Considerations on the regulatory issues for realization of Maritime Autonomous Surface Ships

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Abstract. The Maritime Safety Committee of the International Maritime Organization (IMO) 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. The first step of the RSE is a review of the IMO instruments to identify the provisions which prevent MASS operations or which may need amendments or clarifications. The authors, as representatives of Japan, undertook the initial review of Chapters II-2, VI and VII of the annex to the International Convention for the Safety of Life at Sea and associated codes. As a result, it was revealed that there were a lot of provisions which required manual operations and actions by personnel. To realize MASS without persons on board, appropriate alternative safety measures are needed, taking into account the intentions of the existing regulations. Also, another concept for fire safety and emergency procedures for carriage of cargoes could be introduced, taking into account the reduction of risks owing to absence of persons on board when the cargo does not include any harmful substances for marine environment.

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 99th session (MSC 99) held on May 2018, recognized that, before moving forward with the RSE for the use of MASS, it was necessary to establish a framework in order to provide a common understanding of the work required and how it would be conducted.

Then 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. It was also agreed that the initial review and initial analysis should be conducted by volunteering Member State(s) in these two steps.
At MSC 100, the authors, as representatives of Japan, undertook the initial review of Chapters II-2, VI and VII of the annex to the International Convention for the Safety of Life at Sea (SOLAS Convention) and associated eight codes and one sub-chapter of a code which were made mandatory by these chapters of the annex to the SOLAS Convention.

1.2. Previous studies
Prior to MSC 99, one of the authors investigated the annex to the SOLAS Convention and associated codes and resolutions which were made mandatory by the SOLAS Convention, and identified regulations: (1) which preclude unmanned operations; (2) which would have no application to unmanned operations; and (3) which do not preclude unmanned operations but may need to be amended for enabling the construction and operation of MASS [1].

Subsequently, prior to MSC 100, the authors have considered how cargoes could be safely carried by unmanned MASS, in order to support the RSE, and investigated three chapters related to carriage of cargoes, i.e. II-2, VI and VII, of the annex to the SOLAS Convention and eight codes and one sub-chapter of a code mandated by these chapters of the annex to the Convention [2].

1.3. Purpose
Since the MSC agreed that the review of the IMO instruments should be conducted on a regulation or rule level, it will not be clearly indicated during the RSE which parts of each regulation or rule need to be amended or clarified. The purpose of this study is to indicate some specific parts of provisions which need to be amended or clarified with our original categories and give some suggestions for the amendments to the provisions in order to realize the use of MASS.

2. Terminology and methodology for the RSE for the use of MASS

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 following: “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.” [3].

Also, the degrees of autonomy are organized as shown in Table 1, which does not represent a hierarchic order [3]. It should be noted that MASS could be operating at one or more degrees of autonomy for the duration of a single voyage [3].

| 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. |

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 will identify provisions in IMO instruments which, as currently drafted [3]:
   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.
In the first step, the initial review should be conducted by volunteering Member States [4], and these
instruments should be reviewed on a regulation or rule level [3]. 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
Once the first step is completed, a second step will be 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 [3]:
   1: equivalences as provided for by the instruments or developing interpretations; and/or
   2: amending existing instruments; and/or
   3: developing new instruments; or
   4: none of the above as a result of the analysis.
The initial analysis should be conducted, preferably, by the volunteering Member State(s) that
conducted the initial review [4]. The initial analysis should be high level and should not be conducted
regulation by regulation [4].

3. Scope and assumptions in this article

3.1. Scope
In this article, only the results of the initial review by the authors in the first step of the RSE will be
shown and discussed. As mentioned above, the authors, as representatives of Japan, undertook the initial
review of Chapters II-2, VI and VII of the annex to the SOLAS Convention, associated eight codes and
one subchapter of a code which were made mandatory by these chapters of the annex to the SOLAS
Convention. The titles of these chapters, the associated codes and the subchapter of the code are shown
in Table 2.

3.2. Assumptions for the RSE
For ships of degrees of autonomy one and two, seafarers are assumed to be available on board to take
control and to operate the shipboard systems and functions.
   For ships of degrees of autonomy three and four, it is assumed that persons may stay on board during
   berthing, cargo handling and anchoring.
   For ships of degree of autonomy four, even if the ships are fully autonomous, supervision by persons
   is assumed to be provided at a remote location.

