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| IALA Guideline |

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IALA GUideline on maritime autonomous surface ships for Coastal State Authorities

**Moving towards ARM16**

1. Those that are interested to be part of intersessional work, indicate availability to Guttorm (guttorm.tomren@kystverket.no) within 3 weeks from the date of the final ARM15 plenary
2. Wait for engagement between Phil and ENAV Chair before commencing with intersessional work
3. James to clean up and work on relevant sections

Edition 1.0

Document date

Revisions to this IALA Document are to be noted in the table prior to the issue of a revised document.

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# Aims and Objectives

The aim of this guideline is to:

1. Provide guidance to the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) members and other stakeholders who may be undertaking:
2. Testing;
3. Trials; or
4. Operations

of MASS systems.

1. Provide guidance for organisations implementing policy, procedures and technical solutions to support the introduction of MASS.
2. Identify possible future scenarios while considering the evolution of MASS;
3. Analyse the possible impact of MASS on Marine Aids to Navigation (AtoN);
4. Identify the future requirements on AtoN service; and
5. Identify future MASS Gaps.

# Introduction

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

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

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

## Background

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

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

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

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

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

## IMO’s STRATEGIC APPROACH TO MASS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

MSC 104 decided to establish an agenda item for developing a goal-based MASS instrument, and then at MSC105 (April 2022) commence work with a roadmap for further work (up until 2025).

# IALA and MASS

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

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

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

1. Fixed shore side electronic AtoN
2. Floating electronic AtoN
3. Virtual AtoN
4. Marking of physical AtoN using Synthetic AtoN
5. The transmission of local and applicable AtoN information, MSI, Meteorological and Hydrographic data using Application Specific Messages (ASM) contained in IMO Circular SN.1/ 289
6. Supporting the safe and efficient operations within both national and international waterways
7. Ensuring communication between vessels within and outside of a VTS environment, recognising the different degrees or levels of autonomy
8. Sharing of a common operating picture for situational awareness of the waterway within and outside of Vessel Traffic Services (VTS) environment
9. Applicable to Level 1-3: Scoping and development of guidance on the interaction between VTS and the remote control centre (RCC) for MASS (land-based and / or from another vessel)
10. The tracking of both MASS and non-MASS vessels to support the traffic image
11. Cyber Security – cyber risk management
12. Augmentation of positioning systems
13. Promoting standardisation of data transfer

The above requires digital communication systems that include AIS. The ASM is evolving within VHF Data Exchange System (VDES). The VDE (full description) component, when available, will also be relevant.

Other digital data exchange capabilities, including developments in 4G and 5G, digital VHF Voice and satellite technologies will also be relevant to facilitating MASS operations.

# MASS and Maritime Services

The services delivered using physical, electronic and virtual AtoN environments for each of the four degrees of autonomy identified by IMO could be different, noting that the MASS could change its level of autonomy depending on its phases of voyage.

## CONSIDERATIONS FOR PROVISION OF ATON IN MASS ENVIRONMENT

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

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 all vessels/boats
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

# Development of MASS SYSTEMS

An appropriate means of AtoN and for communications and data exchange, including redundancy, should be provided for the safe conduct of any MASS trial (from MSC.1/Circ.1604).

Website for updates on MASS developments? (perhaps an opportunity to provide IALA members with an online calendar of MASS activity / conferences; reference materials?)

## Management of MASS vessels

### Operational and Evaluation Deployment Planning and Authorisations

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

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

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

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

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

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

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

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

### Environmental Considerations

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

### Health and Safety

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

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

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

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

### Cyber Safety and Security

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

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

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

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

### Regulatory and Legislative Compliance

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

### Allocation and Rules of Test Areas

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.

At the June 2019 meeting, the IMO MSC approved a guideline for testing autonomous ship activities, MSC.1/Circ.1604 (Interim guidelines for mass trials). The purpose of the guideline is to assist 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.

### Changes to National Laws

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 adopting changes in national laws to allow initial testing/trials/operationswith MASS. 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 unmanned voyages (pilotage exemption):

* Pre-trial research activities and phased/scalable trials
* Requirement for the actual vessels navigation and manoeuvre systems
* Criteria/parameter for the actual trials
* Competence regarding test area/fairway area within project organisation, and mandatory procedures for prior consultancy with pilots

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. Pilotage requirements
3. MASS travel at time of day (slot allocating), avoiding congested time periods
4. Provision of AtoN (existing, new or modified types)
5. Transfer of ship data prior to port entry/national water entry (ENAV?)
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. Level 1-3, humans are the safety fallback, service provision to reflect this?
10. MASS vessels inside and outside VTS coverage, consequences for MASS and other vessels
11. Sea Traffic Management (STM) for route exchange, the S-421 standard/SECOM (formerly "VIS", voyage Information Service), for MASS and other vessels
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

## Risk Management & Assessment (RMA)

### Prior to projects launched (national waters)

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

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

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

### Risk Management Assessment prior to MASS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

### Procedures For Reporting Accidents

All accidents and near misses/dangerous occurrences should be reported to the management regardless of the incident size and its severity. The method for reporting of accidents should be well understood by all personnel. This in turn would improve the safety culture practised through the Operator.

MASS operating should report any accidents to the RO and the Operator should therefore have a procedure in place to achieve this requirement.

The accident reporting system should be well documented, with all records retained as per Operator policy for the retention of records.

The system should include procedures ensuring that accidents and hazardous situations are reported to the Operator. After initial actions are completed to safeguard individuals or equipment, an investigation should be conducted. The incident results are to be analysed and recorded, with the appropriate measures subsequently implemented to improve safety and pollution prevention.

This procedure should also include any identified non-conformities to the standards followed after audit or through general observation.

The Operator should establish procedures for the implementation of corrective action, including measures intended to prevent recurrence.

### Procedures For Responding to Emergency Situations

In principle MASS vessels should fail safe i.e. shut down propulsion provide Not Under Command (NUC) lights, anchor as applicable. The risk assessment and hazard identification system process should identify potential emergency MASS situations. 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. 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. 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;

Checklists/Aide Memoires may be useful in this regard onboard the MASS and at control stations.

The roles and responsibilities of all personnel in an emergency situation should be defined and recorded.

The safety management system should provide for measures ensuring that the Operator’s organisation can respond at any time to hazards, accidents and emergency situations involving its MASS. This is particularly important during crewless periods of operation.

It is essential that there is the ability to communicate with the emergency services via the MASS or RCC.

Preparation for emergency situations requires careful consideration and planning. All new and existing personnel should undertake suitable and sufficient training for each of the emergency scenarios. A programme of drills and exercises to react for emergency actions should be incorporated into any vessel management plan.

Any exercises conducted should be recorded. This record should include the names of those who participated

### Personnel and Training

All personnel should receive 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. This training should be recorded in the MASS Operators Training Record Book (see Chapter 13).

As a minimum, this means:

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

Training needs analysis should be conducted regularly for identifying any training, which may be required in support of the Safety Management System (SMS) and ensure that such training is provided for all personnel concerned.

Relevant information on the SMS should be distributed to all personnel in a clear, concise manner, which should include considerations of language.

The SMS should also incorporate an effective feedback procedure such that the MASS’ personnel are able to communicate effectively in the execution of their duties related to the SMS.

* Control of areas around a MASS, on the support vessel whether docked alongside or rafted, or whilst at sea;
* Manoeuvring in all modes at sea;
* Operations in restricted and restricted/busy navigational areas;
* Launching and recovery operations;
* Evacuation from all areas of the MASS;
* Use and handling of emergency equipment/systems.

This training should be recorded in the MASS Operators Training Record Book and signed off as completed by the appropriate authority or responsible person.

## MAINTENANCE OF THE MASS AND EQUIPMENT

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

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

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

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

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

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

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

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

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

MMS.

