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Ships and marine technology — Vocabulary related to autonomous ship systems

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Foreword

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Introduction

Highly automated ships, including fully uncrewed and/or autonomous ships, are part of complex systems that have properties that are very different from conventional ships. This area is still under development and will remain so for many years to come. This means that there is a need for a harmonized and as consistent as possible vocabulary and related definitions for the concepts and objects that are used in the research on, design of and the eventual use of highly automated ships. It is the intention of this document to provide this. Recognizing that the area is developing, this document is published as a technical specification rather than an international standard.

Clause 3 contains the definitions of the vocabulary and is divided into the following parts.

3.1, General terms: the main concepts related to autonomous ship systems.

3.2, Terms related to autonomous ship system components: defining the main components of the autonomous ship system, including required off-ship support. Annex A gives a more extensive and informal overview of these components as well as other entities that the autonomous ship system may have to interact with. Note that the Remote Control Centre (RCC) is also part of the autonomous ship system components, but is defined in 3.1.

3.3, Terms related to operations: this subclause contains vocabulary that can be used to describe aspects of the ship's operational strategies, division of responsibilities between humans and automation, and corresponding system designs requirements. Annex B gives a more extensive and informative overview of some of these concepts.

3.4, Terms related to operator control modes: defining specific modes for operator control mode (3.3.2).

Ships and marine technology — Vocabulary related to autonomous ship systems

1 Scope

This document defines terminology related to autonomous ship systems, which includes ships that can be classified as a "Maritime Autonomous Surface Ship" (MASS) according to the preliminary definitions from the International Maritime Organization (IMO). Autonomous ship system can also be applied to similar ship types for use on inland waterways.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1 General terms

3.1.1
automatic
process or equipment that, under specified conditions, can function without human control

Note 1 to entry: See Annex B.1 for an explanation of the difference between *automation* (3.1.2) and *autonomy* (3.1.3).

[SOURCE: IEC 60050-351[4], modified – "can function" instead of "functions", added Note 1 to entry]

3.1.2
automation
implementation of processes by automatic means

[SOURCE: ISO/TR 11065[3]]

3.1.3
autonomy
processes or equipment in a ship system which, under certain conditions, are designed and verified to be controlled by automation, without human assistance

Note 1 to entry: Autonomy is implemented by automation but emerges when automation is designed and verified to allow operation without human assistance.

Note 2 to entry: This definition qualifies autonomy by giving it a temporal (the period when conditions are satisfied) and a process (one or more processes or equipment) dimension. The term "autonomy" on its own should be avoided unless sufficiently qualified with respect to what processes, period, or conditions it refers to.

Note 3 to entry: See Annex B.1 for an explanation of the difference between *automation* (3.1.2) and *autonomy* (3.1.3).

3.1.4
autonomous
possessing the property of autonomy

Note 1 to entry: Except when used in a general sense, e.g. a*utonomous ship system* (3.1.5), the term "autonomous" on its own should be avoided [refer also to Note 2 of *autonomy* (3.1.3)].

3.1.5
autonomous ship system
elements that interact to ensure effective functioning of the autonomous and non-autonomous processes and equipment that are necessary to perform the ship's operation or voyage

Note 1 to entry: The autonomous ship can depend on systems not located on the ship, e.g. communication systems, shore and port infrastructure, remote control centres etc.

Note 2 to entry: The autonomous ship system refers to a full system, including the ship. If the reference is made to the ship itself, the term "autonomous ship" or just "ship" can be used.

3.1.6
control
purposeful action on or in a process to meet specified objectives

[SOURCE: IEC 60050-351[4]]

Note 1 to entry: The term control does not preclude that the action is only to monitor the process, e.g. to raise an alarm or to request intervention. Control can be exercised by a human or by automation.

