INTERNATIONAL MARITIME ORGANIZATION

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Agenda item 5

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DEVELOPMENT OF A GOAL-BASED INSTRUMENT FOR MARITIME AUTONOMOUS SURFACE SHIPS (MASS)

REPORT OF THE WORKING GROUP

GENERAL

1 The Working Group on Maritime Autonomous Surface Ships (MASS) met from 2 to 9 November 2022 and was chaired by Mr. Henrik Tunfors (Sweden).

2 The Group was attended by delegations from the following Member States:

ARGENTINA
AUSTRALIA
ANGOLA
BAHAMAS
BELGIUM
BRAZIL
CANADA
CHINA
CROATIA
CYPRUS
DENMARK
ESTONIA
FINLAND
FRANCE
GERMANY
GREECE
INDIA
INDONESIA
ITALY
IRELAND
JAPAN
KENYA
LATVIA
LIBERIA
MARSHALL ISLANDS
MALAYSIA
MALTA
MEXICO
MOROCCO
NEW ZEALAND
NETHERLANDS
NIGERIA
NORWAY
PANAMA
PERU
PHILIPPINES
POLAND
QATAR
REPUBLIC OF KOREA
RUSSIAN FEDERATION
SAUDI ARABIA
SINGAPORE
SPAIN
SWEDEN
THAILAND
TÜRKİYE
UNITED ARAB EMIRATES
UNITED KINGDOM
UNITED STATES

* Re-issued on 10 November to correctly reflect the title of ISO/TS 23860 in paragraph 26.

as well as a representative from the following Associate Member of IMO:

HONG KONG, CHINA

and by observers from the following intergovernmental organizations:

EUROPEAN COMMISSION (EC)
INTERNATIONAL MOBILE SATELLITE ORGANIZATION (IMSO)

3 The session was also attended by observers from the following non-governmental organizations in consultative status:

INTERNATIONAL CHAMBER OF SHIPPING (ICS)
INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)
INTERNATIONAL UNION OF MARINE INSURANCE (IUMI)
INTERNATIONAL ASSOCIATION OF MARINE AIDS TO NAVIGATION AND LIGHTHOUSE AUTHORITIES (IALA)
BIMCO
INTERNATIONAL ASSOCIATION OF CLASSIFICATION SOCIETIES (IACS)
INTERNATIONAL MARITIME PILOTS' ASSOCIATION (IMPA)
INTERNATIONAL FEDERATION OF SHIPMASTERS' ASSOCIATIONS (IFSMA)
INTERNATIONAL ASSOCIATION OF INDEPENDENT TANKER OWNERS (INTERTANKO)
INTERNATIONAL PARCEL TANKERS ASSOCIATION (IPTA)
WORLD SAILING LTD.
INTERNATIONAL MARINE CONTRACTORS ASSOCIATION (IMCA)
INTERNATIONAL HARBOUR MASTERS' ASSOCIATION (IHMA)
THE ROYAL INSTITUTION OF NAVAL ARCHITECTS (RINA)
INTERNATIONAL TRANSPORT WORKERS' FEDERATION (ITF)
WORLD SHIPPING COUNCIL (WSC)
THE NAUTICAL INSTITUTE (NI)
SUPERYACHT BUILDERS ASSOCIATION (SYBAss)

and by the following IMO training institute:

WORLD MARITIME UNIVERSITY (WMU)

TERMS OF REFERENCE

4 The Working Group, taking into account the comments and decisions made in plenary, was instructed to:

.1 further develop the draft non-mandatory MASS Code, using document MSC 106/WP.10 as the basis, taking into account documents MSC 106/5/1, MSC 106/5/2, MSC 106/5/3 and MSC 106/5/4, as well as documents MSC 106/INF.4, MSC 106/INF.6, MSC 106/INF.13, MSC 106/INF.14, MSC 106/INF.15, MSC 106/INF.18 and MSC 106/INF.20;

.2 review and identify any issues that may need to be addressed by the Joint MSC-LEG-FAL Working Group on MASS (MSC 105/20, paragraph 7.27), for approval by the three Committees, taking into account document MSC 106/5;

.3 review the documents in MSC.1/Circ.1638, appendix 3, marked as "to be kept in abeyance for future consideration" and identify those which should be considered by the Correspondence Group when further developing the draft MASS Code, taking into account the views of the submitters;

.4 update the Road map for developing a goal-based code for maritime autonomous surface ships (MSC 105/20/Add.2, annex 28); and

.5 submit a written report to plenary by Thursday, 10 November 2022.

CONSIDERATION OF THE STRUCTURE OF THE MASS CODE

5 As instructed, the Group commenced work on the draft framework for the goal-based non-mandatory MASS Code, based on document MSC 106/WP.10, developed by the intersessional Correspondence Group. The Group also had for its consideration documents MSC 106/5/1, MSC 106/5/2, MSC 106/5/3 and MSC 106/5/4, as well as the information documents listed in paragraph 4.1.

6 Having agreed that each of the proposals in the documents listed above were appropriate for inclusion in the MASS Code, the Group incorporated relevant text therein in the draft MASS Code with the understanding that all text required further in-depth consideration and refinement at some later stage.

Risk assessment

7 While agreeing in principle to the proposal in document MSC 106/5/3 on the incorporation of a risk assessment section, a view was expressed that the level of detail for the risk assessment and proposed methodologies was premature. Some delegations were of the opinion that the *Guidelines for the approval of alternatives and equivalents as provided for in various IMO instruments* (MSC.1/Circ.1455) were most appropriate to be used assessing the safety level of MASS while there were also views that concluded that MSC.1/Circ.1455 may require modifications to be applicable to MASS.

8 In addition, some delegations queried where best to place the risk assessment section in the draft Code as the risk concept was part of any goal-based IMO instrument and thus applied as a whole, while certain risk concepts may be specific for particular sections. Subsequently, the Group agreed to place *risk assessment* as section 2.4 in part 2 of the draft MASS Code.

Outcome of the RSE

9 Some delegations indicated that the work on the MASS Code needed to be based on, and take into account, the outcome of the regulatory scoping exercise (RSE) (MSC.1/Circ.1638) as the work carried out already identified the gaps that the Code needed to address; however, it was also stated that the outcome of the RSE should not be regarded as a completed and all-encompassing analysis of regulatory gaps to address, bearing in mind the new risks posed by, or to MASS, some of which were unknown "unknowns".

Agreed structure for the draft MASS Code

10 Acknowledging that future work may lead to further changes, the Group subsequently agreed to the structure of the draft MASS Code, as set out in annex 1.

DEVELOPMENT OF GOALS AND FUNCTIONAL REQUIREMENTS

11 Having agreed to follow closely the *Generic guidelines for developing IMO goal-based standards* (MSC.1/Circ.1394/Rev.2) (Generic GBS Guidelines) for the purpose of developing goals and functional requirements (FR) for the draft MASS Code, the Group discussed at length how best to incorporate the goal-based concept and subsequently concurred, in principle, to the following:

.1 the MASS Code should not repeat provisions or regulations of existing IMO instruments, most notably SOLAS, to avoid duplication, bearing in mind that the Code was intended to complement existing IMO instruments;

.2 work on the MASS Code should focus on developing goals and FRs since Tier IV regulation development may take too long to be completed in time for adoption of the non-mandatory MASS Code with entry into effect in 2025;

.3 in light of sub-paragraph .2, the development of Tier IV regulations, rules or provisions and their subsequent inclusion in the MASS Code may refer to IMO instruments or be based on those developed by national Administrations or other organisations, such as class societies;

.4 Tier III (Verification) requirement under the GBS framework (MSC.1/Circ.1394/Rev.2, paragraphs 16 to 19) should be further considered; and

.5 consideration of the human element was crucial and any work undertaken in developing the MASS Code should take into account the *Checklist for considering and addressing the human element* (MSC-MEPC.1/Circ.5/Rev.3, annex 5).

12 In order to provide for a common understanding on the requirements for formulating goals and FRs, and for ensuring that input for the various sections of the draft MASS Code would follow a consistent and coherent format, the Group considered at length the requirements for goal-based regulations, as contained in MSC.1/Circ.1394/Rev.2, taking into account the examples in the appendices therein, as well as existing or recently developed goal-based IMO instruments (IGF Code, Polar Code, draft IP Code).

Development of an example to be used for the development of future goals and functional requirements

13 Following the discussion on the best way to develop goals and FRs for the draft MASS Code, the Group agreed to conduct a goal-based drafting exercise for developing goals and FRs with the aim of completing an example to be followed for future submissions for other sections in the draft Code so as to ensure that the Code is coherent and conclusive with a consistent format and structure for goals and FRs.

14 The Group commenced the exercise by considering a proposal of the Republic of Korea for fire and flooding emergency response. However, after some discussion it became clear that the concept of emergency response was too complex and not addressed for all emergencies in existing IMO instruments to serve as a good example and, therefore, the Group agreed to use the more widely used concept of fire safety for the exercise.

