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Recommendations for updating the cybersecurity-related chapters of the MASS Guideline

# Summary

The Guideline on Cybersecurity indicates the necessity to review the impact of cybersecurity on MASS. However, there is no description of cyberattacks in the MASS ecosystem and related measures in the MASS Guideline developed by the DTEC Committee. Therefore, a proposal was developed to refine the MASS Guideline by reviewing the cybersecurity challenges inherent in MASS, suggesting relevant mitigation measures, and points to consider for future cybersecurity improvements.

The increasing frequency of cyberattacks in the MASS ecosystem poses complex challenges with wide-ranging impacts. This proposal examines the cybersecurity challenges inherent in MASS, including potential threats to critical systems (ECDIS, GPS, AIS, GIS, and GMMS) and vulnerabilities in digital design. It also puts forward measures to enhance the network security of MASS operation, emphasizes the necessity to take proactive measures to effectively mitigate MASS network threats, and contributes to a more profound comprehension of the challenges and potential countermeasures to protect the network security of the MASS system.

## Purpose of the document

The Guideline on Cybersecurity states that it is necessary to review the impact of the network security review on MASS. However, there is no description of MASS network attacks and relevant measures in the draft of the MASS Guideline. Therefore, the relevant proposal is prepared to incorporate into the cybersecurity chapter of the MASS Guideline the cybersecurity challenges confronting MASS, related mitigation measures, and key points of improving cybersecurity in the future.

## Related documents

DTEC3-11.2.2.6.1 - Draft Guideline MASS for coastal authorities-reviewed

G1182 Cyber Security specifics from an IALA perspective

# Background

The newly revised draft Guideline on Cybersecurity indicates the necessity to review the impact of cybersecurity on MASS. However, there is no description of cyberattacks in the MASS ecosystem and related measures in the MASS Guideline developed by the DTEC Committee. Therefore, a proposal was developed to refine the MASS Guideline by reviewing the cybersecurity challenges inherent in MASS, suggesting relevant mitigation measures, and points to consider for future cybersecurity improvements.

# Discussion

Maritime Autonomous Surface Ships (MASS) have brought about a transformative wave in the marine industry, yielding unprecedented operational advancements and efficiency gains. However, this paradigm shift has concurrently raised substantial cybersecurity concerns, ranging from unauthorised access to data breaches and manipulation of basic navigation systems, posing a substantial threat to the operational integrity of MASS. The impact goes beyond compromising the confidentiality, integrity and availability of sensitive data, and can lead to disruption of ship functions and collisions, navigational errors and security threats. Meticulous attention is therefore required to mitigate the impact of attacks on the stability of MASS.

MASS cybersecurity vulnerabilities are intricately tied to their digital architecture and unified systems that enable autonomous operations. Key components within the digital framework, such as GPS, AIS, ECDIS, GMDSS, and GMMS, play vital roles in ensuring safety, navigation, and communication. However, these systems also present specific threats, including attempts to jam and GPS signal spoofing, manipulate AIS data, target ECDIS, and exploit weaknesses in GMMS. The mutuality of various systems, unauthorised access, or breaches in one area can affect the operation of the entire vessel. In addition to providing suggestions for enhancing MASS cybersecurity resilience against evolving risks, these vulnerabilities should be scrutinised.

China MSA examines the cybersecurity challenges inherent in MASS, suggesting relevant mitigation measures, and points to consider for future cybersecurity improvements. The aim is to ensure a comprehensive understanding of cybersecurity issues in the MASS ecosystem, in order to refine the MASS Guideline.

The detailed revisions are shown in the appendix. Revisions to the text are highlighted in blue. The Committee is requested to discuss and add relevant proposals when revising the MASS Guideline.

# References

1. Draft Guideline MASS for coastal authorities
2. G1182 Cyber Security specifics from an IALA perspective

# Action requested of the Committee

The Committee is requested to:

1. Noted the efforts made by the China Maritime Safety Administration in exploring the challenges and responses to MASS cybersecurity.
2. Include the proposed MASS cybersecurity challenges, related response measures, and key points to be considered for improving cybersecurity in the cybersecurity chapter of the MASS Guideline.

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| IALA Guideline |

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developments and implications of maritime autonomous surface ships (MASS) 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.*

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

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

Evolving MASS technologies will impact the works of IALA to develop a regulatory framework for MASS and MASS-related infrastructure on the relevant Marine Aids to Navigation including VTS, IALA is continuing to consider MASS operations from the operational, technology and regulatory level.