3.1.7
process
set of interrelated or interacting activities that transforms inputs into outputs

[SOURCE: ISO 9000[1]]

Note 1 to entry: Processes onboard a ship can correspond to function as defined in the International Convention on Standards of Training, Certification and Watchkeeping (STCW)[8]. Function means a group of tasks, duties and responsibilities, as specified in STCW, necessary for ship operation, safety of life at sea or protection of the marine environment.

3.1.8
remote control centre
site remote from the ship that can control some or all of the autonomous ship system processes

Note 1 to entry: A remote control centre may consist of more than one control room or stations that may be located at different physical locations. See ISO 11064-3[2] for a more extensive set of terminology for control rooms and centres.

Note 2 to entry: The terms shore control centre and remote operations centre are sometimes used to refer to remote control centres.

Note 3 to entry: When the abbreviated form of the term Remote Control Centre is used, i.e. RCC, one should be careful to avoid confusion with a Rescue Coordination Centre.

3.1.9
uncrewed
ship with no crew onboard

Note 1 to entry: Crew does not include passengers, special personnel etc.

3.1.10
unmanned
ship with no humans onboard

3.2 Terms related to autonomous ship system components

3.2.1
automatic facilities services
collection of automatic offshore services and automatic port services

3.2.2
automatic offshore services
fully or partly automatic services provided from an offshore facility or in the autonomous ship's operational area outside the port, that are defined as part of the autonomous ship system, but that are not located on the ship

Note 1 to entry: Automatic offshore services do not include local sensor systems or planned response services.

3.2.3
automatic port services
fully or partly automatic services provided in a port area, that are defined as part of the autonomous ship system, but that are not located on the ship

Note 1 to entry: Automatic port services do not include local sensor systems or planned response services.

3.2.4
autonomous onboard controller
automation onboard the ship that is used to control one or more of a ship system's processes or equipment, under certain conditions, without human assistance

3.2.5
autonomous remote controller
automation in the remote-control centre that is used to control one or more of a ship system's processes or equipment, under certain conditions, without human assistance

3.2.6
connectivity
network facilities to maintain communication between the ship and other parts of the autonomous ship system

3.2.7
local sensor systems
environment sensors and data processing systems located in the ship's local operating area, but off the ship, that provide additional data and/or information to the autonomous ship system's environment assessment functions

Note 1 to entry: This can be used, for example, to remove radar shadows, improve positioning accuracy and otherwise assist in complex operations, such as in high density traffic or during berthing.

3.2.8
planned response services
services provided by organizations with facilities not located onboard the ship, to assist in situations where the onboard systems are unable to handle the situation alone

Note 1 to entry: This may include, for example, towage in case of critical sub-system failure on board or evacuation services for passengers on an uncrewed ship.

3.3 Terms related to operations

3.3.1
tolerable event
technical or operational event for which there is a designed response that keeps the system within its operational envelope

Note 1 to entry: A tolerable event includes events that are part of routine operations as well as events that are not considered part of normal operation but occur in practice as a result of different operational contexts (e.g. heavy weather, damage, failures, reduced communications capabilities, operator errors, etc.).

3.3.2
operator control mode
working mode, sometimes supported by technology or procedures, that represents the expected class of actions performed by the crew or remote-control centre operators

Note 1 to entry: Modes can be changed during a voyage or operation and/or for specific functions.

Note 2 to entry: 3.4 defines four operator control modes.

3.3.3
fallback state
designed state that can be entered through a fallback function when it is not possible for the autonomous ship system to stay within the operational envelope

Note 1 to entry: Being in a fallback state should not result in an intolerable risk (frequency and severity of any consequence).

3.3.4
fallback function
means to reach a *fallback state* (3.3.3)

3.3.5
fallback space
set of all *fallback states* (3.3.3)

3.3.6
operational envelope
conditions and related operator control modes under which an autonomous ship system is designed to operate, including all tolerable events

Note 1 to entry: The operational envelope should cover at least all relevant voyage or operation phases as well as all relevant autonomous ship system processes. The conditions should include geographic or fairway conditions, environmental conditions, own ship conditions, traffic conditions, division of responsibility between human and *automatic control*, as well as any other factors that have a significant impact on the operation of the autonomous ship system.

