority of the scope of discussions should be considered before starting discussions. It seems that the provisions related to navigation are the most significant issues to realize MASS. Also, most of the technologies under developments seem to be related to navigation systems and tasks conducted by seafarers at present. Taking into account these situations, it is appropriate to give priority to the discussions on the partial automation and remote control of the navigation systems and tasks over the other issues.

5. Conclusions
In this paper, the authors introduced the important common issues among a lot of the IMO instruments under the purview of the MSC and made discussions on the ways of addressing these issues. The suitability of the specific ways of addressing these issues should be considered carefully in the actual works for amendments at the MSC. On the other hand, regarding the priority of the discussions, the authors consider that it is appropriate to give priority to the discussions on the partial automation and remote operation with seafarers on board over the fully autonomous or remote operation without seafarers on board. Also, it seems appropriate to give priority to the discussions on the navigation systems and tasks over the other systems and tasks.

References
[1] Shiokari, M and Ota, S, “Considerations on the regulatory issues for realization of Maritime Autonomous Surface Ships”, Journal of Physics: Conf. Series 1357 (2019) 012005
[2] IMO document MSC 100/20 “Report of the Maritime Safety Committee on its one hundredth session”, Annex 2 “Framework for the regulatory scoping exercise for the use of Maritime Autonomous Surface Ships (MASS)”
[3] IMO document MSC 100/20 “Report of the Maritime Safety Committee on its one hundredth session”, Annex 2, Appendix 3 “Plan of work and procedures for the regulatory scoping exercise”
[4] IMO, International Management Code for the Safe Operation of Ships and for Pollution Prevention adopted by resolution A.741(18), as amended
[5] IMO, International Maritime Dangerous Goods Code adopted by resolution MSC.122(75), as
amended (2016 Amendments to the International Maritime Dangerous Goods Code adopted by resolution MSC.406(96))