4. Results of the initial review of the RSE
In the above mentioned three chapters of the annex to the SOLAS Convention, eight codes and one
subchapter of the code, none of the provisions were identified as “A: apply to MASS and prevent MASS
operations”. Also, only regulation 8 in the International Grain Code, which applied to existing ships,
was identified as “D: have no application to MASS operations”, regardless of degrees of autonomy. In
other words, almost all the provisions were identified as “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”. Therefore, in this section, the authors show
only the provisions which identified as “C”.

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Table 2 IMO instruments reviewed in this article.

| SOLAS Chapter | Title of Chapter, associated code and subchapter of code |
|---------------|----------------------------------------------------------|
| II-2          | Construction - Fire protection, fire detection and fire extinction |
|               | Associated codes |
|               | International Code for Fire Safety Systems (FSS Code) |
|               | International Code for Application of Fire Test Procedures, 2010 (2010 FTP Code) |
| VI            | Carriage of cargoes and oil fuels |
|               | Associated codes and subchapter of code |
|               | International Maritime Solid Bulk Cargoes Code (IMSBC Code) |
|               | Sub-chapter 1.9 of the Code of Safe Practice for Cargo Stowage and Securing (CSS Code) |
|               | International Code for the Safe Carriage of Grain in Bulk (International Grain Code) |
| VII           | Carriage of dangerous goods |
|               | Associated codes |
|               | International Maritime Dangerous Goods Code (IMDG Code) |
|               | International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code) |
|               | International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code) |
|               | International Code for the Safe Carriage of Packaged Irradiated Nuclear Fuel, Plutonium and High-Level Radioactive Wastes on Board Ships (INF Code) |

Hereafter, the expressions “SOLAS Chapters II-2, VI and VII” will be used as the meanings of Chapters II-2, VI and VII of the annex to the SOLAS Convention, respectively, and regulations in these chapters are often expressed with chapter number followed by regulation number, after the word “SOLAS regulation”, e.g. SOLAS regulation II-2/3. Also, the abbreviations of the names of the codes will be used as expressed in Table 2.

4.1. General issues regarding definitions and functional requirements

The meanings of “master”, “crew”, or “responsible person”, etc. should be clarified, taking account of the possibility of that such person of the ship is not on board, for degrees of autonomy two, three and four.

For degrees of autonomy two, three and four, the definitions of “Control stations” and “Safety centre” should be amended to introduce a remote control centre or a remote location for supervision in SOLAS regulation II-2/3 “Definitions”. Also, SOLAS regulation II-2/23 “Safety centre on passenger ships” should be amended so that the safety centre could be remote. In addition, the provision for the functionality of the safety systems required to be available from the safety centre should be amended to include automated, autonomous or remote systems. In relation to this, in Chapter 9 of the FSS code “Fixed fire detection and fire alarm systems”, paragraph 2.1.2.2 needs some clarifications as it requires output signal to the navigation bridge, continuously manned central control station or onboard safety centre. Moreover, in Chapter 14 of the FSS code “Fixed deck foam systems”, paragraph 2.3.1 requires that the main control station for the fixed deck foam system shall be located adjacent to the accommodation spaces, which implies that the main control station cannot be located on a remote control centre. Some clarifications may be required on this requirement.

For degrees of autonomy three and four, the definitions of manned spaces should be amended in SOLAS regulation II-2/3.

Furthermore, for degrees of autonomy three and four, since the decision making will be done remotely, autonomously or automatically, additional functional requirement may be needed to demonstrate that the remote control centre or the autonomous or automated system can detect and control fire in SOLAS regulation II-2/2 “Fire safety objectives and functional requirements”.

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4.2. Provisions related to accommodations

For degrees of autonomy three and four, the following provisions should be amended or clarified, and/or may contain gaps because there are no seafarers on board such ships and there might be no accommodation areas if there are no passengers on board.

In SOLAS regulation II-2/4 “Probability of ignition”, paragraphs 3 and 4.1 prescribe the arrangements for gaseous fuel for domestic purposes and electric radiators, respectively.

