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| IALA Guideline |

Gnnnn

[iala guideline on developments and implications of maritime autonomous surface ships for coastal authorities]

Proposed Table of Contents

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|  |  |  |
|  |  |  |

1. Introduction 6

1.1. Background 6

2. Aims and Objectives 6

3. Developments in MASS 7

3.1. IMO’s Strategic Approach to MASS 7

3.2. IALA and MASS 8

3.3. Review of MASS related Documents 9

3.3.1. Existing high-level documents 9

3.3.2. Other documents 10

3.3.3. Conclusion 11

4. Considerations for MASS 11

4.1. Management of MASS vessels 11

4.1.1. Regulatory Aspects 11

4.1.2. Allocation and Rules of Test Areas 12

4.1.3. Changes to National Laws 12

4.2. Operational aspects 13

4.3. Environmental Considerations 16

4.3.1. Health and Safety 16

4.4. Risk Management and Assessment 16

4.4.1. Risk Management Assessment prior to MASS 16

4.5. Maintenance of MASS and Equipment 18

4.6. Portrayal of MASS 19

4.6.1. On ECDIS/radar/charts/ the ship itself (lanterns, aka submarine) 19

4.6.2. Designated routes on charts 19

4.6.3. MASS developments in IHO 19

4.7. Situational Awareness 19

4.7.1. Resilience of position 21

4.7.2. Data interpretation 21

4.7.3. Monitoring and Control 22

4.7.4. COLREGS 23

5. MASS Systems 23

5.1. Navigation Systems 23

5.1.1. Functional objectives 23

5.1.2. Performance requirements 23

5.2. Communication Systems 24

5.2.1. GMDSS Requirements 25

5.2.2. Communications For Control System Monitoring and Input 25

5.2.3. RF Communications Installation 25

5.3. Cyber Security 26

6. Testing and Auditing of MASS 26

7. MASS Operations 26

7.1. Remote Control Centres 26

7.1.1. Sub-System Architecture 27

7.1.2. Tasking Cycle of the MASS 27

7.1.3. Responsibility of the RCC Operator Within an Operational Hierarchy 27

7.1.4. Transfer of Mass Control 28

7.1.5. Controlling Mass from an RCC 29

7.1.6. Relationship Between Autonomy Levels of Control and RCC 30

7.1.7. Suggested RCC Operational Requirements 30

7.1.8. Working Within Pilotage Waters 31

7.1.9. Managing RCC Workforce Wellbeing 31

7.2. MASS interaction 32

7.3. Rendering assistance 33

7.3.1. Requirements of International Law 33

7.3.2. Applicability to Mass Operations 33

7.3.3. MASS Remote Controller Task Requirements 33

7.4. Salvage and Towage 34

8. Considerations for Provision of MAtoN in a Mass Environment 34

8.1. Delivery of AtoN for MASS Environment 34

8.2. [other?] 35

9. Considerations for Provision of VTS in a MASS Environment 35

9.1. [from VTS Committee] 35

9.2. 35

10. Implications of MASS and IALA Committees 35

11. MASS and IHO 35

12. [other?] 35

13. DEFINITIONS 35

14. abbreviations 35

15. references 35

16. Further reading 36

List of Tables

# 

Table 1 Example of table with row headers 5

Table 2 Example of table with column headers 5

List of Figures

Figure 1 Example of wrapping in line with text 4

Figure 2 Example of wrapped square 5

Figure 3 Example of how to achieve right justified equation number 7

# Introduction

Maritime Autonomous Surface Ships (MASS) is defined by the International Maritime Organization (IMO) as being:

*A ship which, to a varying degree, can operate independently of human interaction.*

There are ongoing discussions and trials surrounding MASS and some of these are being conducted by non-traditional operators. It is imperative that IALA takes note of and support these initiatives to ensure that the marine Aids to Navigation (AtoN) environment is and remains fit for purpose as the MASS technologies advance and that MASS operators implement systems that utilise these AtoN services.

## Background

The development of MASS has continued at a very significant pace over the last few years with more MASS entering operations all the time. They come in a variety of sizes and have a very diverse set of operational capabilities which all place their own unique demands on those who own and operate them and the remainder of the Maritime Community.

The Maritime Safety Committee (MSC) of IMO, at its 103rd session (5 to 14 May 2021), approved the Outcome of the regulatory Scoping Exercise (RSE) for the use of MASS.

In the discussions at IMO it was noted that MASS could be operating at one or more degrees of autonomy for the duration of a single voyage.

During an IALA workshop on MASS it was identified that non-SOLAS i.e. less than 300 GT or less than 24 metres in length vessels are already operating at level 3 and level 4 in some parts of the world either in trials or for purposes such hydrographic survey and or other data acquisition e.g. Metocean.

Both physical and electronic AtoN have a significant role to play in the MASS domain as this matures.

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The aim of this guideline is to provide guidance to IALA members and other stakeholders who may be undertaking testing and trials of MASS systems. This guideline also provides guidance for organisations implementing policy, procedures and technical solutions to support the introduction of MASS, recognising that fact that MASS vessels include smaller vessels as well as large vessels.

Specifically, the

2. Trials or
3. Operations of MASS systems
4. Identify developments and need for certification, testing, and performance standards (approval process by authorities for use),
5. Identify aspects for shore side infrastructure to support MASS such as Shore side support (communications, control centre, etc.); VTS to MASS Communication; VTS support for MASS;
6. Provide guidance for organisations implementing policy, procedures and technical solutions to support the introduction of MASS;
7. and
8. Identify the future requirements on AtoN service.

# Developments in MASS

The development of MASS will bring about change to shipping, port operations and the safety of navigation. It is important to assess and discuss its impact on IALA related services at an early stage of its development.

IALA has been monitoring the development of MASS and some work on guidance documents has been initiated.

To integrate new and advancing MASS technologies into the regulatory framework, IMO have created a framework for MASS developments for the purpose of a scoping exercise on regulations (MSC 100 – 2018). Equally, evolving MASS technologies will impact the works of IALATo develop a regulatory framework for MASS and MASS-related infrastructure on the relevant Marine Aids to Navigation including VTS, IALA is continuing to consider MASS operations from the technological level, as well as the regulatory level.

## IMO’s Strategic Approach to MASS

IMO's [Strategic Plan](http://www.imo.org/en/About/strategy/Pages/default.aspx) (2018-2023) (IMO Resolution A.1110(30) adopted December 2017) has a key Strategic Direction to "Integrate new and advancing technologies in the regulatory framework". This involves:

* balancing the benefits derived from new and advancing technologies against safety and security concerns,
* assessing the impact on the environment and on international trade facilitation,
* assessing the impact on personnel, both on board and ashore.

MSC 98 (June 2017)) noted that the maritime sector was witnessing an increased deployment of MASS to deliver safe, cost-effective and high-quality results. Significant academic and commercial research and development (R&D) was ongoing on all aspects of MASS, including remotely controlled and autonomous navigation, vessel monitoring and collision avoidance systems. It was then agreed at MSC 98 to include the issue of marine autonomous surface ships (MASS) on its agenda and that this would be in the form of a scoping exercise to determine how the safe, secure and environmentally sound operation of MASS may be introduced in IMO instruments.

Although technological solutions were being developed and deployed, delegations were of the view that there was a lack of clarity on the correct application of existing IMO instruments to MASS. Following consideration, MSC 98 agreed to include in its 2018-2019 biennial agenda an output on "Regulatory scoping exercise (RSE) for the use of Maritime Autonomous Surface Ships (MASS)" with a target completion year of 2020.

At MSC 99 (May 2018), the Committee started to develop a framework for the RSE and defined the aim, the objective, the preliminary definition of MASS and degrees of autonomy, the list of mandatory instruments to be considered and the applicability in terms of type and size of ships.

MSC 100 (December 2018) approved the framework for the RSE.

* The aim of the RSE was to determine how safe, secure and environmentally sound MASS operations might be addressed in IMO instruments.
* The objective of the RSE on MASS conducted by MSC was to assess the degree to which the existing regulatory framework under its purview might be affected in order to address MASS operations.

For the purpose of the RSE, "MASS" was defined as “a ship which, to a varying degree, can operate independent of human interaction”.

To facilitate the process of the RSE, the degrees of autonomy were organised as follows:

1. Degree 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.
2. Degree 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. MSC.1/Circ.1638 Annex, page 4
3. Degree Three: Remotely controlled ship without seafarers on board: The ship is controlled and operated from another location. There are no seafarers on board.
4. Degree Four: Fully autonomous ship: The operating system of the ship is able to make decisions and determine actions by itself.

The degrees of autonomy listed above does not represent a hierarchical order. It should be noted that MASS could be operating at one or more degrees of autonomy for the duration of a single voyage.

*Note*: It is important that IALA, in general, does not use the degrees of autonomy listed above as the basic structure in IALA MASS publications, as they are expected to be changed, or even removed in the forthcoming IMO MASS process, with discussions commencing at MSC 105.

