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Agenda item 7.3

Author(s) / Submitter(s) ARM MASS Task Group

ARM INPUT TO THE IALA MASS GUIDELINE

# Summary

Work on a MASS Guideline has been underway in ARM over several committee sessions, most notably with output from ARM 16. The decision was taken at ARM 18 that a MASS Work Group should be established to review the work to date and provide input to the other committees and/or the MASS Task Force. The UK volunteered to lead the Work Group and good progress was made during ARM 18.

Work on the document continued during the summer of 2024 through two intersessional meetings. Discussions also took place in the MASS task Force and it was noted that the ARM MASS document might be best presented as part of an overall Guideline orchestrated by the Task Force/Committees.

## Purpose of the Document

The intention is that the document is finalised during ARM 19, agreed by the Committee and then sent as an output paper to the MASS Task Force/Committees. The Working Group would therefore welcome comments on the document from fellow Committee members either ahead of ARM 19 or during the week in Paris to assist with its completion.

# Background

The Work Group used ARM 18 to develop a new framework and began to revise the ARM 16 document having identified that it should be written for Coastal States while also being of interest to developers and operators. The Group also recognised that, because of rapid developments in MASS, any document produced at this stage by IALA might best be positioned as a Guideline, noting that it will need to be updated regularly as global MASS innovation and regulation arises. As a result the ARM Working Group felt the IALA advice should remain predominantly conceptual at this point and their work reflected this. Technical detail could then be provided by the relevant IALA committees at a later date through appropriate standards and recommendations as regulation is agreed.

# Discussion

## Status of the Document

The document is not intended to be a Guideline in itself, but rather the ARM input to the IALA MASS GUIDELINE that will be produced by the MASS Task Force.

## Content of the Document

It is proposed that the document be forwarded to the MASS Task Force with sections 1-5 recommended as the introduction and early chapters to the Guideline. Section 6 includes information about MASS operations that goes beyond the immediate provision of suitable AtoN, but which nonetheless provides valuable background information on wider MASS issues that might influence Coastal State policies and procedures. Much of this work was already in place from ARM 16. Rather than discard this information, the ARM Working group has gathered it together in section 6 which will hopefully make the work of the Task Force easier and assist the other IALA Committees in their work.

## Specific Content for Review – A proposal by China MSA

Committee member’s attention is drawn particularly to section 5.2 of the document. This proposal from China MSA recommends a classification system for AtoN in a future MASS environment. This section will be one of the key areas for work during ARM 19 and its ongoing presence in the document will be one of the major points for Committee approval.

# PROPOSAL

The ARM MASS Working Group completes the document at the Annex during ARM 19 for endorsement by the Committee as an output paper for the MASS Task Force, copied also to the other Committees.

# Action requested of the Committee

The Committee is requested to:

1. Note the underlying principle used by the Working Group that MASS documentation produced by IALA should, at this stage, be in the form of a Guideline.
2. Note the specific points for consideration raised above in 3.1-3.3.
3. Approve the document once it is completed during ARM 19.
4. ARM MASS WORKING GROUP DOCUMENT

# 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 biggest challenges and opportunities facing Marine Aids to Navigation (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. There is a need for Coastal States to either prepare for, or adapt to, the arrival of MASS operations in their waters. As machines and systems continue to be developed that can interact with AtoN without human intervention, the need for harmonzsation and standardisation of AtoN services around the world has never been more important. Furthermore, MASS operation has to be equally as safe as shipping operations are now and the provision of relevant AtoN will be an important part of ensuring this.

Vital to the deployment of autonomous vessels at sea will be the guaranteed integrity of uninterruptable, assured data that supports their safe navigation and operation. This is of particular interest to Coastal States because the navigational solution being used or developed in the majority of autonomous vessels relies exclusively on GNSS. However, the integrity of GNSS service required to support commercial MASS navigation is not yet guaranteed and remains vulnerable to either natural or man-made interference. Furthermore, such a guarantee of integrity remains unlikely to be deliverable for the foreseeable future. Coastal States will, therefore, need to consider how they might assist MASS ships to navigate safely in their waters through alternative means - planning to continue providing physical AtoN is one possible solution. Coastal States may also consider the extent to which those physical AtoN can interact with MASS. This interaction may range from relatively simple physical AtoN that provide a visual and possibly AIS/RACON enhanced point of reference, through to a new generation of AtoN that are fully integrated into the data networks that support MASS and are capable of providing a wide range of information, either by relaying it, or by generating it themselves.

As the technology supporting MASS evolves, the world-wide harmonisation and scalability of AtoN services becomes increasingly important so that technological solutions that integrate AtoN with MASS in one region can be used in as many other regions as possible. The same applies to navigation solutions developed to support MASS. Ideally, these solutions should be applicable world-wide. To help in the harmonisation of AtoN services world-wide, members are encouraged to share their experiences as they integrate MASS into their waters, ports and harbours.