15 Subsequently, the Group commenced work on the goal and FRs for draft section 5 on "Fire protection/safety", based on existing SOLAS chapter II-2 provisions. Having considered a proposal prepared by the United Kingdom for this purpose, the Group noted the following views expressed:

.1 SOLAS II-2/2.1 and 2.2 contained fire safety goals for ships and were equally applicable to MASS and, therefore, no new goal(s) needed to be drafted;

.2 while the MASS Code would primarily be based on SOLAS requirements, the assumption should not be that SOLAS was the only existing applicable instrument for MASS and, therefore, care should be exercised to ensure that other instruments be referenced, as and when appropriate;

.3 key for developing FRs was the process of hazard identification and ranking which requires an appropriate risk assessment methodology; however, data is scarce for MASS and this therefore posed a particular challenge for the hazard identification; and

.4 use-cases should form a fundamental part in the development of the MASS Code in order to address the uncertainty that existed in foreseeing automation solutions for ships.

16 Having noted that the Generic GBS Guidelines made reference to the *Revised guidelines for Formal Safety Assessment (FSA) for use in the IMO rule-making process* (FSA Guidelines) (MSC-MEPC.2/Circ.12/Rev.2) (appendix 3, paragraph 4), the Group concluded that it may not always be appropriate to use all steps of the FSA process beyond the hazard identification, and that other methods may be applied for the hazard identification.

17 After recalling that the Generic GBS Guidelines provide the option for the development of a hierarchical set from generic to specific FRs in conjunction, the Group agreed to use high-level FRs (e.g. FRs 1.1 to 1.6), as well as autonomy-specific FRs (e.g. FRs 2.1 to 2.11) in the draft fire safety provisions in section 5 of part 3 of the draft MASS Code.

18 In connection with the above and after recognizing the difficulty in developing FRs for the various possible operation modes of MASS (i.e. (reduced) crew on board, remotely controlled MASS with/without crew on board, fully autonomous), several delegations expressed support to formulate high-level FRs which would be universally applicable to MASS, regardless of the mode of operation. The autonomy-specific FRs associated to a high-level FR may then be developed for the various operation modes for MASS.

19 While it was generally acknowledged that the fire protection/safety functional requirements of the draft MASS Code required further consideration and discussion in the Correspondence Group and by fire safety experts, the Group agreed in principle to the goal and functional requirements (FR) 1.1, 1.2, 1.3, as well as associated FRs 2.5 and 2.6, as set out in section 5 of part 3 in annex 1.

20 The Group also agreed that the documentation provided by the United Kingdom for the development of the goal and functional requirements for the draft fire protection/safety of the MASS Code, as revised by the Group and based on the Generic Guidelines, should be retained and serve as an example for the development of goals and FRs for other sections of the MASS Code. The example for the development of functional requirements for the IMO MASS Code, including the Guidance thereto, are contained in annex 2.

21 Furthermore, it was also agreed that the method for documenting the procedure for developing FRs for the MASS Code, as outlined in paragraph 20 and annex 2, using a table to demonstrate how each FR is formulated, should be used for all sections of the MASS Code for transparency and traceability.

22 Although the exercise revealed a high degree of uncertainty and lack of experience and knowledge of developing goals and functional requirements, the Group agreed to recommend to the Committee to request establishing the GBS Working Group at MSC 107 to consider annex 2 and, if considered appropriate, to subsequently amend MSC.1/Circ.1394/Rev.2 to facilitate its use in the future.

Meaning of the term MASS

23 During deliberations for formulating goals and FRs on fire safety, the Group noted a lack of concept for what constituted a MASS, i.e. the question of when a ship would be considered a MASS and whether that translated only to an unmanned ship (fully autonomous or remotely controlled) or whether this would include ships with some (reduced) crew on board.

24 In connection with the above, the Group also recalled the ongoing work in the intersessional Correspondence Group which had agreed to an approach of developing provisions for autonomous functions rather than developing provisions for an autonomous ship. In this respect, one delegation stated that, at some stage in the future, ships will be designed from scratch to be autonomous.

25 It was recognized that the above discussion on the meaning of MASS, which cut into the work of the MASS-JWG, constituted a major obstacle to overcome in developing any safety provisions and the Group concurred that this would need to be clarified in order for functional requirements to be developed in a consistent manner.

26 In order to progress the work and to address the above challenging formulation for MASS, one delegation highlighted that any future work on the MASS Code should take into account ISO/TS 23860 on "Vocabulary related to autonomous ship systems", which the Group agreed to refer to the intersessional Correspondence Group to consider.

27 The Group noted the view of one delegation that MASS, in particular degrees of autonomy 3 and 4, posed important legal challenges in light of UNCLOS, which should be addressed at the competent forum (Meeting of States Parties to UNCLOS).

Volunteering Member States and organizations for the development of selected sections of the draft non-mandatory goal-based MASS Code

28 In considering the large amount of work required for the further development of the MASS Code and drawing from the experience in splitting this work up among participating Member States as part of the regulatory scoping exercise, the Group sought volunteering delegations to develop sections for the MASS Code, based on annex 2.

29 Following this call for volunteering, Member States and observer organizations communicated their interest, all of which were listed together with the section they volunteered for developing, as set out in annex 3.

30 Bearing in mind that other Member States and observer organizations may wish to participate in the work, the Group agreed to invite the Committee to request volunteers to make their interest known to the Coordinator of the intersessional MASS Correspondence Group.

REVIEW OF THE DOCUMENTS KEPT IN ABEYANCE IN MSC.1/CIRC.1638 FOR FUTURE CONSIDERATION

31 The Group reviewed the documents listed in appendix 3 to MSC.1/Circ.1638 marked as "to be kept in abeyance" with the aim of identifying those which should be considered by the Correspondence Group when further developing the draft MASS Code, taking into account the views of the submitters.

32 After consideration, the Group agreed to request the Committee (see annex 4) to:

.1 agree to refer documents MSC 102/5/14 (Russian Federation), MSC 102/5/16 (CMI) and MSC 103/5/10 (Russian Federation) to the MASS Correspondence Group (see also annex 6);

.2 refer document MSC 102/5/2 (IFSMA) to the MASS-JWG 2 in April 2023 while the Correspondence Group should take note of it;

.3 agree that no further consideration of document MSC 102/5/28 (IMSO) was needed after IMSO advised that the document had been submitted before the Committee decided to develop a MASS Code; hence IMSO agreed to provide its input as and when appropriate during the development of the MASS Code;

.4 refer MSC 103/5/7 (Russian Federation) to LEG 110 after conclusion in the Group, supported by the Russian Federation, that the issues therein had been considered in the RSE and that the remaining item on liability insurance was a legal matter; and

.5 agree that no further consideration of document MSC 103/5/8 (Russian Federation) was needed as it related to MASS trials and was, therefore, outside the scope of the current work on the MASS Code.

REVIEW AND IDENTIFICATION OF ANY ISSUES THAT MAY NEED TO BE ADDRESSED BY THE JOINT MSC-LEG-FAL WORKING GROUP ON MASS

33 The Group agreed that the work carried out at MSC 106 did not generate any input on any of the common issues for the MASS-JWG.

34 Notwithstanding the above, the Group noted that the intersessional Correspondence Group had identified issues that could be considered by the MASS-JWG. However, the Correspondence Group was tasked to report to MSC 107 (June 2023) and thus unable to submit any input to the MASS-JWG 2 (April 2023); nevertheless, Member States were free to submit any of the issues identified during the intersessional Correspondence Group to MASS-JWG 2, if it was considered to be an urgent need.

35 Subsequently, the Group recalled that MASS-JWG 3 was likely to be established in the second half of 2023 and that potential issues identified by the intersessional Correspondence Group, which will be reported to MSC 107 (June 2023), could in any case be submitted to that meeting of the MASS-JWG 3.

36 The Group also agreed to update MASS-JWG 2 on the progress made at MSC with respect to MASS through a submission by the Secretariat.

REVISED ROAD MAP FOR DEVELOPING A GOAL-BASED CODE FOR MASS

37 The Group updated the Road Map by, primarily, including items that had not been finalized at this session of the Committee (annex 5).

PROPOSED REVISED TERMS OF REFERENCE FOR THE CORRESPONDENCE GROUP

38 Following the further development of the draft MASS Code by the Group, it was agreed that the Correspondence Group's terms of reference needed to be amended so as to ensure that there was no duplication of work.

39 Subsequently, the Group agreed to propose to the Committee to revise the Correspondence Group's terms of reference, requesting it to work further on the MASS Code based on annex 1, taking into account the example and associated guidance in annex 2, as well as selected documents that had been kept in abeyance since the outcome of the RSE (annex 6).