MSC 101 (June 2019) approved Interim guidelines for MASS trials (IMO MSC.1/Circ.1604). Among others, the guidelines indicate that trials should be conducted in a manner that provides at least the same degree of safety, security and protection of the environment as provided by the relevant instruments. Risks associated with the trials should be appropriately identified and measures to reduce the risks, to as low as reasonably practicable and acceptable, should be put in place.

It is important to recognise that an autonomous vessel does not mean an unmanned vessel: an autonomous vessel may still be manned.

At the MSC 103 (May 2021), the *Outcome of the regulatory Scoping Exercise for the use of Maritime Autonomous Surface Ships (MASS) was approved*, which provides the assessment of the degree to which the existing regulatory framework under purview of the MSC might be affected to address MASS operations. It further provides guidance to the MSC and interested parties to identify, select and decide on future work on MASS and, as such, facilitate the preparation of requests for, and consideration and approval of, new outputs.

Member States and international organizations were invited to take the annex into account when proposing future work on MASS for consideration by the MSC and bring it to the attention of shipowners, operators, academia and all other parties concerned.

The key result was to develop an international code for MASS (similar to Polar code), then work on common gaps and themes, plus further cooperation amongst various committees with MASS tasks (Legal Committee (LEG) and Facilitation Committees (FAL)).

MSC 104 decided to establish an agenda item for developing a goal-based MASS instrument, and then at MSC105 (April 2022) commence work with a roadmap for further work (up until 2025) and a non-mandatory MASS code (with a view to adoption in 2024) to be followed by a mandatory MASS Codes (envisaged to enter into force on 1 Jan 2028).

## IALA and MASS

MASS operations cannot be viewed in isolation but as an addition to the broad range of vessel types and users in the current maritime domain. To this end the 2023 edition of the IALA Maritime Buoyage System (MBS) has been updated and states:-

“Current applications, marks and signals exhibited by AtoN as described in the MBS apply to all vessels, including MASS. MASS operate with varying degrees of autonomy and make use of AtoN based on level of autonomy and type of technology used. MASS may use AtoN described within the MBS and there may be developments of AtoN that are tailored specifically for MASS.”

IMO MSC.1/Circ.1604 states:

“An appropriate means of AtoN and for communications and data exchange, including redundancy, should be provided for the safe conduct of any MASS trial.”

IALA is considering MASS as the operational, technological and regulatory level.The establishment of safe and secure environments in which MASS can operate can be assisted through the provision and adaption of AtoN, beneficial to MASS operations.

MASS operations rely on digital data exchange capabilities, including developments in the VHF Data Exchange System (VDES), International Mobile Technologies (i.e. 4G and 5G), digital VHF Voice and satellite technologies .

IALA provides guidance on AtoN that should be used to support MASS operations within this complex environment, including, but not limited to the:

1. provision of AtoN: fixed and floating shore side electronic AtoN, , virtual AtoN, marking of physical AtoN using Synthetic AtoN
2. transmission information: AtoN information, MSI, Meteorological and Hydrographic data (using Application Specific Messages (ASM) contained in IMO Circular SN.1/ 289 or other systems as may be developed)
3. support of safe and efficient operations within both national and international waterways
4. provision of VTS: communication between vessels within and outside of a VTS environment, recognising the different degrees or levels of autonomy; monitoring and sharing of a common operating picture for situational awareness of the waterway within and outside of Vessel Traffic Services (VTS) environment; interaction between VTS and Remote Control Centres (RCC) for MASS.

consideration of reliable and secure systems:

1. cyber security and management of cyber risk; augmentation of positioning systems; requirement for and promotion of standardisation of data transfer

## Review of MASS related Documents

As for other technologies, there is a compelling need for MASS equipment and functionalities to be tested, verified and validated and certified under the application of performance standards. However, as automation and increasing levels of autonomy in utilized systems are leading to higher complexity, for example by using methods from artificial intelligence, existing conventional standards are no longer applicable. Currently, several organizations have started to work on re-evaluating existing documents and drafting new standards and guidance documents for the usage in certification processes.

### Existing high-level documents

Existing “high-level” documents, that may still be relevant in new processes for the certification of MASS equipment are:

* SOLAS - International Convention for the Safety of Life at Sea (currently not fully applicable to MASS due to requirements regarding personnel etc.)
* STCW – Only partially related to MASS for certification of personnel
* COLREGS – (applicable to the control / navigation of the Autonomous ship – however, currently includes some “soft” definitions such as “safe speed” or “restricted visibility”, that may not be clearly enough defined for implementation in an autonomous system. (cf. <https://www.researchgate.net/publication/336786127_Maritime_Autonomous_Surface_Ships_MASS_and_the_COLREGS_Do_We_Need_Quantified_Rules_Or_Is_the_Ordinary_Practice_of_Seamen_Specific_Enough> )
* ISPS Code - International Code for the Security of Ships and of Port Facilities (generally applicable, but might be relevant regarding cyber security and also needs to be assessed when dealing with unmanned ships).
* IMO A.694(17): General Requirements for Shipborne Radio Equipment Forming Part of the Global Maritime Distress and Safety System (GMDSS) and for Electronic Navigational Aids - resolution -> Generally applicable for electronic Navigational Aids (mainly Hardware)
* IMO A.1047(27): “Principles of Minimum Safe Manning” already takes automation into concern and may be relevant for higher degrees of autonomy.

### Other documents

An extensive overview of requirements for the certification of MASS systems is given in *DNVGL-CG-0264 Edition September 2018: Autonomous and remotely operated ships – Extensive Guideline for the certification of Autonomous Systems on vessels including their engineering and design process*. From the perspective of IALA, the following aspects need to be considered for the development of AtoNs, VTS and Maritime Services in the context of e-Navigation (emphasis added):

* “It shall be possible to plan the intended voyage in advance, taking into consideration all **pertinent information** and make a passage plan.” (p.53)  Relevant for Information Services for MASS (cf. MS in the context of e-Nav)
* “It shall be possible to detect **all external objects of interest** for safe navigation, such as ships, **buoys and lighthouses** in any direction when the vessel is pitching and rolling.” (p.54)
* “It shall be possible to detect and recognise lights and shapes as described in COLREG Part C, and sound and light signals as described in COLREG Part D.” (p.54)
* “Any systems provided for detection of hazards to navigation above the water surface should be able to provide essential information supporting collision avoidance and safe navigation based on the requirements for lookout and horizontal and vertical field of vision described in [3.1.1]. Typical hazards include other vessels, aids to navigation, small unlit boats, floating logs, oil drums, containers, buoys, ice, hazardous waves, etc., thus the size, colour and material of the object are parameters to be considered.” (p.57)

Further requirements are mentioned in the considered document on the topics of:

* Communication Link to VTS (p. 92 / p. 93)
* Situational Awareness in RCC (p.58 ff.)
* RCC Workstation for voyage planning (p. 61)
* RCC in general (p. 83 ff.)

It is also mentioned that new functionalities for which no IMO performance standards exist to the current point in time, “compliance with IMO recommendations on general requirements for GMDSS and electronic navigational aids - resolution A.694(17) - and the appurtenant test standard IEC 60945 or similar should be the minimum applied” (p. 105).

Standards developed by International Electrotechnical Commission Technical Committee 80 (IEC TC 80) could be relevant for the certifying specific communication sub-functionalities of MASS equipment (see https://www.iec.ch/dyn/www/f?p=103:22:702902501236996::::FSP\_ORG\_ID,FSP\_LANG\_ID:1271,25 for an overview of related standards.

Further references to potentially related documents can be found in appendix X.

Finally, related standards that have been mainly applied in other domains may also contribute to a holistic approach for MASS certification. Especially ISO 26262, ISO/PAS 21448 SOTIF or ANSI/UL 4600 Standard for Safety for the Evaluation of Autonomous Products could be relevant.

### Conclusion

Firstly, it should be recognized that providing accurate methods for the validation, verification and certification of automated or autonomous systems are still actively being developed and new or adapted standards and guidance documents may emerge as a result of ongoing activities in the next years. Especially in the area of IALA, there is only very little guidance on how the shore-side support for MASS (radio beacons, AtoN provision, etc.), VTS-to-MASS communication or VTS support in general could be realized. Based on the discussion in the first section of this document, we recommend to either add a new sub-section to chapter 4 dealing with the challenges of MASS certification processes referencing the above-mentioned standards, guidance documents and their requirements or to extend the current sections (especially 4.1, 4.2, 4.3, 4.5, 5, 6.1, 6.2 and 7/8) with the provided information.

# Considerations for MASS

The services delivered using physical, electronic and virtual AtoN environments for each of the four degrees of autonomy identified by IMO could be different, noting that the MASS could change its level of autonomy depending on its area of operation. In addition, as identified in IMO Resolution A.893(21) vessels are required to plan voyages taking into account key factors.