As well as Coastal States considering the integration of AtoN as part of their MASS risk assessment and navigational solution for MASS, it is important the developers and operators of MASS understand the importance of considering physical and virtual AtoN in their Concept of Operations. Reliance on GNSS solutions for MASS navigational integrity must be weighed against the risk of existing system vulnerabilities. Due consideration to using physical AtoN as part of the Navigational solution is likely to provide a level of assurance that purely electronic systems cannot provide for the foreseeable future. Physical AtoN is an important part of a system of systems approach to position, navigation and timing integrity solutions, including those for MASS.

## BACKGROUND

The development of MASS continues globally and at pace with more MASS entering operations all the time. MASS are expected to 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 those who seek to integrate them into their waters.

During an IALA workshop on MASS held in Paris in October 2023, it was noted that non-SOLAS (International Convention for the Safety of Life at Sea) compliant vessels (i.e. less than 300 GT or less than 24 metres in length) are already operating at level 3[[1]](#footnote-1) and level 4[[2]](#footnote-2) in some parts of the world, either in trials or for purposes such hydrographic survey and/or other data acquisition.

Fixed, floating, mobile and electronic AtoN have a significant role to play in the MASS domain as concepts of operation mature, as noted above and as mentioned in the expert meeting on MASS and shore maritime infrastructure, including marine Aids to Navigation, in Tokyo 2020. Furthermore, it is recognised in Recommendation R1001 The IALA 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 MASS’.

The IMO roadmap for developing a code to regulate Maritime Autonomous Surface Ships (MASS) is as follows:

* May 2025: Finalize and adopt non-mandatory MASS Code
* First half of 2026: Develop framework for an experience-building phase (EBP)
* 2028: Begin development of the mandatory MASS Code and consider SOLAS amendments
* By 1 July 2030: Adopt the mandatory Code, effective 1 Jan 2032

It is of essential that guidance is harmonized with other International Organizations remains relevant.

# SCOPE

This Guideline is written for Coastal States and for developers of MASS. Included in this Guideline are references to other bodies and organizations that are dealing with MASS including the IMO and IHO in order to provide Coastal States with a wider appreciation of the challenges and opportunities.

Noting the pace of development of MASS related technology, regulation and policy, this document is designed to provide key considerations that will help with preparations for MASS operations. This Guideline will, therefore, be updated on a regular basis as international regulations, policies and best practice are further developed.

This Guideline offers a Coastal State perspective of:

1. IMO and IHO MASS related issues.
2. MASS testing, trials and operations.
3. The provision of AtoN in a MASS environment – a hybrid solution.
4. The provision of AtoN in a MASS environment – the future, including possible technologies.
5. General points about MASS operations to provide context.

# 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.

## 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.
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 in IALA documentation.

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.

The purpose of the Code is to provide an international regulatory framework to address both, remote control and autonomous operation of key functions and ensure safe, secure, and environmentally sound operation of MASS. The Code further aims to support the safe and secure adoption and integration of new technology for ship operations and provide for consistency of approach to the design, build and operation of MASS.

This Code is developed on the principles that it be:

* supplementary to any applied base instruments, such as SOLAS, and only address MASS functions as far as they are not adequately or fully addressed in the applied base instruments;
* holistic to ensure the objectives, aims and principles of the base instruments are maintained whilst also enabling the MASS functions and operations to be addressed across all instruments;
* goal-based and addressing matters at the functional level;
* non-mandatory although developed in such a way as to facilitate future transition to mandatory status; and
* technology neutral acknowledging industry practices and experience in the deployment of new technologies.

This Code does not apply to:

* Cargo high speed craft to which SOLAS chapter X applies; and
* Warships, naval auxiliaries, and other ships owned or operated by a Contracting Government and used only on Government non-commercial service.

Currently, the IMO aims to have a non-mandatory MASS Code finalized at MSC 110 (1st half of 2025), with a view to entry into force of a formal Code on 1 January 2032.

## IHO and MASS

In May 2021 IHO HSSC established the MASS Navigation Project Team (MASS PT) with a 2 year remit to:

* Identify and prioritize MASS navigation requirements.
* Analyse their impacts on hydrographic standards and services (i.e. S-100).
* 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. This 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 including:

* 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.

During the 16th session of the HSSC from May 27-31, 2024, the IHO endorsed the establishment of a permanent MASS Working Group. The group held its first meeting in July 2024, electing a chairperson, vice-chairperson, and secretary to initiate activities regarding IHO MASS-related issues over the next five years.

The objectives of the MASS Navigation Working Group are:

* Working with the S-100 Working Groups and Project Teams, and other relevant IHO groups to align product specifications and data standards with MASS requirements.
* Inviting representation from industry and academia to the Working Group and engaging with all relevant stakeholders to ensure understanding and communication of navigational data requirements in the context of MASS to the relevant Product Specification Working Groups.
* Liaising and collaborating with other international bodies such as IMO, IALA, and WMO to ensure coherence in developments, activities, and regulations across the autonomous domain.