ACTIONS REQUESTED OF THE COMMITTEE

40 The Committee is invited to approve the report in general and, in particular, to:

.1 note the structure of the draft MASS Code (paragraph 10 and annex 1);

.2 agree, in principle, with the Group's conclusions on how to progress the work on the MASS Code (paragraph 11);

.3 note the Group's conclusion that it may not always be appropriate to use all steps of the FSA process beyond the hazard identification and that other methods may be applied for the hazard identification (paragraph 16);

.4 note the example for the development of functional requirements for the MASS Code, prepared by the Group for developing goals and functional requirements, to be used for other sections in the MASS Code in the future (paragraphs 13 to 21 and annex 2);

.5 agree to establish the GBS Working Group at MSC 107 to consider the *Example for the development of FRs for the MASS Code* (annex 2) and, if considered appropriate, to subsequently amend MSC.1/Circ.1394/Rev.2 to facilitate its use in the future (paragraph 22);

.6 note the difficulties encountered by the Group in the use of the term "MASS" (paragraphs 23 to 27);

.7 note that Member States and observer organizations communicated their interest in developing goals and functional requirements for various sections of the draft MASS Code (paragraph 28 and 29 and annex 3);

.8 request volunteers interested in (co-)developing sections of the MASS Code to make their interest known to the Coordinator of the intersessional MASS Correspondence Group (paragraph 30 and annex 3);

.9 agree to the proposal of the Group on how to proceed with the documents listed in appendix 3 to MSC.1/Circ.1638 marked as "to be kept in abeyance", in particular the request to refer documents:

.1 MSC 102/5/2 (IFSMA) to the MASS-JWG 2; and

.2 MSC 103/5/7 (Russian Federation) to LEG 110 (paragraph 32);

.10 note that the work carried out at MSC 106 did not generate input on any of the common issues for the MASS-JWG (paragraph 33);

.11 agree to inform the MASS-JWG 2 of the progress made at MSC 106 with respect to MASS through a submission by the Secretariat (paragraph 36);

.12 approve the updated Road Map for developing a goal-based code for Maritime Autonomous Surface Ships (MASS) (paragraph 37 and annex 5); and

.13 agree to the revised terms of reference for the intersessional Correspondence Group (paragraph 38 and 39 and annex 6).

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ANNEX 1*

DRAFT INTERNATIONAL CODE OF SAFETY FOR MARITIME AUTONOMOUS SURFACE SHIPS (MASS CODE)

PREAMBLE

1 Existing IMO instruments have historically been developed on the basis that the ship will have at least a minimum level of manning on board to carry out the various tasks required to ensure safe, secure, and environmentally sound ship operations.

2 The ever-increasing use of automation in the operation of ships, along with the anticipated increase in the use of remote control and autonomous operation of key functions, will require a different approach and therefore some adjustment of the accepted norms regarding on board manual intervention and control as contained within SOLAS and other IMO instruments.

3 In facing these challenges, it is recognized that some aspects associated with MASS may not be adequately or fully addressed in SOLAS or other IMO instruments and that additional guidance may be required on the design and operation of MASS to achieve a level of safety that is at least equivalent to that expected of a conventional ship.

4 This Code addresses the functions needed to obtain safe and reliable operations of MASS insofar as they are not adequately or fully addressed in other applied IMO instruments, such as SOLAS, while ensuring that required safety levels are maintained or enhanced through the implementation of remote control, or autonomous operation, of key functions.

5 This Code is intended as a supplement to other IMO instruments, such as SOLAS, and provides a regulatory framework for the performance of remote control and autonomous operation of key functions, as applicable.

6 The safety principles and objectives of this Code reflect changes in the operational risks (increases or reductions) which may result from the introduction of remote control and autonomous operation of key functions and address their management and reduction through mitigation measures and controls.

7 This Code has been developed based on the *Generic guidelines for developing IMO Goal-based Standards* (MSC.1/Circ.1394/Rev.2) and the *Principles to be considered when drafting IMO instruments* (resolution A.1103(29)).

8 The provisions of this Code should be implemented for individual remotely controlled or autonomous functions even where persons are on board to handle other functions.

9 This Code takes into account that certain operational functions may be controlled from a location, or locations, remote from the MASS and addresses necessary aspects of such remote operations centres.

* *Note: The grey-shaded text reflects the changes made against document MSC 106/WP.10*

PART 1 GENERAL

1 Introduction

1.1 Purpose

The purpose of this Code is to provide a coherent international regulatory framework to enable [and ensure] safe, secure, and [environmentally sound] MASS operations. The Code further aims to support the safe adoption and integration of new technology for ship operations and provide for consistency of approach to the design, build and operation of MASS.

1.2 Principles

This Code is developed on the principles that it be:

a. supplementary to any applied base IMO instruments, such as SOLAS, and only address MASS issues insofar as they are not adequately or fully addressed in the applied base instruments;

b. holistic to ensure the objectives, aims and principles of the IMO base instruments are maintained whilst also ensuring that the challenges of MASS functions and operations are addressed across all instruments;

c. goal-based and addressing matters at the functional level;

d. non-mandatory but developed in such a way as to facilitate future transition to mandatory status; and

e. technology neutral and taking note of industry practices and experience in the deployment of new technologies.

1.3 [Goals] [Objectives]

In achieving its Purpose, this Code is intended to:

a. ensure achievement of a level of safety at least equivalent to that expected of a conventional ship;

b. enable all ships to safely coexist without impeding or negatively impacting each other, regardless of whether certain functions are remotely controlled or autonomously operated;

c. ensure that there is no relaxation of the level of accepted standards for design, construction or operation;

d. allow for the application of solutions that are demonstrably safe, secure, and environmentally sound in performing the designated function in all defined conditions; and

e. be cognizant of the potential for the unintended placement of regulatory barriers to new or novel application of remote control or autonomous technology on ships.

[1.4 Verification and validation (GBS Tier III)]

2 Application

2.1 xxxxxxx

2.2 xxxxxxx

3 Code structure and relationship to other IMO instruments

3.1 [Unless expressly provided otherwise, SOLAS applies for the purpose of this Code.]

3.2 xxxxxxx

4 Terminology and definitions

4.1 xxxxxxx

4.2 xxxxxxx

5 Certificate and survey

5.1 xxxxxxx

5.2 xxxxxxx

Part 2 MAIN PRINCIPLES FOR MASS AND MASS FUNCTIONS

2.1 Operational context

[2.1.1 Responsibility for MASS operations:

.1 The MASS owner shall ensure the safe operation of the ship under the applicable international instruments and national regulations of the flag State of the ship, including those relating to life, health and properties of the third parties.

.2 The MASS owner bears the responsibility established by the applicable instruments and national regulations of the flag State of the ship for possible harm to third persons, the environment, as well as to protected public interests incurred due to or concerning the operation of such ship including liability limitations established by the applicable instruments.

.3 Depending on the MASS autonomy degree, enforcement of the requirements concerning safe shipping and environment protection is provided by the shipowner with the help of the crew and/or by the remote crew, if any. The shipowner may entrust the company that is proficient in MASS operation to supervise the ship and operate the ship by the company's remote crew staying outside the ship; meanwhile, the shipowner is responsible for meeting the requirements of safe shipping and environment protection in any case.

.4 Carriage of the cargoes by MASS is performed in accordance with the applicable international practice and rules, and regulations of the State flag of the ship. Unless otherwise directed by the contract of sea carriage or by

the effective international and national regulations, the shipowner of the autonomous ship is responsible for the ship's seaworthiness and safe carriage of the cargo as indicated in the contract of sea carriage.

.5 The shipowner and the cargo owner represent the interests of the shipowner and cargo owner by themselves or by the persons they authorize.

2.1.2 Supervision on MASS operation:

.1 The MASS owner provides continuous supervision and, if required, control over the MASS by a crew on board and/or remote crew outside the ship.

.2 A crewless (fully autonomous) MASS, excluding fully autonomous passenger ship, equipped with autonomous systems allowing her to navigate from the point of departure to the point of destination, and providing safe navigation and sea environment protection without continuous supervision is exempted from continuous supervision and control by a remote crew.

.3 A MASS crew, excluding a fully autonomous ship, includes a shipmaster, other officers and operational staff if proper diplomas and qualification certificates stipulated by the STCW Convention are available. MASS crew members can combine various functions stipulated by the STCW Convention, subject to keeping the established work and rest hours and having the qualifications required for every function they perform.

.4 A fully autonomous ship does not have a crew except the remote one.

.5 The remote crew shall provide remote control of the MASS or render assistance in MASS control to the crew. The remote crew may include a MASS remote master, MASS remote operators and responsible persons meeting the requirements of this Code.

.6 Members of the remote crew of an autonomous ship follow the instructions of the shipowner relating to ship control, including ship navigation and work schedule. The instructions of the charterer concerning the commercial operation of the ship are mandatory for members of the remote crew. Remote operators and responsible persons of the remote crew follow the commands of the MASS master.

.7 A remote crew member directly controlling the MASS via a remote control station located outside the ship is the remote operator. The remote operator is a seafarer, as established by the STCW Convention, who should meet the defined qualification requirements relating to chief mates or shipmasters in accordance with the provisions of regulation I/11 of the STCW Convention and regulations of the flag State of the autonomous ship. The Administration shall establish the requirements for professional training programmes on autonomous ship operations.

