Amendments to "Guide for Maritime Autonomous Surface Ships (MASS)"

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1 GENERAL

1.1 Aim and purpose

The aim of this guide is to provide indications for the design, construction and test of Maritime Autonomous Surface Ships (MASS) by setting the technical preconditions for their operation with the necessary level of safety and security to people, properties and the marine environment.

The purpose of this guide is to address the challenges posed by new technologies that enable to operate ships, to a varying degree, independently of human interaction (MASS technologies), thus modifying the conventional way of performing tasks and/or the assignment of duties and responsibilities, as well as affecting the way such ships interact with other ships.

1.2 Scope of applicability

This guide applies to ships, which, to a varying degree, can operate independent of human interaction.

Such ships may use both traditional and MASS technology. This guide only applies to the latter, while for any other aspect of the ship, all relevant applicable rules are to be complied with.

1.3 Basic principles

1.3.1 Equivalent safety and quality of service

Ship operations carried out through MASS technologies are to provide:

- a level of safety and security to people, properties and the environment, and
- a quality of service

at least equivalent to what is normally provided in the corresponding operations carried out without them (conventional ship operation).

1.3.2 Analysis of MASS technology

1.3.2.1 High-level functions

Several high-level functions can be identified as being part of ship operation, such as:

- Navigation
- Machinery, propulsion and steering management
- Communication
- Cargo and ballast management, including load/unload
- Safety, watertight integrity and fire protection
- Distress, rescue, security
- Habitability and crew/passenger servicing
- and others.

Each high-level function comprises several tasks, duties and responsibilities.

1.3.2.2 Impact of MASS technologies

In conventional ship operation, ~~qualified~~ seafarers play a role in all functions and interact with:

- ship's systems, and
- the environment.

The use of MASS technologies brings changes with respect to conventional ship operation in:

- how tasks are carried out, and
- how duties and responsibilities are assigned.

1.3.2.3 Scope of application of MASS technologies

The MASS technology can be used for both or one of the following scopes:

- Support (monitoring, telemetry, decision support…)
- Operation and Management (execution of control actions on processes, management of operational parameters…)

1.3.2.4 Phases to carry out tasks

The accomplishment of a task occurs in several phases:

a) Situational awareness, that includes:
   1. Acquisition of data from ship systems and external environment
   2. Recognition of events that may trigger decision making and/or action

b) Decision making, that includes:
   1. Identification and definition of possible actions
   2. Application of criteria to rank actions
   3. Selection of action

c) Action implementation, that includes:
   1. Execution of actions
   2. Monitoring and analysis of effects, including management of alerts and indicators

Each phase can be delegated either to humans or to MASS technologies, to a varying degree.

Depending on which phases are delegated to either humans or MASS technologies, and to what degree, assignment of duties and responsibilities may differ.

1.3.2.5 Human role in MASS

When MASS technologies are used to perform some tasks, ~~qualified~~ seafarers may be however in charge of interaction at different levels:

- Explicit approval or overrule of decisions made by MASS technology
- Real-time supervision of MASS technology performance, with possibility to take control and operate directly
- Off-line review of MASS technology performance

The location of ~~qualified~~ seafarers, and in particular physical presence onboard, is a key factor that affects many aspects of human interaction in ship operation. Typically, ~~qualified~~ seafarers can be located:

- on-board, or
- in a remote control centre (RCC), or
- a combination of the above with persons on-board and persons in a RCC.

Human role and location are shown in Figure 1.

Figure 1 – Human role and location

Human role:	Human location:
☐ Approve/overrule decision	☐ On board
☐ Real-time supervise/take control	☐ Remote control centre
☐ Off-line review	☐ Mixed

1.3.3 Concept of operations

The Concept of Operations (CONOPS) defines the high-level function and task (1.3.2.1), the scope of application (1.3.2.3) and the process phases (1.3.2.4) of interest for a given MASS technology (see Figure 2).

Figure 2 – Components of Concept of Operation (CONOPS)

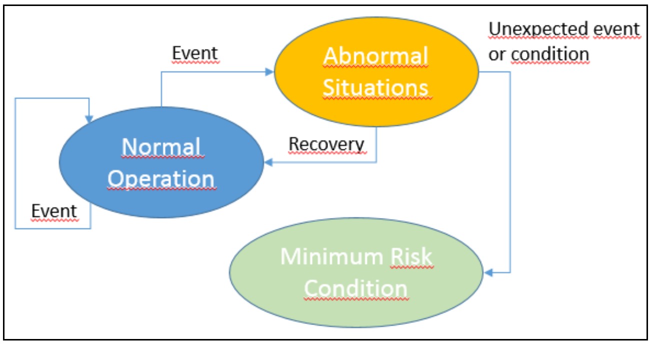
Function:	Scope of application:
☐ Navigation	☐ Support
☐ Machinery and power management	☐ Operation & Mgmt
☐ Communication	Process phases:
☐ Cargo and ballast management	☐ Situational awareness
☐ Safety, watertight integrity, fire protection	☐ Decision making
☐ Distress, rescue, security	☐ Action implementation
☐ Habitability and crew/psg servicing	
Task:	
<description>	

1.3.4 Operational Design Domain

The Operational Design Domain (ODD) defines the operating conditions a MASS technology is specifically designed to manage. Such operating conditions include, but are not limited to, environmental, geographical and other restrictions; and other required characteristics.

The ODD includes information on the conditions for normal operations; a set of abnormal situations that can be foreseen; and the minimum risk condition to be reached in case of failure or unexpected events or conditions (see Figure 3).

Figure 3 - Components of Operational Design Domain (ODD)



1.4 Risk assessment

A risk assessment should be carried out to demonstrate that risks related to the use of proposed MASS technologies have been duly mitigated and made as low as reasonably practicable (ALARP).

The methodology applied for risk assessment, the scoping of work and the level of detail should be selected taking into account the nature, novelty and complexity of the MASS technologies considered and the magnitude of risks involved.

Recognized industrial standards and the Tasneef Guide for Risk Analysis should be used for carrying out risk assessment, that should anyway always take into account:

- Scope of application (1.3.2.3) of MASS technology, considering increasing risk levels from support (lowest) to operation and management (highest)
- Process phases (1.3.2.4) delegated to MASS technology.
- Human role and location (1.3.2.5) of ~~qualified~~ seafarers in charge of interaction with MASS technology, ship systems and the environment.

Risk factors to be considered include:

- Changes in human roles, location and competences with respect to conventional ship operation, with special focus on modes of interaction with ship systems and the environment, latency, etc.
- Presentation and management of alarms and indicators.
- Usability and ergonomics of user interfaces for situational awareness, decision making and action implementation delegated to humans.
- Training for seafarers and shore staff.
- Confidentiality, integrity and availability of data used by either MASS technology or humans.
- Reliability, availability, maintainability, testability, safety and security of MASS technology's components and communication infrastructure,

including hardware, software, network architecture, links, etc.

- Integration between MASS technology and other ship systems.
- Configuration and maintenance procedures.
- Management of failure conditions, human backup and recovery/restore procedures. In particular, the risk that a single failure of MASS technology, including remote control systems, could impair the functionality or performance of propulsion, steering, power generation or any essential service of the ship should be duly addressed and mitigated.