Additionally, key items under consideration for the MASS Working Group's five-year plan include:

* Raising the profile of the MASS domain and promoting MASS navigation issues within the IHO community.
* Engaging with industry, academia, and other MASS interest groups to raise awareness of MASS navigation issues with conventional navigation products and services.
* Providing a focal point and coherence for MASS-related matters across the IHO domain.
* Supporting and evaluating trials of MASS navigation to assess the applicability and interoperability of IHO standards.
* Enhancing S-100 interoperability, synthetic environments, and utilizing artificial intelligence and machine learning.

In the future, the IHO will progress considerations for the preparation of hydrographic information in response to the development of the MASS industry through the MASS NAVIGATION WORKING GROUP. Additionally, joint efforts with international organizations such as IMO, IALA, and WMO are planned.

## IALA and MASS

It is essential to establish the short to medium-term outlook of MASS for the benefit of Coastal States. A dedicated IALA MASS workshop was held 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.



Various committees are considering the detail of integration of MASS into Coastal State operations including the:

1. Provision of AtoN: including fixed and floating, (including MAtoN), shore side electronic, AIS (virtual, synthetic and physical).
2. Transmission of information: including AtoN status information, MSI, Meteorological and Hydrographic data using Application Specific Messages (contained in IMO Circular SN.1/ 289).
3. Provision of Vessel Traffic Services (VTS) including: 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 VTS environment; interaction between VTS and Remote Control Centres (RCC) for MASS.
4. 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.
5. Consideration of reliable and secure standards including: cyber security and management of the cyber risk; augmentation of positioning systems; requirement for and promotion of standardisation of data transfer.
6. It is important to conduct analysis of the performance requirements for future AtoN systems that MASS will require, through consultation with coastal states or relevant stakeholders (such as the autonomous vessel industry). This analysis will guide the direction for the AtoN system that MASS will utilize in the future.

To assist authorities introducing MASS in a worldwide and harmonized way, IALA has undertaken a scoping exercise on all of its guidelines and recommendations, taking the various levels of MASS into consideration – outcomes will need to be considered in this document.

# COASTAL StATE Considerations for MASS

This section examines the key considerations that Coastal States may take into account when preparing for, or integrating their AtoN with MASS operations in their geographical area of responsibility. It is not exhaustive, but is designed to provide a basis from which MASS operations can be developed.

Given the dynamic nature of developments, AtoN Managers are faced with a number of challenges when considering how they should integrate their Aids with MASS. The services delivered by fixed, floating, mobile and electronic AtoN to meet the requirement 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 4.5.

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.

## 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.
* SOLAS (Unless vessels are under 24m or 300grt).
* 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. In particular, MASS will be required to follow Rule 5 in keeping a good lookout by visual as well as hearing and all available means appropriate to the prevailing circumstances and conditions.

## Changes to National Law and Coastal State Considerations

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/ISM Company. (or a person or a system of persons designated ashore).

Nonetheless, Flag and Coastal State authorities will need to ensure a safe operating environment is provided in their waters while integrating MASS and they will therefore need to consider revisions to their laws, policies and procedures. These requirements will be different for each Flag/Coastal state and the situation will be further complicated by IMO regulation now being delayed until 2032. A list of considerations beyond those directly linked to the provision of AtoN can be found in section six. The list is not exhaustive and IMO guidance on MASS (expected 2025) should be consulted once published. Section six nonetheless provides topics that Flag/Coastal state authorities might consider well in advance of MASS operations/trials in their waters to allow time for the enactment of laws, policies and procedures.

Coastal state authorities will need to ensure that the correct approval procedures are put in place and implemented for MASS operating in their waters. Integral to the approval process will be a Concept of Operations. The approval process for MASS should be based on and follow the main principles of the guidelines for the approval of alternatives and equivalents as provided for in various IMO instruments (MSC.1/Circ.1455) taking into consideration parts 2 and 3 of the IMO MASS Code. The level of detail should be proportional to the complexity, level of novelty and associated risk of the MASS and on whether the Submitter is applying for preliminary or final approval and the necessary documentation may vary accordingly.

**ISPS** - Any MASS should be ISPS Certified according to the ISPS Code. The ISPS procedures may be integrated with the ISM system, as long as the required confidentiality is observed.

**Minimum safe manning** - Both the MASS and any ROC operating a MASS shall be furnished with a Minimum Safe Manning Document (MSMD) according to IMO resolution A.1047(27) as amended, and to the satisfaction of the Administration.

## MASS TRIALS AND OPERATIONS

Until regulation for international voyages with MASS is in place, national projects for the development and integration of MASS may have to be considered by Flag and 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 write the necessary policies, contracts and approvals, it may be advisable 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 in the Flag/Coastal State so that a full assessment of the risks to the safe navigation of vessels in their area of responsibility can be made. It will also take a detailed process of review and selection by the ‘Operator/developer’ to identify and match the necessary functional and operational requirements of the vessel to the available water space and conditions. Close liaison between ‘Industry/Operators’ and the Flag/Coastal State will be, therefore, vital to the success of safe MASS operations.