Areas of operations (as identified in IMO MSC.1/Circ.1595) include:

* Port and Approaches
* Coastal waters and confined or restricted areas
* Open sea and open areas
* Areas with offshore and/or infrastructure developments.
* Polar areas
* Other remote areas

Consideration related to voyage planning (IMO Res. A.893(21) refers):

* Under ‘Appraisal’ – relevant permanent or temporary notices to mariners and navigational warnings; up-to-date sailing directions, lists of lights, AtoN information; available port information.
* Under ‘Planning’ – elements of safe navigation including safe speed, course alteration points, meteorology ahd hydrographic information, use of routeing and reporting systems and VTS,
* Under ‘Execution’ – conditions and changes in conditions (meteorological, traffic conditions, etc.)
* Under ‘Monitoring’ – provision of information to support safe navigation (provision to the RCC, MASS operator, etc.)

## Management of MASS vessels

[introductory text]

### Regulatory Aspects

The International

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## Operational aspects

IMO has produced Interim Guidelines for MASS Trials at IMO MSC Circ.1604 (“MSC 101/WP.8” dated 12 June 2019). These guidelines have been developed to assist relevant authorities and relevant stakeholders with ensuring that the trials of MASS related systems and infrastructure are conducted safely, securely, and with due regard for protection of the environment.

Taking into consideration that authorities may be unfamiliar with MASS operations and requirements, and an "‘Industry’ unfamiliar with the route to achieve all the necessary contacts and approvals, it may be prudent to commence with a series of “one-off” requests in order to develop an evaluation, authorisation and approval process to operate.

For MASS deployments, it will take a detailed process of review and selection by the ‘Operator’ to identify and match the necessary functional and operational requirements to the available water space and conditions needed.

To achieve a successful, authorised and approved MASS deployment, a number of relevant inshore to offshore ‘water space’ authorities may need to be consulted dependent on the area requirements and the extent of the evaluation tasking. The principal points of contact would most probably be the Harbour Masters (HM) and Inner Harbour Authorities.

Notice to Mariners and appropriate radio navigation warnings should be issued as appropriate.

During the planning phase of any MASS Operational deployment the following additional operators and or authorities should also be considered, and notification issued and or clearance obtained where relevant:

* Fishermen (Bulletin of intended ops);
* Offshore operators (i.e. Oil & Gas, and Renewable Energy operators/owners);
* Established local water sport leisure clubs and organisations;
* Other stakeholders with economical, safety or environmental interests in intended location.

In working to achieve the necessary approvals, it is expected that a suite of Health, Safety and Environment (HSE) documentation should be provided to support the mission and assure the relevant approving authorities that full consideration to the safety and risk management of the intended operation or evaluation trial has been completed. This may include a full HSE Plan, Launch and Recovery Risk Assessment, Emergency Recovery Plan and Procedure, and the outline Mission Plan and Method Statement. These documents would support the approval application and ensure all operations are conducted within the intent of the requirements to operate. It also provides proof of the application of Industry Best Practice and cognisance of the sensitivity and responsibility to societal acceptance of autonomous systems.

#### Personnel and Training

[Need to focus on training for IALA related aspects / note training for MASS operators. – input ref from DNV training programs?]

All personnel section XX).

#### Procedures for normal operations

#### Responding to Emergency Situations

#### Reporting Accidents

[refer to / update required for IALA G1118 – Marine Casualty / Incident reporting and recording, including near-miss situations as it relates to a VTS? Perhaps this guideline can be revised to include MASS incidents?]

All accidents

## Environmental Considerations

MASS operations (in the same way as non-MASS) need to respect any environmental designations applicable to the area in which the MASS operates. For example, Marine Protected Areas (MPAs) are designated in territorial waters to protect marine wildlife of national and international importance. These include Special Areas of Conservation (SACs), Special Protection Areas (SPAs), Sites of Specific Scientific Interest (SSSIs), the Ramsar Convention on Wetlands of International Importance Especially as Waterfowl Habitat **(**Ramsar) sites (if applicable) and Marine Conservation Zones (MCZs). A large proportion of estuaries, for example, would have one or more of these designations. Operating a MASS in designated areas, particularly at times of the year when there is the potential for disturbance to wildlife (e.g. migrating birds), may be an activity which requires assent from the relevant environmental or conservation authority and their advice should be sought.

### Health and Safety

The MASS industry’s activities and operations can have an impact on the health and safety of their employees, subcontractors and others working within it, both ashore and afloat. The industry has a responsibility to make sure it limits the potential for accidents to occur.

The Owner/Operator of a MASS is responsible for the health and safety of anyone working on or around the MASS. Regulations applicable to the health and safety of employees on or around the MASS, support crew and offices ashore, including Remote Control Centres (RCCs), should be taken into consideration. Complying with all relevant safety rules and procedures is an essential minimum.

Everyone within the industry has a responsibility for safety in the workplace and must be familiar with and comply with each company’s Health and Safety Policy and all local requirements and by thinking through the risks and hazards in our workplace and daily operating environment

Every employer is to be aware of any risks affecting workers and others and to ensure that appropriate measures are taken to minimise them through improving procedures or equipment where necessary. Employers must instruct those affected about the risks and how to ensure their own health and safety and the health and safety of others.

## Risk Management and Assessment

The international legal framework is currently not clear when it comes to MASS operations, including physically unmanned vessels, and today’s regulation entails certain potential limitations.

The possibilities within the framework are highly dependent on the safety measures of the specific project, the exact area to be operated in and the concepts of operation (CONOPS). Therefore, it is important for maritime administrations to get as much information on the projects as possible, in order to be able to find the best solutions within the legal framework.

For non-SOLAS ships the United Kingdom (UK) “Maritime Autonomous Ship Systems (MASS) Industry Conduct Principles & Code of Practice” is a good basis for assessment of the risks.

### Risk Management Assessment prior to MASS

An RMA prior to MASS becomes recognised as ordinary vessel traffic in international trade.

The IMO Regulatory Scoping Exercise have among others identified the following regulatory barriers on the compliance of MASS operations in regard to international regulation:

* COLREG Rule 5 (Proper lookout)
* STCW Section A-VIII/2, part 4-1, rule 14 (Proper lookout)
* STCW Section A-VIII/2, part 4-1, rule 18 (At no time should the bridge be left unattended)
* STCW Section A-VIII/2, part 4-1, rule 24 (Performing the navigational watch)
* STCW Section A-VIII/2, part 4-1, rule 32 (Performing the navigational watch)
* STCW Section A-VIII/2, part 4-1, rule 35 (Performing the navigational watch)

The above identified regulatory barriers or constraints should be taken into account when planning MASS activities.

In principle it is expected that any ship project involving increased automation or remote operation, and thereby not fully complying with the applicable Rules, should make use of the IMO MSC.1/Circ.1455 (Guidelines for the Approval of Alternatives and Equivalents as provided for in Various IMO Instruments), and the operations should be based upon the ISM-Code.

A Risk Assessment (RA) should be performed for the MASS to identify potential failures which could impact on safety through:

* Collision with fixed or floating objects;
* Grounding;
* Becoming a significant obstruction or hazard to other traffic;
* Leakage of noxious substances or other forms of pollution;
* Other potentially hazardous events or situations, which may depend on the type of MASS and how it is deployed and operated.

The RA should consider MASS systems, sub-systems, and components, and should take into account:

* The probability of a failure occurring, in measurable units, e.g. probability per 10,000 hours of operation, and the direct and indirect effects of the failure;
* Whether the MASS is capable of inflicting significant damage in a collision, by reason of its kinetic energy or its mass. Even at zero hull speed, a significant mass may cause damage by drifting onto, being blown by wind or thrown by waves onto another object or vessel.
* Whether the MASS is liable to become a significant obstruction to other traffic, if left to drift without propulsion or steering. This is governed by size and weight and operating area.
* Whether the MASS carries significant quantities of hazardous or pollutant substances.

If the consequence of failure identified in the RA are deemed acceptable then the single point failure modes need not be analysed further, depending the Code of competent authorities.

Failure modes to be considered in the Risk Assessment should encompass, but not necessarily be limited to, the following:

* Power management and distribution;
* Propulsion systems including the control of thrust and its direction;
* Steering systems including actuators and their control;
* Position Referencing Systems (PRS)
* Emergency response systems including shutdowns, firefighting systems (FM200, CO2, Foam, Water Mist)
* Electrical connectors;
* Fuel and hydraulic systems (potential fire, pollution, loss of control);
* Individual sensors and their power supplies;
* Individual actuators and their power supplies;
* Communication systems;
* The platform control system (including autopilots and Collision Avoidance systems);
* The autonomy processor(s), i.e. the interpretation and decision-making system which takes in sensor data and takes decisions on what control actions to take. This may be done on board, off-board, or as a combination of these;
* Signalling and lighting;
* Data quality or inconsistency.