### MASS Vessel Data Recording (M-VDR)

**Data to be recorded – General Principles**

With the increasing numbers of MASS vessels in commercial use and the consequential need to maintain acceptable safety standards and regulatory oversight, the capture and storage of vessel data and the development of MASS vessel monitoring programmes needs to be considered.

Carriage of a VDR is not currently mandatory and due to the nature of remote and autonomous operations, off-board data recording may also be appropriate to fully capture vessel command and control data.

For accident investigation purposes, MASS vessels present new challenges and so data should be recorded and be made available in order to aid investigations.

It is suggested that operators of MASS vessels also look to incorporate vessel data monitoring programmes as part of a proactive Safety Management System. Establishment of a definitions within MASS operations and the development of pan-industry data sharing initiatives on safety related issues is to be encouraged, as this would aid the development of the critical safety standards in this emerging industry.

MASS vessels by their very nature produce large volumes of data of many differing types and in most cases would have to pass this data back to RCC, this annexe suggests the type of data that should be recorded and how it can be made available in the event of accident investigation being required. Vessel data in respect to MASS vessels is complicated by the remote nature of the designated operator, which means that command data that is necessary for accident investigation maybe generated offboard and therefore operators should look to record operator command data and vessel response data as well as recording vessel data parameters.

The vessel owner will, in all circumstances and at all times, own the data produced. However, it is expected that owners/operators will make all vessel onboard and offboard data available to accident investigators as required.

**Duration of storage**

The minimum duration for stored data should be 30 days standard, captured internally and 48 hours for both fixed and float free Final Recording Medium (FRM.) Offboard storage should be maintained for a similar period and it is suggested that operators and owners look to maintain a full history of operational data to aid the development of incident reporting and accident investigation procedures as they pertain to MASS vessels.

**Securing and provision of data**

In the event of an accident or incident, operators should have defined procedures for securing onboard and offboard data and providing it to the relevant authority as required and within 48hrs to the Flag State of operation and registration (if different) that the vessel was operating, for any marine casualty as defined under the IMO Casualty Investigation Code MSC.255(84).

**Post Incident data downloading**

In all circumstances the responsibility to arrange down-loading and read-out of the data from the recovered memory in whatever form should, in the first instance, be undertaken by the investigator who should keep the ship owner fully informed. Additionally, and specifically in the case of a catastrophic accident, where the memory may have sustained damage, the assistance of specialist expertise may be required to ensure the best chance of success.

**Data Format**

If the data format used on-board a vessel is proprietary to the manufacturer or vessel type then a conversion tool to convert to Commercial Off The Shelf (COTS) formats should be made available to the relevant investigating authority. Replay software should be supplied license free to the relevant authority.

**System testing**

Daily Performance testing of recording equipment is recommended, as is performance testing following any maintenance or repair to equipment that supplies data to be recorded.

## Portrayal

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

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

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

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

### Designated routes on charts

Should MASS vessels be treated differently than normal vessels?

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

???

## Situational and Spatial awareness

### Situational Awareness and Control

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

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

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

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

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

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

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

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

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

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

### Resilience of position finding

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

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

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

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

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

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

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

### Data Interpretation

The MASS should have at least one of the following:

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

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

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

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

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

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

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

### 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.

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

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

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

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

### Emergency Stop

The MASS should have a defined condition of Emergency Stop, which must be fail safe under conditions where normal control of the MASS is lost. Under Emergency Stop, propulsion is reduced to a safe level in a timely manner. In this context:

* “a safe level” means a level at which it is not likely to cause damage either directly or indirectly. It should be noted that some MASS (e.g. wave propelled) may not have any means of cutting propulsion power to zero. But in a harbour or sheltered waters the wave propulsive power may reasonably be expected to be a safely low level;
* “in a timely manner” means within a time that is short enough to ensure that the risk from uncontrolled propulsive power can be contained before it is likely to cause damage. In open ocean conditions this may be relaxed, whereas in a docking situation the propulsion may need to be cut more quickly, within seconds or less.

The MASS should have the ability to be placed in an Emergency Stop condition by a human or automatic controller or supervisor with access to sufficient Situational Awareness data to be able to determine when an Emergency Stop command is necessary.

In the case of an automatic operator, the design of that controller or supervisor should be fail safe, in that it should recognise all known unsafe operating conditions with no false negatives and should react to unknown or indeterminate safety conditions by invoking Emergency Stop in a timely manner.

On sensing a failure (or disabling, whether deliberate or not) of all data-links which may carry an emergency stop command, the MASS should enter a ‘render-safe’ procedure. This should culminate in Emergency Stop. The first action should be that, if situational awareness has been, and continues to be, fully operational, the MASS should immediately shape a safe course and adopt a ‘safe speed’ (making appropriate sound and visual signals when feasible) commensurate with weather conditions, COLREGS and safe navigation at the time of loss of data-link. This should minimise hazards to the MASS and other vessels, whilst the MASS and the control station resolve the situation. If the data-link is not re-established after an appropriate grace time, and/or the MASS’s own situational awareness deems it safe/necessary, the MASS should enter Emergency Stop. Consideration may be made of including ‘dropping anchor’ as part of the render-safe procedure, commensurate with accepted safe navigation practices.

In the event that the MASS experiences loss or compromise of Situational Awareness as well as loss of data-link, then Emergency Stop should be immediately initiated (making appropriate sound and visual signals when appropriate).

### Propulsion Control

MASS should have propulsion control as far as necessary to be capable of ensuring that safe operating speeds appropriate to its situation are not exceeded.

### Steering Control

The MASS should have steering control as may be necessary to maintain a safe heading. Note that ‘passive’ MASS, such as drifting sensor buoys, do not have steering control, but the risk is mitigated by deploying in safe areas and monitoring their position, and maintaining the ability to recover the MASS when necessary.

Note on Heading vs Course Over ground (COG). Marine craft may have control of heading but limited control of COG because of environmental influences such as surface currents, waves, or wind, combined with low Speed Through the Water (STW). The risk posed by potential loss of control over COG should be addressed by means of situational awareness, using sensor and almanac data or calculations as necessary to anticipate environmental influences, so as to avoid bringing the MASS into a situation where it is predictably carried in an unsafe direction by overwhelming environmental influences.

### COLREG – Compliant Behaviours and Fail-Safes

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

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

Sense and Avoid systems may be deemed necessary:

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

## Navigation Systems

### Goal

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

### Functional objectives

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

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

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

The navigational systems should be designed and constructed to:

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

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

### Performance requirements

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

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

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

The MASS should:

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

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

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

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

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

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

## Communications Systems

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

RF communications requirements for MASS will include the following:

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

### GMDSS Requirements

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

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

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

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

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

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

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

### Communications For Control System Monitoring and Input

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

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

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

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

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

### RF Communications Installation

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

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

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

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

### Positioning the MASS (onboard ship sensors) (ENAV?)

???

### Positioning the MASS (external sensors/services) (ENAV?)

???

### Route exchange MASS/shore, MASS/ship, MASS/MASS

???

## MASS interaction

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

## Remote Control Centres (RCCs)

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

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

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

### Sub-System Architecture

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

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

### Tasking Cycle of the MASS

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

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

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

The following is an example of possible roles and responsibilities:

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

Receives commands from the Watch Officer;

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

### Dynamic Positioning Station Keeping Systems for Mass and Remote

#### Operations

The emergence of Remote Operation and the growth of the MASS towards 2025 and beyond has seen the number of MASS RCC expanding rapidly as companies are beginning to transition into a remote way of working. Currently there is no mandatory requirement for a ship’s officer to complete dynamic positioning equipment training for the operation of MASS as part of STCW training.

As MASS increase in size and complexity, seafarers qualifying as Unmanned Surface Vessel (USV) Masters and USV Watch supervisors would be required to hold Dynamic Positioning (DP) certification in order to operate DP classed vessels. As a result, The Nautical Institute is exploring the changing needs around DP Certification for USV and MASS operations. These are expected to be issued in January 2022 by The Nautical Institute.

