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| IALA Guideline |

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

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# 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.*

Among the greatest challenges and uncertainties facing AtoN Managers over the next twenty years is the expansion of autonomy and the continued development of automated systems used in maritime operations. Globally, there are ongoing discussions and trials surrounding MASS with some development being conducted by non-traditional operators. IALA recognises the need to take note of and support Coastal State providers of Marine Aids to Navigation (AtoN) as they either prepare for, or adapt to, the arrival of MASS operations in their waters. Underlying this recognition is IALA’s view that the provision of a guaranteed data service, capable of supporting MASS in all circumstances including natural or man-made interference, is unlikely to be deliverable for the foreseeable future. Therefore, Coastal States will need to consider, as a minimum standard, AtoN remaining fit for purpose as MASS technology advances and, where appropriate, integrating their AtoN into the data network supporting MASS.

IALA can play important role in the development of MASS and members are encouraged to share their experience they interact with MASS, thus helping to support a key IALA aim of harmonising AtoN services worldwide.

This Guideline also speaks to the developers and operators of MASS by making clear the importance of considering physical and virtual AtoN in their operational solutions. Physical AtoN will continue to provide an essential element of a system of systems approach to future position, navigation and timing integrity for the foreseeable future.

## Background

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

During an IALA workshop on MASS it was identified that non-SOLAS (International Convention for the Safety of Life at Sea) i.e. less than 300 GT or less than 24 metres in length vessels are already operating at level 3[[1]](#footnote-1) (remotely controlled ship without seafarers onboard) and level 4 (fully autonomous ship) in some parts of the world either in trials or for purposes such hydrographic survey and or other data acquisition.

Both physical and electronic AtoN have a significant role to play in the MASS domain as this matures, as mentioned in the expert meeting on MASS and shore maritime infrastructure including marine Aids to Navigation (Tokyo, 2020). Furthermore, IALA has recognised, in its capstone document the Maritime Buoyage System that:

*Current applications, marks and signals exhibited by AtoN as described in this document apply to all vessels, including Maritime Autonomous Surface Ships (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 maritime buoyage system and there may be developments of AtoN that are tailored specifically for MASS.*

*It is the responsibility of the vessel’s command to ensure they can identify, interpret and assess navigation signals as designed in this reference document, so that levels of safety for life and marine environment are met.”*

Extract from MBS (3.2.6) ‘AtoN in relation to Maritime Autonomous Surface Ships (MASS)’

# Aims and Objectives

This Guideline is written for Coastal States and for developers of MASS. Included in this Guideline are references to other bodies and organisations that are dealing with MASS including the IMO and IHO in order to provide Coastal States with a wider appreciation of challenges and opportunities offered by MASS, some of which fall outside of IALA’s official remit.

In the future IALA intends to produce standards and recommendations for Coastal States operating with MASS, but as development of MASS regulation and policy continues, this document is designed to help guide Coastal States in current developments. This Guideline will, therefore, be updated on a regular basis as international regulations and policies are produced.

This Guideline offers a Coastal State perspective of:

1. IMO and IHO developments in MASS
2. MASS testing, trials and operations.
3. The provision of AtoN in a MASS environment
4. Technical solutions to support the introduction of MASS;
5. Possible future scenarios while considering the evolution of MASS.

# Developments in MASS

As MASS will bring about changes to shipping, port operations and the safety of navigation, it is important that Coastal States remain aware of the latest developments and possible impacts on their services and begin planning as early as possible.

To integrate new and advancing MASS technologies into international regulations, IMO have created a framework for MASS developments for the purpose of a scoping exercise on regulations (MSC 100 – 2018).

## IMO AND MASS

In general, the IMO aims to integrate new and advancing technologies in its regulatory framework. In 2018 the IMO initiated a regulatory scoping exercise (RSE) on Maritime Autonomous Surface Ships (MASS) that was designed to assess existing IMO instruments to see how they might apply to ships that utilize varying degrees of automation. 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.

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. Nonetheless, they form a useful basis for discussion, at this point and are, therefore, referenced throughout IALA documentations.

The regulatory scoping exercise (RSE) for safety treaties was finalized at the 103rd Session of the MSC in May 2021, and for treaties under the purview of the Legal Committee, at its 108th session in July 2021. The FAL Committee approved the outcome of the RSE of treaties under its remit at FAL 46 in May 2022.

Subsequently the IMO initiated the work on a goal-based instrument (MASS Code), and a MASS Working Group was established to progress the work on the MASS Code, and to identify issues relevant to instruments under the purview of the Legal and Facilitation Committee. These are considered by the Joint MSC/LEG/FAL Working Group on MASS.