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.

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 organizations;
* Other stakeholders with economical, safety or environmental interests in the intended location;
* Local port/harbour authorities.

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, as noted by the IMO, will have to conform to the COLREGs as they stand in the same way that vessels with crews have to conform.

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:

* 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 invited to comment and add content if required.

A risk assessment should be conducted to ensure that risks arising from the use of MASS functions, including relevant functions in ROCs, affecting persons on board, the environment, and the safety of the ship are addressed, taking into account identified goals and functional requirements, ensuring a level of safety expected of a conventional ship. The risk assessment can be conducted on MASS as a whole, and/or on the MASS functions. It should also consider the ConOps and its OE of the MASS. The risk assessment should address relevant mitigation measures. Should the risk assessment be carried out on specific MASS functions, the consequences on other ship's functions should be considered and mitigated. The risk assessment should be used to support the appropriate approval process adopted by the Flag Sate. A risk assessment should be carried out by personnel with relevant expertise as required by the Administration of the Flag State. While no specific risk assessment methodology should need to be followed, it is important that the submitter and approving Administration agree on the output format for the risk assessment methodology to be used.

**Operational Envelope** - The OE of the ship should encompass the operational capabilities and limitations of the autonomous or remote operation, and ship-specific capabilities and limitations to indicate the condition in which an autonomous or remotely operated ship can operate safely in all operating conditions, including all reasonably foreseeable degraded states.

**The Operational Design Domain** - (ODD) of individual functions or systems, should be based on the results of a risk assessment including:

* The conditions and limitations under which any individual autonomous or remotely operated system or function operates safely, including all reasonably foreseeable degraded states;
* The extent of human interaction;
* The capabilities and limitations to be accomplished before activation of operation of the individual system or function;
* Descriptions of the external and internal conditions, such as geographical boundaries the ship is to operate in, the maximum wind and sea wave heights etc.; and
* Reasonably foreseen system or equipment malfunctions.

Risk assessment should include a comprehensive description of the autonomous and remote-control function's utilization, effectiveness and reliability performing a thorough hazard analysis, conducting a mitigation analysis, evaluating the identified risks, and implementing effective risk control measures. The risk assessment should analyse and address hazards associated with the intended OE of the MASS including the associated ROCs, as described in the ConOps. Apart from the hazards such as loss of function, cyber attacks, component damage, fire, explosion and electric shock, it should also consider the random, systematic, and systemic hazards involved within the OE. Listed below are some of considerations a Coastal State may wish to consider:

* **Failure** - How MASS will respond to a degraded state, a fall back state and what contingency plans should be put in place will need to be considered. Coastal states will also need to take into consideration the various MoO of MASS which might be changed for various stages of a voyage.
* **Testing and Evaluation** - MASS systems should undergo comprehensive testing and validation to ensure compliance with design specifications and operational requirements. This process includes a structured, procedure comprising detailed simulation, component testing, integration testing, system testing.
* **Systems -** Systems should be designed to minimize risks to the ship, crew, ROC operators, cargo, other ships and the marine environment by incorporating inherently safe design principles. All systems used for MASS operations should include fail-safe mechanisms and emergency protocols to ensure comprehensive safety and effective risk management. Hazards affecting the systems should be eliminated wherever possible, and those that cannot be eliminated should be mitigated as needed by using a risk assessment.
* Coastal state representatives should be actively involved in the system validation phase to ensure that AtoN positioning and design can be optimised.

# Considerations for Provision of AtoN in a Mass Environment

## MASS and Existing AtoN – A Hybrid Environment

As identified in the IALA MASS workshop in October 2023, 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. So *degree four* operations on a large scale over a wide geographical area for any size of vessel are still likely to be some years away. Indeed, the assessment of timelines for the introduction of the various levels of autonomy indicates that the application of autonomy *degrees three* and *four* in larger vessels is probably several decades away, although such vessels will undoubtedly become more automated over time. In the meantime, many small vessels (under 24m) including tugs, ferries, offshore support vessels, survey vessels and military vessels that are becoming more autonomous are already operating at *degree three* and while a few might operate at *degree four* in specific and highly controlled areas. As a result, there will be an ongoing requirement for Fixed, floating, mobile and electronic AtoN that operate much as they have done for the past 20 years, providing visual references for areas of topographical interest with some augmented with RACON, AIS and audible signals. The change in AtoN towards integration with MASS will likely be evolutionary rather than revolutionary. A hybrid state for AtoN will exist for some time as they evolve from an entirely physical presence (pre RACON and AIS) towards a fully digital presence (including fixed, floating or mobile AtoN that have a digital capability that enables them to be fully integrated into the data network supporting vessels, including MASS).