IALA has highlighted the consideration of AtoN in relation MASS within the Maritime Buoyage System (MBS) section 3.2.6:

*“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.”*

# Aims, Objectives and Guideing Principles

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

### Aim

Specifically, the aim of this guideline is to:

1. provide guidance to the International Organization of Marine Aids to Navigation (IALA) members and other stakeholders who may be undertaking:
2. testing
3. trials or
4. operations of MASS systems
5. identify developments and need for certification, testing, and performance standards (approval process by authorities for use),
6. identify aspects for shore side infrastructure to support MASS such as Shore side support (communications, control centre, etc.); VTS to MASS Communication; VTS support for MASS;
7. provide guidance for organisations implementing policy, procedures and technical solutions to support the introduction of MASS;
8. identify possible future scenarios while considering the evolution of MASS;
9. analyse the possible impact of MASS on Marine Aids to Navigation (AtoN); and
10. identify the future requirements on AtoN service.

### Objective

In achieving its Purpose, this Guideline is intended to:

1. ensure achievement of a level of safety at least equivalent to that expected of Marine Aids to Navigation to support safe, efficient and pollution free transits;
2. ensure services are provided that enable all ships to safely coexist without impeding or negatively impacting each other, regardless of whether certain functions are remotely controlled or autonomously operated;
3. ensure that there is no relaxation of the level of accepted standards for design, construction, or operation of MAtoN;
4. allow for the application of solutions that are demonstrably safe, secure, and environmentally sound in performing the designated function in all defined conditions; and
5. be cognizant of the potential for the unintended placement of barriers to new or novel application of remote control or autonomous technology on ships.

### Guiding Principles

This Guideline is developed on the principle that it:

1. is supplementary to any IALA documents, and only addresses MASS issues insofar as they are not adequately or fully addressed in other IALA documents;
2. is holistic to ensure the objectives, aims and principles of the IALA documents are maintained while also ensuring that the challenges of MASS functions and operations are addressed across all standards;
3. addresses risk and mitigation measures at the functional level when addressing MASS aspects from the perspective of coastal authorities for the provision of Aids to Navigation, including VTS;
4. is developed in such a way as to recognise the evolving nature of MASS, and related guidance on MASS; and
5. is technology neutral and taking note of industry practices and experience in the deployment of new technologies.

### G#### Guideline Series

The G#### series of guidelines includes general guidance (this document) and focused guidance for IALA members:

G#### - MASS for Coastal Authorities

G####-1 - VTS Interaction with a Mix of Vessels including MASS

G####-2 - Provision of AtoN to support a MASS environment

# Developments in MASS

As MASS may result in 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

The IMO continues to develop guidance regarding the implementation of MASS, including the development of a MASS Guideline.

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

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

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

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

1. Degree One: Ship with automated processes and decision support: Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised but with seafarers on board ready to take control.
2. Degree Two: Remotely controlled ship with seafarers on board: The ship is controlled and operated from another location. Seafarers are available on board to take control and to operate the shipboard systems and functions. MSC.1/Circ.1638 Annex, page 4
3. Degree Three: Remotely controlled ship without seafarers on board: The ship is controlled and operated from another location. There are no seafarers on board.
4. Degree Four: Fully autonomous ship: The operating system of the ship is able to make decisions and determine actions by itself.

The degrees of autonomy listed above does not represent a hierarchical order. It should be noted that MASS could be operating at one or more degrees of autonomy for the duration of a single voyage. The Maritime Safety Committee (MSC), at its 103rd session (5 to 14 May 2021), approved the Outcome of the regulatory Scoping Exercise (RSE) for the use of MASS.

While the 4 degrees of autonomy were noted during the RSE, the IMO continues to monitor and adapt the concepts of autonomy. It is therefore recommended that these degrees of autonomy are not used in the basic structure of IALA MASS documents, as these 4 degrees are expected to be changed or removed as IMO develops the non-mandatory Code for MASS (expected in 2025) and the mandatory Code for MASS (expected in 2032).

It should be noted that the IMO MASS Code is supplementary to SOLAS, and as a result, does not oblige coastal States to change how they achieve the requirements of SOLAS Chapter V Regulations 12 and 13.

The development of MASS may result in changes to shipping, port operations and the safety of navigation. It is important to assess and discuss its impact on IALA related services at all stages of its development.

## IHO AND MASS

In May 2021 IHO Hydrographic Services and Standards Committee (HSSC) established the MASS navigation Project Team (MASS PT) with a 2 year remit to carry out the following tasks:

• 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.

# IALA and MASS

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

Both physical and electronic AtoN have a significant role to play in the MASS domain as this matures. For MASS operation ship and shore site systems interact intensively and a new understanding of shore site support must be found.

It is recognized that the concept of automation versus autonomy may, to some extent, be construed as debates over wording, definitions, and philosophy, the essence lies in understanding how various types of ships are navigated and controlled. It is crucial to differentiate between automation and autonomy to construct straightforward and illustrative scenarios that capture the evolving landscape of maritime operations.

The four scenarios that sum up IALA’s view of the short to medium term development of MASS are captured as:

* Many crewed ships with automized functions
* Few crewless autonomous ships
* More crewed ships with automized functions
* Some crewless autonomous ships

These scenarios are visualised in [figure 1]

A diagram of a ship

Description automatically generated

1. MASS degrees vs Time Frame

MASS operations cannot be viewed in isolation but as an addition to the broad range of vessel types and users in the current maritime domain.