.8 MASS remote control can be carried out by the remote crew staffed not only by the shipowner, but also by a third-party organization competent in autonomous navigation and having at its disposal technical means to manage MASS as well as experts in MASS control meeting the requirements established for remote operators. The Administration shall establish the requirements for such organizations providing services for MASS operation.

.9 A MASS master (including a remote master, if he/she is located outside the ship) is responsible for MASS control, including navigation, taking measures to ensure the safety of the ship's navigation, marine environment protection, keeping the order on board, preventing harm to the ship, as well as to the people and cargo on board. A MASS master, including a remote master, must have a valid shipmaster diploma and other certificates following the requirements of applied international instruments and national regulations established by the Administration.

.10 When operating a fully autonomous ship that does not have a ship's remote crew, the shipowner must identify the person responsible for managing the fully autonomous ship, who performs all the functions and duties assigned to the ship's master by applicable international instruments and the regulations of the flag State of the autonomous ship.]

[2.1*bis* Principles

2.1.1 Responsibility for the safety of navigation is clearly defined at all times.

2.1.2 Resources are allocated and assigned as needed in correct priority to perform necessary tasks. Especially, manoeuvring of the ship should be appropriate to the urgency of the situation and nature of the emergency.

2.1.3 To ensure compliance with pollution prevention requirements, procedures for monitoring shipboard operations and ensuring compliance with MARPOL requirements are fully observed.

2.1.4 Legislative requirements relating to safety of life at sea and protection of the marine environment are correctly identified.

2.1.5 The autonomous systems for MASS should be tested by the Administration and/or Recognized organization to evaluate performance in executing common operating tasks and to assess performance under normal operating conditions and defined conditions representative.]

2.2 Safe states for the ship

2.3 [~~Functional decomposition and allocation~~ Functions required for MASS

2.3.1 It is required for MASS that all or part of functions below which are performed by seafarers onboard should be automated or remotely controlled:

.1 Navigation;
.2 Cargo handling and stowage;
.3 Controlling the operation of the ship and care for persons on board;
.4 Marine engineering;
.5 Electrical, electronic and control engineering;
.6 Maintenance and repair; and
.7 Radiocommunications

2.3.2 In case of automating or remotely controlling the above functions, Operational Design Domain (ODD) of autonomous system should be defined and Concept of Operation (ConOps) of MASS should be clarified for verification and certification of autonomous systems.Functions related to safety navigation should be maintained at all times and in such a way as to conform to predefined ODD.]

2.4 Risk assessment

[2.4.1 Application
2.4.2 Principle
2.4.3 Definition
2.4.4 Procedure
2.4.4.1 Team of evaluation
2.4.4.2 Safety standards
2.4.4.3 Hazard identification
2.4.4.4 Control measures
2.4.4.5 Record
2.4.5 Risk management
.....
2.4.6 Risk assessment methods
2.4.6.1 Functional Hazard Assessment (FHA)
2.4.6.2 Failure Modes and Effects Analysis (FMEA)
2.4.6.3 Systems-Theoretic Accident Model and Processes (STAMP)]

2.5 System design principles

2.6 Software ~~engineering~~ standards

2.7 ~~Software systems and c~~Communications

2.7.1 This section, when developed, would potentially include consideration of aspects such as traceability, accountability, trust, transparency, reliability, resilience, data, software safety assessment, cyber security/safety, privacy, verification and validation, through life, human oversight, and connectivity.

2.8 Human element

2.8.1 Roles and responsibilities
2.8.2 Manning
2.8.3 Training
2.8.4 Human-Machine Interface (including transfer of responsibility)

~~3.9~~ ~~Verification and validation~~

PART 3 GOALS, FUNCTIONAL REQUIREMENTS AND PROVISIONS

N.B. general consideration on human element and decision-making for all sections below

1 Navigation

[1.1 Goal

The goal of this chapter is to provide for safety navigation of MASS.]

[1.2 Functional requirements

1.2.1 Navigational [related] tasks

1.2.1.1 Voyage plan

"Voyage plan" is to plan and conduct a route, determine position, and then input them in Autonomous Navigation System (ANS) before departure.

Voyage plan should be developed taking into account following issues:

.1 All potential navigational hazards are accurately identified;

.2 Charts and publications are corrected in accordance with the latest information available; and

.3 Performance checks and tests to ANS comply with ANS provider's documentations e.g., safety manuals and recommendations.

1.2.1.2 Situation awareness

[Requirements for detection and integration will be developed.]

Note 1: The following examples which are developed in the reference of related requirements in STCW Code may serve as a basis of discussion to develop this subsection:

.1 The function of event detection should be designed to monitor the operating environment as needed to operate the MASS with adequate equipment e.g., radar, ARPA and ECDIS;

.2 The distress or emergency signal is immediately recognized;

.3 Integrated information is correctly interpreted and analysed taking into account the limitations of the equipment and prevailing circumstances and conditions;

.4 ANS shares accurate understanding of current and predicted vessel state, navigation path, and external environment with crew/remote operator; and

.5 The type and scale of the emergency is promptly identified.

Note 2: The discussion for the necessity of additional sensor(s) from Reg. 19, Chapter V of the SOLAS Convention, such as LiDAR or camera can facilitate and deepen the discussion of functional requirements in this sub-section.

Note 3: The discussion based on resolution MSC.252(83), performance standards for Integrated Navigation System (INS), can facilitate and deepen the discussion of functional requirements in this sub-section.

1.2.1.3 Decision for collision avoidance
[Requirements for analysis and planning will be developed.]

Note: The following examples which are developed in the reference of related requirements in STCW Code may serve as a basis of discussion to develop this subsection:

.1 Action taken to avoid a close encounter or collision with other vessels is in accordance with the International Regulations for Preventing Collisions at Sea, 1972, as amended; and

.2 Decisions and planning to amend course and/or speed are both timely and in accordance with the limitations of ANS.

1.2.1.4 Action
[Requirements for control and actuation will be developed.]

Note: The following examples which are developed in the reference of related requirements in the STCW Code may serve as a basis of discussion to develop this subsection:

.1 ANS should contain capability of controlling the motion of the MASS in response to conditions in the operating environment;

.2 Safe operating limits of ship propulsion, steering and power systems controlled by ANS are not exceeded in normal manoeuvres; and

.3 ANS is capable of adjustments made to the ship's course and speed to maintain safety of navigation.

1.2.1.5 Alert management
[To be developed]

Note 1: The following examples may serve as a basis of discussion to develop this subsection.

"The ANS should provide the alert management functions and data. The examples of required functions are as follows:

.1 A function to notify the designated crew/operator in case that the ship deviates from its intended course or it judges unable to maintain the set speed range;

.2 A function to notify the designated crew/operator in case that appropriate manoeuvring controls are not in place corresponding to the external conditions; and

.3 A function to notify the designated crew/operator in case that any actuator does not respond as commanded."

Note 2: The discussion based on resolution MSC.252(83) (e.g., Module C), performance standards for Integrated Navigation System (INS), can facilitate and deepen the discussion of functional requirements in this subsection.

1.2.1.6 Data record
"Data Record" is to contribute to the safe navigation and the investigation/survey for MASS.
[Requirements will be developed.]

Note 1: The following examples may serve as a basis of discussion to develop this subsection:

.1 A proper record is maintained of the movements, activities and time relating to ANS;

.2 It is desirable that the data retention period is at least 2 years (following performance standards for VDRs in IMO resolution MSC.333(90));

.3 It is desirable that the stored data can be acquired by the interface that communicates;

.4 It is desirable that the stored data are properly protected so that they will not be tampered with; and

.5 A bridge, engine, radio, and medical logs of a fully autonomous ship are carried out by the shipowner in electronic format within the procedures established by the Administration. The logs mentioned and other ships' documents may be kept outside of an autonomous vessel and are presented by the shipowner in electronic format in case of port state control actions and other cases stipulated by international instruments and port State.

Note 2: The discussion for necessary additional recording data from Reg. 20 and 28, Chapter V of the SOLAS Convention can facilitate and deepen the discussion of functional requirements in this subsection.

1.2.1.7 Services for navigation
[Requirements will be developed.]

Note: The discussion based on Reg. 4 to 13, 23, 31 and 33, Chapter V of the SOLAS Convention can facilitate and deepen the discussion of functional requirements in this subsection.

1.2.1.8 Remote navigation
[Requirements will be developed.]

Note 1: The following requirements will serve as a basis of discussion to develop this subsection.

"Degree two: remotely controlled ship with seafarers on board" should have following functions:

.1 Crew members should be ready to respond at all times in case of emergency;

.2 The tasks of remote navigation are clarified

.3 The division of roles between MASS and the remote control/operation centre/station in the navigation tasks is clarified; and

.4 The necessary means of communication between MASS and the remote control/operation centre/station is established."

Note 2: Comprehensive discussion should be required to put these requirements in appropriate chapter(s) in this Code.