### Transfer of Mass Control

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

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

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

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

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

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

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

### Controlling Mass from an RCC

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

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

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

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

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

### Relationship Between Autonomy Levels of Control and RCC

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

### Suggested RCC Operational Requirements

The following operational requirements are provided as illustrations for guidance:

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

### Working Within Pilotage Waters

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

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

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

### Managing RCC Workforce Wellbeing

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

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

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

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

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

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

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

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

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

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

## Rendering of Assistance to Persons in Distress at Sea

### Requirements of International Law

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

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

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

### Applicability to Mass Operations

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

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

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

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

### MASS Remote Controller Task Requirements

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

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

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

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

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

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

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

## Salvage and Towage

As MASS capability becomes more prolific at sea, and also as they grow in size and complexity, they would be subject to the same risks as their manned counterparts. The outcome of these risks may require the MASS to be subject to either Salvage or Towage. It is assessed that the existing body of law is applicable to MASS.

### MASS Salvage

Existing maritime salvage law as it applies to manned ships generally applies to MASS. MASS owners should consider making use of the existing standard salvage contracts, such as the Lloyds Open Form (LOF).

MASS owners should provide salvors with information about the MASS and payload (where applicable) as necessary for the safety of the salvage operation and in any event when such information is reasonably requested by the salvor.

MASS owners should co-operate as fully as possible with salvors in conducting the salvage operation and permit the salvor to make reasonable use of the MASS’s equipment, as appropriate.

MASS owners should accept redelivery of the MASS after the salvage operation when reasonably requested to do so by the salvors.

### MASS Towage

Existing maritime towage law as it applies to manned ships generally applies to MASS. MASS owners should consider making use of the existing standard towage contracts such as the UK Standard Towing Conditions.

MASS owners should disclose and provide to the towage service provider information reasonably necessary for the safety of the towage operation.

MASS owners will have to ensure that all the requisite documentation for towing their MASS platform is in place and up to date; e.g. towing plans.

MASS owners should exercise due diligence at the commencement of the towage to ensure that the MASS is fit to be towed and that the MASS is properly equipped therefore.

MASS owners should resume control of the MASS at the agreed place of destination for the towage service.

Side list for other committees (so that items do not get lost):

1. Status of vessel degree of MASS, systems go, how to check and understand from other vessels, ++ included in VDES development?
2. Loss of GNSS, what is the backup?
3. Will the other committee create separate chapters? Align after PAP meeting.

Coordinate with Jaime and Jillian (ENAV) after PAP

# Related Developments

## Terrestrial AtoN in the aerospace environment

Should be for all vessels

More about fairways – this section better suited in G1078?

10-20 years still have conventional vessels

Table below not really applicable re AtoN within maritime environment

Norway has various levels of AtoN, but does not name it as aerospace does

Contradictory to have AtoN table for MASS only – no separate categorisation for MASS

The avionic domain has various categories for types of airports. It appears that a similar system can be used for AtoN in the various maritime environments.

The aerospace industry has the following definitions for airports:

1. Description of airports by level of approach

|  |  |
| --- | --- |
| **Level** | **Description** |
| Non- precision Approach Runway | An instrument runway served by visual aids and nonvisual aid providing at least directional guidance adequate for a straight-in approach |
| Precision Approach Runway, CAT I | A precision instrument approach and landing with a decision height not lower than 200 feet (60 meters) and with either a visibility of not less than 800 meters or a Runway Visual Range of not less than 550 meters |
| Precision Approach Runway, CAT II | A precision instrument approach and landing with a decision height lower than 200 feet (60 meters) but not lower than 100 feet (30 meters) and a Runway Visual Range of not less than 350 meters |
| Precision Approach Runway, CAT IIIA | A precision instrument approach and landing with a decision height lower than 100 feet (30 meters) or no decision height, and a Runway Visual Range of not less than 200 meters |
| Precision Approach Runway, CAT IIIB | A precision instrument approach and landing with a decision height lower than 50 feet (15 meters) or no decision height, and a Runway Visual Range of less than 200 meters but not less than 50 meters |
| Precision Approach Runway, CAT IIIC | A precision instrument approach and landing with no decision height and no Runway Visual Range limitations |

1. Description of AtoN in various maritime environments (to be developed, taking Table 1 Description of airports by level of approach, into consideration)

|  |  |
| --- | --- |
| **Level** | **Description** |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

## IALA AtoN classification

Using the example of the aerospace sector, it appears that the maritime AtoN environment can develop a similar classification system leading to a known environment within the maritime AtoN area.

1. Example of AtoN area classification

|  |  |
| --- | --- |
| **Level** | **Description** |
| Category 1 | To be developed |
| Category 2 | To be developed |
| Category 3 | To be developed |
| Category 4 | To be developed |
| Category 5 | To be developed |

# Looking AHEAD

## Impact of MASS on current AtoN

Recognised requirements re AtoN for MASS should also serve ALL non-MASS vessels

Also see section 5.8

MASS: Use current AtoN services

**Also see section 7.3**

How to learn from trial. Consolidated trails information being made available?

**Legal**

IALA scoping exercise to be done to amend current legislation, rather than create new legislation

**Extract from C71-8.5.1: VTS49-3.1.2**

The document “Position on the development of marine aids to navigation (AtoN) services” (<https://www.iala-aism.org/content/uploads/2020/02/IALA-Position-Document-on-the-Development-of-Marine-AtoN-Services-2019.pdf>)describes the positions that IALA will take concerning certain critical technical and operational aspects of its work with the object of assisting the work of the technical Committees of IALA and informing IALA members. (IALA, 2019a) In the 2019 edition of the document position statements on MASS are made in three occasions;

1. Impact of autonomous vessels on AtoN infrastructure. This statement belongs to the IALA standard “AtoN and delivery”. (ARM Committee)

2. Autonomous vessels in a VTS area. This statement belongs to the IALA standard “Vessel Traffic Services”. (VTS Committee)

3. Digital services for autonomous vessels. This statement belongs to the IALA standard “Information Services”. (ENAV Committee)

***MASS in the other Committees*** *Position statement*: In future, new AtoN services may be needed for MASS (Maritime Autonomous Surface Ships) as well as for traditionally crewed ships. New requirements for availability, redundancy and continuity may be needed.

IALA will monitor the development of MASS navigation technology and performance, determine what AtoN services should be provided from shore and develop appropriate guidance.

At present it seems likely that an important service that will be required by MASS will be a resilient positioning service. Terrestrial positioning services may be required in some areas to achieve the resilience necessary.

**International meeting for MASS infrastructure**

From 12th to 14th February 2020 there was an expert meeting on MASS and shore maritime infrastructure including marine aids to navigation in Tokyo, Japan. During this meeting, the impact of MASS on shore infrastructure was discussed.

With some testbeds and member state developed roadmaps to introduce MASS it was discussed that visual, Radio, Audible and virtual Aids to Navigation (AtoN) are useful not only for MASS but also for conventional ships operating under harsh environmental conditions or geographic features.

The participants of the meeting recognized that existing visual, radio, and audible AtoN can contribute to forming a suitable platform of complementary and enhanced services for MASS. Studies on the usage of such existing AtoN should be initiated with a goal to develop new technologies and policies. (IALA, 2020b) The use of these technologies should consider the environmental and safety impact and these technologies should also consider cyber security risks. In relation to AtoN’s the participants also discussed Position, Navigating and Timing (PNT) issues and agreed that radio navigation systems such as R-Mode, e-Racon could be useful for MASS operations. (IALA, 2020c)

During the meeting, the participants also discussed the future roles of VTS in MASS operations. It was agreed that VTS should support MASS operations, however, VTS should retain its principle services for all vessels. While VTS maintain their core services, the participants agreed that it could be useful to share information with MASS to improve the ability to share the common operational picture of the area. In order to facilitate data sharing, VTS should be digitized. In that sense, IALA should consider revising the Recommendation V-145 “Inter-VTS exchange format service” to include exchanges with MASS Shore Control Centers (SCCs) and other allied services. As for SCC, the participants agreed that human supervision is required at all levels of autonomy of MASS and the human-machine interface is a key component for ensuring safe MASS operations. Although the VTS Operator (VTSO) may not be involved in controlling a MASS, procedures are necessary how a VTSO should act and communicate in case of an emergency.