IMO MSC.1/Circ.1604 states:

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

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

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 Operation Centres (ROCs) 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 (e.g. 4G and 5G), digital VHF Voice and satellite technologies.

MASS operations rely on positioning, 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 and traffic management and further shore site support.

## Considerations for MASS

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

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

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

Considerations related to voyage planning (IMO Res. A.893(21)) include:

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

## Implications of MASS for Coastal Authorities

Noting the developments of MASS, and the outcomes of the IALA MASS Workshop, there are a number of implications of MASS for Coastal Authorities in the provision of AtoN, including VTS.

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

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

### Operational context for MASS

[to be developed]

### Testing, certification and classification

MASS is a disruptive technology with no general international regulations. Therefore, it is necessary to make precautions and ensure that all test activities are conducted safely for the crew, the ship, other ships in the area and the marine environment, but also to collect and share information, so that it becomes possible to survey operations and to examine the potential of MASS operations.

The specific test areas depend on the individual test activity. Based on the specific technology, the maritime administration establishes the framework for the test area and issue a permit stating the requirements for performing the test. The test area may be a designated area away from or closed to other vessels, or simply an area in which the MASS test is conducted within the existing maritime domain amongst other marine traffic.

IMO MSC MSC.1/Circ.1604 (Interim guidelines for mass trials) assists relevant authorities and stakeholders to ensure that testing activities with MASS and related systems and infrastructure are carried out safely and with regard for environmental protection.

### Risk assessment

While IMO is finalising the MASS Code, the broader international legal framework for the operation of MASS vessels is continuing to develop. For the operation of MASS vessels within coastal and port areas, the provision of AtoN, including VTS, continues to be governed by the overriding principles of the optimum mix of AtoN to support the users. As the user group includes MASS, the risk assessment process must include these users.

From a ship perspective there are different industry codes developed, including the United Kingdom (UK) “Maritime Autonomous Ship Systems (MASS) Industry Conduct Principles & Code of Practice” is a good basis for assessment of the risks. From a Coastal Authority perspective, the risk assessment makes best use of the IALA risk assessment toolbox, with scenarios identified that include the mix of different levels of MASS vessels, as well as traditional vessels, within the waterway.

IALA has an existing risk toolbox (as identified in G1018) that can be used when identifying risks within the port and coastal area, including identification of mitigation measures to address risk scenarios.

A risk assessment process takes into account the existing and developing requirements for waterway usage. This includes identifying potential risk scenarios such as:

* Collision with fixed or floating objects;
* Grounding;
* Becoming a significant obstruction or hazard to other traffic;
* Leakage of noxious substances or other forms of pollution;
* Other potentially hazardous events or situations, which may depend on the type of MASS and how it is deployed and operated.
* The probability of a failure occurring;
* The impact of a MASS vessel that looses power within a waterway if left to drift without propulsion or steering.
* Whether the MASS carries significant quantities of hazardous or pollutant substances.

Based on the outcome of the risk assessment, the Coastal Authority would identify and implement additional mitigation measures. These may include requirements for the company or organisation managing the MASS to meet additional safety measures, implementation of audits of remote control centres, or other operational, technical or regulatory measures. The Coastal Authority may require the operator of the MASS to provide a clearly define risk assessment with mitigation measures that meet the requirements of the Coastal Authority.

The risk assessment undertaken by the Coastal Authority should be able to show that the MASS is able to be operated to a tolerably safe level, ideally proven to be as safe as an equivalent manned counterpart

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

### Environmental considerations

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

### Health and Safety

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

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

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

## Implications for PORTS and Waterways Governance

The operation of MASS within port and waterway governance includes regulatory and operational aspects.

### Regulatory Aspects

The International regulatory development governing MASS is still in progress. In the meantime, the Industry has to conduct activities and operations in full recognition of the status of MASS with respect to:

* COLREGs
* Other maritime laws, rules and conventions where applicable
* Local or temporary arrangements in place in the areas of MASS operations

#### National Regulatory Framework

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

As a first basis, Competent Authorities should establish processes for recognising the need for and adopting changes in the national regulatory framework to allow initial testing/trials/operations with MASS, including the provision of AtoN, including VTS. These should include general terms for requirements on how safe operation of unmanned vessels could be facilitated.

As an example, this might include terms for MASS voyages:

* pre-trial research activities and phased/scalable trials
* requirement for the actual vessels navigation and manoeuvring systems and their operation within a coastal and port environment
* Interaction with AtoN, including VTS and reporting procedures
* criteria/parameter for the actual trials
* knowledge of procedures for prior consultancy with stakeholders with economic, safety or environmental interests in the intended location.