1.5 Structure of guide

This Guide:

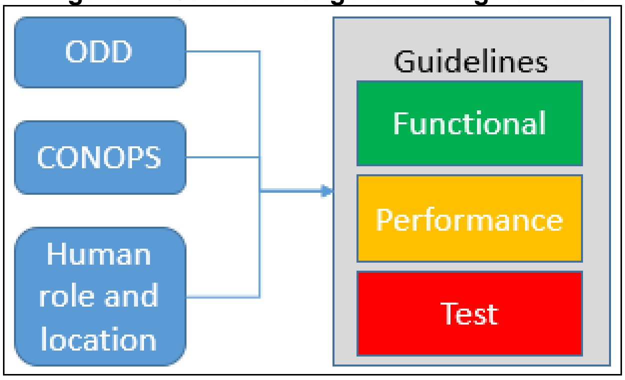
1) for the high-level functions (among those identified in 1.3.2.1) which are more likely concerned by MASS technology, identifies a set of tasks that can be carried out using MASS technologies; and
2) provides recommendations, for each identified task, on the characteristics that the MASS technologies used should have in order to provide a level of safety and security to people, properties and the environment and a quality of service at least equivalent to what is normally provided in the corresponding operations carried out without them.

   In particular, recommendations are given for:

   - concept of operations (CONOPS)
   - operational design domain (ODD)
   - human role and location
   - functionality
   - performance
   - test and evaluation criteria

   (see **Figure 4**).

Figure 4 - Structure of guide for a given task



The principles and methodology adopted in this guide may also be applicable to MASS technologies relevant to other tasks not included in this guide. For such MASS technologies, specific functional requirements, performance requirements and tests are to be defined by the Society, on a case-by-case basis.

2 STATEMENT OF COMPLIANCE

2.1 Documents to be provided

In order to obtain a statement of compliance to this guide for a given MASS technology, the applicant should provide to the Society:

- A CONOPS (1.3.3).
- An ODD (1.3.4).
- Details on human role and location (1.3.2.5).
- Documentation demonstrating the compliance with the applicable functional and performance requirements (4 to 6).
- Reference rules and standards applicable to the corresponding tasks in conventional ship operation with specific indication of the parts that are not applicable, or the application of which requires specific interpretation.
- A risk assessment, also including cyber security risks (1.4).
- Test reports required in 2.2, 3.6 and 4 to 6.

2.2 Tests

Factory tests are to be carried out at the premises of MASS technology's manufacturer.

Acceptance tests to be carried out on board during and/or after installation may also be required.

2.3 Issue and validity

Upon satisfactory review of the documents listed in 2.1 above, a Statement of Compliance is issued by the Society with a validity of 3 years.

If – in the 3-year period of validity of the Statement of Compliance – significant modifications are carried out, the Statement of Compliance is invalidated.

The procedure for the renewal of the Statement of Compliance has to be agreed with Tasneef on a case-by-case basis.

3 COMMON GUIDELINES

3.1 General arrangement design of MASS

3.1.1 Access arrangement and restrictions

Access arrangement of MASS may be specially considered taking into account the absence of persons on board.

Notwithstanding the above, means for safe access to all spaces should be provided for inspection and maintenance purposes.
Specific security boundaries should be foreseen for the access to spaces, if any, where an unauthorized person may get the control of any essential service of the ship or can endanger the safety of the ship.

The opening of a door on the above security boundaries should produce an alarm.

The access of personnel to spaces of the ship containing systems under the direct control of the remote control station or by the MASS technology should be restricted only to authorized persons. The access to such spaces should be recorded: the record should include the identification data of the personnel, the timestamp and the image of the CCTV of the concerned space.

Means to grant access to all spaces in case of emergency situations (e.g. fire, flooding, long term loss of communications, loss of propulsion, loss of power generation) should be provided.

When the doors are operated by the human operator at the remote control station, a clear view of the adjacent spaces should be provided to the human operator.

When the doors can also be operated by the MASS technology autonomously, special care should be paid to avoid the entrapment of persons during the manoeuvring of the door by means of appropriate sensors and audible alarms.

3.1.2 Bulwarks and guard rails

On MASS designed to be operated unmanned, bulwarks and guard rails should however ensure safe access to all spaces and decks for maintenance and inspection purposes; temporary fittings or use of lifelines may be accepted provided that a level of safety comparable to that of bulwarks and guard rails is ensured.

3.1.3 Emergency towing arrangements

On MASS designed to be operated unmanned, pre-rigged emergency towing arrangement should be provided so designed as to facilitate salvage and emergency towing operations.

The emergency towing arrangement should, at all times, be capable of rapid deployment in the absence of main power on the ship and easy connection to the towing ship.

For ships having a gross tonnage below 500 GT, the Society may consider the emergency towing arrangement on a case-by-case basis.

3.1.4 Electrical power in emergency conditions

In emergency conditions, sufficient electrical power should be supplied at least to the following systems, to allow the availability of their provided service for a period of at least 18 hours:

- autonomous control systems for propulsion and steering;
- remote control system of valves and auxiliary equipment necessary for propulsion and steering;
- communication system with the remote control station;
- sensors and systems for the acquisition of data aimed to provide the situational awareness;
- on board data recording and storage system.

~~3.1.5 Spare parts or equipment~~

~~On MASS designed to be operated unmanned, where a spare part or equipment ready to be connected is required by the Reference Rules (2.1), a stand-by equivalent is to be provided instead.~~

3.2 Operational Design Domain

3.2.1 Normal operation

The ODD should provide a description of normal operation defining the limits and conditions within which the ship, when operating using MASS technologies compliant to relevant functional and performance requirements, is expected to successfully pass the required tests.

3.2.2 Abnormal situations

The ODD should provide a definition of abnormal situations for MASS technologies including specifications on the expected behaviour and recovery procedures in case the limits of normal operation are exceeded.

When events or conditions occur that configure an abnormal situation, MASS technologies should be able to keep the ship in a safe condition and understandable information should be provided to a responsible human operator, including system diagnostics and information on the event or conditions that has determined the transition to the abnormal situation.

When the conditions determining an abnormal situation are removed, MASS technologies should be able to recover to normal operation.

3.2.3 Minimum risk condition

The ODD should provide a description of one or more Minimum Risk Conditions to be reached in case of unexpected or unmanageable failures or events. Minimum risk condition usually implies aborting the current operation and calling for assistance, and may be different depending on the environmental conditions, the voyage phase of the ship (e.g. port depart/arrival vs. open sea passage) and the events occurred.

Examples of Minimum Risk Conditions are:

- Stay moored at quay;
- Move away from quay and other vessels;
- Keep position;
- Move at limited speed, or as slowly as possible, to a predefined position or to next waypoint;
- Stop as soon as possible;
- Drop (emergency) anchor.

3.3 Human role and location

In any operational condition, MASS technologies should be able to provide clear and understandable information to a responsible human operator and allow complete human takeover.

MASS technologies should allow human takeover from on-board and/or from a RCC. Specifications on the location of control stations and roles of responsible human operator (1.3.2.5) should be provided.

Procedures shall be established for transfer of control among control stations and between MASS technologies and human operators. These procedures should be such as to avoid possible conflicts and to make clear at any time who has control and from what location.

3.4 Functional requirements

MASS technologies should provide means for a responsible human operator to have:

- complete and timely information of all instruments and other sensors used for situational awareness, in a clear and easily understandable form;
- complete and timely information of all the decision making carried on by MASS technology, with possibility to explicitly approve or overrule any decision taken by the MASS technology;
- complete and timely information on the alerts and indicators raised during operation, with the possibility to take full control over the ship systems operated by the MASS technology;
- the possibility to overview the operation of MASS technology by means of logs or other persistent recording;
- complete and timely diagnostic information of all components and communication links, able to identify single failures and communicate to responsible human operator in a clear and understandable way; and
- complete information on means and/or procedures for the exclusion of MASS technologies from the operation control loop, and restore full functionality for conventional navigation or for operation under exclusive human control from a remote or on-board control station.

3.5 Performance requirements

In any operational condition, MASS technologies should provide to a responsible human operator at least as much information as to allow a situational awareness and control over operation equivalent to conventional ship operation regarding environmental conditions potentially restricting operation or maneuverability of the ship.