1.2.2 Redundancy
[Requirements will be developed.]

Note: The following example may serve as a basis of discussion to develop this subsection.
"Redundancy design of ANS should be considered as necessary based on a result of risk assessment taking into account its degree of autonomous/remote navigation. Additionally, it is important to thoroughly consider and implement the required cyber security measures."

1.2.3 Human Machine Interface (HMI)
[Requirements will be developed.]

Note 1: The following examples may serve as a basis of discussion to develop this subsection:

.1 Monitor information for crew/operator should be displayed in a manner that contributes to safe navigation; and

.2 ANS should have data presentation/indication functions such as:

.1 Presentation/Indication of status of manoeuvring control of the ship;

.2 Presentation/Indication of items out of control range;

.3 Presentation/Indication of mode-switching to evasive navigation mode;

.4 Display of evasive action plan/route;

.5 Display of “under evading navigation”;

.6 Notification of termination of automated operations;

.7 Presentation/Indication of the causes for termination of automated operations;

.8 Presentation/Indication of the causes for changeover to manual operations; and

.9 Presentation/Indication of action to be taken by designated crew/operator after changeover to manual operations

Note 2: Resolution MSC.252(83), performance standards for Integrated Navigation System (INS), (e.g., chapter 22 "Central alert management HMI") and MSC.302(87) (e.g., chapter 9 "Central alert management human machine interface (CAM-HMI)"), can facilitate and deepen the discussion of functional requirements in this sub-section.

1.2.4 Override and safe fallback response
[Requirements will be developed considering override, fallback response and MRM (minimal risk manoeuvre).]

Note: These terms (override, fallback response, MRM) should be defined in MASS Code on the basis of common understandings.]

2 Remote operations

3 Communications

4 Subdivision, stability and watertight integrity

5 Fire protection/safety

Goal
Note: The MASS WG at MSC 106 agreed, in principle, to the goal.
The goal of this section is to fulfil the fire safety objectives of SOLAS, taking into account the number of persons on board and the level of autonomy.

High-level functional requirements
*Note: The MASS WG at MSC 106 agreed, in principle, to FR 1.1 to 1.3, the remaining high-level FRs had not been considered and thus kept in square brackets. Further, t*he MASS WG at MSC 106 agreed, in principle, to FRs 2.6 and 2.7, the remaining specific FRs had not been considered and thus kept in square brackets.

[For the purpose of this section, MASS means …]

FR1.1: A MASS should comply with all relevant SOLAS fire safety requirements as modified by the specific Functional Requirements below.

FR1.2: The use of [additional] automated[autonomous]/[remotely-controlled] fire-fighting systems should not endanger the safety of persons on board or of the ship.

FR1.3: Onboard [and remote] management of automated[autonomous] fire-fighting systems should be provided to enable control and isolation of the systems.

[FR1.4: Means shall be provided to enable the assessment of fire-fighting effectiveness and fire extinction.

FR1.5: A MASS shall remain under control during and following a fire event.

FR1.6 The use of automated [autonomous] systems shall not prevent the effective prevention, detection, containment and extinction of fires on board nor the maintenance of effective control during and following a fire event.

FR1.7: ….]

Specific functional requirements

[FR2.1: Isolation of compartment boundaries shall occur automatically [autonomously] to enable effective fire fighting.

FR2.2: Shutdown and isolation of systems shall occur automatically [autonomously] to enable effective fire-fighting, however this should not damage them or endanger the vessel further.

FR2.3: Critical systems for maintaining appropriate control of the vessel shall be protected from foreseeable fire events.

FR2.4: Fire detection shall be provided in all compartments and open deck areas to enable onboard and remote understanding of the fire, where appropriate this shall initiate automatic [autonomous] fire-fighting measures.

FR2.5: Effective fire-fighting measures are to be provided in all compartments/open deck areas where there is a fire-fighting hazard which are able to extinguish a sustained fire of the type likely to be expected in that space/area. These may be active or passive.]

FR2.6: Provision should be made to enable fire-fighting control and response to be undertaken on board by an external responder. This should include provisions for establishing communications with the remote operating centre and a response to a fire on board.

FR2.7: The fire-fighting media and by-products of any automated [autonomous]]/[remotely-controlled] fire-fighting system should be managed so that they do not present an increased risk to the safety of persons on board or of the ship.

[FR.2.8: Automated [autonomous] fire-fighting systems shall be able to be safely isolated for compartment access or maintenance and shall provide onboard indication and warning of activation.

FR2.9: Management of a fire event shall be possible from the remote operating centre and the operator shall be provided with sufficient information to understand the scale, impact, response and success of the fire and fire-fighting measures.

FR2.10: An appropriate level of communication between the MASS and the remote operating centre shall be maintained during and following a fire event.

FR2.11: Upon identification of a fire event the MASS shall enter an appropriate fall-back state and be capable of maintaining that state during and following the fire event to the degree necessary to prevent it becoming a hazard. Post fire capability shall be determined by the Owner.

FR2.12: ….]

6 Life saving appliances and equipment

7 Management of safe operations

8 Controlling the operation of ship
N.B. could address: full autonomy, disparity in awareness on board and ashore, ship control

9 Security

[10 Search and rescue]

11 Cargo handling

[12 Personnel safety and comfort]

13 Towing and mooring

14 Marine engineering/Machinery installations

15 Electric and electronic engineering/ Electric Installations

16 Maintenance and repair

17 Emergency response

17.1 Goals

[The goal of the section is to ensure safe, effective and efficient handling of onboard fire emergencies on MASS.]

Regarding the case of fire or flooding accidents, key components to consider in in the accident response system for MASS;

17.2.1 Sensor system

Various sensor systems with different methods according to compartment characteristics (engine room, battery room, etc.), potential fire types (oil, gas, and metal, electrical or chemical) must be installed to detect fire and flooding and to prevent sensor malfunctions.

17.2.2 Data communication

Data communication between ships and remote-control centers onshore in real-time is essential for the operator to recognize the operational situation to ensure safe navigation, especially in high-density traffic areas, narrow routes, night, and bad weather conditions.

17.2.3 Redundancy

As redundancy is claimed to be a primary means of reducing accidents, sensor networks must be implemented with redundancy because some sensors may malfunction from fire and flooding accidents.

17.2.4 Engineering calculation and simulation database

Engineering calculation and simulation database can provide predictive information on what will happen to a ship by the accident and support to make informed decisions within minutes.

17.2.5 The operation of MASS with 3 or 4 degrees of autonomy (DoA) shall consider the following approaches and requirements for optimal accident response or damage control:

.1 Accident confirmation: In the case of an accident, the data transmission system to the remote operation center must be designed to consider the limitation of data capacity, speed, and reliability.

.2 Troubleshooting for accident responses: When the initial accident response fails, the self-decision-making facility of an accident response system should be designed as a backup.

.3 Verification of accident response results: In order to verify the accident result, unless there is a crew on board, the accident response system of the ship must equip the ability to assess the result and take additional action when required.

.4 Configuration and requirements: The major elements and suggested requirements for DoA 3 MASS include sensors, image sensor processing, communication ability, redundancy, response procedure, confirming accident response results, engineering analysis, self--adaptation, and user interface.

17.3 Provisions
XXXXXXXX

18 Care for persons onboard

19 xxxxxxxx

PART 4 SPECIFIC PROVISIONS FOR REMOTE CONTROL OF SHIP FUNCTIONS

1 Remote operations and control centres

1.1 xxxxxxx
1.2 xxxxxxx

~~**2 Software systems and communications**~~

~~This section, when developed, would potentially include consideration of aspects such as traceability, accountability, trust, transparency, reliability, resilience, data, software safety assessment, cyber security/safety, privacy, verification and validation, through life, human oversight, and connectivity.~~

~~**3 Human element**~~

~~3.1 Roles and responsibilities~~
~~3.2 Manning~~
~~3.3 Training~~
~~3.4 Human-Machine Interface (including transfer of responsibility)~~

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ANNEX

MASS TRIALS – MSC.1/Circ.1604 – "Interim Guidelines for MASS Trials"

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ANNEX 2

EXAMPLE FOR THE DEVELOPMENT OF FUNCTIONAL REQUIREMENTS FOR THE IMO MASS CODE

Part A – Guidance for the use of the example in part B

Introduction
The following guidance has been provided to assist the development of functional requirements for the IMO MASS Code. It is intended to provide a context specific process for the application of the *Generic guidelines for developing IMO goal-based standards* (Generic Guidelines) (MSC.1/Circ.1394/Rev.2), drawing on the outcomes of the MSC Regulatory Scoping Exercise (RSE) (MSC.1/Circ.1638) and to complement but not replace the principles of the Generic Guidelines. This document should be read in conjunction with the Generic Guidelines, in particular appendix 3.

Tier I – Goals
A goal should first be established for each chapter/section of the MASS Code which addresses the issue of concern and reflects the required level of safety (Generic Guidelines, section 10).