The terms and conditions would then be subject to consideration with regard to the actual project, test area and traffic diversity (volume of traffic and degree of risk). Until regulation (in general) for international voyages with MASS is in place, national projects might have a high degree of case-by-case nature. This would require a high level of competence from the Competent Authority in assessing the MASS projects.

Competent Authorities would have to develop a policy/set of criteria when trials/use of MASS, would be acceptable, within specific areas, with various mix of traffic and risks relating to the marine environment.

A Competent Authority would need to consider/develop a policy on, but not limited to (not in order of priority):

1. Sea area allocation/marine spatial planning, and possible dedicated MASS routes
2. Reporting requirements (VTS, ship reporting systems)
3. MASS travel at time of day (slot allocating), avoiding congested time periods (embedded in a general traffic management)
4. Provision of AtoN (existing, new or modified types)
5. Transfer of ship data prior to port entry/national water entry using standard formats
6. Pre-arrival checklists for MASS onboard systems (flag: systems GO)
7. Pre-arrival checklists for MASS shoreside systems (flag: systems GO)
8. Systems for fallback arrangements, contingency plans, with failures.
9. MASS vessels inside and outside VTS coverage, consequences for MASS and other vessels
10. Sea Traffic Management (STM) for route exchange, the S-421 standard for MASS and other vessels
11. Secure data exchange using SECOM
12. Means for communication with MASS, and vice-versa
13. Communication systems for MASS control system monitoring and input
14. Redundancy relating to all onboard and shore-based related equipment and systems including MASS to shore communication systems, and vice-versa
15. Security including Cybersecurity, piracy and other physical breaches (port visits)
16. Other infrastructure deemed necessary based on local conditions, such as back-up facilities for emergency response

### Operational Aspects

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

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

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

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

Maritime Safety Information (MSI) including Notice to Mariners and radio navigation warnings should be issued as appropriate.

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

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

The navigation system should be designed and arranged to meet the required level of integrity established, considering the Autonomy Level, equipment type, and expected operations.

Port and Coastal Authority notes that 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.

## Facilities, systems and equipment

### Resilience of position

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

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

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

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

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

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

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

### Personnel and training

Port and Coastal Authorities can expect that all personnel operating MASS have received training appropriate to the tasks they undertake. It is the responsibility of the Operator to ensure that this training is given, and that the personnel have an understanding of the relevant regulations and rules.

As a minimum, for the MASS vessel, this means:

* For the Operator, the relevant qualifications;
* For the crew, relevant qualifications and any additional training appropriate to their designated duties.

From an IALA perspective, there is a requirement to ensure that those who are managing AtoN and working within a VTS Centre are aware of the minimum qualifications for the MASS operators. In addition, persons working to provide AtoN and work within the VTS centre require a minimum level of training on the expectations and implications of MASS vessels operating within the port and coastal environment.

Prior to the implementation of MASS within the port and coastal environment, a training needs analysis should be conducted. As MASS continues to develop there is a need to review and revise the training needs analysis on a regular basis.

Relevant information should be distributed to all personnel in a clear, concise manner, which should include considerations of language. The information and training should include, but is not limited to:

* Identification of control of areas around a MASS, on the support vessel whether docked alongside or rafted, or whilst at sea;
* manoeuvring modes – operations and limitations;
* operations in restricted and restricted/busy navigational areas;
* use and handling of emergency equipment/systems.

### situational awareness

For the operation of the MASS, a situational awareness and control system can include the onboard sensors interaction with offboard information sources (audio and visual), communications links and control logic that allow the MASS to operate safely. When interacting with MASS, it is important to know the level of autonomy and the approach to contact the MASS vessel operator.

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

From a port and coastal authority perspective it is important to note that the MASS may include command and control over the MASS, in order to ensure its safe operation. This has specific implications for VTS, and is further detailed in *the IALA Guideline #### VTS Interaction with a Mix of Vessels including MASS*.

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

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

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

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

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

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

### Data interpretation

Ports and Coastal Authorities should be aware that, from an operational perspective, it if important to note that the MASS should have at least one of the following:

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

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

* A human operator working in an ROC;
* 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.

# MASS OPERATIONS

The Ecosystem – refers to Section 2 of the draft IMO MASS Code

Implications / what has changed within a MASS ecosystem

## Navigation

The navigation system should be designed with a level of integrity sufficient to enable the UMS to be operated and maintained safely as and when required within its design or imposed limitations in all Reasonably Foreseeable Operating Conditions. MASS will rely on shore site support (new types of AtoN, shore control station, traffic management additional VTS functionality) which must been taken into consideration. Further details are provided in IALA G####.# Guidelines on the provision of AtoN to support a MASS environment.