MASS technologies should provide communication links such that time constraints for an effective and safe operation of the ship are fulfilled in any situation considered in the ODD, in particular taking into account the worst-case latency.

Communication links among the components used to gather information for situational awareness should ensure reliable communication and be tolerant to single failures.

Communication link connecting MASS technologies and on board or remote control station should ensure reliable and complete transmission of information.

Communication with the on board or remote control station should be tolerant to single failure of any component and should provide latency times short enough to enable decision making and action implementation compatible with a safe operation of the ship.

The maximum time necessary to MASS technologies for decision making should be such as to ensure that the corresponding selected action can be performed keeping the ship in a safe condition.

Options for overruling decisions taken by MASS technologies or requests for explicit selection or approval of action shall be communicated and managed taking into account latency times.

Commands to the ship’s propulsion and steering systems should be issued in due time in order to ensure the effectiveness of action and that manoeuvring is carried out keeping the ship in a safe state.

Effects of commands issued should be monitored and errors in the performance of intended action should be detected in due time in order to allow either human takeover or adaptive corrections, keeping the ship in a safe condition and avoiding collisions.

Alerts and indicators should be detected and managed in a timely manner, also recognizing events and conditions that may configure abnormal situations or the need to enter a minimum risk condition.

Procedures for recovering from failure conditions that can be recovered autonomously should be carried out within time frames that ensure continuous safe operation of the ship and a sufficient provision of all essential services.

Reaction to failure conditions that cannot be recovered autonomously should be carried out within time frames that ensure that the ship is put in a minimum risk condition as quickly as possible, however keeping the ship in safe state.

Safety margins should be kept against the ship's design parameters, including hull strength, stability, power availability, manoeuvring capability, etc. taking into account possible limitations due to ship condition, limited operational capabilities, prescriptions imposed by Class or Administration, etc.

3.6 Tests and evaluation criteria

Factory, integration and acceptance tests should be designed, executed and documented aimed at demonstrating to what extent MASS technologies comply with the relevant functional and performance requirements, in the normal conditions specified in the ODD and for the specified CONOPS and human roles and locations.

Specific tests should also be carried out to demonstrate the ability of MASS technologies to manage the transition from normal operation to abnormal situation and recovery.

Criteria for the evaluation of test results are:

- time required for communicating to a responsible human operator the occurrence of failures or any other event or condition that determines an abnormal situation;
- completeness and clarity of information transmitted to the remote control station in case of normal operation, abnormal situation and minimum risk condition, including how alerts and indicators are raised and managed;
- modes, procedures and monitoring capabilities implied in the recovery from abnormal situations to normal operation;
- identification and management of single failures of equipment and systems or any other part essential for navigation or dynamic positioning, sensors and/or actuators;
- identification and management of unavailability of situational information;
- timely detection and signalling of inconsistencies in situational information or errors in the ship's manoeuvring;
- timely raising and management of alerts and indicators;
- identification, ranking and implementation of recovery actions, where possible.

Specific tests should also be carried out to demonstrate the ability of MASS technologies to manage the transition to minimum risk condition.

Criteria for the evaluation of test results are:

- time taken for detection of unrecoverable failures, unexpected events or conditions is comparable to or shorter than equivalent time necessary in conventional ship operation;
- the minimum risk condition is correctly reached in case of unrecoverable failures, unexpected events or conditions, and unavailability of recovery actions;
- the stability and integrity conditions of the ship are maintained in all situations according to the loading condition of the ship.

Simulator-based testing can be considered for the development of MASS technologies; however, such tests should be complemented by tests in real-world operating conditions to the satisfaction of the Society.

4 NAVIGATION FUNCTION

4.1 Task: Collision and grounding avoidance

4.1.1 Concept of operations

4.1.1.1 Task description

Collision avoidance consists in the conduct of the vessel at sea according to the navigation rules to be followed to prevent collisions between two or more vessels or contact with dock, marine mammals, people, or with other objects or obstacles that may be encountered during navigation.

Grounding avoidance consists in the conduct of the vessel at sea to prevent impact on seabed or waterway side.

4.1.1.2 Scope of application and process phases

The scope of application and process phases for a MASS technology used for collision and grounding avoidance should be defined in the CONOPS according to 1.3.2.3 and 1.3.2.4.

For collision and grounding avoidance:

- Support scope may include obstacle detection, warning to operators and shore (e.g. VTS), decision support to route planning, etc.
- Operation and Management scope may include regulation of speed, heading, signal lights, shapes or whistle signals, radio communication, etc.

4.1.2 Operational Design Domain

4.1.2.1 Normal Operation

The ODD should provide information on normal operation as per 1.3.4 and 3.2.1.

In the definition of normal operation, the following should be at least specified:

- Requirements and restrictions in the ship loading conditions, draught, trim, speed, underkeel clearance etc.
- Requirements and restrictions in the operational conditions of ship systems such as propulsion, steering, other machinery, electrical installations, power generation, etc.
- Requirements and restrictions in the environmental conditions, e.g. light, weather, temperature, wind, horizon visibility, traffic density, etc.
- Required manoeuvring capabilities such as stopping distance, minimum steering radius, backwards manoeuvring, etc.
- Required information from navigation instruments and other sensors for situational awareness and relevant specifications, required certification or compliance to standards.
- Minimum size of detectable object and other characteristics required for detection, e.g. color, relative speed, etc.

4.1.2.2 Abnormal situations

The ODD should provide information on abnormal situations as per 1.3.4 and 3.2.2.

Aspects to be considered in the definition of abnormal situations include:

- Exceeding normal operation limits in ship operational parameters such as loading conditions, draught, trim, speed, underkeel clearance etc.
- Exceeding normal operation limits in performance of propulsion, steering, other machinery, electrical installations, power generation, etc.
- Exceeding normal operation limits in environmental conditions, e.g. light, weather, temperature, wind, horizon visibility, traffic density, etc.
- Absence or degradation of information from navigation instruments and/or other sensors for situational awareness.

4.1.2.3 Minimum risk conditions

The ODD should provide information on Minimum risk Conditions as per 1.3.4 and 3.2.3, specifying at least the ship's speed, heading, position, route and/or other conditions to be reached and maintained in order to minimize the risk of contact with other vessels, dock, marine mammals, people, or with other objects or obstacles that may be encountered during navigation.

4.1.3 Functional requirements

4.1.3.1 General

MASS technology for collision and grounding avoidance should comply with the functional requirements in 3.4.

4.1.3.2 Situational awareness

MASS technologies used for collision and grounding avoidance should be able to:

- Acquire from conventional ship's navigation systems all the information useful to determine the ship's position, heading, speed, etc., including alerts and indicators, with standardized communication protocols and interfaces.
- Acquire information on the position, heading, speed, size and type of objects external to the ship within a visual range equivalent to the unrestricted and unobstructed visibility range assumed in conventional navigation.
- Acquire other environmental information (such as weather or sea state information) to be taken into account for keeping the ship safe in case manoeuvring for avoiding collisions is necessary, considering the worst-condition option.
- Acquire information about all the ship's motion parameters, including at least roll, pitch and yaw. For ships sailing at high speed, the vertical acceleration at the centre of gravity and at the bow is to be monitored.
- Transmit all the information to the on board or remote control station, including alerts and indicators.

4.1.3.3 Decision making

MASS technologies used for collision and grounding avoidance should be able to:

- Identify objects in the vicinity of the ship and make calculations to anticipate their possible route.
- Identify seabed, reefs, waterway sides and other possible environmental obstacles to navigation in

the vicinity of the ship and make calculations to anticipate the possibility of impact with them.