Recognising the impact that MASS will have on Coastal State operations, it is important that AtoN development is not focussed exclusively on support to MASS. Coastal States will also need to continue to develop and deploy AtoN that enable a wide range of other vessel types to be navigated safely. Equally, developers of autonomous vessels should be aware that sensors on MASS must be capable of interacting with AtoN (e.g. visual, infrared, machine vision) with sufficient repeatability and integrity to make a positive identification and assist in determining position in conjunction with other systems, including GNSS and ECDIS.

The degree to which Coastal States decide to integrate their AtoN with MASS in the future will vary for a variety of reasons including:

* The degree of risk to traffic and the environment and the volume of traffic.
* The extent to which the key operators using their waters seek to embrace autonomy.
* The type of funding and research being provided – whether private and or government/state funded.
* The financial benefits offered by varying degrees of autonomy.
* The extent to which onward supply chains choose to invest in/integrate with maritime autonomy.

Existing AtoN, with relatively few additional technological additions, have a strong visual and in some cases enhanced presence through, for instance, RACON and audible devices, that can provide some support to MASS. When considering vessels with full remote control or fully autonomous operation, the support provided by these existing buoys is limited to providing a fall-back, reversionary mode that the MASS could adopt if it looses its primary navigation system. After such a loss the MASS may go into a reversionary mode that uses, for example, high definition cameras to identify physical AtoN in the immediate vicinity to help guide the vessel to a safe location.

To provide higher levels of support to MASS, AtoN will need to be modified/enhanced. Such modifications could facilitate machine as well as human (based in a ROC) recognition of AtoN and their characteristics through, for instance, visual/infra-red cameras, radar, pulsed lights/lasers, AIS, and radio. AtoN could also be designed to be more intelligent and provide a wider range of information beyond just positional reference, including environmental, hydrographic and meteorological data. AtoN could be positioned in strategically important positions not only for navigational dangers, but also to support data networks and connectivity including VDES. Intelligent AtoN could also provide feedback and information to the AtoN operator to verify their position and function and their status in terms of interaction with vessels.

## Delivery of AtoN in a MASS Environment – A Classification System

To assist with assessing the merits of and planning various possible levels of interaction between AtoN and MASS, Flag/Coastal State authorities may consider a classification system for various types of AtoN to support varying degrees of remote control and autonomy and for various types maritime environment. This approach is designed to assist with providing a logical process for evaluation of AtoN capabilities and to support the risk assessment process. For instance, assessment of existing physical and digital AtoN may be necessary to enable the guidance of MASS safely through an area. Modifications to shore infrastructure and support which contribute to enhance VTS systems with full detection and precise PNT, interacting with objects and advanced decision support should be considered. MASS will also operate outside VTS coverage areas, and coastal states will need to consider the risk involved and take the appropriate action to mitigate it.

IALA has identified six levels of potential interaction as described below. In most cases the interaction between MASS and existing AtoN will be at the first three levels. These three levels are not designed to provide direct support MASS when they are using their primary navigation mode (e.g. GNSS), but could be used as described above, to assist MASS during a navigational system failure. Level AL0 is described as ‘Non Intelligent’ and applies to many AtoN currently deployed. These AtoN have in most cases just shape and colour to provide identification. Some may have lights, but none are remotely controlled or monitored. Level AL1 AtoN have telemetry so their status and position and can be monitored remotely. Level AL2 have telemetry and remote control that is capable of fully monitoring the AtoN and diagnosing faults as well as being able to change the characteristics of the AtoN and activate reversionary modes if available. (Table requires further consideration).

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| --- | --- | --- | --- | --- |
| **Level** | **Description** | **Operational Function** | **Description** | **Able to support MASS as a primary navigational aid** |
| AL0 | Non-Intelligent | Independent operation without telemetry. | The AtoN conforms to IALA standards for shape, size, colour, characteristics. AtoN is not monitored remotely. | No |
| AL1 | Telemetry | Telemetry allows monitoring of operating status including lamp, position and energy levels. | The AtoN conforms to IALA standards for shape, size, colour, characteristics. AtoN is monitored remotely. | No |
| AL2 | Telemetry Plus | Telemetry allows monitoring and management of operating status including lamp, position and energy levels and characteristics. |  | No |
| AL3 | Remote Intelligent | Telemetry allows monitoring and management of operating status including lamp, position and energy levels and characteristics. AtoN is capable of relaying digital services as directed from ashore. | The AtoN conforms to IALA standards for shape, size, colour, characteristics. AtoN is monitored and its operation and characteristics can be controlled remotely. The AtoN is capable of interacting with autonomous vessels with management of those services being controlled remotely through human intervention. | Yes |
| AL4 | Remote Intelligent Plus | Telemetry allows monitoring and management of operating status including lamp, position and energy levels and characteristics. AtoN is capable of relaying digital services and autonomously sensing, processing and transmitting its own data to minimise the risk to navigation. | The AtoN conforms to IALA standards for shape, size, colour, characteristics. AtoN is monitored and its operation and characteristics can be controlled remotely. The AtoN is capable of interacting with autonomous vessels with management of those services being controlled remotely. Remote control is managed autonomously with human input only required in emergency/failure states. | Yes |
| AL5 | Remote Autonomous | The AtoN is capable of intelligent and fully autonomous operation, acting dynamically and independently to minimise the risk to navigation. | The AtoN is capable of interacting with vessels without management from ashore. The AtoN is fully integrated into digital services. Remote control is managed autonomously with human input only required in emergency/failure states. | Yes |