Experts agreed that radiocommunication infrastructure for MASS operation should be robust and redundant. Guidance materials for the use of VHF Data Exchange System (VDES) and other potential technologies such as 5G should be developed, while taking cyber security issues into consideration. (IALA, 2020c)

Harmonization of data models of different sectors will be the key to intermodal transport involving MASS. Therefore MASS operations requires interoperability across transport modes such as sea, rail, road and air, and could include coordination with intelligent transport system standardization initiatives. (IALA, 2020c) We also can learn from trials, testbeds and experience in other industries such as road and railroad.

Finally, the participants concluded that sharing information about testbeds on a central hosted website is important. Testbed information on MASS operations supports the development of new infrastructure. (IALA, 2020b)

***Shore infrastructure and AtoN***

It is obvious that all levels of MASS will be sailing from destination to destination in the future, the responsibility of MASS and its behaviour has to be discussed and determined in IMO. Sailing through ports, coastal and VTS areas, however, belongs to IALA responsibility. MASS operation requires digital and automated processes. AtoN’s could provide these service but to do so future AtoN’s should be smarter in a way that they also can provide and receive information to and from MASS. Physical and digital assessment of existing AtoN’s is necessary to guide MASS safely through an area. Modifications of shore infrastructure and support which contribute to enhance VTS systems with full detection and precise PNT, interacting objects and advanced decision support should be studied and discussed. Where necessary Guidelines and Recommendations on VTS and AtoN’s should be developed or amended to enhance the infrastructure and to give authorities an instrument to allow MASS in their management area. To start this process it is recommended to do a scoping exercise on existing IALA guidelines and recommendations.

To help authorities introducing MASS in a worldwide harmonized way it is important to do a scoping exercise with the four levels of MASS on all IALA’s guidelines and recommendations. The scoping exercise will learn which guidelines and recommendations need amendments or where new guidelines or recommendations have to be developed. With the scoping exercise awareness and knowledge about MASS will be brought in all IALA Technical Committees. The introduction of MASS and the resulting scoping exercise is a major task and request intensive international co-operation.

*Action Point 3*

*The PAP, in support of Secretariat, invited to consider a scoping exercise, in relation to MASS, and its impact on IALA Guidelines and Recommendations.*

***Cyber security***

MASS relies on the exchange of digital information with other systems like shore infrastructure, VTS and other ships. Digitalization and connectivity make systems vulnerable for cybercrime. In the maritime domain malfunctions of systems can have enormous consequences for safety and the environment. It might be obvious that reliable cyber security measures for the operation of MASS are of major importance. To introduce MASS on a global scale there is a strong need for international accepted Guidelines and Recommendations on how to deal with cyber security when a port or VTS authority allows MASS within their area.

*Action Point 4*

*With the introduction of MASS, authorities should always be aware of cyber security risks. Therefore, special attention should be given to MASS when developing cyber security related Guidelines and Recommendations.*

***Guideline for MASS testbeds***

IALA should endeavour to agree on conditions for MASS trials within VTS areas, which are in line with IMO’s interim guidelines for MASS testbeds. This includes, but is not limited to the following:

• To define the scope for application of IALA Guidelines and Recommendations in ensuring that the intent is met;

• To develop risk mitigating measures and emergency plans pertaining to communications and data exchange, reporting, cyber risk etc.;

• To determine the extent to which MASS of varying degrees of autonomy should and could interact with each other, with the VTS and with manned vessels, during trials in VTS areas.

• To determine how VTS emergency procedures should be adjusted or created when MASS of varying degrees are allowed in a VTS area.

Some countries and some ports are already in a front running position. They already allow MASS trials within their areas. It is recommended to use the experience of these trials in the development of a guideline for MASS testbeds.

*Action Point 5*

*The IALA VTS Committee should consider the need to develop guidance on MASS testbeds in VTS areas, similar to the IMO’s interim guidelines for MASS trials.*

The aim of this guideline is to provide guidance to IALA members who may undertaking testing and trials of MASS systems. This guideline also provides guidance for organsations implementing policy, procedures and technical solutions to support the introduction of MASS.

***Sharing information of MASS developments***

Use **extracts from the IALA MASS Workshop in May 2021** to populate earlier sections, and/or section 7

**Extract from the IALA MASS Workshop in May 2021**

* Marine Aids to Navigation will continue to be essential infrastructure for all degrees of maritime autonomy on vessels and will continue to be required to support safe, efficient and pollution free transits. This includes identifying options for position, navigation and timing (PNT). This may lead to the development of adaptive AtoN to support different degrees of autonomous vessels. Should be mentioned earlier in the document?
* There is a growing need for IALA standards to embrace the digital domain to facilitate the advent of MASS.
* The increasing number of testbeds being conducted globally provides an opportunity for engagement to facilitate a greater understanding of the implications for Marine Aids to Navigation as automation technologies evolve and mature. Testbeds will provide information for future (AtoN and others) requirements

IALA: Provide for spatial awareness (marking)

Situations develop within/off port limits – other vessels not reacting as expected

MASS and MSI, the latter is mitigation risks

Takes long time for artificial intelligence (AI) / technology to be better than humans

Level 4 still far away, human contributions will still be required is future; technology to support navigators.

Not complete Digital coverage in maritime domain

What happens when technology fails, e.g. onboard / off vessel comms fails?

Future

Monitoring of MASS developments

## future scenarios while considering the evolution of MASS

**Extract from the IALA MASS Workshop in May 2021**

* There are **already** some ships operating in degree two and three, in particular non-SOLAS ships **( up to 300 tonnes less than 24 metres)** such as survey vessels.
* MASS will require a robust and resilient communication ‘system of systems’ to support complex and vital communication needs, allowing communication between ships, remote control centres, VTS, AtoN and other elements that may be required in a MASS operating environment.
* The management of ship traffic to ensure the safety and efficiency of ship movements by VTS will evolve with the advent of MASS. This may involve managing ‘big data’, interacting with MASS using digital means, with possibly centralised, distributed and/or virtualised VTS ‘centres’ in the future.
* All developments in the provision of AtoN to support MASS must consider their role in a mixed maritime environment which includes both conventional vessels and MASS, and be fully compatible with both.
* Developments in technology and the regulatory environment to support MASS, as well as ethical / value expectations of society should be considered in the development of MASS and systems related to MASS.

**Foundation Det Norske Veritas  (DNV GL AS)**

New operational concepts are today introduced based on technologies that are still under development. It

is foreseen that the technology and concept developments will go hand-in-hand for the first pilot projects,

where the properties of the technologies will be scrutinized on pilot vessels, and operational concepts for

the pilot vessels adjusted accordingly. This may result in a more integrated qualification process for the

technologies and the concept for the first pilot projects.

Cyber security

Control Centres will be playing a big role going forward

Approval process required by Coastal Stae Authorities for MASS to be tested/operated

Qualification of technology related to systems supporting autonomous and remote control of vessel functions

International performance specifications??

Extract from the following hazards are examples that are found to be

typical to the navigational function:

— collision/contact with dock

— collision with other vessels

— collision/contact with pleasure crafts or persons in water

— collision/contact with foreign objects/obstacles (non-detected and detected)

— unexpected manoeuvres and drive-off

— collision with other vessels or pleasure crafts when sailing in reduced visibility

— grounding due to loss of propulsion

— grounding due to loss of steering control

— grounding due to deviation from planned route

— grounding due to error in planned route

— unable to follow COLREG due to errors in propulsion and steering

— loss of communication with remote control centre

— cyber security breaches

— sabotage, e.g. blocking vessel fairway

— other vessel calling to agree on a non-COLREG compliant meeting situation

— hitting fishing equipment/nets in fairway

— instability due to shifting cargo etc.