- Provide a range of possible adjustments to the ship's route aimed to avoid collision with objects in the vicinity of the ship.
- Apply criteria for the selection of best-choice among feasible options, in compliance with applicable rules and regulations and keeping the ship in a safe state.
- Communicate options for possible actions to be taken in a clear and timely manner to the on board or remote control station.
- Communicate to the on board or remote control station and clearly present requests of explicit selection/approval of action by responsible human operator, or overruling autonomously taken decisions.

4.1.3.4 Action implementation

MASS technologies used for collision and grounding avoidance should be able to:

- Communicate commands to the ship's propulsion and steering systems using protocols compatible with such systems.
- Monitor effects of command issued and detect errors in the performance of intended action.
- Manage alerts and indicators in a timely manner, also recognizing events and conditions that may configure abnormal situations or the need to enter a minimum risk condition.

4.1.4 Performance requirements

MASS technology for collision and grounding avoidance should comply with the performance requirements in 3.5.

In addition to the above:

- The MASS technology should be able to provide a complete picture of the environment surrounding the ship as it may be required to a human watch on the bridge in accordance with the Reference Statutory Rules (2.1).
- The accuracy of the acquired image should allow easy detection of any ship, object or obstacle in short and mid-range distance.
- The MASS technology should be able to magnify images in direction of targets and to acquire infrared images during night.
- The MASS technology be able to detect and track surrounding ships and objects in due advance to allow collision avoidance manoeuvring.
- The MASS technology should be able to detect floating or partly submerged objects of standard container size in a mid-range distance and a life raft or a person in the water in a short-range distance.

4.1.5 Test and evaluation criteria

4.1.5.1 Determine position

The MASS technology should demonstrate the ability to determine the ship's position by means of systems and sensors for situational awareness including navigation instruments, vision systems and other sensors, taking into account lighthouses, buoys, beacons, wind, tides, current and estimated speed and heading.

Criteria for the evaluation of test results are:

- Comparison of estimated position against other methods used in conventional navigation and estimation of differences. Acceptable error threshold should be fixed depending on the expected performance of the MASS technology, vessel characteristics and intended service.
- The effect of deadweight, draught, trim, speed and underkeel clearance are duly taken into account and do not compromise the ability of the ship to determine its position within due tolerance limits.
- The effect of environmental factors like wind, tides etc. are duly taken into account and do not compromise the ability of the ship to determine its position within due tolerance limits.

4.1.5.2 Conduct a passage avoiding collisions

The MASS technology should demonstrate the ability to conduct a passage in normal operation conditions by means of situational awareness, decision making and action implementation systems, as available, avoiding collisions with other vessels or grounding, or contact with dock, marine mammals, people, or with other objects or obstacles that may be encountered during navigation.

Criteria for the evaluation of test results are:

- All obstacles are correctly identified and avoided.
- Communication with other ships and shore is correctly carried out and understood.
- Lights, shapes and sound signals are correctly identified and understood (situational awareness) and correctly set (action implementation).
- Time for obstacle detection, signaling and action implementation is comparable to or shorter than equivalent time necessary in conventional ship operation.
- The effect of deadweight, draught, trim, speed and underkeel clearance are duly taken into account and do not compromise the ability of the ship to avoid collisions.

- The effect of environmental factors like wind, tides etc. are duly taken into account and do not compromise the ability of the ship to avoid collisions.
- Limitations in manoeuvring capabilities such as stopping distance, minimum steering radius, backwards manoeuvring, etc. are duly taken into account and do not compromise the ability of the ship to avoid collisions.
- The stability conditions of the ship are maintained in all situations.

4.2 Task: Route management

4.2.1 Concept of operations

4.2.1.1 Task description

Route management consists in adaptively planning and following the path for the intended voyage from start to finish, via predefined waypoints, taking into account all pertinent information and requirements such as travel time limits, fuel consumption, supplies, weather conditions and any other information or requirement that might affect navigation.
Route management may imply continuous speed and heading adaptation during navigation, based on continuous monitoring of environmental factors and ship systems' status.

4.2.1.2 Scope of application and process phases

The scope of application and process phases for a MASS technology used for collision and grounding avoidance should be defined in the CONOPS according to 1.3.2.3 and 1.3.2.4.

For route management:

- Support scope may include planning and optimization based on multiple criteria.
- Operation and management scope may include adaptive conduction of passage following pre-defined paths and waypoints, regulation of speed and heading, rerouting based on e.g. real-time weather or sea conditions, adjustment of autopilot operational parameters, adjustment in thresholds for warnings and alarms such as off-course alarm, etc.

4.2.2 Operational Design Domain

4.2.2.1 Normal Operation

The ODD should provide information on normal operation as per 1.3.4 and 3.2.1.

In the definition of normal operation, the following should be at least specified:

- Requirements and restrictions as per 4.1.2.1 for collision and grounding avoidance.
- Required information from external sources, such as marine traffic information systems, port of call, weather forecast and sea condition information bulletins.
- Requirements and restrictions in the presence or absence of other MASS technologies, such as those for collision and grounding avoidance, or other.

4.2.2.2 Abnormal situations

The ODD should provide information on abnormal situations as per 1.3.4 and 3.2.2.

Aspects to be considered in the definition of abnormal situations include:

- Aspects to be considered as per 4.1.2.2 for collision and grounding avoidance.
- Absence or degradation of information from external sources, such as marine traffic information systems, port of call, weather forecast and sea condition information bulletins.
- Absence or degradation of functionality or performance of other MASS technologies, such as those for collision and grounding avoidance, or other.
- Detection of off-course warning or alarm conditions (over threshold displacement) due to manual overrule of programmed course or intervention of other MASS technology such as collision avoidance or other.

4.2.2.3 Minimum risk conditions

The ODD should provide a definition of the Minimum risk condition for route management as per 1.3.4 and 3.2.3, specifying at least the ship's speed, heading, position, route and/or other conditions to be reached and maintained in order to minimize the risk of over-threshold off-course displacement and avoiding unsafe paths.

4.2.3 Functional requirements

4.2.3.1 General

MASS technology for route management should comply with the functional requirements in 3.4.

When the scope of operation of MASS technology for route management covers operation and/or management, the MASS technology should fulfil also the functional requirements for collision and grounding avoidance (4.1.3), or specific MASS technology for these tasks, with equivalent scope of operation, should be provided.

4.2.3.2 Situational awareness

MASS technologies used for route management should be able to:

- Acquire from conventional ship's navigation systems all the information useful to determine the ship's position, heading, speed, etc., including alerts and indicators, with standardized communication protocols and interfaces;
- Acquire other environmental information (such as weather or sea state information) to be taken into account for keeping the ship safe in case manoeuvring for modifying the planned route is necessary, considering the worst-condition option;
- Acquire information from external sources, such as marine traffic information systems, port of call, weather forecast and sea condition information bulletins;
- Transmit all the information to the on board or remote control station, including alerts and indicators.

4.2.3.3 Decision making

MASS technologies used for route management should be able to:

- Identify different phases of the voyage (e.g. mooring/unmooring, manoeuvring in/out of harbour, navigation in open sea, navigation in zones with restrictions, etc.) and apply different criteria for selection of actions accordingly.
- Provide possible adjustments to the ship's route, including revision of waypoints if needed, aimed at managing unplanned situations and/or avoid adverse or dangerous navigation conditions.
- Apply criteria for the selection of best-choice among feasible options, in compliance with applicable rules and regulations (e.g. during navigation in Emission Control Area zones) and keeping the ship in a safe state
- Apply criteria for the selection of best-choice among feasible options, taking into account requirements for fuel, water, lubricants, chemicals, supplies and any other requirements for the successful and safe completion of the voyage, and for the safe management of cargo.
- Communicate options for possible actions to be taken for route management in a clear and timely manner to the on board or remote control station.
- Communicate to the on board or remote control station and clearly present requests of explicit selection/approval of action by responsible human operator, or overruling autonomously taken decisions.