### Functional objectives

Navigational systems should identify all navigation hazards, fixed or mobile, and measure and interpret environmental data. Shore support is expected to be included, with implications for port and coastal authorities. Examples include:

* MASS should be able to navigate to minimise risk of grounding, collision and environmental impact.
* MASS, shore site control stations and VTS should be able to communicate its limitations and navigational intentions to other vessels.
* the navigational systems should be designed and constructed to:
* enable their operation in all Reasonably Foreseeable Operating Conditions;
* operate in a predictable manner with a level of integrity commensurate with operational and safety requirements;
* meet requirements for watertight, weathertight and fire integrity;
* minimise the risk of initiating fire and explosion; (e) Enable the maintenance and repair in accordance with the maintenance philosophy.

### Performance requirements

The ship and shore navigation systems 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 will be supported by shore site systems and new types of AtoN.

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

The MASS should:

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

The Shore side systems and AtoN should:

1. Use ship and shore sensors to gain a sufficient operational picture.
2. Support MASS to gain a sufficient operational picture.
3. Predict danger of collision, grounding etc. assessment
4. Support MASS collision avoidance operations
5. Support for uncontrollable MASS.

### Colregs

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

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

From a port and coastal authority perspective, it can be anticipated that MASS vessels will interact with each other, and with traditional vessels, according to COLREGS.

## Remote Operation Centres

Port and Coastal Authorities should be aware of the role of ROCs in the operation of MASS. The ROC 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 ROC enables the command and control of the MASS. The ROC may be located afloat on a separate ship or ashore. The ROC may also interface with other ROCs that are separately located; the risk assessment would indicate which ROC has responsibility for a MASS at a specific time.

The ROC may be a fixed stationary installation, or fitted within a highly modular and portable unit, either of which may be controlling MASS from an ROC 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 ROCs is an important matter for the international community and owners/operators should take this into account in the development of their operational procedures.

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

It is highlighted the VTS is not the same as an ROC Operator, and VTS will not take over ROC duties. However, the ROC operator would be expected to comply with the requirements identified by the port and coastal authority, as per SOLAS Chapter V Regulation 11 (aids to navigation ) and Regulation 12 (VTS).

Detailed information on the interaction of MASS within a VTS area is included in IALA G ####.# VTS Interaction with a Mix of Vessels including MASS.

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 ROC operator.

The following is an example of possible roles and responsibilities:

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

### Relationship Between Autonomy Levels of Control and ROC

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

### Working Within Ports and VTS Areas

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.

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

Detailed information on the interaction of MASS within a VTS area is included in IALA G ####.# VTS Interaction with a Mix of Vessels including MASS

## Remote Operations

The remote operations of MASS vessels have specific relevance to the provision of AtoN to support MASS and VTS interactions.

### Monitoring and control

The MASS should have the ability to be controlled by a Control System which may be an on-board, off-board system or human operator, or a distributed system involving one or more of these elements. This information is provided to assist in the overall knowledge of the MASS operations, noting that these elements are outside of the specific remit of IALA.

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

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

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

### MASS Remote Controller Task Requirements

It is noted that the duty to render assistance will fall to be discharged, if at all, by the MASS Master, potentially delegated to the controller. The duty is qualified by what is reasonably to be expected given the limitations and characteristics of the relevant MASS. The implications of this within a port and coastal area, from the perspective of VTS, is identified in IALA G ####.# VTS Interaction with a Mix of Vessels including MASS

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

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

## Communications

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.

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 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.

Port and Coastal Authorities can expect a MASS vessel to be able to communicate with shore stations using the same manner as traditional vessels. As digital communication technologies evolve, it can be expected that machine-to-machine communication will increase. Detailed information on the interaction of MASS within a VTS area is included in IALA G ####.# VTS Interaction with a Mix of Vessels including MASS

### 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.

MASS vessel operations will be assessed with a focus on the response to a risk of loss of control communications and ability to execute the emergency stop function. These risks should be reduced to a level As Low As Reasonably Practical (ALARP).

Port and Coastal Authorities should confirm the procedures for loss of connectivity with MASS vessels when they are transiting in their areas. Detailed information on the interaction of MASS within a VTS area is included in IALA G ####.# VTS Interaction with a Mix of Vessels including MASS

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.

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

## Security

[introduction text to be developed]

### Cybersecurity

The increasing frequency of cyberattacks in the MASS ecosystem presents complex challenges with wide-ranging impacts. These attacks, ranging from unauthorised access to data to breaches and manipulation of basic navigation systems, pose a substantial threat to the operational integrity of MASS. The impact goes beyond compromising the confidentiality, integrity and availability of sensitive data; it can also lead to disruption of ship functions and collisions, navigational errors and security threats.

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

MASS cybersecurity vulnerabilities are intricately tied to their digital architecture and unified systems that enable autonomous operations. Key components within the digital framework, such as GPS, AIS, ECDIS, GMDSS, and GMMS, play vital roles in ensuring safety, navigation, and communication. However, these systems also present specific threats, including attempts to jam and GPS signal spoofing, manipulate AIS data, target ECDIS, and exploit weaknesses in GMMS. The mutuality of various systems, unauthorised access, or breaches in one area can affect the operation of the entire vessel.