The RA should be able to show that the MASS is able to be operated to a tolerably safe level, ideally proven to be as safe as an equivalent manned counterpart (i.e. similar size and carrying similar payload / cargo).

The protection measures afforded on a manned MASS, e.g. emergency engine stop in the case of fire, often rely on a human operator to detect the fault and to trigger the stop mechanism. On MASS, these measures must be fully automated unless the attendant risk can be otherwise reduced to an acceptable level (e.g. using electric propulsion, no fuel aboard; nobody on board put at direct risk; etc).

The RA should highlight all potentially critical failure modes which are mitigated using failure sensors and/or “defence in depth”, dual or multiple redundant safety features, as these need to be identified for the purpose of test and accreditation of the MASS.

## Maintenance of MASS and Equipment

[other input?]

A Maintenance Management System (MMS) is another important integral part of the MASS safety management regime.

Procedures need to be established to ensure that the MASS is maintained to conform with the provisions of the relevant rules and regulations and with any additional requirements which may be established by the Operator.

To ensure conformity to these requirements the Operator should ensure that:

* Inspections are held at appropriate intervals;
* Any non-conformity is reported, with its possible cause, if known;
* Appropriate corrective action is taken; and
* Records of these activities are maintained.

The equipment should be checked and tested in accordance with defined schedules produced by the Original Equipment Manufacturer (OEM) and operator procedures when in use. This is in addition to the tests referred to in the procedures to ensure safe operation of MASS in compliance with the Regulations and Rules of the ISM Code.

There should be procedures for a more detailed inspection and maintenance programme of the MASS and equipment, which may be conducted by an outside authority/classification society. The frequency of the inspections should be determined by the Operator in conjunction with the OEM Schedule and Classification Society/Professional Bodies requirements, but every event should be planned and recorded.

A checklist could be employed as an aide-memoire for the inspection of equipment.

The Operator should identify critical equipment and technical systems, which, if subject to sudden operational failure, may result in hazardous situations. The SMS should provide for specific measures aimed at promoting the reliability of such equipment or systems. These measures should include the regular testing of stand-by/ reversionary arrangements and equipment or technical systems that are not in continuous use.

The inspections mentioned, as well as the measures referred to, should be integrated into the MASS operational

MMS.

## Portrayal of MASS

MASS needs to be clearly defined and possibly to be observed as such. Other vessels should have the means for understanding the intention of a MASS manoeuvre.

### On ECDIS/radar/charts/ the ship itself (lanterns, aka submarine)

MASS will require updates in IMO, the International Electrotechnical Commission (IEC), the International Telecommunications Union (ITU) and the International Hydrographic Organisation (IHO) standards for displaying vessel information on radar/Electronic Chart Display and Information System (ECDIS) and designated symbols/ship codes/signals/lanterns must be developed.

For other vessels only observing the MASS visually, means for identification MASS status, including the level of autonomy, should be available. This might require signalling equipment/lanterns aligned with other International Regulations for Preventing Collisions at Sea (COLREG) signals, or additional signals that might be developed. Particular consideration should be given to MASS when navigating in areas with a mix of traffic, MASS and non-MASS vessels, including smaller crafts/non-SOLAS ships.

### Designated routes on charts

Should MASS vessels be treated differently than normal vessels?

In some congested waters it may not be possible to designate special routes for MASS vessels.

???

### MASS developments in IHO

## Situational Awareness

A situational awareness and control system for a MASS can include the onboard sensors and offboard information sources (audio and visual), communications links and control logic that allow the MASS to operate safely.

The goal of Situational Awareness and Control is to ensure that the MASS, and RCC when appropriate, have sufficient information, interpretation and control of its position and systems, to enable it to be as safe as a manned counterpart operating in similar circumstances. Any decision making that impacts safety and is performed by the MASS (i.e. independent of a human operator) should have been adequately demonstrated to be commensurate with that which a competent seafarer would correctly perform in the same circumstances.

It may be necessary to exert command and control over the MASS, in order to ensure its safe operation. In the case of a propelled and steered craft, this includes the ability to direct the MASS along a safe route at a safe speed. It also includes the ability to ensure that on-board systems are deployed in a safe manner, e.g. switching off or diminishing high power transmissions when they could cause harm to vulnerable systems or personnel nearby.

Operators, including RCC operators should be provided with adequate access, information and instructions for the safe operation and maintenance of the control system.

External sensors may be fitted to sense and/or measure the environment, surroundings, navigational data, and other platforms and systems, which may include, but not be limited to, the following:

* Global Navigation Satellite System (GNSS) (Lat/Long), with position integrity provided by Satellite Based Augmentation Systems (SBAS) and/or terrestrial Directional GNSS (DGNSS) beacons.

GNSS and, in particular, the US Global Positioning System (GPS), is pervasive across increasingly digital infrastructure, enabling positioning, navigation and timing (PNT) applications. The ease of implementation of GPS receivers, particularly for timing and synchronisation, has led to unknown dependencies across critical national infrastructure. It should be noted that GNSS are very vulnerable to interferences, such as jamming, spoofing and solar storms, and GNSS interference and resultant outages could result in large financial losses, both to a country and the shipping industry at large, hence the need for, especially for MASS, the inclusion of a complementary backup system for resilience against GNSS interference, jamming and spoofing;

* Heading (may be considered essential, unless operated at a range of less than 300m from a manned ground control station within Line of Site (LOS) and capable of commanding Emergency Stop);
* Sea state (may be measured using pitch and roll sensors);
* Wind speed and direction;
* Depth below keel;
* Radar targets, and automatic target tracking;
* Sound signals;
* Visual signals, such as shapes, carried by other vessels or navigational marks;
* VHF capability to receive and transmit messages;
* Relatively small floating objects that may reasonably be expected to be found in the area of operation.

Third party data feeds, including Notices to Mariners and other bulletins, may also be required, subject to their limitations, including:

* AIS data
* Weather forecast data
* Tidal almanac data.
* ENCs
* High resolution bathymetry
* Environmental Protected Areas
* Wrecks
* Cables
* Anchorage areas

### Resilience of position

A navigation system must be able to provide continuity of service; that is the determination of a vessel’s position, to an acceptable level of accuracy in all circumstances which may be encountered during the vessel’s intended operations.

Resilience should be delivered through the selection of sources of positional information which offer independent Primary, Tertiary and Backup sources of position. It should be accepted that a drop off in accuracy may be inevitable with the loss of higher tier sources of position, however the three tiers of position finding should enable the vessel to be safely navigated throughout the voyage in the event of disruption to two of the minimum three sources of positional information. It is prudent to consider the Primary and Tertiary sources in the context of maximising accuracy, while a Backup source should be that which provides the greatest resilience when used with the appropriate navigation techniques and processes.

By examining the sources and applicable navigation techniques and processes available during each of the stages of the vessels intended operations it should be possible to identify the most appropriate Primary, Tertiary and Backup sources of position, recognising that these may change based on the area and nature of the operation.

In more complex systems, the use of Inertial Navigation Systems (INS) to bridge the gap between disruptions and outages may be of benefit.

Although reference is made here to Primary, Tertiary and Backup sources of position finding it should be noted that this constitutes a minimum safe provision. A navigation system should make use of all available sources of position finding and periodically, at an interval appropriate to the proximity of navigational hazards, verify the veracity of the vessel’s position by reference to all available sources of information.

Resilience of position finding should be addressed by conducting a Position, Navigation and Timing Risk Assessment. The factors considered should include, but are not limited to:

* Required navigation accuracy during each stage of the vessels intended operations;
* The quality of navigation products, services or data supporting the generation of position finding, and the avoidance of grounding (for example the quality of survey data);
* The sources of position and time which are likely to be available during each stage of the vessels intended operations and their projected accuracies;
* The identification of the most appropriate Primary, Tertiary and Backup sources of position finding during each stage of the vessel’s intended operations, noting that these may change;
* The impact on the accuracy of navigation resulting from the loss of either Primary, Tertiary or Backup sources of position during each stage of the vessel’s intended operations;
* The method by which the degradation, denial or loss of an intended Primary, Tertiary or Backup source of position finding will be detected during each stage of the vessel’s intended operations;
* The action to be taken, during each stage of the vessel’s intended operations, following the detection of a degradation, denial or loss of a Primary, Tertiary or Backup source of position finding, noting that this may result in the consideration for an additional available source.

### Data interpretation

[revise to focus on IALA specific aspects?]

The MASS should have at least one of the following:

* The ability to interpret sensor data on board in a timely manner with regard to its impact on MASS safety and performance and to execute its responsibilities in accordance with COLREG and international law;
* The ability to transmit sensor data in a timely manner to an off-board system or human operator who can interpret the data with regard to its impact on MASS safety and performance; and to receive appropriate commands in response, in a timely manner.