Note 2 to entry: The operational envelope (OE) is inspired by the operational design domain (ODD) as defined in SAE J3016[5]. However, as the OE also includes operations under human control, and as the relationship between OE and fallbacks are somewhat different than for the ODD, it has been decided to not use the name ODD and rather call this operational envelope. See B.3 for further details.

3.3.7
system control tasks
process control tasks, implemented by automation and/or humans, that are required to sustainably operate the autonomous ship system within its operational envelope

Note 1 to entry: A process control task is the control task or function related to a specific process. The task or function can be automatic or performed by a human.

3.4 Terms related to operator control modes

3.4.1
monitoring
operations which monitor a situation but do not take any action to influence necessary processes

Note 1 to entry: In monitoring mode, operators may adjust non-necessary processes or equipment to facilitate gathering of information. Monitoring can, for example, be to adjust a system for exclusively human use, such as external lights or cameras, or to inspect equipment or trends in performance parameters.

3.4.2
strategic control
operations to issue fleet-wide instructions that implement and, if appropriate, define specific functions to be used by the automatic decision-making units

Note 1 to entry: Strategic control corresponds to a Master's standing orders on a conventional ship.

3.4.3
tactical control
operations to influence the conclusion made by the automatic decision-making units of the autonomous ship for a particular purpose

Note 1 to entry: Tactical control includes, for example, changing the required minimum closest point of approach to other ships or the port of destination and letting the autonomous ship system afterwards construct the avoidance manoeuvre or route itself. It can also be adjustment of a technical alert level, based on prevailing conditions, for example, the time delay in actuation of the bilge alarm.

3.4.4
direct control
operations to control a specific function or parameter

Note 1 to entry: Direct control means, for example, that the operator changes a waypoint that would otherwise be decided by the autonomous ship systems directly, or that the operator selects and overrides the machinery standby configuration, such as changing of generator or pump standby status.

Annex A
(informative)

The components and context of the autonomous ship system

A.1 Overview of the autonomous ship system components

A.1.1 General

The autonomous ship system is illustrated in Figure A.1, which shows some of the main components that can be included in the autonomous ship system. In addition, there will be other services that are used by the ship system but that are under control of other parties. These are schematically illustrated in Figure A.2 and briefly described in A.2. The arrows represent the connectivity between the different components of the system.