In SOLAS regulations II-2/9 “Containment of fire”, paragraphs 2.3.1 and 2.3.2 prescribe methods of protection in accommodation area and requirements for bulk heads within accommodation area, respectively. Also, paragraph 2.3.4 prescribes protection of stairways and lift trunks in accommodation spaces, service spaces and control stations.

In Chapter 16 of the IGC code “Use of cargo as fuel”, paragraph 16.4.1.1 requires that fuel piping shall not pass through accommodation spaces.

In Chapter 17 of the IGC code “Special requirements”, paragraphs 17.5.5 (for cargoes requiring type 1G ship, i.e. some of toxic cargoes) and 17.13.5 (for Chlorine) prescribe the requirements for the provision of a space within the accommodation area to protect personnel against the effects of a major cargo release.

4.3. Provisions about systems and appliances which require manual operations

For degrees of autonomy three and four, the following provisions which require manual operations should be amended because there are no seafarers on board such ships.

4.3.1. Systems and appliances related to fire extinction which require manual operations

Portable fire extinguishers are required by paragraph 5.1.3 of SOLAS regulation II-2/4, paragraph 3 of SOLAS regulation II-2/10 “Fire-fighting”, paragraph 3.7 of SOLAS regulation II-2/19 “Carriage of dangerous goods” and paragraph 6.2 of SOLAS regulation II-2/20 “Protection of vehicle, special category and ro-ro spaces”. Manually operated fire-fighting systems are also required by SOLAS regulation II-2/10. Both of them cannot be used when there are no seafarers on board. Moreover, in SOLAS regulation II-2/14 “Operational readiness and maintenance”, paragraph 2.1.2 requires that portable fire extinguishers which have been discharged shall be immediately recharged or replaced with an equivalent unit.

In SOLAS regulation II-2/18 “Helicopter facilities”, paragraph 5 should be amended as it requires manually operated fire-fighting systems and appliances for helidecks. Also, Chapter 17 of the FSS code “Helicopter facility foam firefighting appliances” prevents helicopter operations on ships of degrees of autonomy three and four, for the reason that manual release of foam is required.

In SOLAS regulation II-2/19, paragraph 3.1 should be amended as it requires a certain capability of water supply from the fire main, which needs manual operation.

In Chapter 6 of the FSS code “Fixed foam fire-extinguishing systems”, paragraph 3.1.1 requires the capability of manual release for fixed high-expansion foam fire-extinguishing systems.

In addition, Chapter 11 of the IBC code “Fire protection and fire extinction” requires chemical tankers to comply with SOLAS Chapter II-2 with some exceptions. Foam applicators required by paragraph 11.3 are deemed unusable during sailing when there are no seafarers on board.

Also, Chapter 11 of the IGC code “Fire protection and fire extinction” requires gas carriers to comply with SOLAS Chapter II-2 with some exceptions. Fire mains and hydrants required by paragraph 11.2 and dry chemical powder fire-extinguishing systems required by paragraph 11.4 are deemed unusable during sailing when there are no seafarers on board.

Moreover, a water fire-extinguishing system and fixed fire-extinguishing arrangements for machinery spaces of category A (Chapter 3 of the INF code “Fire safety measures”) may not be effective when there are no seafarers on board.
4.3.2. Other systems and appliances which require manual operations
For degrees of autonomy three and four, instruments for gas measurement and detection (both portable and fixed) required by paragraph 5.7 of SOLAS regulation II-2/4 and drip pans required by paragraph 5.9 of SOLAS regulation II-2/4 cannot be used or inspected when there are no seafarers on board. Also, in SOLAS regulation VI/3 “Oxygen analysis and gas detection equipment”, paragraph 2 requires that the Administration shall take steps to ensure that crews of ships are trained in the use of appropriate instruments for measuring the concentration of gas or oxygen in the air. As this requirement means that these instruments need manual operations, it needs to be amended.

Means of control for the air supply (SOLAS regulation II-2/5 “Fire growth potential”) include manual operation, e.g. closing appliances and stopping devices of ventilation.

The requirements for manually operated call points in passenger ships and for special category spaces (paragraph 7 of SOLAS regulation II-2/7 “Detection and alarm” and paragraph 4.3.2 of SOLAS regulation II-2/20, respectively) should be amended.