Currently, the IMO aims to have a non-mandatory MASS Code finalized in the 2nd half of 2024, and the adoption of a mandatory Code at MSC 110 (1st half of 2025), with a view to entry into force on 1 January 2028.

## IHO and MASS

In May 2021 IHO HSSC established the MASS Navigation Project Team(MASS PT) with 2 years remit to carry out the following tasks.

* To identify and prioritize MASS navigation requirements
* To analyse their impacts on hydrographic standards and services (i.e. S-100)
* To develop a set of recommendations/issues to be addressed by existing working groups

The IHO MASS PT discovery and reporting phase encompassed several working packages, addressing a variety of activities. These included ascertaining and documenting the test bed activities occurring within each region while identifying the predominant levels of autonomy utilized. The phase also involved providing a comprehensive report on the data currently employed by MASS operators and their navigation systems. Additionally, it detailed the navigational data specified by each PT Member State's regulators for use in MASS navigation, applicable to both trials and operational deployments. The involvement of PT Member States in MASS trials or operations was evaluated, including the data they are currently supplying. The phase also covered the documentation of trials conducted with new navigational standards, such as S-100 for MASS, and research into machine-readable data conducted across various regions. Reports were consolidated and detailed navigation requirements for MASS were synthesized. During this phase, 45 individual issues and requirements were identified, covering various themes.

* Modelling certainty/uncertainty of positions
* Modelling certainty/uncertainty of tidal height information and seabed mobility.
* A need for more visually conspicuous features to be shown along with more land based topography.
* A need for more geospatial polygon features with appropriate attribution to capture constraints and restrictions.
* A need for near or real time data feeds.
* 3D synthetic environments for navigation purposes.
* Removal of verbose natural language text paragraphs to be replaced with machine readable attributes and enumerations.

IHO's [Strategic Plan](http://www.imo.org/en/About/strategy/Pages/default.aspx) (2024-2029) has two tasks for the reflection of the onboard MASS system which is now developing and converging. it is crucial to summarize hydrographic data which is distributed and defined for each S-100 product. The two tasks are as follows,

* Propose a new data model or concept of summarized hydrographic information for MASS operation (up until 2026)

## IALA and MASS

IALA has proactively sought to establish the short to medium-term outlook of MASS for the benefit of its members and held a dedicated MASS workshop in October 2023 involving industry, technical, academic and subject matter experts in order to identify possible future scenarios regarding the development and evolution of MASS.

The main findings from the workshop (forwarded to the IMO as 108/INF8 Dated 5 March 2024) were as follows:

1. **Investors,** including ship owners, shipbuilders, and banks, are driven by the prospect of a favourable business case, seeking opportunities for profitability and returns on investment;

2. **The shortage of qualified seafarers,** especially if steps are not taken to improve seafarer recruitment and retention, drives interest in autonomous solutions;

3. While there is recognition that **human error contributes to accidents**, and MASS could help in reducing human error, **not everyone is convinced that autonomy is the solution.** There is particular concern that, in the case of navigating by remote control, errors may be merely shifted ashore. The complexity surrounding human error, but also preventative human intervention make safety a multi-faceted consideration;

4. Potential **efficiency gains** are a compelling factor for investment. This includes tangible benefits such as fuel reduction and MASS tending to adopt cleaner fuels;

5. There is a potential **benefit of being a pioneer** with MASS. The prospect of leading the way and being recognized as a "first mover" in this transformative field may result in a boost in publicity for a company. This reputation-building aspect can significantly influence investment decisions and contribute to a stakeholder’s prominence within the industry;

6. There is an increasing willingness to **address regulatory challenges** and enhance cooperation between countries including examples of **bilateral and multilateral agreements**, including the Memorandum of Understanding between Belgium, Denmark, the Netherlands and the United Kingdom, to demonstrate frameworks for potentially enabling autonomous operations internationally; and

7. The current outlook on implementing MASS technology in tankers, medium and large passenger ship categories is cautious, with concerns about operational and safety challenges specific to these vessel types.

**In conclusion**, for the foreseeable future, there will be a mixed fleet of conventional ships with different degrees of automation in combination with an increasing number of MASS. The take-up timing for MASS varies, suggesting a coexistence of conventional and autonomous ships in the maritime industry for an extended period. Unmanned ships face a longer adoption timeline due to technological and legal constraints.



Furthermore, IALA has recognised that MASS operations cannot be viewed in isolation, but rather 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.”*

The various IALA committees are considering MASS through the following areas:

1. Provision of AtoN: fixed and floating AtoN (floating AtoN includes MAtoN), shore side electronic AtoN, AIS AtoN (virtual, synthetical, physical)
2. Transmission of information: AtoN status 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. 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.
4. Consideration of reliable and secure systems: cyber security and management of cyber risk; augmentation of positioning systems; requirement for and promotion of standardisation of data transfer.
5. Reliance 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.