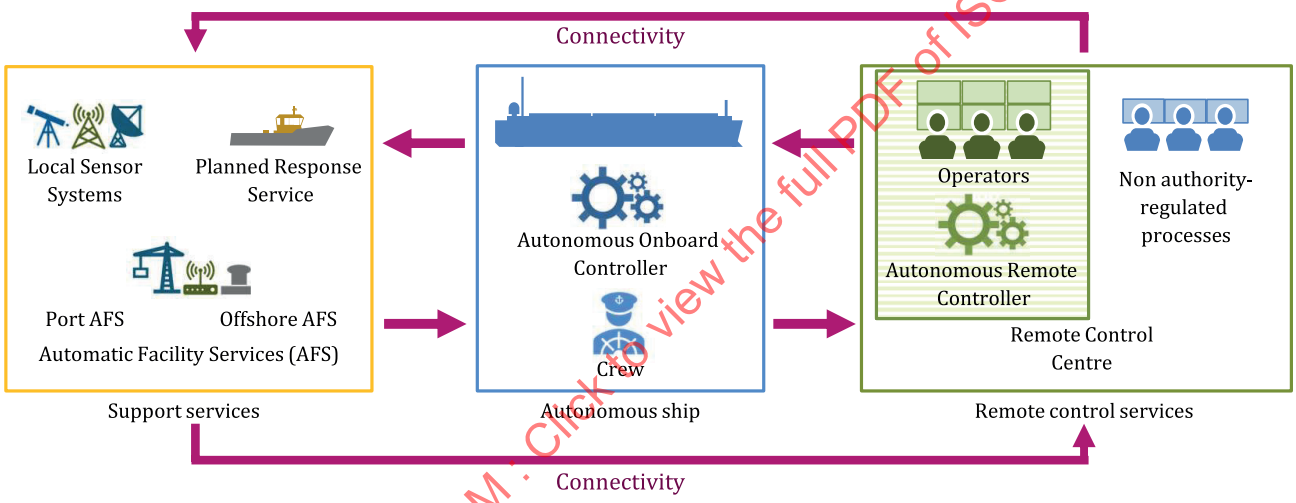

Figure A.1 — Autonomous ship system

Here, the autonomous ship system is illustrated as four main groups of components that for the purpose of this annex are grouped into the following clusters:

a) the autonomous ship itself (middle);

b) the remote-control services(s) where some of the ship system's control functions may reside (right);

c) support services located in the ship's operational area (left); and

d) the connectivity (arrows) which provides communication between the components.

Figure A.1 describes some common system components. All components may not be used in all scenarios and situations, and any given autonomous ship system may also need additional components.

A.1.2 The autonomous ship itself

An autonomous ship typically consists of the ship structure itself; various on-board equipment for power generation, propulsion, cargo handling; sensors, automation and communication systems, as well as any crew. The automation system onboard the ship will be referred to as the *autonomous onboard controller* (3.2.4).

A.1.3 The remote control service(s)

The remote control functions are collectively referred to as the *remote control centre* (3.1.8). Some of these may be related to mandatory services that have been taken over from the onboard crew on the ship. In the remote control centre, there may also be automatic control functions that can control some of the ships processes. These control functions will be referred to as *autonomous remote controller* (3.2.5).

The remote control centre can also be referred to as a remote operations centre or a shore control centre.

A.1.4 The support services in the ship's operational area

The autonomous ship may also be designed to use other specialized services that are located off-ship. To be included in the autonomous ship system, these should be services that are designed especially for use by autonomous ships and will not include normal nautical services such as VTS, aids to navigation, etc. The latter are considered to be in the ship's context as described in A.2.

The support services may include *local sensor systems* (3.2.7), *planned response services* (3.2.8) or *automatic facilities services* (3.2.1). The latter can be divided into *automatic port services* (3.2.3) when located in the port area or *automatic offshore services* (3.2.2.) when located outside the port area.

The local sensor systems can be used, for example, to remove radar shadows, improve positioning accuracy and otherwise assist in complex operations including high density traffic or berthing.

Examples of automatic facility services include automatic mooring systems and automatic cargo handling. The service may also include digital services, such as precision positioning systems for berthing and similar, but it will not include environment sensing services, as that is included in the local sensor systems.

A.2 The context of the autonomous ship system

A.2.1 General

The autonomous ship system as outlined in A.1, operates in a context like the one shown in Figure A.2. Dependent on the intended system operation, the actual entities in the context may change. This clause gives an informative overview of some of the entities that may be encountered.

Figure A.2 only shows some of the entities. In addition, there may be a need to contact entities such as maritime rescue coordination centres and suppliers of nautical publications. Some of the entities may also in the future have extended functionality to better cater to autonomous and smart ships, including smart aids to navigations and extended vessel traffic services (VTS). An operator icon is added to some entities to indicate that interfacing to these entities often will require human to human communication.

A.2.2 Fairway information

Fairway information consists of various information that is made available to the autonomous ship system. Maritime safety information (MSI) is transmitted from coastal authorities to ships sailing in their area of responsibility, typically related to changes in navigable waters or infrastructure that may have impact on safe passage. Aids to navigation (AtoN) are various physical or virtual devices that are installed to directly assist in the ship's navigation. It can be lighthouses, markers and buoys, or virtual AIS-based AtoN.