— unable to detect sound signals from other vessels or people

— unable to detect vibrations and heavy movements in the vessel

— unable to detect degradation of navigational sensors

— inability to detect deterioration of own performance

— too much trust/confidence in vessel autonomous action in critical situations

— failure in mooring sequence.

design and arrangements of systems supporting autonomous and

remote operation of vessels, with the objective to ensure a level of safety of navigation that is equivalent

or better compared to a conventional vessel where navigation is performed by navigators on board

**Determination of own position for grounding avoidance**

The vessel shall be equipped with navigational and position keeping equipment necessary to execute a safe

voyage plan. In this process, there shall be a possibility to determine the vessel position by use of various

and independent positioning methods or a combination of such. As a general rule, position determination

shall be based on minimum two independent methods.

3.1.2.1 Applicable methods for determination of vessel position

1) Relative terrestrial by use of optical methods/sensors. With reference to performance requirements for

bearing devices:

— Optical sensors used for taking bearings shall have the capability to take bearings of distant objects

whose altitudes are between 5° below and 30° above the horizontal.

— Horizontal maximum relative bearing error shall not exceed 0.3°.

2) Relative terrestrial by use of electronic, non-optical means

— radar range/bearing

— range finder

— soundings

— radio fixing aids

— sonar ranges

Of the above it is assumed that the radar range and bearings are the most common used today.

3) Dead reckoning.

Upon loss of continuous positioning or between position fixes a method or system for determining the

position based on vessel movement between other position fixes.

4) Electronic Position Fixing System (EPFS) suitable for the waters to be navigated.

3.1.2.2 Operational requirements for position fixing

Operational requirements for position fixing shall comply with the minimum requirements set out in IMO

Res. A915(22), A1046(27) and MSC.1/Circ.1575. Based on this the absolute position accuracy with 95%

probability shall be:

1) For navigation in ocean waters - 100 m.

2) For automatic collision avoidance operations and navigation in harbour entrances, harbour approaches

and coastal waters – 10 m.

3) For manoeuvring in port – 1 m.

4) For automatic docking operations - 0.1 m

**Condition detection by system**

Continuous transmission of high definition images covering a wide sector may not be a feasible solution

during all operational phases. Object detection by humans based on image and audio transmissions will also

make a further condition analysis and action planning by systems challenging. In order to enable remote

navigation watch for parts or the whole voyage, it is considered a necessity that the vessel is provided with

an object detection system. An object detection system with verified performance capabilities providing an

equivalent safety level will then replace the need for situational awareness with respect to object detection in

the remote workstation for navigation,

Diagram

Description automatically generated

**Performance parameters for object detection systems**

When an object detection system is intended to be used in a concept to replace the look-out function on

board, the needed performance of the system to obtain an equivalent or better object detection capability

should be determined as part of the concept process described in Sec.3 [2].

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.

Additionally, in clear weather conditions, other ships should be possible to be visually detected at any time

in accordance with the visibility specifications for navigational lights - see COLREG Rule 22. Other hazards

should be possible to detect at a distance that allows the vessel to make evasive maneuvers in order to avoid

the object in question.

The specific detection-range requirements should be decided per concept qualification project and will depend

on ship-type, size, maneuverability and speed.

Baseline

Facilities supporting the classification of objects detected should be provided.

Classification of other vessels should include the ability to distinguish between the following vessel classes -

see COLREG Rule 18:

Section 4

Class guideline — DNVGL-CG-0264. Edition September 2018 Page 58

Autonomous and remotely operated ships

DNV GL AS

— power-driven vessels underway

— vessel not under command

— vessel restricted in her ability to manoeuvre

— vessel engaged in fishing

— sailing vessel

* + - Other small craft.

1. Autoremote vessels

A sufficient situational awareness necessary to analyse a navigational situation should be obtained by the

personnel responsible for remote navigation in the RCC. The situational understanding should ensure that the

navigation can be planned and executed with an equivalent or better safety compared with the situational

understanding obtained by navigators on board.

**Virtual models**

Use of different sensor technologies, the fusion of the sensor data and representation in a virtual model may

provide an equivalent situational awareness for a remote navigator compared to transmitted images.

Object classification supported by AIS

Technology may be used to support in the classification of objects, see Figure 6. An example of such

technology is the AIS (James’ remark – should this lead AIS being a carriage requirement for ALL vessels, irrespective its size?) to be eq, which may provide digital information sufficient to classify other vessels for the

purpose of navigation in accordance with COLREG.

Diagram

Description automatically generated

**Deviation from planned route**

**RCC**

: Examples of relevant hazards may be:

— RCC fire and evacuation

— external power grid black-out

— communication latency and failures

— handover of responsibilities from one operator to another

— unauthorized person(s) accessing the RCC

— unauthorized person(s) accessing the vessel

— cyber attacks

Real-time situational awareness

Operation of the function in the remote location should be based on real-time situational awareness for the remote operator. Real-time information should not be based on observations by personnel on board.

Therefore, in regard to assisting the remote operator with situational awareness, this guideline is not distinguishing between operational concepts that require personnel on board from those without personnel on board.

However, if response to an event or failure condition is considered not to be time critical, it may be evaluated case-by-case whether the situational awareness for the remote operator may be partly based on information from the on-board personnel. Special considerations should then be made to the reliability of communication and the complexity in describing the condition, event or observation to the remote operator.

**COMMUNICATION FUNCTIONS**

**1 Purpose**

Communication plays an important role in most autoremote concepts and systems. This section provides

guidance regarding functionality and cyber security of the communication to and from the vessel.

**2 Hazards**

At least the following incidents and failures should be included when performing a risk analysis of the

communication systems and functions:

— unauthorized persons gaining access to the communication link

— jamming of wireless communication links

— interception of data traffic by 3rd party

— spoofing of data by 3rd party

— malware entering the systems

— failure of electronic components in the communication links

— less than ideal radio-coverage for wireless links

— error in transmission of data (also known as bit-faults)

— lack of acknowledgement of command(s)

— wrong configuration of communication functions

— unexpected reduction of available bandwidth during operations

— unexpected increase of latency during operations

— unstable data-links over time

— network storms

— loss of power.

Vessel data communication with RCC

**4.1.1 General**

The communication link between the ship and a remote control centre (RCC) should be available, secure

and capable of supporting the intended use. The more responsibility the RCC has for the operation of vessel

functions, the more available, robust and secure the communication link needs to be.

Coverage-analysis of the different wireless communication solutions must be performed for each concept

qualification project in order to determine the suitability of a specific solution or technology.

The aspects listed below serves as the basic guidance for any communication link between the ship and a

remote control or monitoring center:

— The maximum bandwidth required should be calculated and documented. The calculation should consider

the worst case scenario based on the intended use, e.g. where real-time transmission of sensor-data from

multiple sensors like video-cameras, images, radar-information, audio, etc. is transmitted and received at

the same time.

— The actual latency requirements (based in the intended use) should be calculated and specified.

— The communication between the ship and the RCC should be monitored so that the on-board system and

the RCC independently will detect a loss of communication within a reasonably time.

— A cyber-security analysis should be performed on the total communication system, including the shipsystems,

the datalink, and the remote control centre (see [4.5]).

— All interfaces and protocols used in the communication link should be specified and described.

**Communication for operational purposes**

If vessel key functions are depending on ship systems having access to off-ship systems and sensors to

execute relevant functions, the communication link between the vessel and these systems/sensors should

follow the guidance in [4.1.2].

Examples of off-ship systems and sensors are:

— shore-based radar

— weather forecast service

— automated VTS communication

— shore-based cameras (e.g. for docking operations).

Vessel external communications

When the navigation functions are under responsibility of remote operation from the RCC, the autoremote infrastructure will still need to be able to communicate with external stakeholders to the ship.