# COASTAL StATE Considerations for MASS

This section looks at the key considerations that Coastal States should take into account when preparing for, or integrating their AtoN with MASS operations in their geographical area of responsibility.

Given the dynamic nature of developments in MASS, AtoN Managers are faced with a number of challenges when considering how they should integrate their Aids with MASS. The services delivered using physical, electronic and virtual AtoN for the environment created by each of the four degrees of autonomy identified by the IMO may well be different and there is the added complication that vessels may be capable of changing their level of autonomy depending on where they are operating.

In the first instance, Coastal States should have a thorough understanding of the risks, challenges and opportunities offered by their geographical area of responsibility. Part of this understanding will come from the personal experience of those involved in delivering Coastal State responsibilities and the IALA Risk Management Tools can also be used to assist in forming this understanding. More advice on how the Risk Management Tools might be of help can be found in section …...

Coastal States will also need to take into account in their risk assessment how vessels are required to plan their voyages which should be in accordance with the relevant IMO resolution).

## Management of MASS vessels

This Guideline does not consider the detail of MASS management, but Coastal States may find the following useful.

### Regulatory Aspects

While international regulatory development governing MASS is still in progress, the maritime industry has to conduct activities and operations in full recognition of the status of MASS with respect to:

* COLREGs.
* IMO MASS Code and maritime laws, rules and conventions where applicable.
* Local or temporary arrangements put in place by the Flag or Coastal States in the areas of MASS trials/operations.

### COLREGS

The current direction from the IMO is that MASS vessels of all levels must be capable of, and comply with, COLREGS.

### Allocation and Rules of Test Areas

IMO MSC.1/Circ.1604 dated 12 June 2019 (Interim guidelines for mass trials) provides useful information to authorities and stakeholders to help them ensure that testing activities with MASS and related systems and infrastructure are carried out safely and with regard for environmental protection.

### Changes to National Laws

Existing rules and laws regarding the safe operation of vessels (SOLAS, COLREGs), state that the responsibility for the safe operation of a vessel remains with the owner/master (or a person or a system of persons designated ashore).

### 4.1.3.1 MASS Operations and Large-Scale Trials

Until regulation (in general) for international voyages with MASS is in place, national projects for the development and integration of MASS may have to be considered by Coastal States on a case-by-case basis. Indeed, taking into consideration that Flag/Coastal States and ‘Industry/Operators’ may be unfamiliar with MASS operations and requirements and how to achieve all the necessary contacts and approvals, it may be prudent to commence engagement with MASS through a series of ‘one-off’ requests in order to develop the necessary evaluation, authorisation and approval processes. This will require a high level of competence from the Flag/Coastal State in assessing the risk of MASS projects to the safe navigation of vessels in their area of responsibility. It will also take a detailed process of review and selection by the ‘Operator’ to identify and match the necessary functional and operational requirements of the vessel to the available water space and conditions needed. Close liaison between ‘Industry/Operators’ and the Flag/Coastal State will be, therefore, vital to the success of safe MASS operations.

As well as liaising directly with Industry/Operators Flag/Coastal State representative may consider also liaising with the following on MASS related issues:

* 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 the intended location.

It may also be appropriate for the relevant authorities to issue Notice to Mariners and Radio Navigation Warnings that MASS may be undertaking trials in a certain area at a certain time. The caveat would, nonetheless, be that notification of MASS trials would be for awareness only and it would not necessarily mean that the vessel/s would be readily identifiable as MASS or that other vessels should in any way alter their approach to the COLREGs as a result. The underlying principle here is that MASS vessels will be considered, in in terms of the COLREGS, the same as vessels with crews.

Where local laws put restrictions on regular vessels, then similar restrictions will apply to MASS vessels (visibility, max. current, max. wind, sea state, etc.), unless technological features present in the MASS can been proven to mitigate sufficiently these effects.

Competent/Local authorities should consider developing a policy/criteria to determine when and where the operation of MASS would be acceptable and how the risks of operating MASS in a mixed vessel scenario might be best managed. Recognising that each case will be different and, therefore, individual cases will require individual solutions, a Flag/Coastal States might consider the following while developing policies and procedures for the successful and safe integration of MASS in their geographical area of responsibility (not in order of priority):

1. Whether it is appropriate to designate a specific sea area for MASS trials;
2. How marine spatial planning and changes to AtoN deployment might reduce the risk of MASS trials;
3. Whether it might be appropriate to designate dedicated MASS routes;
4. Whether there are any pilotage requirements;
5. Whether it would be appropriate to restrict MASS movements to certain times (slot allocating), avoiding congested periods;
6. How AtoN might need to be redeployed, modified or augmented to support MASS;
7. Whether MASS operations would be better supported and risks minimised through operations being supported by VTS;
8. Whether Sea Traffic Management (STM) might reduce any perceived risks from the operation of MASS.