A.2.3 Traffic services

Ships interact with shored-based traffic services such as VTS, mandatory ship reporting system (MRS) and river information services (RIS). Interaction includes sending reports and sometimes receiving advice. Today, reporting is normally via voice VHF, but digital messaging standards are being developed.

Note that RIS is defined as a general information service in EU Directive 2005/44/EC[6]. Here it is mainly looked at as a service similar to VTS that interacts directly with the ship.

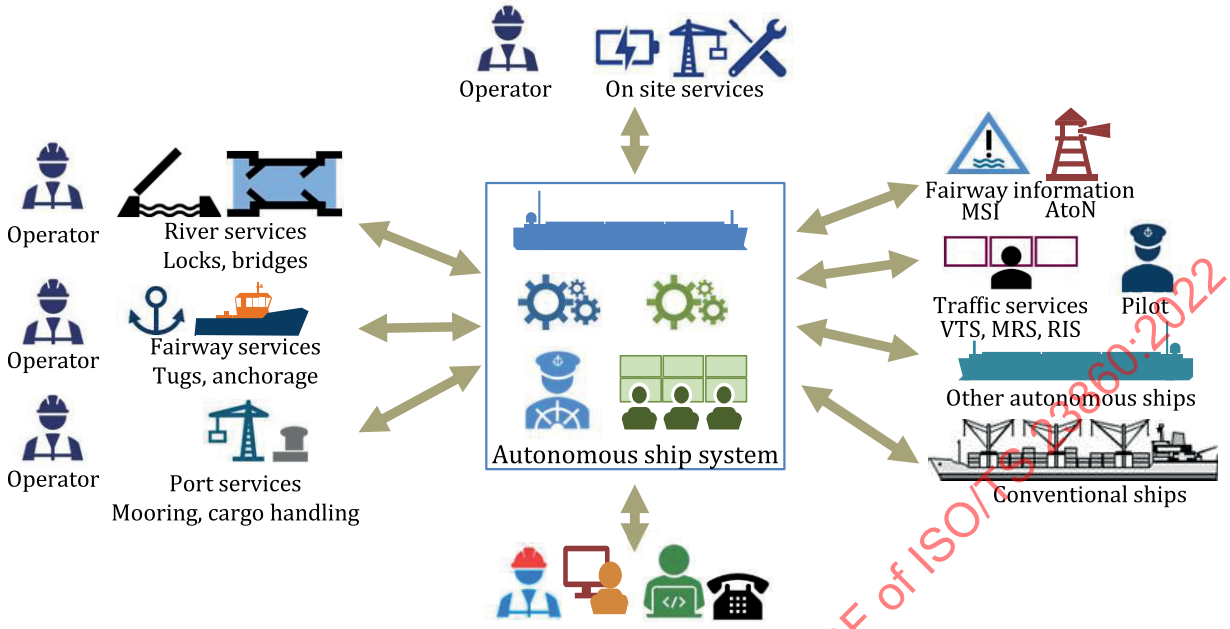

Figure A.2 — Autonomous ship system wider context

A.2.4 Pilotage

Pilot may also be a mandatory service for the autonomous ship. For an uncrewed ship one may need some form of remote pilotage, although there are various concerns and considerations for future formulation of policies and technical solutions pertaining to pilotage for autonomous and remote-controlled vessels.

A.2.5 Other autonomous ships

In the future one may expect to need special interactions with other autonomous ships. This should in general be based on standardized digital messages and mainly for ensuring safe and coordinated behaviour.

A.2.6 Conventional ships

Interaction with conventional ships is a major challenge for the realization of autonomous ships. Autonomous ships should behave in a way that makes their intentions clear and they should also be able to communicate with other ships via AIS and VHF communication.