An example of the goal for fire safety may be formulated as follows:

> *The goal of this section is to fulfil the fire safety objectives of SOLAS taking into account the number of persons on board and the level of autonomy*.*

The goal should encompass the full scope of the chapter/section under consideration and define an acceptable level of safety that is at least equivalent to the level of safety expected for by the applicable primary IMO instrument. Reference should be made to examples of goals in other IMO instruments to assist in developing the goals for the IMO MASS Code.

Tier II – Functional Requirements
Functional requirements should then be developed which provide complete coverage of all hazards within the scope of the goal, these are discussed in the annex to the Generic Guidelines, paragraphs 11-15.

For the MASS Code a hierarchical structure of functional requirements is proposed within Tier II (annex to the Generic Guidelines, paragraph 13.2):

.1 high level (generic) functional requirements that can be achieved for all types of MASS regardless of the level of autonomy*; and

.2 autonomy specific functional requirements that respond to the particular hazards associated with specific level of autonomy*.

Note: Two levels of functional requirements are proposed (high level and specific functional requirements), which both relate to each other, in line with the Generic Guidelines.

The first level is required to provide functional requirements which are agnostic to the realization of autonomy, while a second level is needed to provide autonomy-specific functional requirements, dependant on autonomy or the presence of people (e.g. functional requirements for manned vessels and functional requirements for unmanned vessels).The relationship would be that all first level functional requirements are to be met, as well as those of the specific functional requirements for the specific application of autonomy.]

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* *"Level of autonomy" does not present a hierarchical order or refers to degree of autonomy as defined in the RSE.*

Development of functional requirements

A structured process for developing functional requirements will ensure:

- consistent development of functional requirements.
- justification of functional requirements.
- a source of information for future Code development.

Appendix 2 and 3 to the Generic Guidelines define the process for formulation and development of functional requirements. However, the following notes are provided to assist in the practical application of the table in appendix 2 and the directions in appendix 3.

Appendix 3 states:

"3 The development of functional requirements comprises three steps:

.1 identification, ranking and selection of relevant hazards;

.2 developing risk mitigating functions and expected performance; and

.3 formulation of functional requirements including description, rationale and expected performance".

Using the table in appendix 2, amended as shown below, to record all of the information, decision-making and thought processes relating to the selection and development of functional requirements will assist with the review and future development and application of the Code.

Description (1) (Functional objective)	**Rationale (2)** (Reason for inclusion)	**Expected performance (3)** (High-level Hazard Mitigation)	**Linked Functional Requirement (4)**
Used to derive High-Level (Generic) Functional Requirements	Justification for the Hazard/Risk/Scenario being addressed	Used to derive Autonomy Specific Functional Requirements and/or Tier 4 Rules & Regulations	Reference to Functional Requirement/s which have been developed
[Example from Appendix 2: Survival at sea Provide means for survival at sea	Persons in distress are endangered by starvation, dying or thirst or injuries Persons on board are endangered by consequences of injuries	Means are provided to • Sufficiently supply people with water • Sufficiently supply people with calories • Allows first medical aid for injuries • All provided for anticipated time of rescue.	
IMO Convention Objectives [Insert rows here relating to objectives identified from the relevant instrument analysed in the RSE]			
Autonomy Specific Objectives [Insert rows here relating to gaps or specific MASS related objectives in addition to the analysed instrument, ensure references to RSE outcomes and relevant IMO instruments in the rationale]			

Step 1 – Identification, ranking and selection of relevant hazards

In the first step, columns 1 and 2 (description and rationale) should be populated by identifying, grouping and ranking the key hazards.

1a) Identify the key hazards:

- Hazard identification should be undertaken using recognised techniques, see footnote.[1]

- Also draw upon experience and the results of the RSE (MSC.1/Circ.1638).

See also 1c) regarding the use of other IMO instruments or standards which may already contain hazards or functional objectives appropriate to the chapter/section under review.

1b) Rank the hazards

It is important to ensure that hazards are grouped and ranked so that only appropriately high-level functional requirements are derived and to avoid the development of technical requirements in the Tier IV level.

Group and rank the hazards:

- according to similar functions or significant accidents[2],
- by identifying whether higher-level hazards exist which provide overlapping coverage,
- by considering how the hazard directly impacts vessel safety or safety of life,

1c) Complete the table

For each identified ranked hazard:

- in column 1: record a brief description of the functional objective which addresses the hazard,
- In column 2: record a brief rationale for the inclusion of this objective
- Hazards/objectives which are covered by the existing IMO instruments should be recorded together, and
- Hazards/objectives unique to MASS applications should be recorded together.

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1 Examples of techniques that could be used include the *Revised guidelines for Formal Safety Assessment (FSA) for use in the IMO rule-making process* (FSA Guidelines) (MSC-MEPC.2/Circ.12/Rev.2), or other approaches that consider the following steps:

- Identification of unsafe conditions/modes associated with control actions
- Identification of causal factors which may initiate the unsafe conditions/modes
- Description of the worst-case outcomes from (unmitigated) unsafe conditions/modes
- Assessment of the worst-case outcomes severity
- Description of relevant operational restrictions and limitation
- Fault Detection, Isolation and Recovery mechanism

2 They could be grouped in a number of ways.

- Time based – prevent, detect, assess, prosecute, recover from a fire.
- Function based – propulsion, steering, power generation, electrical distribution
- Process based – design, build, operate
- Scenario based – collision, machinery fire, cabin fire.
- Hazard Based – fire, smoke, combustion, flame spread, ignition.

Reference should be made to functional objectives that may already exist within existing IMO instruments, or other relevant standards – for example the Polar Code, IGF Code, IP Code or NATO Naval Ship Code.[3]

Step 2 Developing risk mitigating functions and expected performance
In the second step, column 3 should be populated by establishing the expected level of performance in relation to the mitigation for the derived hazard management objective.

This should be done with:

- specific reference to the RSE which identifies the particular issues associated with the application of the IMO instruments.
- Other mitigations or performance requirements may come out of the hazard identification process and may be specific to particular levels of autonomy.

Step 3 - Formulation of functional requirements
In the final step, high level functional requirements should be derived from the functional objectives in column 1 and autonomy specific functional requirements should be derived from the expected performance objectives in column 3.

These should be written up:

- separately in a formal style and presented as draft text for inclusion within the Code.
- presented in a manner which best suits the designer and operator, the users of the Code, and
- with the relationship between high level and autonomy specific functional requirements clearly defined.

Column 4 (Linked functional requirement) should be completed to provide a link between the derived functional requirements and the rows (hazards/objectives) that they address; functional requirements may cover more than one row.
If performance objectives in column 3 are considered to be too specific or low level and are considered to be covered by other higher level functional objectives, it would be appropriate to exclude them at this stage but identify them for future inclusion in Tier IV rules and regulations.

Step 4 - Review
On completion, functional requirements should be:

- reviewed for gaps or overlaps,
- tested to ensure that they are independent of technological realisations, and
- checked to confirm complete coverage of the goal.

It may be necessary to re-visit the goal and functional requirements until no gaps or overlaps exist in order to ensure a complete solution for the Code chapter/section is achieved.

Conclusion
The guidance provided above is intended to assist in the application of the generic Guidelines to the development of the MASS Code; specifically to ensure a consistent approach and consistent reporting outcome in the development of functional requirements.
The provision of completed tables capturing the process of deriving the functional requirements will support their direct review in the wider MASS working group by assisting reviewers in linking them back to specific hazards/hazard management objectives and providing the rationale for their inclusion.

[3] The NATO Naval Ship Code (ANEP77) is a goal-based safety standard which was initially developed by the International Naval Safety Association (INSA) as a 'navalised' SOLAS – whilst it has specific naval application it does provide goal-based requirements which achieve SOLAS equivalent outcomes.

Part B – Example

Fire Safety

Goal[4]
The goal of this section is to fulfil the fire safety objectives of SOLAS, taking into account the number of persons on board and the level of autonomy.

Justification (from MSC.1/Circ.1394/Rev.2, Appendix 2)

Description	**Rationale**	**Expected performance**	**Linked Functional Requirement**
Derived 1st Tier Functional Requirement	Hazard/Risk being addressed	Possible 2nd Tier Functional Requirement/Tier 4 Solution	
SOLAS Functional Objectives (Ch.II-2, Reg.2.2)			
.1 division of the ship into main vertical and horizontal zones by thermal and structural boundaries;	Fires need to be contained in the space of origin to limit escalation and to protect critical functions	As per a SOLAS ship - Boundary penetrations to be automatically isolated (Deg 3/4) - Systems to be isolated and shutdown (Deg.3-4)	FR1.1 FR2.1 FR2.2
.2 separation of accommodation spaces from the remainder of the ship by thermal and structural boundaries;	Critical compartments (systems/people) need to be protected from spaces containing higher fire risks	As per a SOLAS vessel - Critical functions/systems may need to be protected (a la SRtP) (Deg2/3/4)	FR1.1 FR2.3

[4] Note: The MASS WG at MSC 106 agreed, in principle, to the goal.