* + - 1. Cyberattacks in the MASS ecosystem

Cyberattacks in the MASS environment include sophisticated techniques such as denial of service, jamming, and spoofing, each of which presents unique challenges to the security and reliability of MASS operations. The figure below illustrates the various cyberattacks in the MASS ecosystem.

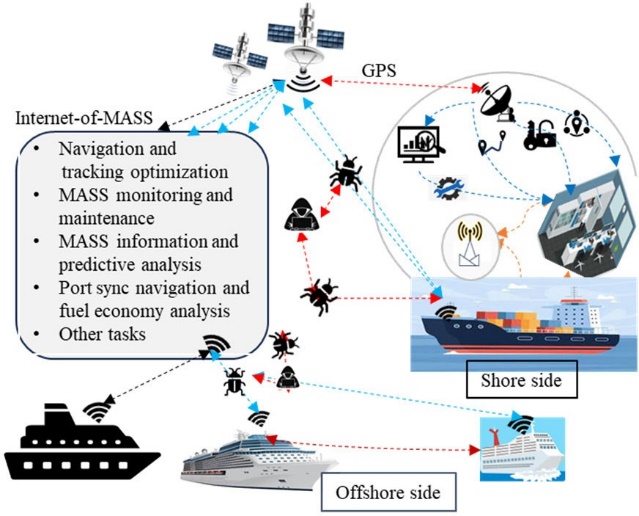


Figure Cyberattacks in the MASS ecosystem

* + - * 1. Spoofing attack

Spoofing attacks within the MASS domain involve manipulating data to deceive the vessel’s systems, introducing false information to its sensors like GPS, GNSS, ECDIS or communication networks. This malicious behaviour poses a substantial threat to MASS operations, as the ship may receive inaccurate data concerning its location, surroundings, or other critical parameters

MASS ships rely on sensor data, which attackers can simulate to trigger false alarms or send false conflicts to collision avoidance systems to manipulate the trajectory of the target vessel and affect its course. Spoofing attacks on MASS have the potential to cause faulty navigation, increase the risk of collisions, and compromise situational awareness and communication reliability.

* + - * 1. Jamming attack

Jamming attacks focus on disrupting communication signals by emitting interference. Within MASS, jamming can compromise the accuracy of navigational data (e.g. GPS, GMS), leading to misguidance and potential safety hazards. Firstly, the key frequency of the target RF interference is identified, and then the interference signal is sent to carry out the interference attack. Intermittent transmission of interference signals can be used to complicate countermeasures.

RF jamming in AIS, indicated by overloading AIS channels with white noise, poses a substantial threat, potentially disrupting communication by jamming valid packets. The AIS outlines the use of cyclic redundancy check as the method for error detection, but none of the systems inform the user about the identified incorrect packets. For example, a small frequency offset causes the receiver to inaccurately flag legitimate AIS packets as invalid. In addition, signal distortion, which is prevalent in crowded radio frequency channels, is another potential source of inaccuracy.

* + - * 1. Coordinated attack

Coordinated attacks are when multiple attackers cooperate to launch a network attack on the system at the same time. It poses a significant cybersecurity threat in the MASS domain. Attackers can collaborate to capture and analyse network traffic to identify vulnerabilities, and intercept and impersonate altered communications. For example, exploiting vulnerabilities in the Maritime Mobile Service Identity (MMSI) number for AIS transmissions, attackers collaborate to transmit multiple signals with varying values in specific AIS data fields but with the same MMSI number. This coordinated manipulation facilitates rapid alterations in the ship’s information, including position, type, and size, posing severe risks to communication with other vessels and Vessel Traffic Services. Potential consequences encompass miscommunications, navigation errors, and perilous scenarios.

* + - * 1. DoS attack

DoS attacks on a MASS are a deliberate attempt by an attacker to disrupt or prohibit authorised users from utilizing vital functions of the autonomous system. This type of attack poses a significant threat to the operational integrity of MASS, aiming to deplete resources and disrupt normal operations. Attackers employ various tactics, such as flooding communication channels or overloading sensor networks, to overwhelm the MASS’s critical components and hinder its ability to process data, execute commands, or maintain efficient communication. Synchronization protocols can also be controlled to attack the network infrastructure. The impact of DoS attacks on MASS operations is profound, with the potential to compromise navigation, communications, and the integrity and reliability of the entire system.

* + - * 1. Vision device attack

While at sea, MASS rely heavily on visual aids, including plotted charts and radar screens supported by AIS. Deceptive AIS transmissions can greatly impair this visual device navigation process. When ships using a variety of MMSI and geographic coordinate data are surrounded by a large number of fake information, ship operators face potential confusion, severely affecting situational awareness.