In SOLAS regulation II-2/8 “Control of smoke spread”, paragraph 5 requires capability of manual control of the smoke extraction systems in atriums of passenger ships.

In SOLAS regulation II-2/9, paragraphs 2.2.6 and 4.1.1.9 require that partial bulkheads shall be capable of being opened by the crew and that the damper shall be capable of being manually closed, respectively. In addition, paragraph 7.4.4 requires that an automatic smoke dumper fitted to a duct shall also be capable of being closed manually and each duct shall be provided with a manually operated smoke dumper.

In Chapter 5 of the FSS code “Fixed gas fire extinguishing systems”, paragraph 2.2.4.13 prescribes that if a device is provided which automatically regulates the discharge of the rated quantity of carbon dioxide into the protected area, it shall be also possible to regulate the discharge manually.

In Chapter 16 of the FSS code “Fixed hydrocarbon gas detection systems”, paragraph 2.2.3.2 requires means of measurements of hydrocarbon gas with portable instruments.

In Chapter 15 of the IBC code “Special requirements”, paragraph 15.8.23.1 (for propylene oxide or ethylene oxide/propane oxide mixtures with an ethylene oxide content of not more than 30% by mass) requires local manual operation of the control system of any cooling system. Also, paragraphs 15.3.21 (for carbon disulphide) and 15.8.29 (for propylene oxide or ethylene oxide/propane oxide mixtures with an ethylene oxide content of not more than 30% by mass) require remote manual operation for remote starting of pumps supplying the water-spray system and for remote operation of any normally closed valves in the system from a location adjacent to the accommodation spaces.

In Chapter 16 of the IGC code, paragraphs 16.4.6.2.2 and 16.4.6.3.2 require that the individual master valve of the gas fuel supply to each individual space containing a gas consumer(s) or through which fuel gas supply piping is run shall operate manually. Paragraph 16.5.2 requires that all rotating equipment utilized for conditioning the cargo for its use as fuel shall be arranged for manual remote stop from the engine room. Also, paragraph 16.6.3.2 requires that a manually operated shut-off valve shall be fitted on the pipe of each gas-burner.

4.4. Provisions which require actions by personnel
For degrees of autonomy three and four, the following provisions should be amended or clarified, and/or may contain gaps because no seafarers are on board such ships.

4.4.1. Provisions which require supervisions or patrols by personnel
Paragraph 8 of SOLAS regulation II-2/7 requires fire patrols in passenger ships. Also, paragraph 4.3 of SOLAS regulation II-2/20 requires an efficient fire patrol system for special category spaces.

In Part 7 of the IMDG code “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, paragraph 7.8 refers to the judgment by the master in the event of incidents. Moreover, the requirements for “on deck stowage” in this part, together with Part 3 “Dangerous goods list, special provisions and exceptions”, should be amended, taking into
account the fact that constant supervision and accessibility will not be maintained on the ships of degrees of autonomy three and four, and the following principle of “on deck only” stowage, which was included in up to 35-10 version of the IMDG Code:

“7.1.1.8 Stowage “on deck only” has been prescribed in cases where:
.1 constant supervision is required; or
.2 accessibility is particularly required; or
.3 there is a substantial risk of formation of explosive gas mixtures, development of highly toxic vapours, or unobserved corrosion of the ship.”

4.4.2. Provisions which require actions by personnel in case of emergency

In SOLAS regulation II-2/15 “Instructions, onboard training and drills”, paragraph 2.1.3 requires fire-extinguishing parties capable of completing their duties at all times while the ship is in service.

In SOLAS regulation II-2/18, paragraph 8.3 requires that fire fighting personnel consisting of at least two persons trained for rescue and fire fighting duties and fire fighting equipment shall be immediately available at all times when helicopter operations are expected. This provision prevents helicopter operations on ships of degrees of autonomy three and four.

In appendix 1 to the IMSBC code “Individual schedules of solid bulk cargoes”, in sections for “Carriage” of some individual schedules for solid bulk cargoes which may liquefy, the ship’s master is required to take appropriate actions to prevent cargo shifting and potential capsize of the ship, and give consideration to seeking emergency entry into a place of refuge when a cargo shows an indication of liquefaction. Furthermore, there are some provisions for the ship’s master’s obligations during “carriage” in some individual schedules, e.g. for COAL.