Sufficient data from the sensors (internal and/or external) should be made available in a timely manner to a System which is capable of exerting control over the MASS, bringing it to a safe haven or away from a danger area when deemed necessary. The System, in this context, must include at least one of:

* A human operator working in an RCC;
* An on-board or remote automatic system;
* A distributed system comprising on-board and off-board elements, which may or may not include a human operator or supervisor, with appropriate communication links between them.

In order to interpret sensor data in regard to its impact on MASS performance, the System should be capable of determining or forecasting, by means of algorithms or data, as necessary to ensure safe operation:

* Safe operating limits for sensor data where applicable;
* Permitted geographic area(s) and time window(s) for MASS operation;
* Expected water depth in relation to geographic position and time;
* Expected water current or tidal stream speed and direction in relation to geographic position and time.

Where applicable and deemed necessary the MASS is to be capable of de-conflicting the data presented by different sources (e.g. navigational data and sensor data).

The System should be capable of taking operational decisions in accordance with the sensor data interpretation, in order to maintain the safety and integrity of the MASS, surrounding objects and personnel, and to pursue its mission subject to those safety considerations.

### and Control

[ensure this section focuses on IALA specific elements… include section on monitoring that for IALA elements]

The MASS should have the ability to be controlled by a Control System which may be an on-board, off-board system or human operator, or a distributed system involving one or more of these elements.

Control is typically a combination of high level and low-level functions and behaviours, which may be implemented in separate modules, such as the following examples:

* Sub-second control of a rudder actuator, with a feedback loop in order to control heading in response to Heading and Rate of Turn (ROT) set points;
* Following a sequence of waypoints by issuing Heading and ROT set points;
* Generating or selecting waypoints, and selecting which route to follow;
* Enabling waypoint-following, or superseding the mission controller with heading and speed set points calculated by a collision avoidance algorithm.

It should be noted that the MASS’s ability to transmit situational awareness data to an off-board controller has been covered in the previous Chapter. This, and the ability to receive appropriate and timely commands from the controller, should be borne in mind in cases where some of these functions are performed remotely.

The control functions, (on-board, remote, or distributed) should be capable of exerting timely and accurate control in such a manner as to maintain safety of (1) the platform; (2) surrounding persons, structures, ships; and (3) the environment.

### COLREGS

The Control System appropriate to the MASS level should be capable of operating in compliance with COLREGS.

The Control System may include a system or systems designed to sense and avoid obstacles. These obstacles may be fixed (e.g. coastline) or moving (drifting or other craft).

Sense and Avoid systems may be deemed necessary:

* When operating within LOS, as directed by area control authorities;
* When operating outside LOS.

# MASS Systems

[introductory text]

## Navigation Systems

The navigation system should be designed with a level of integrity sufficient to enable the UMS to be operated and maintained safely as and when required within its design or imposed limitations in all Reasonably Foreseeable Operating Conditions.

### Functional objectives

Navigational systems should identify all navigation hazards, fixed or mobile, and measure and interpret environmental data.

The MASS should be able to navigate to minimise risk of grounding, collision and environmental impact.

The MASS should be able to communicate its limitations and navigational intentions to other vessels.

The navigational systems should be designed and constructed to:

* 1. Enable their operation in all Reasonably Foreseeable Operating Conditions;
  2. Operate in a predictable manner with a level of integrity commensurate with operational and safety requirements;
  3. Meet requirements for watertight, weathertight and fire integrity;
  4. Minimise the risk of initiating fire and explosion; (e) Enable the maintenance and repair in accordance with the maintenance philosophy.

Additional systems or equipment not directly covered by this Chapter, should not affect the navigation systems. 3.1.5 Operators should be provided with adequate access, information and instructions for the safe operation and maintenance of the navigation system.

### Performance requirements

The navigation system should be designed and arranged to meet the required level of integrity established, considering the Autonomy Level, equipment type, function and the effect of flood or fire.

The MASS should be provided with sufficient sensors and systems to determine, display and record its present time, position, orientation and movement in relation to the earth and the rate of change of the parameters measured at an appropriate interval and accuracy to ensure safe navigation to its required level of integrity.

Ambient conditions should be controlled, where required, to suit the operating environment and the navigation system requirements

The MASS should:

1. Be provided with appropriate sensors and processing equipment to adequately measure, analyse, assess, display and record fixed and mobile hazards in its physical environment for the conduct of safe navigation.
2. Have a means to measure its depth (where applicable), direction and speed
3. Have a means to display its manoeuvring limitations.
4. Have a means to control its illuminated appearance.
5. Have a means to communicate with other vessels.
6. Have a means to alert other vessels that it is in distress.
7. Be fitted with systems in order to receive, transmit, record and analyse navigation data, in recognised formats, relevant to safe navigation, for the duration of the mission. These systems should be protected against unauthorised access.
8. Be able to exhibit, by day and night, in all weathers, appropriate lights and shapes in order to indicate size, orientation, activity and limitations so as to facilitate the determination of risk of collision by other mariners. The Operator is to be aware of the conditions in which the MASS is operating and which lights and shapes are being displayed at any time.
9. Be able to generate, by day and night, in all weathers, sound signals, in order to indicate its orientation, activity and limitations to facilitate the determination of risk of collision by other mariners. The Operator is to be aware of the conditions in which the MASS is operating and which sound signals are being broadcast at any time.
10. By day and night, in all weathers, should be able to detect the presence of nearby vessels, monitor their speed and direction and take measures as required to avoid a collision.
11. Always have sufficient power and a means of manoeuvring available to ensure proper control.

Any penetrations in watertight and weathertight boundaries due to the navigation systems should be designed, taking into the requirements of stability into consideration.

Equipment necessary for the safety of navigation should be capable of being safely accessed for the purpose of repair and routine maintenance.

Operators should be provided with adequate information and instructions for the safe and effective navigation of the MASS. These should be presented in a language and format that can be understood by the Operator in the context in which it is required.

It should be possible to disable and isolate the Navigation system to allow inspection and maintenance tasks to be safely performed on the MASS.

System diagrams and instructions should be provided for maintenance of the Navigation system in a language and format that can be understood

## Communication Systems

MASS will be heavily dependent on communications systems for control and monitoring of the MASS, irrespective of any existing regulatory requirements for carrying radio-communications systems.

RF communications requirements for MASS will include the following:

* Global Maritime Distress & Safety System (GMDSS) compatibility;
* Communications for Control System Monitoring and Input.

### GMDSS Requirements

The application of SOLAS Chapter IV (Radiocommunications) is to cargo ships of 300 gross tonnage and upwards on international voyages.

The Merchant Shipping (Radio Installations) Regulations (SI 1998 No. 2070) require cargo ships of 300 gross tonnage and upwards on domestic voyages to carry a GMDSS radio installation as described in the regulations. MASS of 300 gross tonnage and upwards should therefore comply with these regulations.

There are no requirements for ships under 300 gross tonnage, although any ship using the frequencies of the GMDSS are bound by the requirements of the ITU Radio Regulations.

The radio equipment to be carried depends on the capabilities of the MASS and the area of operation. The minimum and recommended radio equipment is given in Table 10-1.

The controller of the MASS while operating should, when practicable, be capable of receiving, interpreting and acting upon information transmitted via the following communications channels:

* Where practicable on VHF channel 16;
* On VHF DSC channel 70;
* If fitted with an MF installation, on DSC 2187.5 kHz;
* If fitted with a satellite installation, with enhanced group calling;
* For broadcasts of Maritime Safety Information e.g. by NAVTEX.

The controller of the MASS should hold a certificate of competence for distress and safety radiocommunications (e.g. GMDSS Short Range Certificate or Long Range Certificate as appropriate).

### Communications For Control System Monitoring and Input

RF Communications systems that are required to exercise the required Level of Control (LoC), or are necessary to enable the Emergency Stop functionality, should be provided with reversionary modes and backup energy supplies, the scope of which will depend on both the MASS Classification.

These reversionary modes and energy supplies should be considered in the Risk Assessment, such that the risk of loss of control communications and ability to execute the emergency stop function is reduced to a level As Low As Reasonably Practical (ALARP).

The communication suite is assumed to reflect the holistic coding requirements or registration certification of the MASS. Any reduction in system fit should be formally recorded, with each new mission/task requirement being reviewed and documented as ‘fit for task’ prior to operation.

If alternative communication systems are adopted as the primary method, the appropriate minimum level of RF communication capability should be fitted relative to the specific operation cycle.

In the case of a wider system failure, an adequate failsafe communication system to support COLREG compliance should be fitted. This system should have suitable range and endurance capabilities as to enable the operator to effect appropriate safe management of the uncontrolled MASS.

### RF Communications Installation

All radio communication equipment should be of a type which is approved by the relevant authority.

VHF transmission and reception ranges are reliable only within the LOS ranges of the aerials.

Aerials should be mounted as high as is practicable to maximise performance. When the main aerial is fitted to a mast, which is equipped to carry sails, an emergency aerial should be provided.