4.2.3.4 Action implementation

MASS technologies used for route management should be able to:

- Plan and follow a route according to the selected voyage plan, taking into account environmental conditions and limitations, in compliance with applicable rules and regulations and keeping the ship in a safe state.

  The route planning is to include, at least departure point and time and arrival point and estimated time.

  The voyage planning may also include:

  - way points with relevant estimated time;
  - conditional instructions ("if-then" cases);
  - priority on routing calculation and update (time to arrival, fuel consumption, etc.);
  - limit parameters for voyage length;
  - estimated arrival time for updated voyage plan.
- Avoid collisions and grounding autonomously, or in cooperation with collision and grounding avoidance MASS technologies, if available
- Sail according to the voyage plan keeping the ship within its design parameters, including hull strength, stability, power availability, manoeuvring capability, etc.
- Sail according to the criteria established in the voyage plan and their priority (time of arrival, fuel consumption, route optimization criteria, etc.)
- Sail according to possible limitations due to ship condition, limited operational capabilities, prescriptions imposed by Class or Administration, etc.
- Communicate commands to the ship's propulsion and steering systems in a secure and timely manner, using protocols compatible with such systems.
- Monitor effects of command issued and detect errors in the performance of intended action.
- Provide continuously and timely information to the responsible human operator about the ship's position, speed, trim and heading, expected time of arrival, weather conditions, weather forecast, alerts and indicators, off-course detection etc., also recognizing events and conditions that may configure abnormal situations or the need to enter a minimum risk condition.
- Continuously record the parameters of ship movements and the activities relating to the navigation of the ship, including events and/or conditions determining rerouting or entering abnormal conditions.

- Record actions taken to avoid collisions or grounding and relevant amendments to course and/or speed.

4.2.4 Performance requirements

4.2.4.1 General

MASS technology for route management should comply with the performance requirements in 3.5

In addition to the above:

- MASS technology should be able to autonomously detect the need of modifying route plans at the least based on the following causes:
  - actual weather conditions,
  - weather forecast,
  - ship's conditions (failures, reduced capabilities, etc.);
- When any of the conditions for the safe execution of planned route is not complied with, due information should be provided to the responsible human operator as per 3.5 with clear indication of the missing conditions and the planning is to be aborted. Modified route plans are to be confirmed by means of a two-step validation procedure.

4.2.5 Test and evaluation criteria

Tests described in 4.1.5 for collision and grounding avoidance apply. In addition, the following tests apply.

4.2.5.1 Follow planned path

The MASS technology should demonstrate the ability to plan and follow the path for the intended voyage from start to finish, via predefined waypoints, taking into account all pertinent information and requirements such as travel time limits, fuel consumption, supplies, weather conditions and any other information or requirement that might affect navigation.

Criteria for the evaluation of test results are:

- The route is correctly planned according to the criteria established and their priority.
- The route is correctly followed through waypoints according to the plan and according to possible limitations occurring during navigation.
- The position along the route is determined and kept within the limits of acceptable instrument and system errors
- ETA is fulfilled.
- The information obtained from navigational charts and other navigational instruments are interpreted correctly and properly applied.
- The information obtained from marine traffic information systems, port of call, weather forecast and sea condition information bulletins are interpreted correctly and properly applied.
- All potential navigational hazards are accurately identified and avoided.
- Errors in navigational information are correctly detected and taken into account.
- A proper level of information about ship position, speed, heading and trim is given to the human responsible operator and in each active control station.
- Lights, shapes and sound signals are correctly recognized.
- The navigation parameters are recorded according to data security criteria and available for examination and analysis.

4.2.5.2 Path re-planning

The MASS technology should demonstrate the ability to adaptively re-plan and follow the path for the intended voyage from start to finish, via predefined waypoints, based on changes in environmental conditions and/or human overrule, taking into account all pertinent information and requirements such as travel time limits, fuel consumption, supplies, weather conditions and any other information or requirement that might affect navigation.

Criteria for the evaluation of test results are:

- The amendments to original path take into account the requirements for fuel, water, lubricants, chemicals, supplies and any other requirements for the successful and safe completion of the voyage, and for the safe management of cargo.
- Unfeasible changes are rejected and timely and sufficient information is provided to the human responsible operator, including reasons for rejecting the path and possible alternative options, including overruling and taking full control.
- A proper level of information about changes made to original path, reasons for changes and requests for confirmation/overrule is given to the human responsible operator and in each active control station.

4.3 Task: Speed, draught and trim control

4.3.1 Concept of operations

4.3.1.1 Task description

Speed, draught and trim control consists in the adaptive modification of the ship's floating position and speed during sailing, usually aimed at optimizing the vessel's energy demand for propulsion.

4.3.1.2 Scope of application and process phases

The scope of application and process phases for a MASS technology used for speed, draught and trim control avoidance should be defined in the CONOPS according to 1.3.2.3 and 1.3.2.4.

For speed, draught and trim control:

- Support scope may include fuel consumption optimization based on multiple criteria.
- Operation and management scope may include adaptive modification of the ship's floating position and speed during sailing, modification of criteria for optimization, sensitivity to environmental parameters, adjustment in thresholds for warnings and alarms, etc.

4.3.2 Operational Design Domain

4.3.2.1 Normal Operation

The ODD should provide information on normal operation as per 1.3.4 and 3.2.1.

In the definition of normal operation, the following should be at least specified:

- Requirements and restrictions in the ship loading conditions, draught, trim, speed, underkeel clearance etc.
- Requirements and restrictions in the operational conditions of ship systems such as propulsion, steering, other machinery, electrical installations, power generation, etc.
- Requirements and restrictions in the environmental conditions, e.g. light, weather, temperature, wind, etc.
- Required information from navigation instruments and other sensors for situational awareness and relevant specifications, required certification or compliance to standards.

4.3.2.2 Abnormal situations

The ODD should provide information on abnormal situations as per 1.3.4 and 3.2.2.

Aspects to be considered in the definition of abnormal situations include:

- Exceeding normal operation limits in ship operational parameters such as loading conditions, draught, trim, speed, underkeel clearance etc.
- Exceeding normal operation limits in performance of propulsion, steering, other machinery, electrical installations, power generation, etc.
- Exceeding normal operation limits in environmental conditions, e.g. light, weather, temperature, wind, sea state, wave height, etc.
- Absence or degradation of information from navigation instruments and/or other sensors for situational awareness.
- Absence or degradation of information from external sources, such as marine traffic information systems, port of call, weather forecast and sea condition information bulletins.
- Detection of warning or alarm conditions relevant to ship stability or hull strength.

4.3.2.3 Minimum risk conditions

The ODD should provide information on Minimum risk Conditions as per 1.3.4 and 3.2.3, specifying at least the ship's speed, draft, trim and other conditions to be reached and maintained in order to minimize the risk of compromising safe management of the ship and cargo.

4.3.3 Functional requirements

4.3.3.1 General

MASS technology for speed, draught and trim control should comply with the functional requirements in 3.4

4.3.3.2 Situational awareness

MASS technologies used for speed, draught and trim control should be able to:

- Acquire from conventional ship's navigation systems all the information useful to determine the ship's position, heading, speed, draught, trim etc., including alerts and indicators, with standardized communication protocols and interfaces.
- Acquire information on the ballast and cargo status, weight distribution, hull strength and stress status.
- Acquire other environmental information (such as weather or sea state information) to be taken into account for keeping the ship safe in case modification of ballast or cargo arrangements is necessary, considering the worst-condition option.
- Transmit all the information to the on board or remote control station, including alerts and indicators.