In Chapter 16 of the IBC code “Operational requirements”, paragraph 16.3.3 requires that officers shall be trained in emergency procedures to deal with conditions of leakage, spillage or fire involving the cargo and a sufficient number of them shall be instructed and trained in essential first aid for cargoes carried.

4.4.3. Provisions which require onboard training and drills

For degrees of autonomy three and four, the requirements for onboard training and drills (paragraph 2.2 of SOLAS regulation II-2/15) should be amended because there are no seafarers on board.

4.5. Provisions which require ready/easy accessibility

For degrees of autonomy three and four, the following provisions should be amended or clarified, and/or may contain gaps because there are no seafarers on board.

Some provisions require that some positions or systems shall be readily/easily accessible, such as:

- the manual operating position of an automatic closing fire damper (paragraphs 4.1.1.9 and 7.2.6 of SOLAS regulations II-2/7);
- fire dampers (paragraph 7.1.3 of SOLAS regulation II-2/7);
- the means of closing the main inlets and outlets of ventilation systems (paragraph 7.1.5 of SOLAS regulation II-2/7);
- the means of control of any fixed gas fire-extinguishing system (paragraph 2.1.3.3 of Chapter 5 of the FSS code);
- the system source of power supply, foam concentrate supply and means of controlling the fixed high-expansion fire-extinguishing system (paragraph 3.1.12 of Chapter 6 of the FSS code);
- the means of control of any fixed low-expansion fire-extinguishing system (paragraph 4.2.2 of Chapter 6 of the FSS code);
- the stop valve in each section of sprinklers (paragraph 2.4.2.2 of Chapter 8 of the FSS code “Automatic sprinkler, fire detection and fire alarm systems”); and
the location where remote manual operation for remote starting of pumps supplying the water-spray system and for remote operation of any normally closed valves in the system can be carried out (paragraphs 15.3.21 and 15.8.29 of Chapter 15 of the IBC code).

4.6. Provisions regarding the facilities which are effective only when seafarers are on board

For degrees of autonomy two, three and four, the requirements for alarms and indications onboard, indicated below, should be amended:

- paragraph 5.10.1 of regulation 4, paragraph 9 of regulation 7, paragraphs 4.1.1.5.6, 4.1.1.9, 6.2, 7.1.5, 7.2.6 and 7.3.1.3 of regulation 9 and paragraph 3.1.3 of regulation 20 of SOLAS Chapter II-2;
- paragraph 2.5.2 of Chapter 8, paragraph 2.4.1 of Chapter 10 “Sample extraction smoke detection systems”, paragraphs 2.2.4, 2.3.2 and 2.4.2 of Chapter 15 “Inert gas systems” and paragraph 2.2.3.3 of Chapter 16 of the FSS code;
- paragraph 15.19.7 of Chapter 15 of the IBC code; and
- Chapters 16 and 17 of the IGC code.

For degrees of autonomy three and four, SOLAS regulation II-2/12 “Notification of crew and passengers” should be amended because there are no seafarers on board except during berthing, cargo handling and anchoring. Also, Chapter 11 of the INF code “Notification in the event of an incident involving INF cargo” should be amended in order to determine what circumstances need the notification and how to form the report.

For degrees of autonomy three and four, SOLAS regulation II-2/13 “Means of escape” should be amended because there are no seafarers on board except during berthing, cargo handling and anchoring. In addition, distribution of persons to calculate the dimension of the means of escape (paragraph 2.1.2.2.2 of Chapter 13 of the FSS code “Arrangement of means of escape”) should also be amended. Also, Chapter 10 of the INF code “Shipboard emergency plan” should be modified because no procedure or actions would be taken for persons on board.

For degree of autonomy two, the provisions for fire safety operational booklets, specified in SOLAS regulation II-2/16 “Operations”, should be amended along with the role of automation in relation to fire safety and management. Also, the interaction between the automated or autonomous systems and human actions (how the systems keep track of what people, fire or the ship is doing) should be considered. On the other hand, for degrees of autonomy three and four, the provisions for fire safety operational booklets should also be amended since there are no seafarers on board except during berthing, cargo handling and anchoring.