# UNDERSTANDING MORE ABOUT MASS Systems and operation

Much of the information in Chapter six falls outside the direct remit of IALA, but it is included to provide context around the development of autonomous and increasingly automated vessels to help Coastal States make informed decisions about their future AtoN services. This information is not exhaustive and Coastal States are encouraged to seek other sources of information, particularly that provided by other international and regulatory organisations.

## 6.1 Certification

### Vessel Certification

MASS vessels will need to be certified either after an initial or a renewal survey. Certificate requirements will be decided and implemented by Administrations (Governments) with due regard to the IMO MASS Code. While the IMO has yet to fully agree, certification is expected to follow, as far as possible, current SOLAS requirements. MASS vessels will also be expected to hold a MASS Record including the following:

* A description of the MASS approved Concept of Operations (ConOps), Operational Envelope (OE), and Modes of Operation (MoO);
* All operational restrictions on the MASS and the Remote Operating Centre (ROC);
* Survey requirements as associated with the system in question;
* A list of all ROC approved for working with this particular MASS;
* Approved way of connection between MASS and controlling ROC; and
* Any exemptions from or equivalences to SOLAS or other IMO instruments made possible by employing the MASS Code.

### Remote Operating Centres

The IMO envisages every ROC requiring a valid MASS ROC Certificate. As with MASS vessels, MASS ROCs will be required to hold their own MASS ROC record that should include:

* A description of the ROC approved ConOps and OE;
* All operational restrictions on the ROC;
* Survey requirements as associated with the system; in question;
* A list of all MASS approved for working with this particular ROC; and
* Approved connectivity between MASS and controlling ROC.

### Training and Professional

Coastal states will need to consider how STCW compliance and applicability is integrated into the ConOps also noting the requirement for additional specific training and familiarisation associated with MASS operations both at sea and ashore.

## Navigation Systems

## 6.2.1 Functional Objectives

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. 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.

The navigation system should not only meet the general navigation requirements of ships stipulated by the international regulations, MASS should also carry voyage data recorders (VDRs) and automatic ship identification systems (AIS). The navigation system should meet the requirements of the Coastal State and be capable of interacting with the local navigation and positioning equipment to facilitate monitoring of MASS operations, especially in the case of emergencies when communication with MASS may be difficult.

Coastal States should provide vessel operators with adequate information and instructions for the safe and effective navigation of 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. System diagrams and instructions should be provided for maintenance of the Navigation system in a language and format that can be understood. Official internationally recognised languages are recommended.

It should be possible to disable and isolate a MASS Navigation system to allow inspection and maintenance tasks to be safely performed on the MASS. Provision in vessel operating instructions must be made to alert Coastal States and obtain permission in advance of a MASS Navigation system being isolated or turned off for maintenance. The protocol for this request would need to include:

* Exact location of the MASS before the navigation system is disabled
* Status of the vessel, (underway, making way, at anchor/moored),
* Route the vessels is planned to take while the navigation system is disabled
* Location where the navigation system is expected to be reinstated.
* Any other relevant information

Regular communication between the MASS vessel operator and the relevant Coastal State authorities during such maintenance or as a result of a failure would essential.

## 6.2.2 Resilience of position

A 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 reduction 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 secondary 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 vessel’s intended operations it should be possible to identify the most appropriate primary, secondary 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, secondary 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, secondary 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, secondary 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, secondary or backup source of position finding, noting that this may result in the consideration for an additional available source

## 6.2.3 Monitoring Alarm System

For ships with autonomous navigation functionality, an appropriate human-computer interface should be installed in appropriate locations to allow adequate information exchange between the crew and the MASS systems. As a minimum this information should include navigation system status/mode, control status, route information. More generally there should be interfaces that allow exchange of meteorological information including sea state, wave periodicity and direction, spatial awareness around the ship (visual, radar, AIS, infra-red, acoustic), ship command information, ship system status information.

The ship's main steering and propulsion shall be able to operate and run automatically according to the instructions of the autonomous navigation system or remote-control station, and must be capable of being switched to manual operation at any time.

It should be clear to the vessel operator and to Coastal States which ROC is currently controlling any particular vessel. Control status must also be clear to both operators and potentially to Coastal States if they insist.

All systems should have appropriate audible and visual alarm systems capable of informing personnel on board, at the ROC and potentially in Coastal State operations/VTS centres when a failure of the ship's autonomous navigation and/or remote-control functions is detected.