4.3.3.3 Decision making

MASS technologies used for speed, draught and trim control should be able to:

- Determine floating position of the ship and perform calculations considering wave breaking resistance, frictional resistance and other parameters, aimed at defining new target values for speed, draught and trim that meet the desired criteria

- Apply criteria for the selection of best-choice among feasible options, in compliance with applicable rules and regulations and keeping the ship in a safe state.
- Communicate options for possible actions to be taken for speed, draught and trim control in a clear and timely manner to the on board or remote control station.
- Communicate to the on board or remote control station and clearly present requests of explicit selection/approval of action by responsible human operator, or overruling autonomously taken decisions.

4.3.3.4 Action implementation

- Commands to the ship's ballast and cargo control systems should be issued in order to ensure the effectiveness of action and to avoid exceeding stability and/or hull strength limits and that manoeuvring is carried out keeping the ship in a safe state.
- Effects of command issued should be monitored and errors in the performance of intended action should be detected in due time in order to allow either human takeover or adaptive corrections, keeping the ship in a safe condition and avoiding collisions.
- Alerts and indicators should be detected and managed in a timely manner, also recognizing events and conditions that may configure abnormal situations or the need to enter a minimum risk condition.
- Speed, draught and trim control should be possible, in all conditions of normal operation, including incomplete availability of information, if foreseen in the CONOPS, keeping the ship in a safe state
- Safety margins should be kept against the ship's design parameters, including hull strength, stability, power availability, manoeuvring capability, etc. taking into account possible limitations due to ship condition, limited operational capabilities, prescriptions imposed by Class or Administration, etc.

4.3.4 Performance requirements

MASS technology for route management should comply with the performance requirements in 3.5

4.3.5 Test and evaluation criteria

4.3.5.1 Define optimal values for speed, draught and trim

The MASS technology should demonstrate the ability to detect sub-optimal speed, draught and trim conditions with respect to given optimum criteria and provide optimized values, taking into account all pertinent information and requirements such as ship design conditions, fuel consumption, weather conditions and any other information or requirement that might affect navigation.

Criteria for the evaluation of test results are:

- The information obtained from navigational instruments and environmental sensors are interpreted correctly and properly applied.
- The new values provided for speed, draught and trim lead to better performance, according to the given calculation model and fulfil the requirements.
- The new values provided for speed, draught and trim are implemented correctly and according to possible limitations occurring during navigation.
- The information obtained from marine traffic information systems, port of call, weather forecast and sea condition information bulletins are interpreted correctly and properly applied.
- All potential dangerous situations are accurately identified and avoided.
- Errors in navigational or environmental information are correctly detected and taken into account.
- Unfeasible changes are rejected and timely and sufficient information is provided to the human responsible operator, including reasons for rejecting and possible alternative options, including overruling and taking full control.
- A proper level of information about ship speed, draught and trim is given to the human responsible operator and in each active control station.
- The navigation parameters are recorded according to data security criteria and available for examination and analysis.

5 MACHINERY MANAGEMENT FUNCTION

5.1 General

5.1.1 Automation vs. autonomy technology

The level of automation for machinery systems and equipment in conventional ship operation is today very high, enabling automatic execution of complex control procedures, even with non-trivial interaction among different systems.

This guide focuses on technologies that go beyond machinery automation technologies already available today for conventional ship operation. The focus is indeed on technologies that allow ship autonomy, i.e. operation of ship's machinery systems independent of human interaction, to a varying degree.

5.1.2 Local control

Machinery installations depending on remote control systems, regardless to their complexity, are however subject to mandatory regulations on local control, such as:

- SOLAS II-1/Reg. 31.2 (Machinery controls)

  “Where remote control of propulsion machinery from the navigating bridge is provided, the following shall apply:
  […]
  It shall be possible to control the propulsion machinery locally, even in the case of failure in any part of the remote control system. It shall also be possible to control the auxiliary machinery, essential for the propulsion and safety of the ship, at or near the machinery concerned”
  […]
- SOLAS II-1/Reg. 49 (Unattended machinery spaces)

  “[…] It shall be possible for all machinery essential for the safe operation of the ship to be controlled from a local position, even in the case of failure in any part of the automatic or remote control systems”.

When MASS technologies for machinery management are adopted, options for controlling essential machinery and its auxiliaries in case of any failures affecting the remote control system should be provided, enabling manned local control at or near the machinery served and disconnecting any remote control systems, in order to operate the machinery locally.

In particular, the local control system:

- Should include necessary Human Machine Interface (HMI) for effective local-equivalent operation.
- Should not depend on other systems or unreliable communication links for its intended operation.
- Should not be impaired by a single failure, e.g. by providing redundancy and/or independent segregated systems.
- Should be under direct control of a human responsible operator.

When MASS technologies for machinery management are adopted, additional measures should be implemented to reduce as much as possible failures and incidents potentially leading to the need of local operation, repairs or manual work.

Failure modes whose recovery, in conventional ship operation, implies manual work should be appropriately compensated e.g. by increased redundancy, increased fault tolerance (including tolerance to common-cause failure modes) and/or other measures not requiring human intervention, as possible, according to a FMEA and a risk assessment.

In case of unmanned operation of the ship, or operation with reduced manning on board, when local operation is required, the MASS technology for machinery management should force a Minimum risk condition and communicate the current status to the on board or remote control station.

5.1.3 Common tests and evaluation criteria

Common tests and evaluation criteria indicated in 3.6 apply also to MASS technologies for machinery management.

5.2 Task: Engineering watch keeping

5.2.1 Concept of operations

5.2.1.1 Task description

Engineering watch keeping consists in the safe and efficient operation and upkeep of ship machinery, including supervision, inspection, monitoring, servicing, testing and operation, as required, of all systems and equipment affecting the safety of the ship, such as propulsion, steering, power management, etc. under the circumstances, conditions and modes of operation foreseen in normal and emergency operation.

5.2.1.2 Scope of application and process phases

The scope of application and process phases for a MASS technology used for engineering watch keeping should be defined in the CONOPS according to 1.3.2.3 and 1.3.2.4.

For tasks related to machinery management function:

- Support scope may include supervision, monitoring, fault-finding and optimization, based on multiple criteria.
- Operation and management scope may include adaptive governing of on-board ship machinery, modification of criteria for optimization, sensitivity to environmental parameters, adjustment in thresholds for warnings and alarms, etc.

5.2.2 Operational Design Domain

5.2.2.1 Normal Operation

The ODD should provide information on normal operation as per 1.3.4 and 3.2.1.

In the definition of normal operation, the following should be at least specified:

- Requirements and restrictions in the operational conditions of ship systems such as propulsion, steering, other machinery, electrical installations, power generation, etc.

- Requirements and restrictions in the environmental conditions, e.g. light, weather, temperature, wind, etc.
- Required information from navigation instruments, machinery equipment and other sensors for situational awareness and relevant specifications, required certification or compliance to standards.
- Required information from, and interaction with computerized maintenance systems (e.g. Planned Maintenance Systems, Condition-based, preventive, or other).
- Requirements and restrictions in the communication system, such as protocols for communication with bridge, shore, etc.
- Requirements and restrictions in the availability, type, functionality, performance, redundancy, fault tolerance and communication capabilities of machinery systems, components and equipment.

5.2.2.2 Abnormal situations

The ODD should provide information on abnormal situations as per 1.3.4 and 3.2.2.

Aspects to be considered in the definition of abnormal situations include:

- Exceeding normal operation limits in performance of propulsion, steering, other machinery, electrical installations, power generation, etc.
- Exceeding normal operation limits in environmental conditions, e.g. light, weather, temperature, wind, sea state, wave height, etc.
- Absence or degradation of information from navigation instruments and/or other sensors for situational awareness.
- Absence or degradation of information from computerized maintenance systems.
- Exceeding normal operation limits in performance of communication systems.
- Exceeding normal operation limits in availability, functionality, performance, redundancy, fault tolerance and communication capabilities of machinery systems, components and equipment.
- Failures of machinery systems, components or equipment which cannot be duly recovered by the MASS technology e.g. by autonomous servicing, replacement, switch to redundant equivalent, or in other ways.