This means that the following functions need to be taken care of, either by relaying the task to personnel in the RCC, or by automatic systems on board:

— Communicating with other vessels, VTS, tugs, pilot station, etc. using VHF transmitter on board the vessel.

— Transmit emergency messages from the vessel.

— Relay emergency messages received by the vessel.

— Reply to messages from other vessels.

— Interpret sound and light signals around the vessel and recognise day shapes and navigation lights (e.g. vessels not under command).

— Voice communication with crew and passengers on board the vessel.

— Voice communication with humans near the vessel.

RCC communication with external stakeholders

The RCC personnel should be able to reliably and securely communicate with external stakeholders like the emergency services, VTS, pilot, tug-boat operators etc. using communication means that are not dependingon the communication link between the RCC and the vessel.

**Navigation functions**

— Voyage planning

— Route planning

— Determine ship position, course and speed

— Follow route

— Keep general lookout

— Determine CPA and TCPA for potential navigational dangers/objects and other ships

— Monitor depth, sea-state, tide, current, weather and visibility

— Monitor seakeeping performance

— Monitor for, and react to, distress signals from other seafarers

— Determine the situational mode (e.g. unrestricted, dense traffic, costal navigation, narrow passage, restricted visibility, heavy weather, very cold weather, ice conditions, pilot required)

— Docking

— Undocking

— Manoeuvring

— Propulsion control

— Steering

— Grounding and collision avoidance

— Weather routing

— Communication with other vessels

— Communication with shore (e.g. notice to mariners, vessel traffic service, weather forecast, rescue services, pilot services, etc)

— Navigation lights and sound signals

— Overall supervision of bridge-related systems

— Overall supervision of own ship's state and operational capabilities

**Special operations**

— Position keeping (dynamic positioning)

— Seabed mapping

— Fire-fighting

— Rescue operations

— Damage control

**Carriage requirements for SOLAS V and 2000 HSC Code and**

**relevance for autoremote vessels**

2.1 Heading information systems and tools

**2.1.8 Nautical charts – SOLAS V/19**

— Applicable for all ships irrespective of size and HSC.

— This requirement cover nautical charts and nautical publications to plan and display the ship’s route for the intended voyage and to plot and monitor positions throughout the voyage.

**2.1.9 Electronic Chart Display and Information System (ECDIS) – ref. IMO Res. MSC.232(82)**

— Applicable for passenger ships above 500 GT, cargo ships above 3000 GT and HSC.

— The primary function of the ECDIS is to contribute to safe navigation by reducing the navigational workload for the OOW compared with paper charts. ECDIS will cover the requirements for nautical charts

if approved ENCs and adequate back-up arrangements are provided.

— An ECDIS using approved ENCs is assumed to form the basis, or being a major part, for anti-grounding in a Navigation Decision Support system for Collision- and Grounding Avoidance – NDSS CA-GA and hence assumed required for remotely operated- and autonomous vessels.

**2.1.10 Back-up arrangements to ECDIS - ref. IMO Res. MSC.232(82)**

— Applicable for all ships irrespective of size where ECDIS is required or if ECDIS is used to cover the chart requirements.

— The purpose of an ECDIS back-up system is to ensure that safe navigation is not compromised in the event of ECDIS failure. This should include a timely transfer to the back-up system during critical navigation situations. The back-up system shall allow the vessel to be navigated safely until the termination of the voyage.

— Back-up arrangements may be either up-to-date paper charts, a type approved electronic back-up ECDIS or a second independent ECDIS.

— As a chart system is forming the major part of NDSS CA-GA, electronic back-up arrangements should be available for remotely operated- and autonomous vessels.

**2.1.11 Electronic position fixing system (EPFS) – ref. IMO Res. A.1046(27)**

— Applicable for all ships irrespective of size and HSC.

— SOLAS and the 2000 HSC Code describe a global satellite navigation system – GNSS or a terrestrial radio navigation system suitable for the operational area and forms the main position input to the ECDIS. No electronic back-up is described.

— Where a radio navigation system is used to assist in the navigation of ships in ocean waters, the system should provide positional information with an error not greater than 100 m with a probability of 95%.

— Where a radio navigation system is used to assist in the navigation of ships in harbour entrances harbour approaches and coastal waters, the system should provide positional information with an error not greater than 10 m with a probability of 95%.

— For remotely operated - and autonomous vessels a redundant position fixing system able to give input of position and timing information is assumed necessary. In addition, we assume that at least two separate methods for position determination should be part of the system where GNSS seems like the most suitable main method.

**2.1.12 Radar reflector – ref. IMO Res. A.384(X)**

— Applicable for ships below 150 GT.

— The radar reflector shall enhance the radar return and thus to improve the ship's visibility to radar with an adequate polar diagram in azimuth, and an echoing area:

— preferably, of at least 10 m, mounted at a minimum height of 4 m above water level; or

— if this is not practicable, of at least 40 m, mounted at a minimum height of 2 m above water level.

— Smaller remotely operated- and autonomous vessels, and in particular those made of glass reinforced plastic, may be required to be equipped with a radar reflector.

**2.1.19 Automatic Identification System - AIS - ref. IMO MSC.74(69) Annex 3**

— Applicable for ships above 300 GT on international voyages, all ships above 500 GT, all passenger vessels and all HSC.

— The Automatic Identification System, AIS, is an autonomous and continuous vessel identification system used for safety and security of maritime and inland waterway areas. It allows vessels to electronically exchange with other nearby ships and provide authorities ashore with the vessel identification data, position, course and speed.

— As AIS presently is the only approved ship-ship communication system that automatically communicate with other vessels it is assumed as a major input to the NDSS CA-GA for communication of own and surrounding ships' static and dynamic data for use in anti-collision and for classification purposes

2.1.22.4 Electronic plotting aid (EPA)

— Applicable for ships above 300 GT.

— Covered radar equipment CAT 3 for manual direct plotting.

— Covered by radar equipment CAT 2 and 1.

— Assumed inadequate to cover needed plotting capabilities for remotely controlled- and autonomous vessels

2.1.22.5 Automatic tracking aid (ATA)

— Applicable for ships above 500 GT and HSC.

— Covered by radar equipment CAT 2.

— The radars used on remotely controlled- and autonomous vessels should be equipped with facilities for automatic acquisition and tracking of other vessels. Setting up the radar to avoid land may be correlated with the chart function in the NDSS CA-GA.

2.1.22.6 Automatic radar plotting aid (ARPA)

— Applicable for ships and HSC above 10.000 GT.

— The radars used on remote- and autonomous vessels should be equipped with facilities for automatic acquisition and tracking of other vessels. Setting up the radar to avoid land may be correlated with the chart function in the NDSS CA-GA

**2.1.25 Long-range identification and tracking of ships (LRIT)**

— Applicable for most vessels engaged on international voyages. LRIT is in short, a surveillance/security tool for Flag states to have control on the movements of international shipping.

— Initially remote operated and autonomous vessels are assumed not to perform international voyages; hence LRIT is assumed not required for such ships in the near future. For local authorities to gain control of ship movements, the use of AIS will most probably be the preferred tool.

3.5 Grounding avoidance – decision support systems

**3.5.1 Chart information**

An ECDIS or another approved system for reading of electronic navigational charts (ENC) with appropriate

accuracy (see Sec.4 [3.1.2.3]) should form the basis for a safe planning and execution of a voyage plan.

**3.5.2 Track control**

A track control system able to execute and deviate from the voyage plan should be provided.