Unresolved faults should not be capable of being overwritten by new faults; Monitoring and alarm systems, control systems and safety systems should be designed so that the risk of one failure resulting in others is reduced to the lowest possible degree.

## 6.2.4 Collision Avoidance System

If the vessel is fitted with a collision avoidance system, or a semi-autonomous system designed to support a human watchkeeper, it will need to be type approved and may be capable of multiple modes of operation depending on the volume of traffic and the degree of risk similar to the Traffic Collision Avoidance System (TACKS). When designing a vessel collision avoidance system it will be necessary to consider own ship turning and manoeuvring characteristics and the extent to which an ROC or operators on board may need to intervene to ensure sufficient action is taken in time. Actions taken/recommended by the system should be capable of being transmitted to an ROC or of alerting an operator on board. Actions that require a change to the route may be applied automatically or with human intervention/oversight. Coastal States may consider the level to which they need to be informed about autonomous collision avoidance and operators will need to ensure that such systems are fully integrated into communications with the ROC and may also need to ensure the Coastal State can be kept informed in real time.

## 6.2.5 Power Supply

Power supply systems, batteries and other energy equipment supporting the navigational system must meet international standards and requirements imposed by Coastal States. The system will need to have two independent power supplies from the main switchboard, one of which may be supplied by the emergency switchboard. When one power supply fails the system must be capable of automatically reverting to the second supply and there should be sufficient battery backup to enable the vessel to be navigated to a safe location.

## 6.2.6 Route Planning and Execution

MASS voyage planning will need to include, but not be limited to:

* The vessel’s technical conditions and performance
* Specific navigation risks and opportunities
* Vessel’s draft conditions
* Cargo characteristics/shipment schedule
* Operational mode (personnel on board or ROC operated)
* Environmental conditions including wind, wave, current.

The vessel must be capable of transmitting its navigation plan to Coastal States and Coastal States should have regulation and processes in place to review and approve plans. MASS operations should only take place once all approvals are in place.

Navigation plans will, nonetheless, be dynamic and will need to be amended due to factors at sea including weather and collision avoidance. MASS vessels should have the capability to convey changes to their navigation plan in real time to Coastal States. Coastal States will take their own view as to whether their regulations require every alteration to a MASS navigational plan to receive approval. It may be that in the early days of MASS operation that every change to a navigational plan will require approval, but as operators and Coastal States become more accustomed to each other’s operations and trust is built, Coastal States may consider reducing the level of scrutiny for navigational plan changes.

## 6.2.7 Control and Reversionary Modes

The performance of navigation systems should be consistent across different modes with route planning and changeover between different modes being possible without effecting the operational effectiveness of the equipment. Difference modes of operation may include:

* Manual operation (as currently conducted on most vessels either with paper or electronic charting) controlled/overseen on board;
* Automated navigation functionality controlled/overseen on board (watchkeeper is not necessarily permanently on the bridge);
* Manual operation as above, but controlled remotely;
* Automated navigation functionality controlled/overseen remotely;
* Fully autonomous navigation that is remotely controlled.

Vessel operators will need to ensure that failure of the navigation system or of the remote-control function there is made apparent to those in command and control of the vessel through sufficient visual and audible alarms. There must also be a seamless and *safe* transition of the operation of the navigation or remote control system, if it fails, to a reversionary mode. Furthermore, operators will need to ensure there is an assured method of transferring control of a vessel to or from an ROC.

## SAFETY MANAGEMENT SYSTEM

**Safety Management System** - Every International Safety Management (ISM) compliant company conducting autonomous or remotely controlled operations should develop its own Safety Management System. The ISM compliant company should ensure that a Safety Management System (SMS) is implemented and maintained on the ship and at any Remote Operating Centres (ROC)s involved in its operation. The ISM compliant company should clearly identify and document the subdivision of tasks and relationships between itself, its MASS ships and any associated ROCs.

## COMMUINICATION SYSTEMS

MASS will be heavily dependent on communications systems for their control and monitoring. Such communications must meet the requirements of and be compatible with the Global Maritime Distress & Safety System (GMDSS). Vessels using GMDSS frequencies are bound by the requirements of the ITU Radio Regulations. The exact radio equipment to be carried by MASS will depend on its capabilities and the area of operation and any requirement to fit additional equipment to any existing ITU regulatory requirements. All radio communications equipment, including any additional to the GMDSS requirement should be type approved by the relevant Flag State authorities before MASS vessels operate in their waters.

The MASS communication system needs to ensure that it can establish reliable voice and data communication with the ROC and the Coastal State. This requirement should include sufficient bandwidth to ensure smooth data and information exchange and timely communication with operators and the Coastal State and sufficient redundancy to ensure uninterrupted coverage after failure or in an emergency. It is recommended that Coastal States provide an emergency communication contact for MASS in accordance with COLREG compliance and the regulatory requirements of each Flag State. This is to ensure communication in the event of an emergency and/or equipment failure so that operators or Coastal States can ensure appropriate safety management of uncontrolled MASS.