A.2.7 Other port operations

These are various services provided to the ship when in port. It may be related to supplying the ship with maintenance or supplies or various authority functions related to inspections and certification.

A.2.8 Port services

These are services rendered by systems or operators in the port that are not automatic. Coordination with these services will often use VHF communication. These services may be related to mooring, cargo handling, shore power supply or other.

A.2.9 Fairway services

During transit through the port area, it may be necessary to get assistance from tugs or to wait and drop anchor in a waiting area before proceeding to berth. Support is expected to be coordinated through the use of VHF communication to operators of these services.

A.2.10 River services

These are physical objects that need to be controlled to allow ships to pass. Operators will often be involved in the shore control of these objects.

A.2.11 On-site services

These are services that may be provided to autonomous ships outside normal cargo and port services. This can be related to survey missions or special transport contracts that are not delivered at conventional ports.

Note that Figure A.2 only includes entities with which the autonomous ship exchanges information. Geographic objects or unknown objects in the water are not included in this diagram. This is not a complete diagram of all possible entities that the ship may interact with and not all entities will be used in a given autonomous ship operation.

Annex B
(informative)

Operational envelope and system control tasks

B.1 General

This annex will give some informative background on how autonomous ship systems can be described and how the operational envelope can be used in the description.

IMO has suggested the following preliminary definition: "Maritime Autonomous Surface Ship (MASS) is defined as a ship which, to a varying degree, can operate independent of human interaction"[7]. Autonomy versus automation has caused some disagreement in the autonomous system community. SAE[5] as an example, suggest depreciating the word "autonomy" and rather using "automation" as a more consistent term. However, "autonomous" is already used in the shipping community, and "autonomy" as currently defined by IMO does point to structural changes in how regulation and approval of autonomous ship systems will be done. For the time being, it is therefore useful to retain the concept of autonomous for the new developments that will challenge the current regulatory and operational framework.

As the above discussion shows, ship autonomy is likely to be implemented only partially, and the autonomous ship system will rely on humans to share some of the control functions. This means that the relationship between human and automation is an important issue. This also means that the description of the autonomous ship system's capabilities should have mechanisms to differentiate between the human's and the automation's responsibilities. For this reason, the operational envelope is introduced to define the capabilities of the system and how the responsibility is shared.

B.2 Descriptive components

The relationships between main descriptive components of an autonomous ship systems are represented in a simplified manner in Figure B.1. The starting point is a description of the autonomous ship systems and its processes, the context the autonomous ship system operates in and the intended voyage or operations. This can be used to describe an operational envelope and the corresponding system control tasks as well as associated fallback functions.

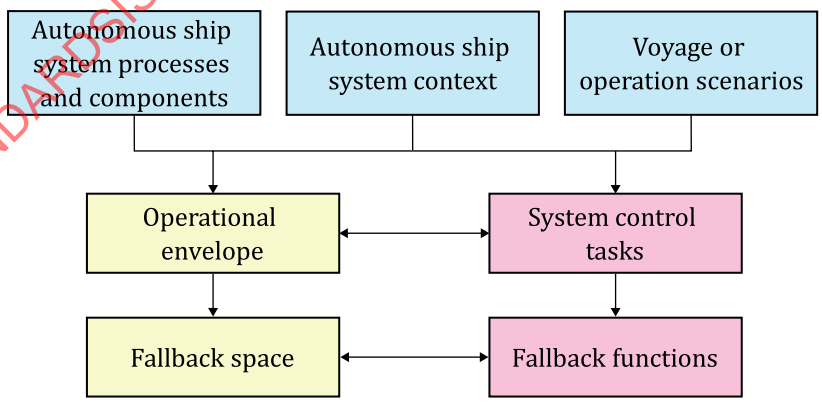

Figure B.1 — Some descriptive elements for autonomous ship system control

In conjunction with the definition of the operational envelope and the system control tasks, it is also necessary to define the fallback space and fallback functions.