For degrees of autonomy three and four, paragraphs 2.3.2 and 2.4.2.5 of Chapter 8 of the FSS code, which require a glass gauge to indicate the correct level of the water in the pressure tank and a gauge indicating the pressure in the system at each section stop valve, respectively, need to be amended.

5. Discussions

In this section, we discuss the specific ways to amend or modify the provisions identified above.

5.1. General issues regarding the definitions and the functional requirements

The meanings of “master”, “crew”, or “responsible person”, etc. should be clarified as mentioned in Section 4.1, taking into account that some of such persons could be possibly not on board, but in a remote control centre or remote location for supervision for degrees of autonomy two, three and four.

Also, for degrees of autonomy two, three and four, it will be needed to modify the definitions and functional requirements of control stations and safety centre in order to introduce a remote control centre or a remote location for supervision, for examples, modifying the definitions to allow control stations or safety centre to be located in a remote control centre, and developing the new definitions and functional requirements for a remote control centre to be able to detect and control fire remotely. In addition, the definition of manned spaces needs to be amended according to the manning levels required
for each degree of autonomy and the roles of automated or autonomous systems and a remote control centre.

5.2. Provisions related to the accommodations
As mentioned in Section 4.2, some provisions that prescribe the systems for domestic purposes and protection of accommodation areas should be amended because there are no seafarers on board ships of degrees of autonomy three and four. Specifically, these provisions may be moderated when there are no seafarers nor passengers on board. For examples, the requirements for fire integrity in SOLAS regulation II-2/9 may be moderated if fire-fighting becomes to be conducted entirely automatically, autonomously or remotely, bearing in mind that persons may stay on board during berthing, cargo handling and anchoring. These requirements should be amended with those for fire-fighting in SOLAS regulation II-2/10.

5.3. Provisions about systems and appliances which require manual operations
The manual operations required in the provisions mentioned in Section 4.3 would be done automatically, autonomously or remotely for degrees of autonomy three and four. 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. Therefore, for these provisions, it is necessary to understand the intentions of them and consider the alternative means for achieving the intended functionalities.

One way of addressing this problem might be to amend these provisions introducing the alternative means instead of or along with the existing ones, and another way might be to apply SOLAS regulation II-2/17 “Alternative design and arrangements” to ships of degrees of autonomy three and four, for the most of the provisions in SOLAS Chapter II-2 and the FSS code mentioned in Section 4.3. When SOLAS regulation II-2/17 is applied, fire safety design and arrangements may deviate from the prescriptive requirements set out in the regulations 4 to 23 other than 17 of SOLAS Chapter II-2. For the time being, appropriate safety measures would be conducted by “engineering analysis” (paragraph 3 of SOLAS regulation II-2/17) since it would be difficult, in general, to apply the prescriptive requirements to ships designed with novel technologies.

In any case, appropriate alternative safety measures should be adopted to achieve the equivalent functionalities intended by the existing regulations. On the other hand, it could also be considered to ensure the safety based on another concept. In such a case, one of the future issues is how to evaluate to what extent the risks related to fire or toxicity will be reduced owing to absence of persons on board.

5.4. Provisions which require actions by personnel
The requirements for fire patrols might be amended to allow the patrols to be conducted automatically, autonomously or remotely.

Also, the requirements for stowage of dangerous goods in the IMDG Code should be amended, taking into account that the existing IMDG Code requires to stow high fire risk dangerous goods “on-deck” and that it is more difficult to extinguish on-deck fire remotely or autonomously compared to extinguishment of fire under deck.

The requirements for fire-extinguishing parties or fire-fighting personnel should be amended according to the results of the amendments on the requirements for fire-fighting systems. When fire-fighting becomes to be conducted entirely automatically, autonomously or remotely, these requirements will not be necessary any longer.

For the carriage of cargoes by ships of degrees of autonomy three and four, one of the big challenges is how to establish the emergency procedures to deal with conditions of leakage, spillage or fire involving the cargo. It would be possible to introduce absolutely different procedures, developing new exemption provisions for MASS when there are no persons on board and the cargo does not include any harmful substances for marine environment.

