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| IALA Guideline |

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IALA GUideline on developments in maritime autonomous surface ships

Edition 1.0

Document date

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

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# Introduction

Maritime Autonomous Surface Ships (MASS) are defined by the International Maritime Organisation (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 take note of and support these initiatives to ensure that the AtoN environment is and remains fit for purpose as the MASS technologies advance.

## Background

To facilitate the progress of the regulatory scoping exercise the IMO identified four degrees of autonomy:

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

The report of IMO MSC 100 states that “With regard to expanding the degrees of autonomy, the Chair noted that some delegations had indicated their support for a more detailed description of degrees of autonomy, but that this should be conducted after the scoping exercise. A view was also expressed that IMO should be the leading organization in defining the different degrees of autonomy and related terminology.” (MSC100/20 paragraph 5.9)

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.

Aids to Navigation (AtoN) have a significant role to play in the MASS domain as this matures.

# Aims and Objectives

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

# Overview of 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,
* identifying the potential costs to the industry, and
* assessing the impact on personnel, both on board and ashore.

In 2017, following a proposal by a number of Member States, IMO's Maritime Safety Committee (MSC) [agreed](http://www.imo.org/en/MediaCentre/MeetingSummaries/MSC/Pages/MSC-98th-session.aspx) to include the issue of marine autonomous surface ships (MASS) on its agenda. It was agreed 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.

The MSC 101 session, in June 2019 approved Interim guidelines for MASS trials (IMO MSC.1/Circ.1604).

Among other things, 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.

## Levels of Autonomy

Although the IMO have identified four degrees of autonomy for the purposes of the Regulatory Scoping Exercise (RSE), more finely graduated definitions are available in other industries. These can include anywhere from 4 – 10 levels for autonomy.

The original levels of autonomy often referenced in academic literature is Human and Computer Control of Undersea Teleoperators – Thomas B Sheridan and William L Verplank, 1976.

This document provides an IALA comparison of the Sheridan levels with the degrees of autonomy from IMO (Table 1).

1. IALA comparison of Sheridan levels of autonomy with IMO degrees of autonomy

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| **International Maritime Organisation** | **Sheridan Levels of Autonomy[[1]](#footnote-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. | Level 1 – The computer offers no assistance, human in charge of all decisions and actions |
| Level 2 – The computer offers a complete set of decision alternatives |
| Level 3 – The computer narrows alternatives down to a few |
| **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. | Level 4 – Computer suggest a single alternative |
| Level 5 – The computer executes the suggested action if the human approves |
| Level 6 – The computer allows the human restricted time to veto before automatic execution |
| **Degree three**: Remotely controlled ship without seafarers on board: The ship is controlled and operated from another location. There are no seafarers on board. | Level 7 – The computer executes automatically, when necessary informing human |
| Level 8 – The computer informs human only if asked |
| Level 9 – The computer informs human only if it (the computer) decides so |
| **Degree four**: Fully autonomous ship: The operating system of the ship is able to make decisions and determine actions by itself. | Level 10 – The computer does everything autonomously, ignores human |

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## IALA and MASS

The establishment of safe and secure environments in which MASS can operate can be helped through the provision of AtoN. IALA provides guidance on AtoN that can be used to support a MASS environment, including:

1. Fixed shore side AtoN
2. Floating 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 a VTS environment
7. Ensuring communication between vessels within a Vessel Traffic Services (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 standardization of data transfer

The above requires digital communication systems that include AIS. The ASM is evolving within VDES. The VDE 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 phase of voyage.

## considerations for provision of Marine aton in MASS environment

The AtoN that may need to be delivered to support the various degrees of autonomy for MASS operations need to be identified using a risk assessment based on volume of traffic and degree of risk considering:

1. Vessel traffic mix and density
2. Existing AtoN type and availability
3. Intended MASS degree and operating area
4. MASS service requirements
5. Services to be rendered to support safe navigation
6. Channels for service delivery / provision
7. AtoN service requirements in and adjacent to pilotage waters
8. Remote berthing and connections to shore services
9. VTS environment interaction
10. Route Message transfer
11. Local situational awareness
12. Metrological systems and data
13. Hydrographic systems and data
14. Adaptation of traditional AtoN services to support MASS
15. Adopt, adapt or extend existing technology

# Development of MASS

An appropriate means 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?)

## Related Developments

### Terrestrial AtoN in the aerospace environment

The avionic domain has a 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

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| **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 |

## 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

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| **Level** | **Description** |
| Category 1 | To be developed General Navigation low density/low risk |
| Category 2 | To be developedGeneral navigation high density/greater risk /uncontrolled TSS, fairways , straits and ports |
| Category 3 | To be developed VTS controlled;, TSS, straits& fairways |
| Category 4 | To be developed VTS controlled Port approaches |
| Category 5 | To be developed VTS controlled Internal port area |

# Definitions

*Suggested text:* 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.

[Need to consider adding definitions to support MASS as appropriate]

# Acronyms

IMO International Maritime Organization (Acronym style)

MASS Maritime Autonomous Surface Ships

AIS Automatic Identification System

ASM ASM as part of the VHF Data Exchange System

ASM Application Specific Message

VDES VHF Data Exchange System

VTS Vessel Traffic Services

# References

https://www.maritimeuk.org/media-centre/publications/maritime-autonomous-surface-ships-uk-code-practice/

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1. HUMAN AND COMPUTER CONTROL / OF UNDERSEA TELEOPERATORS Thomas B Sheridan and William L Verplank 1976, [↑](#footnote-ref-1)