.3 restricted use of combustible materials;	The fire fuel load shall be minimised/controlled to reduce the intensity/escalation of a fire	As per a SOLAS ship	FR1.1
.4 detection of any fire in the zone of origin;	Fires need to be detected in order to initiate a response	As per a SOLAS ship - Addressable system to be provided (Deg 3/4) - Detection should initiate fire-fighting (Deg 3/4)	FR1.1 FR2.4
.5 containment and extinction of any fire in the space of origin;	Fires need to be segregated and contained in order to implement effective fire fighting measures	Exceed a SOLAS ship - firefighting to be effective in all (likely) compartments/open deck spaces (Deg 3/4) - firefighting shall be effective to guarantee extinction - Use of inert gas to prevent fires may be considered (including risks of using)	FR1.1 FR2.5
.6 protection of means of escape and access for fire-fighting;	Critical systems (people) need to be protected to enable effective firefighting to be implemented and survivial of the system (people)	As per a SOLAS ship - Critical functions/systems may need to be protected (a la SRtP) (Deg2/3/4) - Fire-fighting access for onboard/offboard responders shall be possible (incl. communication with ROC) (Deg 3/4)	FR1.1 FR2.3 FR2.6
.7 ready availability of fire-extinguishing appliances; and	Fires need to be able to be promptly and readily dealt with	Exceed a SOLAS ship - Fire fighting to be automated (Deg 3/4) - Manual appliances to be maintained to assist offboard/onboard responders (Deg 3/4)	FR1.1 FR2.6

.8 minimization of possibility of ignition of flammable cargo vapour.	Fire or explosions due to flammable vapours need to be prevented	As per a SOLAS ship (tanker)	FR1.1
Additional MASS Objectives (Derived)			
.9 automated fire fighting and by-products should not endanger persons onboard or off-board responders or vessel safety (propulsion, stability)	safety of life/vessel should not be compromised by automatic activation of fire-fighting systems Shutdown and isolation of systems for fire fighting should not damage them or endanger the vessel	Compartments with automated systems/inert gas should be access controlled onboard /gas/smoke should be managed Alarms/indicators/warnings should be provided where systems have been activated	FR1.2 FR2.7
10. onboard/remote intervention/control/isolation of firefighting systems should be possible	Onboard/remote responders may need to take control of fire-fighting systems for maintenance and/or fire fighting	Local control panels/remote control panels should be provided to enable management of firefighting response system isolation should be possible for access/maintenance	FR1.3 FR2.6
11. Assessment of fire-fighting effectiveness and completion (extinction) should be possible	An operator should understand whether fire-fighting systems are working and whether a fire has been extinguished	Fire protected systems should be provided to enable fire-fighting response to be measured (camera, temperature gauge,..)	FR1.4 FR2.8
12. An appropriate fall back state should be achieved during and following a fire	The vessel should not become uncontrollable during a fire or following a fire and fall-back safeguards should be protected and remain available Systems should be put into a safe state	Communication shall be maintained Fall back state to be identified and achieved Re-start/recovery/maintenance of fall back state to be achieved post fire (does not necessarily mean propulsion)	FR1.5 FR2.10 FR2.11

*Note: The MASS WG at MSC 106 agreed, in principle, to FR 1.1 to 1.3, the remaining high-level FRs had not been considered and thus kept in square brackets. Further, t*he MASS WG at MSC 106 agreed, in principle, to FRs 2.6 and 2.7, the remaining specific FRs had not been considered and thus kept in square brackets.

High-level functional requirements

[For the purpose of this section, MASS means …]

FR1.1: A MASS should comply with all relevant SOLAS fire safety requirements as modified by the specific Functional Requirements below.

FR1.2: The use of [additional] automated[autonomous]/[remotely-controlled] fire-fighting systems should not endanger the safety of persons on board or of the ship.

FR1.3: Onboard [and remote] management of automated[autonomous] fire-fighting systems should be provided to enable control and isolation of the systems.

[FR1.4: Means shall be provided to enable the assessment of fire-fighting effectiveness and fire extinction.

FR1.5: A MASS shall remain under control during and following a fire event.

FR1.6 The use of automated [autonomous] systems shall not prevent the effective prevention, detection, containment and extinction of fires on board nor the maintenance of effective control during and following a fire event.

FR1.7: ….]

Specific functional requirements

[FR2.1: Isolation of compartment boundaries shall occur automatically [autonomously] to enable effective fire fighting.

FR2.2: Shutdown and isolation of systems shall occur automatically [autonomously] to enable effective fire-fighting, however this should not damage them or endanger the vessel further.

FR2.3: Critical systems for maintaining appropriate control of the vessel shall be protected from foreseeable fire events.

FR2.4: Fire detection shall be provided in all compartments and open deck areas to enable onboard and remote understanding of the fire, where appropriate this shall initiate automatic [autonomous] fire-fighting measures.

FR2.5: Effective fire-fighting measures are to be provided in all compartments/open deck areas where there is a fire-fighting hazard which are able to extinguish a sustained fire of the type likely to be expected in that space/area. These may be active or passive.]

FR2.6: Provision should be made to enable fire-fighting control and response to be undertaken on board by an external responder. This should include provisions for establishing communications with the remote operating centre and a response to a fire on board.

FR2.7: The fire-fighting media and by-products of any automated [autonomous]]/[remotely-controlled] fire-fighting system should be managed so that they do not present an increased risk to the safety of persons on board or of the ship.

[FR.2.8: Automated [autonomous] fire-fighting systems shall be able to be safely isolated for compartment access or maintenance and shall provide onboard indication and warning of activation.

FR2.9: Management of a fire event shall be possible from the remote operating centre and the operator shall be provided with sufficient information to understand the scale, impact, response and success of the fire and fire-fighting measures.

FR2.10: An appropriate level of communication between the MASS and the remote operating centre shall be maintained during and following a fire event.

FR2.11: Upon identification of a fire event the MASS shall enter an appropriate fall-back state and be capable of maintaining that state during and following the fire event to the degree necessary to prevent it becoming a hazard. Post fire capability shall be determined by the Owner.

FR2.12: ….]

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ANNEX 3

VOLUNTEERING MEMBER STATES AND ORGANIZATIONS WITH OBSERVER STATUS* FOR THE DEVELOPMENT OF SELECTED SECTIONS OF THE DRAFT NON-MANDATORY GOAL-BASED MASS CODE (MSC 106/WP.8, ANNEX 2)

Section of the MASS Code	Volunteering State and/or organization	Lead State or organization
Part 3, section 1: **Navigation**	Bahamas, China, France, India, Japan, Republic of Korea, Russian Federation, Saudi Arabia, Singapore, Spain, United States, United Arab Emirates, ICS and the Nautical Institute, INTERTANKO, WMU	tbc
Lookout function:	Finland, Spain and EC	tbc
Part 3, section 2: **Remote operation**	Bahamas China, France, India, Japan, Republic of Korea, Russian Federation, Singapore, Saudi Arabia, United States, United Kingdom, United Arab Emirates, IMCA and INTERTANKO, WMU	tbc
Part 3, section 3: **Communication**	China, Russian Federation, United Arab Emirates, ICS, ITF and WMU	tbc
Part 3, section 4: Subdivision, stability and watertight integrity	EC and BIMCO	tbc
Stability	EC	
Part 3, section 5: **Fire protection/safety**	Norway, Spain and United Kingdom	tbc
Part 3, section 6: **Life saving appliances and equipment**	Canada and United States	tbc
Part 3, section 7: **Management of safe operations**	Denmark, [Germany], Sweden, BIMCO and IMCA, WMU	tbc
Part 3, section 9: **Security**	Republic of Korea, Spain and IMCA	tbc
Part 3, section 10: **Search and rescue**	Spain, ICS and IMCA	tbc
Part 3, section 11: **Cargo handling**	BIMCO and IPTA	tbc
Part 3, section 12: **Personnel safety and comfort**	Philippines, United Kingdom and Nautical Institute and ITF	tbc
Part 3, section 13: **Towing and mooring**	Canada	tbc

Part 3, section 14: **Marine engineering/Machinery installations**	Australia, Canada and United States	tbc
Part 3, section 15: **Electric and electronic engineering/ Electric Installations**	Australia, Canada and United States	tbc
Part 3, section 16: **Maintenance and repair**	Australia and Canada	tbc
Part 3, section 17: **Emergency response**	Denmark, [Germany], Republic of Korea and Sweden	tbc