In working to achieve the necessary policies and procedures it is expected that Flag/Coastal States will require a range of Health, Safety and Environment (HSE) documentation to be provided by Industry/Operators to support MASS operations. This may include a full HSE plan, a launch and recovery risk assessment, emergency recovery plan and procedure and a mission plan and method statement. By demanding a range of health and safety documentation the Flag/Coastal State would be signifying that it expects Industry/Operators to provide proof of the application of industry best practice and to demonstrate responsibility towards the societal acceptance of autonomous systems.

For further debate:

* Placeholder for text, consider the input paper from China MSA, regarding AtoN classification
* Using the example of the aerospace sector, it appears that the maritime AtoN environment can develop a similar classification system leading to a known environment within the maritime AtoN area

## Risk Management and Assessment

Working Group 3 to add content.

# Considerations for Provision of AtoN in a Mass Environment

## Impact of MASS on current AtoN

### A Hybrid Environment

## FUTURE Delivery of AtoN IN A MASS Environment

# UNDERSTANDING MORE ABOUT MASS Systems and operation

[introductory text]

## Navigation Systems

The navigation system should be designed with a level of integrity sufficient to enable MASS 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. 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. (this text covers aspects relating to DP/track control, mental note for further discussion).

Ambient conditions should be controlled, where required, to suit the operating environment and the navigation system requirements. As guidance, principles and requirements used for classification of DP operations may be used).

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.).

## Cyber Security

The need to implement effective cyber security strategies grows every day. Cybercriminals continuously derive more sophisticated techniques for executing attacks.

All aspects of Cyber Safety and Security should be embedded in the initial design of all software and hardware in MASS. The integration of these systems needs to be considered throughout the design process. Consequent updates and patches could have unforeseen, undesirable adverse effects on the functions and security integrity of the whole system.

IMO resolution MSC.428(98) was adopted in 2017 and there are ongoing discussions at IMO to address ‘Cyber risk management in Safety Management Systems’. For the shipping industry, resolution MSC.428(98) established a clear intent that the regulatory requirements of the Organisation for cyber risk management were embodied in the provisions of SOLAS chapter IX and the International Safety Management (ISM) Code (IMO). Administrations are expected to clarify and enforce this intent. Effective management of cyber risks by companies, in accordance with the international regulatory requirements, is understood to be demonstrated by:

* Evidence of the continuous improvement of approved safety management systems conforming to the requirements of the ISM Code to take into account cyber risks; and
* Implementation of policies and procedures for effective cyber risk management

## Remote Control Centres

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.

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. Likely roles will include a Master/Commanding Officer with overall responsibility for the ship and her crew and all operations including those involving off board systems (MASS). This individual will also authorises the passage plan. There may also be a RCC Watch Officer who manages and commands the complete MASS mission and co-ordinates activity in the RCC that corresponds to activity onboard. There may also be an RCC Operator who receives commands from the Watch Officer and is responsible for the MASS command and control when operated from the RCC. They may also be responsible for mission planning, execution and post mission evaluation. There may also be a ship crane operator and a payload operator.

### MASS 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

## 5.2 MASS OPERATIONS IN VTS ENVIRONMENT

* [from VTS Committee]

### Resilience of position

MASS 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, Secondary 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

Flag/Coastal States should expect MASS to 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.

# Definitions

[to be developed if needed? Check IMO references.

Trial means an experiment or series of experiments, conducted over a limited period, in order to evaluate alternative methods of performing specific functions or satisfying regulatory requirements prescribed by various IMO instruments, which would provide at least the same degree of safety, security and protection of the environment as provided by those instruments (IMO MSC.1/Circ.1604)

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.

# REFERENCES

# Further reading

1. 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. Degrees of Autonomy
     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 COMMISSION
* 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. ???
  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](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 (Title: *Being a Responsible Industry Maritime Autonomous Ship Systems (MASS) UK Industry Conduct Principles and Code of Practice - A Voluntary Code*)

http://maritimeuk.org

* 1. Classification 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](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>

* + 1. Others

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

* Include full title CCS
* Include full title CRS
* Include full title IRCLASS
* Include full title Class NK
* Include full title PRS
* Include full title RINA
* Korea Register of Shipping (KR)

1. See section …….. [↑](#footnote-ref-1)