* + - * 1. Physical network attack

By manipulating physical systems through the network, such as PLC systems or SCADA operating systems, manipulate legitimate devices in the physical process to attack MASS networks, and carry out network attacks targeting the vulnerabilities in SCADA communication protocols.

* + - 1. Cybersecurity countermeasures in MASS

In view of the interconnected nature of various systems and stakeholders, coordinated efforts are needed to build strong defense mechanisms to keep MASS operating optimally. It is vital to ensure seamless integration of cybersecurity measures across the entire ecosystem to guarantee that an overall defense strategy enhances the overall cyber resilience of MASS and the broader maritime infrastructure.

A multifaceted approach to countermeasures against attacks is required to enhance the cybersecurity of MASS. A range of countermeasures are essential to address the cybersecurity threats facing MASS, ensuring the confidentiality, authenticity, integrity, availability, control, and utility of information in the maritime ecosystem. Firstly, implementing strong access controls and authentication mechanisms is a requisite. This includes rigorous verification processes for on-board and remote access to MASS systems, ensuring that only authorised personnel interact with critical ship components. Advanced access controls should include user privilege management and strict segregation of duties, limiting access to sensitive information to only those personnel who require it for their specific roles.

Secondly, advanced encryption protocols are also essential in ensuring the integrity of communication channels and data. Encrypting data transmitted between MASS components and external systems significantly reduces the risk of unauthorised access and data manipulation.

Thirdly, segment the Network Architecture, using VLANs, micro-segmentation, and access control lists (ACLs) to divide the MASS network and limit the lateral attack. Regular ACL audits ensure configurations align with security policies.

Fourthly, deploying intrusion detection and prevention systems becomes critical for real-time network monitoring, identifying and mitigating potential cyber threats before they compromise the ship’s operational integrity, and constantly improving its response mechanisms in response to evolving cyber threats. Meanwhile, developing resilient communication protocols and alternative frequency channels enhances the system’s robustness against jamming attempts.

Furthermore, constant tracking and regular vulnerability assessments are critical components of an effective cybersecurity strategy for MASS. This entails proactively identifying potential software, firmware, and communication protocol flaws, allowing for timely patching and updates to address emerging threats.

Finally, human error is still a common entry point for cyberattacks, so emphasizing cybersecurity awareness and training for ship personnel is equally important. Continuous training covers phishing awareness, secure practices, and reporting procedures, to improve the ability to identify and mitigate potential cyber threats.

* + - 1. Key points to be considered for improving MASS network security

Integrating state-of-the-art cybersecurity solutions into MASS brings a variety of challenges that need to be appropriately addressed. The following are some key considerations:

* + Development and Implementation Costs: The development and implementation of state-of-the-art cybersecurity solutions can incur significant expenses. Therefore, MASS developers and operators need to weigh up the benefits and drawbacks.
  + Maintenance Costs: Frequent updates, fixes, and improvements will be necessary to keep the cybersecurity measures effective. Over the system’s lifetime, this will result in additional costs.
  + Compatibility with Current Technologies: New cybersecurity measures must work effectively with the present components and technology ofMASS. Compatibility issues may arise if the solutions are not developed with compatibility in mind.
  + Legacy Systems: It is probable that certain MASS systems are still running on outdated hardware or legacy systems. It might be challenging to add new cybersecurity protections to these sorts of systems and further changes might be required.
  + Regulatory Compliance: MASS systems must follow regulations and industry best practices. It is imperative that new cybersecurity solutions are implemented in conformity with these criteria in order to preserve legal and regulatory compliance.
  + Regulations pertaining to data protection: It is essential to respect privacy and data security laws. Cybersecurity measures should safeguard sensitive and private data.
  + Industry Wide Adoption Standardization: It is frequently necessary to achieve industry-wide acceptance of cybersecurity solutions. The establishment and implementation of standard cybersecurity procedures throughout the MASS development and operational groups require consensus.
  + Scalability for Future-Proofing: MASS systems should be designed to accommodate future technological advancements and cybersecurity threats. The chosen cybersecurity solutions should be scalable and adaptable to evolving challenges.
  + User Acceptance Usability: The effectiveness of cybersecurity measures is also dependent on user compliance. If security measures are too complex or impede the functionality of the MASS system, users may resist their implementation.
  + Training and Awareness: Users must be educated about the importance of cybersecurity and how to use the implemented measures effectively.
  + Cyber Defense Adaptation: MASS systems must constantly update and adjust their cybersecurity defences to address new security concerns.

Addressing cyber threats in the MASS ecosystem requires a collabotive effort to strengthen the resilience of MASS networks. Stakeholders must collaborate to share threat intelligence, enhancing cooperative defense posture. Emphasizing standardization and adopting industry-wide cybersecurity protocols becomes crucial in fostering a cohesive and secure maritime environment.