Masters, owners and operators should be aware of VHF coverage and capability in the intended area of operation. Where the certainty of good VHF coverage in the coastal area is in doubt, masters, owners and operators should seek advice from the Flag/Coastal State administration on whether Medium Frequency (MF) or other equipment with long range transmission capability should be carried.

### **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.

## CYBER SECURITY

MASS vessels are particularly vulnerable to a range of network risks, including attacks, information theft, virus implantation, etc. The severity of the impact of a cyber-attack will depend on the type of vessel, cargo and risks associated with the area of operation and the level of data protection must be commensurate. The maritime industry relies heavily on wireless communication with many associated vulnerabilities. Many wireless communication systems in use around coasts and in ports are generally unauthenticated. Most well-known are VHF voice communication and AlS messages, but this also applies to many GMDSS technologies and other wireless communication. There is currently no technical means to validate the source of a message, and in most cases authentication of these means of communication requires human verification. Cyber safety and security must therefore be a very a high priority in MASS vessels and must be embedded in the initial design of all software and hardware systems in MASS.

Flag/Coastal States will need to take a significant interest in clarifying whether MASS vessels operating in their waters have adequately addressed cyber risks and management measures and whether appropriate risk assessments have been conducted in accordance with regulations. Flag/Coastal States may need to insist that cyber security risk assessment reports are submitted by vessel operators for reference. Flag/Coastal States may consider refusing permission to vessels to sail/operate in their waters if the required cyber security standards cannot be demonstrated. For controllable risks, the prevention and handling capabilities of networks should be improved in terms of infrastructure and emergency support measures to reduce the impact of network loss. Operators should be responsible for ensuring that through the whole life cycle of the ship, if there is a major change in the network system, the cyber risk assessment is updated and corresponding measures are implemented to reduce risk.

MASS vessels should have inbuilt monitoring where possible to detect threats and keep track of network risks during their voyages. Network risks during trials should be monitored in real time, and the necessary measures should be taken immediately when there is an anomaly. Specific measures should be specified in the pre-voyage risk management plan that should be shared with Coastal States when appropriate.

## REMOTE OPERATION CENTRES

Higher degrees of autonomous operation of vessels will require remote monitoring and varying levels of remote control from ashore. Coastal States will need to understand the capabilities of ROCs as they plan their AtoN services of the future, particularly as ROCs may be located in other countries where different maritime regulations apply.

Coastal States will need to be assured that ROCs have sufficient voice and data communications to ensure reliable and resilient command and control that facilitate the safe conduct of vessels and the ability to communicate effectively with Coastal States.

Coastal States will also need to be aware that the relationship between ROCs and the vessels they are monitoring/controlling will depend on a number of factors, some of which have yet to be agreed at the IMO:

* The Flag/Coastal State approval/status of autonomous operations in their area;
* Vessel operator policies and the technical and professional proficiency/certification of their operators;
* The reliability of communications/data transfer between ROC and vessels;
* The level of crewing on board a vessel and the level of vessel autonomy/automation in use;
* The definition of command and where that responsibility is discharged (if there are crew members on board should they have command of the vessel?);
* Available and reliable reversionary modes of command and control (related to whether there are any crew on board, their level of oversight of autonomous operation and their delegated authority to take action in the event of a failure of remote command and control systems).

## MASS WITHIN PILOTAGE WATERS

Prior to MASS operations in a port or harbour environment, close liaison will be required between the vessel operator and the local authority. The local authorities will need to be assured that the operator has the required certification and processes in place to enable the safe operation of their vessels. The local authorities will need to conduct appropriate risk assessments from which they can consider, amongst other things, their own processes, regulations, AtoN service delivery and emergency procedures. Local authorities may decide to introduce traffic management measures such as VTS or consider compulsory pilotage for semi-autonomous vessels.

Considerations that local authorities might consider ensuring operators of MASS vessels are aware of include:

* Pilotage regulations;
* Marine Navigation Acts/local bylaws;
* Environmental conservation zones, protected areas or restricted zones;
* Emergency plans and procedures - e.g. Fire, Pollution, Mooring failure etc;
* 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 a 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/Examination process and standards.

## 6.8. MASS OPERATIONS IN A VTS ENVIRONMENT

Based on the distributed perception principle, a comprehensive maritime picture of vessel movements and intentions, or other vessel related traffic information is pushed to MASS to enhance the accuracy and understanding of MASS situational awareness.

Communication channels and transmission rates are customisable to ensure safe, efficient, economical and reliable navigation information exchange between local authorities and MASS.

The use of satellite differential positioning technology or terrestrial navigation enhancement technology is used to significantly improve the accuracy of MASS positioning and navigation and is capable of supporting intelligent MASS navigation systems.

# 7. Definitions

# 8. References

# 9. Abbreviations

1. Remotely controlled ship without seafarers on board, see section……….. for more detail. [↑](#footnote-ref-1)
2. A fully autonomous ship capable of making its own decisions. [↑](#footnote-ref-2)