5.2.2.3 Minimum risk conditions

The ODD should provide information on Minimum risk Conditions as per 1.3.4 and 3.2.3, specifying at least the status of machinery systems such as propulsion, steering, power generation, ballast and cargo control systems and other conditions to be reached and maintained in order to minimize the risk of compromising safe management of the ship and cargo.

Special care should be put on the definition of requirements for power supply to the MASS technology's electronic equipment, also in case of blackout, in order to ensure sufficient up time and other conditions allowing a human responsible operator to take control or provide servicing and allowing the systems onboard to receive, execute and respond to the instructions.

5.2.3 Functional requirements

MASS technology for engineering watch keeping should comply with the functional requirements in 3.4

5.2.3.1 Situational awareness

MASS technologies used for engineering watch keeping should be able to:

- Acquire from conventional ship's machinery systems all the information useful to determine the operational parameters of all systems providing essential and auxiliary services, including alerts and indicators, with standardized communication protocols and interfaces;
- Acquire information on the ballast and cargo status, weight distribution, hull strength and stress status.
- Acquire other environmental information (such as weather or sea state information) to be taken into account for keeping the ship safe in case modification of ballast or cargo arrangements is necessary, considering the worst-condition option.
- Transmit all the information to the on board or remote control station, including alerts and indicators.

5.2.3.2 Decision making

MASS technologies used for engineering watch keeping should be able to:

- Determine the operational status of all machinery systems providing essential and auxiliary services to the ship, also taking into account alarms and indicators.
- Combine and interpret sensor readings, such as temperature, noise, vibration, fumes, images, etc. to recognize potentially critical situations, failure conditions, out-of-bounds values of operational parameters or known patterns leading to potentially critical situations.
- Use knowledge in manuals, manufacturer's data sheets, operating instructions, maintenance strategies, etc. to devise possible actions to be taken.

- Apply criteria for the selection of best-choice among feasible options, in compliance with applicable instructions, rules and regulations and keeping the ship in a safe state.
- Communicate options for possible actions to be taken for speed, draught and trim control in a clear and timely manner to the on board or remote control station.
- Communicate to the on board or remote control station and clearly present requests of explicit selection/approval of action by responsible human operator, or overruling autonomously taken decisions.

5.2.3.3 Action implementation

- Orders from bridge or equivalent remote control station should be correctly understood and duly implemented.
- Commands to the ship's machinery systems should be issued in order to ensure the effectiveness of action and to avoid exceeding machinery operational limits, stability and hull strength limits, and that manoeuvring is carried out keeping the ship in a safe state.
- Effects of command issued should be monitored and errors in the performance of intended action should be detected in due time in order to allow either human takeover or adaptive corrections, keeping the ship in a safe condition
- Alerts and indicators should be detected and managed in a timely manner, also recognizing events and conditions that may configure abnormal situations or the need to enter a minimum risk condition.
- Failure conditions that can be recovered autonomously should be duly logged and timely communicated to the on board or remote control station and clearly presented, and appropriate recovery procedure should be carried out.
- Failure conditions that cannot be recovered autonomously should be promptly communicated to the on board or remote control station and the affected machinery should be put in a safe state, according to the ODD.
- Safety margins should be kept against the ship's design parameters, including hull strength, stability, power availability, manoeuvring capability, etc. taking into account possible limitations due to ship condition, limited operational capabilities, prescriptions imposed by Class or Administration, etc.
- A log book should be maintained keeping trace of all the actions taken.

5.2.4 Performance requirements

MASS technology for engineering watch keeping should comply with the performance requirements in 3.5

5.2.5 Test and evaluation criteria

5.2.5.1 Operate main and auxiliary machinery

The MASS technology should demonstrate the ability to operate main and auxiliary machinery, in particular for:

- Preparation of main machinery and auxiliary achinery for operation
- Operation of steam boilers and monitoring/control of water level
- Start up and shutdown of main propulsion and auxiliary machinery, including associated systems.
- Location of common faults in machinery and plant in engine and boiler rooms and action necessary to prevent damage.

Criteria for the evaluation of test results are:

- Operations are carried out in accordance with applicable rules and procedures.
- Deviations from expected behaviour of machinery are promptly detected and corrected.
- Machinery systems are kept in a safe and efficient condition as expected.
- Causes of malfunctions are promptly identified and actions are designed to ensure safe operation, taking into account prevailing circumstances and conditions.
- Engine performance and capacity is monitored and controlled and complete information is given to human operator and logged.
- Engine performance levels are in accordance with technical specifications.

5.2.5.2 Operate pumping system

The MASS technology should demonstrate the ability to operate the pumping system, in particular for:

- Routine pumping operation
- Operation of bilge, ballast and cargo pumping systems

Criteria for the evaluation of test results are:

- Operations are carried out in accordance with applicable rules and procedures
- Deviations from expected behaviour of pumping systems are promptly detected and corrected
- Pumping systems behave safely and efficiently as expected

- Causes of malfunctions are promptly identified and actions are designed to ensure safe operation, taking into account prevailing circumstances and conditions
- Water levels and steam pressures are maintained

5.2.5.3 Operate generators and power management systems

The MASS technology should demonstrate the ability to operate generators and power management systems, in particular for:

- Preparing, starting, coupling and changing over alternators or generators
- Location of common faults and actions to prevent damage

Criteria for the evaluation of test results are:

- Operations are carried out in accordance with applicable rules and procedures.
- Deviations from expected behaviour of generators and power management systems are promptly detected and corrected.
- Generators and power management systems behave safely and efficiently as expected.
- Causes of malfunctions are promptly identified and actions are designed to ensure safe operation, taking into account prevailing circumstances and conditions.

5.2.5.4 Safety procedures for maintenance

The MASS technology should demonstrate the ability to carry out basic functions related to maintenance of machinery, in particular for:

- Safe isolation of electrical and other types of plants and equipment required before human personnel are permitted to work for servicing and repair

Criteria for the evaluation of test results are:

- Isolation of electrical plants is duly carried out
- Clear and complete information is given to the human operators
- Sequence of maintenance activities and accessibility to plants are clearly communicated.

5.2.5.5 Manage fuel and ballast operations

The MASS technology should demonstrate the ability to carry out fuel and ballast operations, in particular for:

- Fuel changeover
- Pollution prevention

Criteria for the evaluation of test results are:

- Fuel and ballast operations meet the operational requirements and are carried out to prevent pollution of the marine environment

5.2.5.6 Test, detect and recover from faults

The MASS technology should demonstrate the ability to test and detect faults, in particular for:

- Testing and maintenance of electronic, pneumatic and hydraulic systems, including fault finding and diagnostics.
- Detect and identify the cause of machinery malfunctions, correct faults and maintain and restore equipment to operating condition.

Criteria for the evaluation of test results are:

- The effect of malfunctions on associated plants and systems is accurately identified, actions taken are justified.
- Monitoring and recovery activities are planned in accordance with technical, legislative, safety and procedural specifications.
- The activities and relevant parameters are recorded according to data security criteria and available for examination and analysis.
- Safety and emergency procedures and immediate actions are taken in the event of fire, flooding or other accident, changeover of remote/automatic to local control of all systems.

5.2.5.7 Communication

The MASS technology should demonstrate the ability to communicate with bridge, in particular for:

- Understanding orders and being understood in matters relevant to engineering watch keeping duties.

Criteria for the evaluation of test results are:

- Transmission and reception of messages from bridge and/or control station are consistently successful.
- Communication records are complete, accurate and comply with statutory requirements.