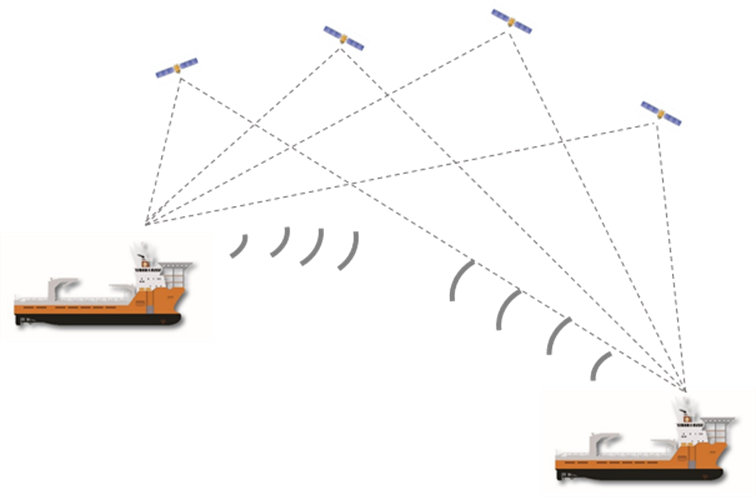
**3.5.3 Electronic position fixing**

Minimum two separate and independent electronic position fixing systems (EPFS) based on different technologies, both suitable for the area of operations should be part of the grounding avoidance system.

3.6 Weather surveillance and vessel monitoring

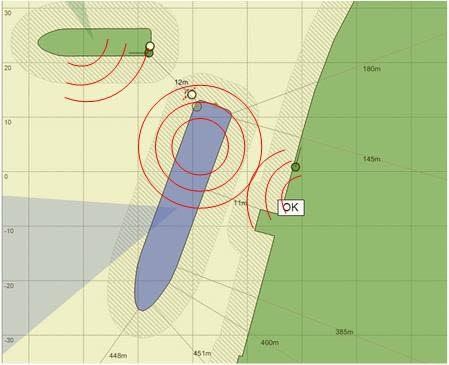
A system for determination of local weather and the influence this may have on the ship and a system for monitoring of ship movements and hull stress should be provided.

**Using EGNOS and Galileo to support Autonomous Maritime Operations**



**Objectives**

* The overall objective of the project is to address the need of the maritime community to safely navigate in close proximity of other vessels and objects, being stationary or moving.
* The objective will be met using EGNOSS in combination with sensors, communications and data processing.
* High accuracy, relative position measurements using GNSS service, dual frequency and multiple constellations.
* Hull to hull navigation information.
* GNSS services supporting autonomous maritime operations.
* Establishing an open standard for secure exchange of navigation data supporting relative positioning and exchange of 3D models.
* End-to-end pilot implementation that will be used in demonstrations and also is prepared for future projects.
* Providing user requirements and recommendations for standardisation.
* Promoting the results of the project.



**Finish Ministry of Transport - Charting Regulatory Frameworks for Maritime Autonomous Surface Ship Testing, Pilots, and Commercial Deployments**

Autonomous navigation

When moving from remote control towards autonomous operation, the related technical

challenges shift from connectivity towards efficient onboard computing. As outlined

above, for large-scale automatic scene understanding, a situational awareness system

needs to perform sensor fusion, i.e. combine data from multiple high-bandwidth

perceptual sensors, and extract and classify features in the obtained data using e.g. deep

neural networks. Thus, obtained semantic information can be combined with spatial

information from lidar and radar measurements to provide data for mapping, localization,

and dynamic route planning. It can be assumed that there is less need to continuously

transmit sensor data between the ship and shore when a vessel is in autonomous

operation mode, as opposed to remote control mode. It may, for example, be sufficient

to transmit only sensor fusion -based object information on the autonomously operating

vessel’s surroundings, as well as the ship’s own location and route plan information.

This high-level situational awareness and route plan information is highly compressed,

compared to unprocessed sensor data, with an estimated bandwidth requirement of the

order of less than one megabyte per second. Such bandwidth is available through existing

maritime satellite connectivity solutions, meaning that from the connectivity perspective,

autonomous navigation is feasible globally. However, as discussed above, fallback to

remote control may not be possible in areas where e.g. sufficient cellular connectivity is

not available.

Summary of communication scenarios and requirements

Table 2. Example orders of magnitude for uplink data rate requirements in autonomous operation, remote

control, and data collection for machine learning and logging.

Sensor Source data rate

(MB/s)

Autonomous

navigation

(MB/s)

Remote control

(MB/s)

Data log

offloading

(MB/s)\*

Cameras

(Encoded, 5 visual + 5 thermal) 10 0 10 100

Radar (uncompressed spoke data) 1 0 0 10

Lidar (uncompressed point cloud) 0,1 0 0,1 1

GNSS+INS (uncompressed location/pose) 0,01 0,01 0,01 0,1

AIS (standard messages) 0,001 0 0 0,01

Sensor fusion output (object locations) 0,01 0,01 0,01 0,1

Total order of magnitude 10,00 0,01 10,00 100,00

\* For data log offloading, it is assumed that 1) all sensor and sensor fusion output data is collected

and 2) the vessel collects data for 22 h and has 2 h to offload the data when docked

**Aids to Navigation – text extracted**

Generally, metrics for evaluating object detection models need to take into account

several factors, such as object location estimation accuracy, probabilities of correctly

several factors, such as object location estimation accuracy, probabilities of correctly

detecting an object (true positive detections), falsely detecting non-existent objects (false

positive detections), and classification accuracies for individual object classes. It should

be noted that these are statistical variables, which can be evaluated only using sufficiently

large test data sets. Also, the relevance of different performance metrics may depend

on the specific use and purpose of the model in the navigation system. For example,

reliable classification between different types of cargo vessels may not be critical for basic

navigation planning, whereas visual identification of aids to navigation, such as lateral and

cardinal marks, may be a critical system requirement.

Overview of ML model training and deployment process: A randomly selected person may not, for example, be able to reliably identify many types of ships or aids to navigation. Thus, to generate high-quality domain-specific annotation data, it may be necessary to employ domain experts and to manually review the annotations.

Regulators should, thus, focus their work on developing an appropriate and effective regulatory framework for autonomous navigation systems. However, the new MASSready navigational regulation will unlikely resemble its predecessor. The previous SCTW and SOLAS navigation rules do little to make sure that MASS situational awareness and navigational planning systems, in fact, will navigate the ships safely. The previous rules were designed to control sociotechnical processes where humans made decisions based on informational inputs from both their own senses, other people’s senses, and a variety of navigational aids. The new reality is high-tech, computerized, and dominated by algorithms.

Regulators should focus their work on developing an appropriate and effective regulatory framework for high-tech computerized autonomous navigation systems dominated by algorithms.

4.2.3 Navigational ethics flash points

4.2.3.1 Introduction

MASSs will increasingly rely on technological systems for navigation. This will constitute

the fundamental change in maritime risk patterns. Immediate human errors and

negligence in navigation, an important root cause for many maritime accidents, will be

eliminated to the degree autonomous navigation systems are involved in navigation with navigational safety risks increasingly transforming from human risks into technological

risks. As a result, technology-mediated navigation will constitute the most important

domain for ethical analysis and design in MASSs.

Navigational technology designs are the ethical focal point in MASSs.

The report will, in the following, identity and discuss five ethical flash points:

1) the general level of risk at which MASSs should be allowed,

2) the ethical questions that arise when sensory capabilities are designed,

3) the ethics of operational ontologies in semantic signal processing,

4) uncertainty management, and

5) the ethics of path planning.

4.2.3.3 Sensor ethics

Sensors constitute the second ethical flash point as sensory capabilities significantly

affect the MASS safety level. To illustrate how, imagine a road ferry operating in a densely

populated archipelago. The ferry could, conceivably, cross paths with a swimmer. Should

the ferry have a sensory capability to detect swimmers in time to evade them?