## Emergency Response

In principle MASS vessels should fail safe i.e. shut down propulsion provide suitable navigation status on AIS and with appropriate lights (i.e. Not Under Command (NUC) anchore as applicable). The risk assessment and hazard identification system process should identify potential emergency MASS situations should be shared with the port and coastal authorities when a MASS vessel is transiting the area. Safe systems of work and procedures should then be developed to respond to them. An Emergency Situation should be considered to have occurred when a signal has not been received from or by the MASS for a critical time period, with standard response procedures developed. This critical time period will be related to, but not dependent upon, the MASS last confirmed location, its risk level and cargo. The appropriate authorities should be informed as soon as it is recognised by the Master and operators that the Emergency Situation exists.

Procedures for responding to emergency situations should be clearly established, and be inline with existing procedures for traditional vessels. These may include but are not limited to:

* Loss of Control of MASS for a critical time period;
* Fire;
* Collision;
* Grounding;
* Flood;
* Violent act;
* Main propulsion or steering failure;
* Man overboard (if vessel manned);
* Abandon MASS procedure (if vessel manned).
* Propulsion or steering failure;

Detailed information on the interaction of MASS within a VTS area is included in IALA G ####.# VTS Interaction with a Mix of Vessels including MASS

## Reporting accident

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

All accidents and near misses/dangerous occurrences should be reported as per existing requirements. The method for reporting of accidents should be well understood by all personnel.

Detailed information on the interaction of MASS within a VTS area is included in IALA G ####.# VTS Interaction with a Mix of Vessels including MASS

## Portrayal of MASS

MASS needs to be clearly defined and easily recongised on display systems. Other vessels and shore authorities/VTS should have the means for understanding the intention of a MASS manoeuvre.

### DST, ECDIS, radar, charts

Portrayal of MASS on Decision Support Tools will be required to support VTS operations. Portrayal will be in line with updates in IMO, the International Electrotechnical Commission (IEC), the International Telecommunications Union (ITU) and the International Hydrographic Organisation (IHO) standards for displaying vessel information while addressing the specific needs of VTS.

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

Detailed information on the interaction of MASS within a VTS area is included in IALA G ####.# VTS Interaction with a Mix of Vessels including MASS

### Designated routes on charts

[To discuss – should MASS be put into specific, designated routes for MASS? Initial discussion indicate that this is not viable and should not be considered for port and coastal areas, noting choke points and existing routing limitations. ]

# CONSIDERATIONS FOR THE PROVISION OF ATON IN A MASS ENVIRONMENT

The AtoN to be delivered to support the various degrees of autonomy for MASS operations need to be identified considering factors that include:

1. Risk Mitigation
2. Services to be rendered to support safe navigation
3. Methods for service delivery / provision
4. MASS service requirements
5. Remote berthing and connections to shore services
6. VTS environment interaction
7. Route Message transfer
8. Local situational awareness and control including tracking of vessels
9. Metrological systems and data
10. Hydrographic systems and data
11. AtoN availability
12. Vessel traffic and density
13. Adaptation of traditional AtoN services to support MASS, including in pilotage waters
14. Adopt, adapt or extend existing technology
15. Communication services
16. Sustainability of AtoN

The AtoN to be delivered to support the various degrees of autonomy for MASS operations need to be identified considering: MASS interaction with:

* Fixed, floating, electronic and radio AtoN
* Position support mechanisms as technology evolves
* Manned vessels
* Choice of media (voice, digital, etc)
* How to inform other seafarers (COLREG rules 16++)
* How to interact with smaller vessels, kayaks, rowing boats etc. (including target detection)
* GMDSS compatibility
* Offshore structures
* MASS/MASS
* Other shore based infrastructure

## Operational Aspects for AtoN in a MASS environment

[introduction text to be developed]

### Applicability to Mass Operations

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

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

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

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

## Systems, technology

[introduction text to be developed]

### Testing and auditing of MASS

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

# CONSIDERATIONS FOR THE PROVISION OF VTS IN A MASS ENVIROMENT

Detailed information on the interaction of MASS within a VTS area is included in IALA G ####.# VTS Interaction with a Mix of Vessels including MASS

# DEFINITIONS

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

# abbreviations

Note the terminology developing at IMO, ISO, DNV

[to be developed]

NGO Non-governmental organization

VTS Vessel Traffic Services

# references

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

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

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

For example:

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

should be included in the reference list as follows:

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

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

# Further reading

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

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

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

* 1. Existing high-level documents

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

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

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

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

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

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

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

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

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

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

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

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

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

* Safemass

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

* 1. National Authorities
     1. US Federal Registry

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

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

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

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

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

* 1. 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

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

* ISO/TC8/WG10 Smart Shipping

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

* 1. Certification Authorities
     1. Bureau Veritas

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

* + 1. DNV

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

* + 1. LLOYD’s Register

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

* + 1. American Bureau of Shipping (ABS)

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

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* + 1. Others

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

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

1. Leave open if uncertain [↑](#footnote-ref-1)