Masters, Owners and Operators should be aware of VHF coverage in the intended area of operation. Where the certainty of good VHF coverage in the UK coastal area is in doubt, Masters, Owners and Operators should seek advice from the Administration on whether Medium Frequency (MF) or other equipment with long range transmission capability should be carried. (i.e. Mobile Satellite Communications Systems, etc.).

## 

The need

# Testing and Auditing of MASS

[Require input on this concept – could be related to work on AI auditing. Input from MASS operators? (OI, Autoship – perhaps DNV documents?]

# MASS Operations

## [introductory text]Remote Control Centres

[confirm level of detail here for RCC aspects]

The RCC is the set or system of equipment and control units that are needed at the site or sites where safe and effective remote command, control and/or monitoring of the MASS, or several MASS, is conducted.

The RCC enables the command and control of the MASS. The RCC may be located afloat on a separate ship or ashore. The RCC may also interface with other RCCs that are separately located; the risk assessment would indicate which RCC has responsibility for a MASS at a specific time.

The RCC may be a fixed stationary installation, or fitted within a highly modular and portable unit, either of which may be controlling MASS from an RCC in a separate country to the location of the ship. This raises complicated questions as to the effective enforcement of maritime regulation. These include practical issues about the limitations on a port or coastal State’s ability to satisfy itself as to the safety of the operation and maintenance of a MASS when the control centre is located in another country. Questions of jurisdiction and responsibility pertaining to the regulation of RCCs is an important matter for the international community and owners/operators should take this into account in the development of their operational procedures.

### Sub-System Architecture

The RCC architecture will vary from system to system, but enables the following tasks to be undertaken to a level appropriate for the mission, in accordance with the risk assessment:

* Operation Planning;
* Operation Control;
* Post Operation Analysis.

### Tasking Cycle of the MASS

The MASS tasking cycle is a sub-set of the overarching system life cycle and includes a number of tasks that involve the operation of the RCC. It is necessary to clearly define the concept of use and tasking cycle of the MASS and the roles, responsibilities and boundaries of those involved in these tasks.

### Responsibility of the RCC Operator Within an Operational Hierarchy

In most cases, there will have to be several personnel involved in the operation of the MASS with different types and levels of responsibility. The titles given to these personnel will differ depending on the type of commercial or military application. It is necessary to have a clear understanding of the responsibilities of all involved in the operation, particularly the RCC operator.

The following is an example of possible roles and responsibilities:

* Master/Commanding Officer
* Overall responsibility for the ship and her crew and all operations including those involving off board systems (MASS);
* – Authorises the mission plan.
* RCC Watch Officer
* Manages and commands the complete MASS mission;
* Manages the interaction between MASS RCC operator, crane operator, payload operators etc;
* Involved in mission planning, execution and post mission evaluation;
* Direct communication with equipment operators;
* If the MASS Watch Officer (MWO) is located in the Operations Room, then the oversight of crane/deck operations will pass to the commanding officer on the bridge.
* RCC Operator
* Receives commands from the Watch Officer;
* Responsible for the MASS command and control when operated by the RCC;
* Responsible for mission planning, execution and post mission evaluation;
* Could be fully or partially responsible (shared by payload operator) for launch and recovery of vehicle payloads (ROVs, AUVs, towed systems and Unmanned Aerial Systems (UAS);
* Communicates with other operators, e.g. crane operator, secondary operator on deck and payload operators.
* Ship Crane Operator
* Receives commands from the Watch Officer;
* Responsible for lifting and lowering MASS to/from water;
* Will require to have communication with the MASS RCC and MASS secondary operator on deck as appropriate.
* MASS Payload Operator

Receives commands from the Watch Officer;

* Could receive commands directly from the MASS RCC Operator;
* Responsible for operation of payload;
* Could be fully or partially responsible (shared by RCC operator) for launch and recovery of vehicle payload (ROVs, AUVs, towed systems and UAS);
* Will have communication with MASS RCC Operator;
* This role could be conducted by the RCC Operator.

### Transfer of Mass Control

The person responsible for the operation of the MASS is normally the Primary RCC operator, however, in certain circumstances, this responsibility may be transferred to another person within the operation. Any hand-over of control of the MASS, whether internally or externally, should be formally planned and strict procedures developed and adhered to such that the full and itemised responsibility is always clearly allocated and promulgated both in terms of personnel and jurisdiction.

Control of the MASS could be transferred from the Primary RCC operator to one of the following operators:

* RCC (Secondary) Operator - Where a network of two or more RCCs are used at different locations;
* Remote control using portable / handheld console - for example, during launch and recovery to/from mother ship or shore side;
* Manual operation - For optionally manned MASS, a qualified coxswain may take control of the MASS from the helm, for example, during transit, test scenarios, launch and recovery to/from mother ship or shore side;

Fully autonomous operations – it is conceivable that in some circumstances full automated control could be given to the MASS. In this event, an RCC must be nominated as the immediate fall back if required;

* Pilotage – where port or other regulations require that a pilot is “embarked”, suitable provision must be made to allow the pilot (embarked on the MASS or using other arrangements) to discharge his duties, (including taking Legal Conduct of the navigation of the vessel within stipulated pilotage waters where applicable), with due regard to any communications latency issues.

It may be necessary for the RCC operator to interact with other operators and consideration should be given to the level of interaction required, methods of communication and any interdependencies. For example:

* MASS Payload Operation:
* MASS payloads such as hull mounted sensors, towed sonars, may be controlled by a separate operator. This may form part of the MASS system and associated RCC or configured as a stand-alone system with its own dedicated RCC.
* MASS Launch and Recovery System:
* Launch and recovery of the MASS may involve the operation of a davit, crane or similar device. During these events, the davit/crane operator will have control of the MASS for a period of time;
* MASS start-up / shut down and transfer of control between the RCC operator and lifting device operator needs to be coordinated:
* External support e.g. chases boats, port/harbour control, with the responsibility of controlling other vessels within the operational Waterspace.

### Controlling Mass from an RCC

The RCC should enable the operator to effectively monitor the behaviour of the MASS at all times, with a sufficient level of data to assess and react to requests including the following examples:

* Health Status of MASS, including warnings and alerts:
* Built in Test Equipment (BITE) data presented to RCC;
* Battery status;
* Fuel level;
* Engine or equipment condition and performance warnings;
* Fire on-board.
* MASS navigational data:
* Actual position, True Heading, CoG, Speed Over ground (SoG);
* Planned course.
* MASS requests:
* Request to perform some form of action that requires RCC authorisation.
* Situational Awareness data within vicinity of MASS; For example:
* Target/obstacle Track Data;
* Camera data;
* Radar data;
* In water sensor data (e.g. obstacle avoidance sonar);
* Sound data (e.g. warnings from other vessels).
* Collision Avoidance:
* Warnings of potential obstacles.
* MASS intended action (autonomy level dependent)
* Attack or interference with the MASS or its subsystems.
* Chart overlays, including land mass, shipping lanes, charted obstacles, seabed topography (if required).

When designing the RCC, the type and quality of data presented at the RCC should be assessed to ensure that a sufficient level of safety and incident management is provided. This will depend on several factors; for example:

* Type of MASS:
* Small MASS will be limited in their ability to support situational awareness and collision avoidance sensors.
* Operation:
* What other measures are available, if any, to provide situational awareness and communication with other vessels?
* Where is the MASS operating, e.g. confined waters with high density traffic or blue waters?
* LoC available:
* Data latency and ageing;
* Reliability of Communications Link;
* Weather;
* Geographic location.

*Note:* VTS will not take over RCC duties and the vessel operator needs to comply with VTS requirements in the VTS area.

### Relationship Between Autonomy Levels of Control and RCC

The RCC should be designed to enable the operator to take control of the MASS at any time, including the ability to change the LoC or shut down the MASS completely.

### Suggested RCC Operational Requirements

The following operational requirements are provided as illustrations for guidance:

* The RCC should enable the operator to plan the MASS mission;
* The RCC should enable the operator to execute a MASS mission;
* The RCC should enable the operator to evaluate the MASS mission;
* The RCC should provide the operator with a sufficient level of situational awareness information both for the safe navigation and control of the MASS;
* The RCC should provide the ability for the operator to re-programme the required activities and responses of the MASS in timescales appropriate to the MASS’ configuration, location and shipping conditions;
* The RCC should enable the operator to take direct control of the MASS at any time:
* In cases where the RCC is unable to assert direct control of the MASS, special provisions and control measures should be required to ensure safe operation.
* The RCC should alert the operator of any emergency warnings or a change in condition such as risk of collision, fire on board MASS, MASS equipment or functional failure/defect or 3rd party attack/interference;
* The RCC should alert the operator of any changes to the planned mission, such as change in speed, heading, collision avoidance manoeuvres;
* The RCC should be arranged such that the transfer of control from one base station to another or from one MASS to another may be undertaken safely;
* The RCC should store data (See also Para on MASS Vessel Data Recording (VDR):
* This could include log data for fault diagnosis, scenario reconstruction, (e.g. collision event), last known coordinates following communications loss etc;
* Sufficient to meet international/local regulations;
* Two or more RCCs could be used to control one MASS from different locations. Only one RCC should provide control at any one time. Transfer of control from one RCC to another should be a simple seamless transition
* It is possible that certain MASS functions (e.g. payload – instruments and their data) may be controlled from separate RCCs;
* The RCC should clearly indicate the control status of the RCC and any other RCC that form part of a networked control;
* The RCC should provide a sufficient level of security to prevent unauthorised access. This may include separate account access levels for Operator, Maintainer and Supervisor purposes;
* The RCC should be easy to use. The type of information displayed should be based on the priority of importance. Safety related warnings, graphical or audible, should be displayed on the Graphical User Interface (GUI), regardless of the GUI configuration.

