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| IALA Guideline |

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IALA GUideline on developments in maritime autonomous surface ships

Edition 1.0

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# Aims and Objectives

The aim of this guideline is to provide guidance to the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) members and other stakeholders who may be undertaking:

1. Testing;
2. Trials; or
3. Operations

of MASS systems.

This guideline also provides guidance for organisations implementing policy, procedures and technical solutions to support the introduction of MASS.

# 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.

## 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.

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.

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

Current applications, marks and signals exhibited by AtoN as described in the Maritime Buoyage System (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 of AtoN, beneficial to MASS operations. IALA provides guidance on AtoN that can be used to support a MASS 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 Meteorological and Hydrographic data using Application Specific Messages (ASM) contained in IMO Circular SN.1/ 289
6. Supporting the safe and efficient operations within, and outside a Vessel Traffic Service (VTS) environment
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 Vessel Traffic Services (VTS) environment
9. Scoping and development of guidance on the interaction between VTS and the control centre for MASS (Shore Control Centre, SCC)
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 establishing a suitable MASS environment.

# 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. AtoN requirements in pilotage waters
6. Remote berthing and connections to shore services
7. VTS environment interaction
8. Route Message transfer
9. Local situational awareness and control including tracking of all vessels/boats
10. Metrological systems and data
11. Hydrographic systems and data
12. AtoN availability
13. Vessel traffic and density
14. Adaptation of traditional AtoN services to support MASS
15. Adopt, adapt or extend existing technology
16. Communication services

# 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 trials activities, as opposed to operational 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 would also 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

### Trade Restrictions and Export Controls

The MASS industry will have to be involved with International, cross-border business and as such must be familiar with the appropriate national policies and procedures for handling goods, technology and data or providing services which may come into or go outside of a country.

Involvement may mean simply having contact with a foreign or dual national inside a company facility for instance at a trade show. It can mean sending a technical drawing to a potential supplier in another country or submitting a proposal to a foreign government.

If the Industry fails to observe export control laws, companies (and individuals) may face fines, criminal prosecution and loss of export privileges.

Company policies and procedures must take these regulations and laws into account and so it is important to be familiar with them.

Companies will have to provide training to those employees who are involved in export and import, or that regularly have contact with foreign nationals.

### Regulatory and Legislative Compliance

The 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 still a disruptive technology with no general 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.

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 with 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

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 should be capable of operating to a level of compliance with COLREGS appropriate to the MASS class.

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:

* 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
* Shore based
* Fixed and floating AtoN

## 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 tobe 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.

### 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

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 |

# 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

# References

1. IMO MSC.1-Circ.1638 - Outcome of The Regulatory Scoping Exercise for the use of Maritime Autonomous Surface Ships
2. Maritime UK Maritime Autonomous Ship Systems (MASS) , UK Industry Conduct Principles and Code of Practice, Version 5, November 2021
3. DNV.GL, Group Technology and Research, Position paper 2018, Remote Controlled and Autonomous ships
4. AWA Position paper, Rolls Royce, Remote and Autonomous Ships, the next steps
5. Review of Maritime Transports, 2018, UNCTAD
6. Lloyds Register, Code for Unmanned Marine Systems, February 2017