Furthermore, the provisions which require onboard training and drills may have to be reconsidered depending on the results of the RSE on SOLAS chapter III “Life-saving appliances and arrangements”,

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regulation 19 “Emergency training and drills”, as these provisions require fire drills in accordance with paragraph 3 of SOLAS regulation III/19.

5.5. Provisions which require ready/easy accessibility
The purpose of these provisions is considered that some manual operations will be required for the systems in these locations, when necessary. Therefore, the possible ways of addressing these provisions are the same as mentioned in Section 5.3.

5.6. Provisions regarding the facilities which are effective only when seafarers are on board
For degrees of autonomy two, three and four, the requirements for alarms and indications should be amended so that alarms and indications are also available in a remote control centre or a remote location for supervision.

For degrees of autonomy three and four, the requirements for notification, means of escape and emergency plan should be amended because there are no seafarers on board except during berthing, cargo handling and anchoring. For example, these requirements should be reconsidered with expected areas where seafarers may exist during berthing, cargo handling and anchoring, as well as anticipated maximum number of seafarers in these areas. On the other hand, if there are passengers without seafarers on board, it should be considered how to ensure the safety of passengers without seafarers, for example, guidance of evacuation.

Also, for degree of autonomy two, the contents of fire safety operational booklet should be modified, because it depends on the roles of automated or autonomous systems, responsibilities of seafarers on board or remote operators in a remote control centre, and interactions between persons and the systems. For degrees of autonomy three and four, the provision which prescribe the locations where the booklet shall be provided (paragraph 2.2 of SOLAS regulation II-2/16) should be amended, for example, the locations should be changed to the expected areas where seafarers will exist during berthing, cargo handling and anchoring.

Since a glass gauge indicating the water level in the pressure tank and a gauge indicating the pressure in the system required by the provision in Chapter 8 of the FSS code cannot be used when there are no seafarers on board, the provision should be amended so that these indication functionalities could be automatically, autonomously or remotely, for degrees of autonomy three and four.

6. Conclusions
In this article, the authors conducted the initial review of provisions in SOLAS Chapters II-2, VI and VII, associated eight codes and one subchapter of a code, as a part of the first step of the RSE for the use of MASS and indicated the provisions which require amendments or clarifications in Section 4. Also, we made some suggestions for the ways to amend the provisions in order to realize the use of MASS in Section 5.

As a result of the initial review, it was found to be necessary to clarify the meanings of “master”, “crew”, “responsible person”, etc. and to amend some provisions regarding definitions and functional requirements in order to introduce a remote control centre or a remote location for supervision.

Also, it was revealed that there were a lot of provisions which required manual operations and other actions by personnel on board. Especially, many of them are for fire safety. One way of realizing MASS without persons on board in respect of fire safety is to amend such provisions so that these operations and actions will be allowed to be done automatically, autonomously or remotely. Another way is to apply the SOLAS regulation II-2/17 “Alternative design and arrangements” when these provisions are parts of SOLAS Chapter II-2. In any case, appropriate alternative safety measures should be adopted to achieve the equivalent functionalities intended by the existing regulations. On the other hand, it could also be considered to ensure safety based on another concept. In such a case, one of the future issues is how to evaluate to what extent the risks related to fire or toxicity will be reduced owing to absence of persons on board.
In addition, for the carriage of cargoes by ships without persons on board during sailing, one of the big challenges is how to establish the emergency procedures to deal with conditions of leakage, spillage or fire involving cargoes. It would also be possible to introduce absolutely different procedures, developing new exemption provisions for MASS when there are no persons on board and the cargo does not include any harmful substances for marine environment, which is also one of the future issues.

In relation to the above issues, there are also some provisions regarding fire integrity in accommodation spaces and other provisions regarding spaces within accommodation areas for protecting personnel against the effects of a major cargo release. These provisions may be moderated, taking into account the reduction of risks owing to absence of persons on board.

Moreover, there are many provisions regarding accessibility and facilities which are effective only when seafarers are on board. They should also be amended in conjunction with the amendments to the provisions which require manual operations and other actions by personnel on board.

These suggestions could be used as a basis for discussions on amendments for these provisions at IMO meetings in the future.

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