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ANNEX 4

CONSIDERATION OF DOCUMENTS KEPT IN ABEYANCE AS PART OF THE OUTCOME OF THE REGULATORY SCOPING EXERCISE

Document	Summary	Recommendations to be further considered by CG
MSC 102/5/2 IFSMA	the role of the shipmaster, which was identified as a common potential gap during the regulatory scoping exercise of the Maritime Safety Committee on Maritime Autonomous Surface Ships (MASS), its relevant to UNCLOS Article 94 (Duties of a flag State), IMO Convention, Article 1), Responsibilities of the shipmaster COLREG, SOLAS chapter V and STCW	IFSMA advised it'd be best considered by the MASS-JWG and taken into account by the int. CG
MSC 102/5/14 Russian Federation	the need for a deterministic approach in interpreting the current version of COLREG 1972 regulations for the purpose of MASS automatic collision avoidance.	Yes
MSC 102/5/16 CMI	identifies horizontal legal issues relevant to the instruments under the purview of the Maritime Safety Committee such as: 1. terms and definitions; 2. safety of manning, training and certification; 3. preventive measures, emergency arrangements and related procedures; 4. ships' bridge and human presence requirement; 5. control and communication requirements; and 6. documents and certification.	Yes
MSC 102/5/28 IMSO	It provides Comments on document MSC 102/5/1 – Potential gaps and themes regarding connectivity, cybersecurity and the implication of MASS on search and rescue	No IMSO to provide relevant input as and when appropriate directly to the MASS CG/WG
MSC 103/5/7 Russian Federation	This document comments on document MSC 102/5/14 (Russian Federation) on the legislative matters of the Russian Federation concerning the MASS operation.	No, it has been partially covered in RSE as common potential gaps and/or themes. The other part related to liability insurance concerning the

		risks involved in operation of autonomous ships should be covered by LEG; MSC 106 requested to refer this document to LEG 110
MSC 103/5/8 Russian Federation	This document is to inform IMO on the experiment on autonomous ship trials carried out in the Russian Federation.	No. However, it may contribute in further improvement of "MASS TRIALS– MSC.1/Circ.1604" which is considered to be as an annex to MSC 106/WP.10
MSC 103/5/10 Russian Federation	The documents suggests a remote control station (RCS) should be considered equivalent to a navigation bridge and central control station under the relevant SOLAS provisions, but the RCS is located outside the autonomous ship and has a high degree of control automation	Yes

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ANNEX 5

DRAFT ROAD MAP FOR DEVELOPING A GOAL-BASED CODE FOR MARITIME AUTONOMOUS SURFACE SHIPS (MASS)

SESSIONS OF MSC	WORK PLAN
MSC 107 (June 2023)	○ Consideration of key principles and common understanding of the purpose and objectives for the new instrument - If necessary, continue: ○ consideration of common potential gaps and/or themes identified during the Regulatory Scoping Exercise (RSE) (MSC.1/Circ.1638, section 5) ○ consideration of glossary/terminology ○ identifying issues for possible consideration by a Joint MSC/LEG/FAL Working Group (JWG) - Continue the development of the non-mandatory MASS Code, including High priority items (MSC.1/Circ.1638, paragraphs 6.11.1 to 6.11.3), include but are not limited to: ○ consideration, together with relevant documents, whether to amend the definition for MASS and degrees of autonomy (including the respective definition) ○ meaning of the terms master, crew or responsible person ○ remote control station/centre ○ determination of the remote operator as a seafarer; as well as to: ○ continue to review the scope and framework ○ develop provisions for a goal-based instrument, taking into account the input from sub-committees, as appropriate - Commence development of glossary/terminology, taking into account any input from the MASS-JWG 2, to be further developed throughout the process of drafting ○ development should take into account previous submissions made to the Committee - Continue consideration of the scope and framework of the mandatory and/or non-mandatory instrument to be developed - (including structure of instrument, areas it should encompass, parts/chapters, etc.) for a goal-based instrument (MASS Code) and other associated non-mandatory instruments - In the process of developing provisions, consider the impact and identify changes to existing IMO instruments and make recommendation on how to address the changes to those instruments, as appropriate, also taking into account any recommendations from the Joint

	MSC/LEG/FAL Working Group (JWG). In doing so, the necessary amendments should focus on those classified as "High-priority"[1] during the RSE: ○ SOLAS chapters II-1, II-2, III, IV, V, VI, VII, IX, XI-1 and XI-2; ○ COLREG; ○ STCW Convention and Code; ○ STCW-F Convention; ○ 1966 LL Convention and 1988 Protocol thereto; ○ 1979 SAR Convention; ○ FSS Code; ○ IMSBC Code; ○ IMDG Code; ○ TONNAGE 1969; ○ IBC Code; and ○ IGC Code - Consider the involvement of sub-committees[2] and ○ initiate overall coordination with other committees ○ liaise with other international organizations such as ILO, ISO, IHO, IALA and IMSO - Update this road map
MSC 108 (1st half 2024)	- If necessary, continue: ○ consideration of common potential gaps and/or themes ○ consideration of glossary/terminology ○ identifying issues for possible consideration by a Joint MSC/LEG/FAL Working Group (JWG) - Continue the development of the non-mandatory MASS Code ○ continue to review the scope and framework ○ develop provisions for a goal-based instrument, taking into account the input from sub-committees, as appropriate - Decision on the means to adopt the mandatory instrument (Code): implementation through one Convention or through several conventions. If needed, develop amendments to existing instruments necessary for the entry into force of the new instrument and need to be approved and/or adopted at the same time as the new Code - continue consideration of any subsequent amendments to other existing IMO instruments, impacted by the entry

[1] Medium and low priority instruments in accordance with the outcome of the RSE will be dealt with at a later date (MSC.1/Circ.1638, paragraphs 6.8.1 to 6.9.3).

[2] Tasks for the sub-committees will be included in this road map when agreed by the Committee.

	into force of the new Code, including the *Interim Guidelines on MASS Trials* (MSC.1/Circ.1604) - finalize the non-mandatory MASS Code as annex to a draft MSC resolution - Consider the procedures for amending existing IMO instruments o consider whether amendments to those instruments could be done under the existing output, or whether there is a need for the MASS Working Group to develop new outputs for this work - Update this road map
MSC 109 (2nd half 2024)	- Finalization and adoption of the new non-mandatory MASS Code - Finalization of the draft mandatory MASS Code, based on the approved non-mandatory MASS Code - Finalization and approval of amendments to existing instruments necessary for the entry into force of the new instrument - Continue the review of existing IMO instruments, under the purview of MSC, with a focus on those classified as "High-priority" during the RSE - Identification of future work o consider whether a new output would be needed, or the existing output should be amended - Update this road map
MSC 110 (1st half 2025)	- Adoption of a mandatory MASS Code[3] [4] and associated Convention(s) giving effect to the new MASS Code - Adoption and/or final approval of amendments to existing instruments necessary for the entry into force of the new instrument - Finalize the review of existing IMO instruments with a focus on those classified as "High-priority" during the RSE; and agree on remaining future work and the way forward.

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[3] Adoption should take into account the progress made by other Committees and the JWG, if established.

[4] Entry into force date of 1 January 2028 means adoption on 1 July 2026 at the latest (first half of 2026).

ANNEX 6*

DRAFT TERMS OF REFERENCE FOR THE MASS CORRESPONDENCE GROUP

The Correspondence Group, under the coordination of the Marshall Islands, taking into account the comments and decisions made at MSC 105, is instructed to:

.1 consider key principles and common understanding of the purpose and objectives for the new instrument;

.2 continue the development of the non-mandatory goal-based MASS instrument (MASS Code), based on annex 1 to document MSC 106/WP.8 ~~commence the development of the non-mandatory goal-based MASS instrument (MASS Code)~~, taking into account the example and associated guidance in annex 2 to document MSC 106/WP.8 , as well as potential gaps and themes identified, the scope and framework of the non-mandatory code, as well as documents MSC 105/7/2, MSC 105/7/3, MSC 105/7/6, MSC 105/7/7, MSC 105/7/8 and MSC 105/7/9;

.3 consider also, as part of the work under sub-paragraph .2, documents MSC 102/5/14, MSC 102/5/16 and MSC 103/5/10, taking also into account document MSC 102/5/2 and ISO/TS 23860;

.4~~3~~ consider the common potential gaps and/or themes identified during the Regulatory Scoping Exercise (RSE) (MSC.1/Circ.1638, section 5), focusing on the high priority items (MSC.1/Circ.1638, paragraphs 6.11.1 to 6.11.3);

.5 ~~4~~ if time permits, develop MSC MASS WG positions on the following points with the intention that these are submitted to a Joint MSC/LEG/FAL Working Group in the future, (MSC.1/Circ.1638, paragraphs 6.11.1 to 6.11.3), which include, but are not limited to:

.1 consideration, together with relevant documents, whether to amend the definition for MASS and degrees of autonomy (including the respective definition);

.2 meaning of the terms master, crew or responsible person;

.3 remote control station/centre; and

.4 determination of the remote operator as a seafarer,

and advise on a way forward in addressing them;

.6 ~~5~~ limit the development of the non-mandatory MASS Code to cargo ships with a view to consider the feasibility for application to passenger ships at a future stage;

.7 keep the list of Volunteering Member States and organizations with observer status for the development of selected sections of the draft non-mandatory goal-based MASS Code under review and update it (MSC 106/WP.8, annex 3); and

.8 ~~6~~ submit a written report to MSC 107.

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* *Note: The grey-shaded text indicates the changes to the terms of referenced approved by MSC 105 (MSC 105/20, paragraph 7.31)*