5.2.5.8 Ensure safe working practices

The MASS technology should demonstrate the ability to ensure safe working practices.

Criteria for the evaluation of test results are:

- Potentially unsafe working practices, or practices not in accordance with legislative requirements, codes of practice and environmental concerns, are detected, forbidden or discouraged

6 COMMUNICATION FUNCTION

6.1 General

Communication function consists in the exchange of information between ship and shore, ship to ship or between different locations onboard the ship, aimed at providing instructions or information for the safe operation of the ship.
Communication is usually carried out by radio equipment. Such equipment is assumed as compliant to all applicable rules.

Communication is an essential part of all MASS technologies, in particular for those enabling remote operation of the ship. For such technologies, e.g. for navigation and machinery, guidelines and requirements on communication are indicated in chapter 3 and in dedicated paragraphs for each task or technology and are not repeated in this chapter.

This chapter focuses on technologies that are aimed to modify the way communication function is carried out in conventional ship operation by human radio operators.

However, considering the variety of communication types, the technical issues related to the correct understanding and synthesis of natural language, the substantial impact of human element in radio communication, the level of knowledge and analytic capabilities required for formulation of questions and replies, etc., only MASS technologies enabling radio communication carried out by a human operator from a remote control station are considered in this guide. Other technologies implementing more advanced autonomy are not considered. Such other technologies should be considered on a case-by-case basis.

6.2 Task: Radio watch keeping

6.2.1 Concept of operations

6.2.1.1 Task description

Radio watch keeping consists in the safe and efficient operation and upkeep of radio communication systems and execution of communication procedures including ship-to-ship, ship-to-shore and internal ship communication under the circumstances, conditions and modes of operation foreseen in normal and emergency operation.

6.2.1.2 Scope of application and process phases

The scope of application and process phases for a MASS technology used for radio watch keeping should be defined in the CONOPS according to 1.3.2.3 and 1.3.2.4.

For tasks related to communication function:

- Support scope may include continuous monitoring of radio channels, recognition of conditions contributing to degradation of communication quality, recognition and categorization of standard messages, etc.
- Operation and management scope may include correction of conditions contributing to improve the quality of communication, composition of standard replies, etc.

6.2.2 Operational Design Domain

6.2.2.1 Normal Operation

The ODD should provide information on normal operation as per 1.3.4 and 3.2.1.

In the definition of normal operation, the following should be at least specified:

- Requirements and restrictions in the operational conditions of ship systems such as electrical installations, power generation, etc.
- Requirements and restrictions in the environmental conditions, e.g. light, weather, temperature, wind, etc.
- Requirements and restrictions in the communication system, such as availability and quality of radio channels, protocols for communication with bridge, shore, other ships, etc.

6.2.2.2 Abnormal situations

The ODD should provide information on abnormal situations as per 1.3.4 and 3.2.2.

Aspects to be considered in the definition of abnormal situations include:

- Exceeding normal operation limits in performance of electrical installations, power generation, etc.
- Exceeding normal operation limits in environmental conditions, e.g. light, weather, temperature, wind, sea state, wave height, etc.
- Exceeding normal operation limits in performance of communication systems or availability of radio channels.

6.2.2.3 Minimum risk conditions

The ODD should provide information on Minimum risk Conditions as per 1.3.4 and 3.2.3.

Special care should be put on the definition of requirements for communication systems also in case of blackout, in order to ensure sufficient up time and other conditions allowing a human responsible operator to take control or provide servicing and allowing the systems onboard to receive, execute and respond to the instructions.

6.2.3 Functional requirements

MASS technology for radio watch keeping should comply with the functional requirements in 3.4

6.2.3.1 Situational awareness

MASS technologies used for radio watch keeping should be able to:

– Acquire from radio communication systems all the information useful to determine the operational status and quality of radio communication.

– Acquire other environmental information (such as weather information) to be taken into account for keeping the radio communication of good quality and minimize degradation and faults.

– Transmit all the information to the on board or remote control station, including alerts and indicators.

6.2.3.2 Decision making

MASS technologies used for radio watch keeping should be able to:

– Determine the operational status of all radio communication systems, also taking into account alarms and indicators.

– Combine and interpret data, such as temperature, weather conditions, electrical noise, interference on radio channels, etc. to recognize potentially critical situations, failure conditions, out-of-bounds values of operational parameters or known patterns leading to potentially critical situations.

– Use knowledge in manuals, manufacturer's data sheets, operating instructions, maintenance strategies, etc. to devise possible actions to be taken.

– Apply criteria for the selection of best-choice among feasible options, in compliance with applicable instructions, rules and regulations and keeping the ship in a safe state.

– Communicate options for possible actions to be taken in a clear and timely manner to the on board or remote control station.

– Communicate to the on board or remote control station and clearly present requests of explicit selection/approval of action by responsible human operator, or overruling autonomously taken decisions.

6.2.3.3 Action implementation

MASS technologies used for radio watch keeping should be able to:

– Act on radio equipment and monitor the effects of actions. Errors in the performance of intended action should be detected in due time in order to allow either human takeover or adaptive corrections, keeping the ship in a safe condition

– Detect and manage alerts and indicators in a timely manner, also recognizing events and conditions that may configure abnormal situations or the need to enter a minimum risk condition.

– Recover from failure conditions when possible and timely communicate to the on board or remote control station.

– Failure conditions that cannot be recovered autonomously should be promptly communicated to the on board or remote control station.

– A log book should be maintained keeping trace of all the actions taken.

6.2.4 Performance requirements

MASS technology for radio watch keeping should comply with the performance requirements in 3.5

6.2.5 Test and evaluation criteria

Radio communication procedures affected by MASS technology should be tested against normal verification procedures applicable in conventional ship operation. ~~Properly trained seafarers with due certification should be used for testing.~~

6.2.5.1 Transmit and receive general radio communications

The MASS technology should demonstrate the ability to allow correct and efficient operation of all radio systems, equipment and ancillary devices from a remote control station under normal conditions and typical radio channel availability and quality conditions. In particular:

Criteria for the evaluation of test results are:

– Radio communications, including ship-to-ship, ship-to-shore and ship-internal communications are correctly received and transmitted in a timely and understandable manner

– Receiver and transmitter adjustment for the appropriate mode of operation are possible

– Antenna realignment and adjustment as appropriate are possible and proper feedback to the remote control station is given.

– Deviations from expected behaviour of radio equipment are promptly detected and corrected.

– Causes of malfunctions are promptly identified and actions are designed.

– Messages transmitted and received are understood and properly managed, particularly concerning distress, urgency and safety procedures.

6.2.5.2 Receive and transmit distress alerts (GMDSS)

The MASS technology should demonstrate the ability to transmit and receive distress alerts to/from a remote control station as per applicable rules in a timely and understandable manner.
Criteria for the evaluation of test results are:

- Shore-to-ship distress alerts are correctly received in a timely and understandable manner.
- Ship-to-ship distress alerts are correctly transmitted in a timely and understandable manner.

6.2.5.3 Receive and transmit search and rescue (SAR) communications

The MASS technology should demonstrate the ability to transmit and receive search and rescue communications to/from a remote control station as per applicable rules a timely and understandable manner.

Criteria for the evaluation of test results are:

- SAR co-ordinating communications are correctly received and transmitted in a timely and understandable manner.
- SAR on-scene communications are correctly received and transmitted in a timely and understandable manner.

6.2.5.4 Receive maritime safety information

The MASS technology should demonstrate the ability to receive maritime safety information and forward to a remote control station as per applicable rules in a timely and understandable manner.

Criteria for the evaluation of test results are:

- Maritime safety information are correctly received and forwarded in a timely and understandable manner.