### Working Within Pilotage Waters

Working within the jurisdiction of a Harbour Authority and other Marine organisations can present specific challenges. Factors such as traffic density, local Port operations, including pilotage, VTS, and liaising with other stake holders, may subject the vessel to compulsory pilotage.

Prior to entry of a Harbour or Marine facility, an RCC operator may be required to demonstrate they have sufficient skill, experience, and local knowledge to operate within the area.

Knowledge of possible local:

* Pilotage Acts
* Marine Navigation Acts
* Local Pilotage Regulations
* Local Emergency plan and procedures - e.g. Fire, Pollution, Mooring failure etc.
* Local Bye-laws
* Local VTS traffic management regulations, protocols, and restrictions
* National occupational standards for Marine Pilots
* Obligatory additional technology required by the port authority - e.g. RCC operator equipped with something akin to a heavyweight pilot’s PPU for overall situational awareness of port moments etc.
* Achieving a Pilotage Exemption certificate, which may require: -
* Local experience gained under supervision of experienced pilots.
* Additional training requirements (e.g. use of tugs in event of equipment malfunction)
* Assessment process and standards
* Examination syllabus, procedure, and standards

### Managing RCC Workforce Wellbeing

The human element has been seen to be a consistently occurring factor in the majority of maritime incidents. The nature of remote vessel operation can intensify the importance of some of these people-related factors.

Managing workforce wellbeing should be a priority in the management of any RCC operation. Placing adequate importance on human performance, as well as system performance, is necessary to ensure the safety of operations as well as an obligation towards the health of the workforce.

Human factors, including management of the so called ‘deadly dozen’ people-factors, should be considered in both planning and operation of any RCC:

* Being aware of Situational Awareness to allow for the three elements, perception, comprehension and projection for dealing with operational risks;
* Building a Just Culture to promote alerting and raising issues, counteracting risks of distractions, complacency and memory lapses;
* Enabling strong and resilient communication structures and working language protocol;
* Recognising the risks of complacency adjusting work patterns and structures to eliminate complacency risk where possible;
* Development of a strong culture based on strong safety behaviours and compliance to practices that underpin safe operations;
* Ensuring continuity of practices between RCC and local operations where relevant, such as the use of the same software and operational practices:
* Fostering efficient teamwork between personnel in the RCC, multiple control centres, support personnel locally and shore management;
* Ensuring a capable and competent workforce who have been trained in both technical and soft-skills to be able to perform in routine and emergency situations;
* Planning operations, workforce quotient and resources to limit the build-up of real or perceived pressure that can degrade performance;
* Minimising distractions and putting barriers in place to ensure operations in the RCC are not compromised by unnecessary distractions or interference;
* Putting fatigue mitigation measures in place to minimise the risk of fatigue, and developing a fatigue-conscious workforce;
* Prioritising workforce fitness for duty and providing sufficient support in case fitness for duty is compromised.

The nature of RCC operations can result in a significant use of display screen equipment. The risks and potential impact on workforce health should be assessed and mitigated.

The design and layout of the control stations, taking into account human factors, should be considered in the design of RCCs.

Fatigue Risk Management policies and procedures should be developed and enacted by operators to minimise the long-term impact of fatigue, over and above the procedures to manage short-term tiredness that may impact RCC operations.

Where RCC operations require a shift pattern, particular attention should be given to the mitigation of fatigue, and particularly the high-risk times for fatigue:

* Long continuous work durations;
* Work between 00:00 and 06:00 during the ‘circadian low’ period;
* Handover periods at the beginning and end of shifts;
* Initial night duty in a shift rotation:
* Where shift patterns have not allowed for enough recovery time between shifts.

Mental workload and the risks on safe operation of MASS should be mitigated considering operational practices, design factors and efficient planning.

## 

[Consider content from an IALA perspective]

## Rendering assistance

### Requirements of International Law

Article 98 of UNCLOS requires flag States to enact laws to require the Master of one of its flagged ships to render assistance to any person(s) found at sea in danger, insofar as it can be done without serious danger to the ship.

In particular, the Master, if informed of persons in distress, must proceed with all possible speed to the rescue of such persons insofar as such action may reasonably be expected of him.

SOLAS prescribes the same obligation to contracting States in Regulation 33 of Chapter V (Navigation), adding that masters who have embarked persons in distress at sea should treat them with humanity, within the capabilities and limitations of the ship.

### Applicability to Mass Operations

The international State obligation of rendering assistance is to be practically discharged by the Master of a ship, rather than the ship itself. Therefore, the duty cannot lie with the MASS, but only potentially to persons operating it.

The State obligations will only find application to MASS operators to the extent that both:

* the MASS is itself a “ship”; and
* an individual operator can be regarded as its “master” at the time of becoming aware of an incident.

A “master” under s.313 of the Merchant Shipping Act 1995 is the individual with “command or charge of a ship”.

### MASS Remote Controller Task Requirements

The duty to render assistance will fall to be discharged, if at all, by the MASS Master, potentially delegated to the controller.

The duty is qualified by what is reasonably to be expected given the limitations and characteristics of the relevant MASS. The duty does not require, nor is it limited to, taking persons on board.

The remote controller of a MASS will not breach the duty for failing to render a particular form of assistance on account of the MASS technical limitations or for the MASS’ inability to take persons on board.

The MASS’s technical capabilities will define the nature and the requirements of the duty and not vice versa. However, situational cognisance and communications capability may be required by other international regulations, considered elsewhere.

On the assumption that the MASS will have stand off and close up monitoring capability giving continuous feedback to the remote controller, as a minimum:

* Having become aware of persons in distress, the MASS remote controller should make best endeavours to inform the appropriate search and rescue authorities through whichever means appropriate i.e. radio, camera live feed.
* In most circumstances, the MASS remote controller should ensure that the MASS is brought or remains in reasonable proximity with persons found in distress, to act as a visual reference point and communications point for research and rescue authorities.

Efforts should not be made to embark persons if this cannot be done safely, relative to the peril faced by persons in distress.

## Salvage and Towage

[Consider content from an IALA perspective]

# Considerations for Provision of MAtoN in a Mass Environment

The AtoN

## Delivery of AtoN for MASS Environment

## [other?]

# Considerations for Provision of VTS in a MASS Environment

## [from VTS Committee]

## 

# Implications of MASS and IALA Committees

# MASS and IHO

# [other?]

# DEFINITIONS











The definitions of

terms used in this Guideline can be found in the *International Dictionary of Marine Aids to Navigation* (IALA dictionary) at <http://www.iala-aism.org/wiki/dictionary> and were checked as correct at the time of going to print. Where conflict arises, the IALA Dictionary should be considered as the authoritative source of definitions used in IALA documents.

# abbreviations

[to be developed]

NGO Non-governmental organization

VTS Vessel Traffic Services

# references

References are sources directly referred to in the running text and should be given a sequential number, starting at 1. The reference number should be included as close to the referenced text as possible and included as a number within square brackets.

The reference should be listed in the References section in the following syntax using the **Reference** **list** style:

[Author surname,] <space> [initial.] <space> [year] <space> [title.]

For example:

“Hawking also suggests ways that quantum mechanics can be combined with the theory of special relativity [1]. This text builds on his discussion of the instability of black holes described in *A Brief History of Time* [2].”

should be included in the reference list as follows:

1. Hawking, S. (2001) The Universe in a Nutshell.
2. Hawking, S. (1988) A Brief History of Time.

The **Reference list** style will add a number for the reference as soon as you start typing the text and the paragraph will automatically align with the first line of text. Press return to enter a new reference in the list.

# Further reading

Any texts that are recommended to the reader without direct reference in the text should be listed within this section using the same syntax as the reference list. Sources should be listed using the **Further reading** style.

1. Einstein, A. (1905) Relativity: The Special and General Theory of Relativity
2. Idle, E. (1984) The Galaxy Song
3. Further references for MASS

There are a number of existing and developing references for MASS. These include documents regarding the levels of autonomy, documents from specific agencies (international and national), and documents from classification and certification authorities.