In situational awareness, the most significant applications for machine learning models are

detecting objects from various sensor data and classifying these objects according to pretrained

categories. Such models provide both robustness for estimating object locations

based on multiple sensor inputs and semantic information on objects such as types of

vessels and aids to navigation. Automating visual watchkeeping as mandated by current

maritime regulations requires the use of machine learning models, as no conventional

rule-based algorithms provide comparable accuracy. In navigational planning, machine

learning models can be used for example to predict the future trajectories of other vessels

or control vessel manoeuvring systems in complex scenarios where it is not feasible to

base route plans on explicit rules or conventional optimization algorithms. However, in

navigational planning, ML models are not strictly required for any critical functionality, and

ML models for sensor signal processing For example, reliable classification between different types of cargo vessels may not be critical for basic navigation planning, whereas visual identification of aids to navigation, such as lateral and cardinal marks, may be a critical system requirement.

Would VDES play a roll?

## Future requirements on AtoN service

Data collection and analysis

Detailed risk analysis to assess threats and identify failure modes and their risks.

AtoN with Artificial Intelligence ??

Monitoring??

Reporting??

AtoN redundancy (duplicated)?

MASS requires communication; AtoN are placed at strategic locations, and be used for terrestrial comms networks; e.g. uploads of documents to MASS

Norway installed 5G infrastructure

Onboard sensors, redundant comms

Sensors - camera route: should IALA be looking at colour spectrum of AtoN, day and night display in terms of human and machine recognition

## IDENTIFY FUTURE MASS related GAPS

1. l

# Definitions

The definitions of terms used in this IALA 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.

“Accident investigator” refers to the Marine Casualty Investigator of the flag State or, where it has been agreed, for Investigation of Marine Casualties and Incidents, that another State will lead the investigation, the Marine Casualty Investigator of that State

“Area of operation” are those identified and promulgated by competent authorities

“Automatic” - Pertaining to a process or device that, under specified conditions, functions without human intervention (ISO/TR 11065).

“Autonomy” - In the context of ships, autonomy (e.g. as in "Autonomous Ship") means that the ship can operate without human intervention, related to one or more ship functions, for the full or limited periods of the ship operations or voyage.

“Autonomous Ship System” - All physical and human elements that together ensure sustainable operation of an autonomous ship in its intended operations or voyage.

“Company” means the owner of the ship or any other organisation or person such as the manager, or the bareboat charterer, who has assumed responsibility for the operation of the ship from the ship owner and who, on assuming such responsibility, has agreed to take over all duties and responsibility (and by extension the associated IMO instruments).

"Competent Authority", in respect of operating qualifications (Ch 0), means either the MCA or an organisation that issues Certificates of Competence which has applied for and been granted recognition by the MCA as having the appropriate technical and administrative expertise in accordance with the procedures established for vessels of any type or size.

“Control position” means a location on the ship/seagoing vessel/watercraft during any periods of manned operation from which control of propulsion, steering and other systems can be exercised.

“Controller” means a person undertaking control functions appropriate for the LoC of the MASS. The controller may report to either a Watch Officer or the Master depending on the constitution of the control function, the MASS category and the required LoC.

“Coxswain” refers to any person controlling the MASS, either remotely (depending on the category of control applicable to the MASS during an operation) or to a person controlling the MASS from an onboard control station during any period of operation under direct manned control (e.g. pilotage).

“Crew” means a person employed or engaged in any capacity on-board a ship on the business of the ship or any person engaged in the direct control and operation of the ship from a remote location.

“Crewless Ship” means a ship with no crew on board. Crew does not include passengers, special personnel etc.

“Degrees of Autonomy” The Degrees of Autonomy as established by the IMO for their Regulatory Scoping Exercise.

“Designated Person Ashore” identified in the IMO ISM Code as a person ashore who should be designated by the company who has direct access to the highest level of management.

“Emergency Stop” means the ability to reduce propulsion to a safe state in a timely manner. In this context:

“Safe state” means a level at which it is not likely to cause damage either directly or indirectly. Note that some MASS (e.g. wave propelled) may not have any means of cutting propulsion power to zero but in a harbour or sheltered waters the wave propulsive power may reasonably be expected to be a safely low level

“In a timely manner” means within a time that is short enough to ensure that the risk from uncontrolled propulsive power can be contained before it is likely to cause damage. In open ocean conditions this may be relaxed, whereas in a docking situation the propulsion may need to be cut more quickly, within seconds or less;

“Full Shut Down” means the ability to turn off all systems as required on the MASS remotely, for example in the case of a fire.

“Just Culture” is a prerequisite to a Reporting Culture where people feel they will be treated fairly, are encouraged to and therefore readily report hazards, safety concerns, errors and near misses which provide the organisation with vital safety-related information.

“Fail Safe” is a design feature or practice that in the event of a specific type of failure, inherently responds in a way that will cause no or minimal harm to other equipment, to the environment or to people. Unlike inherent safety to a particular hazard, a system being "fail-safe" does not mean that failure is impossible or improbable, but rather that the system's design prevents or mitigates unsafe consequences of the system's failure. That is, if and when a "fail-safe" system fails, it remains at least as safe as it was before the failure. Since many types of failure are possible, failure mode and effects analysis are used to examine failure situations and recommend safety design and procedures

“MASS” – Maritime Autonomous Surface Ship is a term adopted by the IMO for their scoping exercise which means a surface ship that is capable of being operated without a human onboard in charge of that ship and for which the LoC may encompass any of those shown at Table 1-4.

“MASS system” means …………………..

“MASS Watch Officer” is the individual who has responsibility for the MASS when it is operational.

“Operator” – An entity (e.g. a company) that discharges the responsibilities necessary to maintain the MASS in a seaworthy condition and compliant with all relevant IMO Instruments and national legislation. The operator is also responsible for ensuring that all staff concerned with the control of MASS hold appropriate qualifications as required by IMO instruments and national legislation.

“Remote Control” – Operational control of some or all ship operations or functions, at a point remote from the ship.

“Remote Control Centre” (RCC) is a site off the ship from which control of an autonomous ship can be executed. The RCC may be located either ashore or afloat and may exercise varying degrees of control as defined under “Levels of Control”. An RCC may consist of more than one Control Station or Room.

“Remote Monitoring” – Monitoring some or all ship operations or functions at a point remote from the ship.

“Unattended” – Used for a control position, e.g. an unattended bridge, without a crew available to operate it.

“Uncrewed” – This term is reserved for a ship with no crew on board. Crew does not include passengers or special personnel.

“Unmanned” – An unmanned ship is a ship with no humans onboard.

# Acronyms (At end, check completeness and sort in alphabetical order)

AIS Automatic Identification System

ALARP As Low As Reasonably Practicable

ASM ASM as part of the VHF Data Exchange System ???

ASM Application Specific Message ???

AUV Autonomous Underwater Vehicle

COG Course over Ground

COLREG International Regulations for Preventing Collisions at Sea 1972, as amended (IMO)

DGNSS Differential Global Navigation Satellite System

GMDSS Global Maritime Distress & Safety System

GNSS Global Navigation Satellite System

GPS Global Positioning System

GUI Graphical User Interface

IMO International Maritime Organization

ISM International Safety Management Code (IMO)

ISO International Organisation for Standardisation

ISPS International Ship & Port Facility Security Code (IMO) (should this feature somewhere in the document?)

ITU International Telecommunications Union

LoC Level of Control

LoS Line of Sight

MARPOL International Convention for the Prevention of Pollution from Ships 1973/78, as amended (IMO)

MASS Maritime Autonomous Surface Ships

MASS Maritime Autonomous Ship System

MMS Maintenance Management System

MPA Marine Protected Areas

MSC Maritime Safety Committee (IMO)

OEM Original Equipment Manufacturer

RCC Remote Control Centre

RoT Rate of Turn

ROV Remotely operated vehicle

SMS Safety Management System

SoG Speed over Ground

SOLAS Safety of Life at Sea 1974, as amended (IMO)

STCW Standards of Training, Certification and Watchkeeping for Seafarers 1978, as amended (IMO)

STW Speed Through the Water

UAS Uncrewed Air System

UNCLOS United Nations Convention on the Law of the Sea, 1982

USV Unmanned Surface Vessel

VDES VHF Data Exchange System

VTS Vessel Traffic Services

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