* 1. 1. IMO Definition

(https://wwwcdn.imo.org/localresources/en/MediaCentre/PressBriefings/Documents/MSC.1-Circ.1638%20-%20Outcome%20Of%20The%20Regulatory%20Scoping%20ExerciseFor%20The%20Use%20Of%20Maritime%20Autonomous%20Surface%20Ships…%20(Secretariat).pdf )):

* Degree 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.
* Degree 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.
* Degree Three: Remotely controlled ship without seafarers on board: The ship is controlled and operated from another location. There are no seafarers on board.
* Degree Four: Fully autonomous ship: The operating system of the ship is able to make decisions and determine actions by itself.
  + 1. Sheridan Definition

As defined in ‘Human and Computer Control / of undersea teleoperators’ (Thomas B Sheridan and William L. Verplank, 1976)

* Level 1 – The computer offers no assistance, human in charge of all decisions and actions
* Level 2 – The computer offers a complete set of decision alternatives
* Level 3 – The computer narrows alternatives down to a few
* Level 4 – Computer suggest a single alternative
* Level 5 – The computer executes the suggested action if the human approves
* Level 6 – The computer allows the human restricted time to veto before automatic execution
* Level 7 – The computer executes automatically, when necessary informing human
* Level 8 – The computer informs human only if asked
* Level 9 – The computer informs human only if it (the computer) decides so
* Level 10 – The computer does everything autonomously, ignores human
  1. International and Regional Agencies
     1. Maritime Safety Committee (MSC) of the IMO
* MSC-MEPC.2/Circ.12/Rev.2: REVISED GUIDELINES FOR FORMAL SAFETY ASSESSMENT (FSA) FOR USE IN THE IMO RULE-MAKING PROCESS

https://wwwcdn.imo.org/localresources/en/OurWork/Safety/Documents/MSC-MEPC%202-Circ%2012-Rev%202.pdf

* Regulatory Scoping Exercise at MSC 103 in May 2021
* Interim guidelines for MASS trials
* IMO’s Maritime Safety Committee finalizes its analysis of ship safety treaties, to assess next steps for regulating Maritime Autonomous Surface Ships (MASS).

https://www.imo.org/en/MediaCentre/PressBriefings/pages/MASSRSE2021.aspx

* Annex to the report of MSC 103 (MSC 103/21/Add.1, annex 8) and can also be found in circular MSC.1/Circ.1638 (Outcome of the Regulatory Scoping Exercise for the use of Maritime Autonomous Surface Ships (MASS))

https://wwwcdn.imo.org/localresources/en/MediaCentre/PressBriefings/Documents/MSC.1-Circ.1638%20-%20Outcome%20Of%20The%20Regulatory%20Scoping%20ExerciseFor%20The%20Use%20Of%20Maritime%20Autonomous%20Surface%20Ships…%20(Secretariat).pdf

* + 1. European Commmission
* EU Operational Guidelines for Safe,Secure and Sustainable Trials of Maritime Autonomous Surface Ships (MASS)

https://transport.ec.europa.eu/document/download/9987d7c6-3e10-4206-b71d-2340807f3984\_en?filename=guidelines\_for\_safe\_mass.pdf

https://transport.ec.europa.eu/news/european-commission-encourages-maritime-future-which-includes-autonomous-and-sustainable-ships-and-2020-11-30\_en

* Safemass

https://emsa.europa.eu/mass.html

* 1. National Authorities
     1. US Federal Registry

https://maritimesafetyinnovationlab.org/wp-content/uploads/2020/09/Federal-Register-USCG-2019-0698-RFI-Integration-of-Automated-and-Autonomous-Commercial-Vessels-and-Vessel-Technologies-Into-the-Maritime-Transportation-System.pdf

* + 1. UK Maritime and Coastguard Agency
* MCA RP545: Development of guidance for the mitigation of human error in automated ship- borne maritime systems

https://maritimesafetyinnovationlab.org/wp-content/uploads/2020/09/MCA-RP545-Development-of-guidance-for-the-mitigation-of-human-error-in-automated-shipborne-maritime-systems.pdf

* Maritime Autonomous Surface Ships (MASS) UK Industry Conduct Principles and Code of Practice

<https://maritimesafetyinnovationlab.org/wp-content/uploads/2020/10/code_of_practice_V3_2019_8Bshu5D.pdf>

* 1. and Certification Authorities
     1. International Association of Classification Societies (IACS)

https://iacs.org.uk/media/8673/iacs-mass-position-paper-rev2.pdf

* Goal Based instruments for MASS, as agreed on by MSC 104, identified in ‘Generic Guidelines for developing IMO goal-based standards’ (MSC.1/Circ.1394/Rev.2)

https://wwwcdn.imo.org/localresources/en/OurWork/Safety/Documents/GBS/MSC.1-Circ.1394-Rev.2.pdf

* Human presence required in 191 IACS Resolutions (not including the Common Structural Rules, CSR)
* Participation in the IMO Work – Regulatory Scoping Exercise (RSE) (2021) (IACS involved in SOLAS Chapter II-2)
  + 1. International Standards Organization (ISO)
* Draft Technical Specification ISO/ DTS 23860 Terminology related to Autonomous Ship Systems (2020)

https://www.iso.org/standard/77186.html

http://www.autonomous-ship.org/events/190116-lon/iso-standard.pdf

* ISO/TC8/WG10 Smart Shipping

https://committee.iso.org/sites/tc8/home/about/working-groups.html

* 1. Certification Authorities
     1. Bureau Veritas

• https://www.marineinsight.com/shipping-news/bureau-veritas-and-the-french-flag-develop-compliance-for-remotely-operated-services-at-sea/

* + 1. DNV

• https://rules.dnv.com/docs/pdf/DNV/cg/2018-09/dnvgl-cg-0264.pdf

* + 1. LLOYD’s Register

• https://maritimesafetyinnovationlab.org/wp-content/uploads/2020/06/LR\_Code\_for\_Unmanned\_Marine\_Systems\_\_February\_2017.pdf

* + 1. American Bureau of Shipping (ABS)

• https://maritimesafetyinnovationlab.org/wp-content/uploads/2020/09/ABS-Advisory-on-Autonomous-Functionality.pdf

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* + 1. Others

Other organisations that are working in the area of MASS include:

* CCS,
* CRS,
* IRCLASS,
* Class NK,
* PRS,
* RINA,
* Korea Register of Shipping (KR)

Appendices should be started on a separate page and contain information that is directly relevant to the main body of the text at a certain point, but that would be too large or distracting to include at that particular point. There are four levels of appendix heading styles available in the **Style Gallery.**

* 1. Example of Appendix Head 1 style
     1. Example of Appendix Head 2 Style

At the end of the **Appendix head 2** style text press carriage return, the following paragraph is **the Heading 1 separation line** style, press carriage return again, and the following line will be in **Body text** style.

* + - 1. Example of Appendix head 3 style

The same following formatting applies to the **Appendix Head 3** style i.e., press carriage return, the following paragraph is the **Heading 2 separation line** style, press carriage return again, and you will be back to body text.

* + - * 1. Example of Appendix Head 4 style

The Appendix Head 4 style is followed by body text and does not have a separation line. Only the level 1 **Appendix Title** will appear in the TOC.

* + - * 1. Example of Appendix Head 5 style

The **Appendix Head 5 style** is followed by body text and does not have a separation line. Figure and tables should be labelled as a continuation from the main Guideline content.

1. Example of Annex title (Head 1) style

Annexes should include information that can exist in isolation e.g.

* a technical specification for a new piece of equipment;
* the content and structure of a new training module; or
* the detail associated with a new recommendation for an AIS.

Annexes can include appendices if required. There are also four levels of annex heading styles available in the **Style Gallery.** In addition to the **Annex title** (**Head 1)** style there is **Annexe Head 2**, **Annexe Head 3** and **Annexe Head 4**. These follow a similar format to the appendix heading styles. As many annexes can be included as needed and it is advisable to separate them with a page break. Only the level 1 **Annex title** style text will appear in the TOC.

* 1. Example of Annex Head 2 style
     1. Example of Annex Head 3 style
        1. Example of Annex Head 4 style

Annex figures and tables should be labelled with the **Annex Figure Caption** and **Annex Table Caption** styles respectively, rather than the main figure and table caption styles. This ensures the annex can be read logically in isolation and that annex figures and tables are not included in the List of Figures and Tables respectively on the main Guideline contents page.

1. Example of annex figure caption
   * + - 1. Example of Annex Head 5 style

Simon – every MASS need a secondary positing system – ENG input.

Need to provide input into IMO on the role of AtoN – can adjust guideline after.

VTS – developing a high level brief on the implications for VTS

Neil – what are the opportunities for IALA to be engaged in the development of the roadmap at MSC

Road Map for the MASS Guidelines