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DEVELOPMENT OF A GOAL-BASED INSTRUMENT FOR MARITIME AUTONOMOUS SURFACE SHIPS (MASS)

Terminology, definitions, and levels of automation for Maritime Autonomous Surface Ships (MASS)[1]

Submitted by Finland

SUMMARY

Executive summary:	This document contains information on the considerations made by the One Sea association to facilitate the discussions on terminology, definitions, and levels of automation for Maritime Autonomous Surface Ships (MASS)
Strategic direction, if applicable:	2
Output:	2.23
Action to be taken:	Paragraph 30
Related document:	MSC.1/Circ.1638

1 This document is submitted in accordance with paragraph 6.12.3 of the *Organization and method of work of the Maritime Safety Committee and the Marine Environment Protection Committee and their subsidiary bodies* (MSC-MEPC.1/Circ.5/Rev.2). The Working Group on Maritime Autonomous Surface Ships recognized that, given the complexity of the matter, an efficient and systematic approach for future work was important for the development and adoption of MASS instruments. MSC.1/Circ.1638 provides guidance to the interested parties to facilitate further work and identifies as a priority the need to consider the review of terminology and definitions.

2 The submitter of this document offers information on the experience gained in development and testing of new technologies done by the members of the One Sea ecosystem. One Sea (OS) is a global alliance of public and private stakeholders in the maritime cluster with an interest to ensure the harmonization of the regulations and standards, interfaces and testing regimes for automated and autonomous maritime transport systems.

[1] Document had been distributed as MSC 105/7/1, reissued as MSC 105/INF.2

Introduction

3 The creation of the conditions needed to deliver automated or autonomous maritime logistics and transport systems will require global harmonization of the regulations and standards, interfaces and testing and certification regimes necessary for safe operation of these technologies and systems.

4 Taxonomy and definitions for the levels of automation need to be developed to provide a common understanding of the different technologies and concepts among the stakeholders. An unambiguous taxonomy is needed for the regulators to define rules, regulations, and certification policies. It is also a precondition to enable the industry to develop common standards, offer solutions and to develop and produce products. Owners and operators will need to be able to identify available concepts and technology to determine what kind of automation level for a vessel or function would best fit their envisaged operation. Infrastructure providers need the common taxonomy to be able to provide solutions that fit the technologies. Also, the public will need to be able to understand what is meant by the different services and concepts.

Automation terminology, general principles

5 When considering the appropriate terminology for the involvement of a human to an automated system, a clear distinction needs to be made to the differences of attended, attention, involvement and operation.

6 The level of automation is linked to the level of human attendance required. The lower the automation level is, the more continuous human attendance is required. Basic single unit automation usually requires hands-on involvement by a human to control or operate the process. In more automated systems, the systems perform the actions and require varying levels of attendance.

7 The level of human attendance is guided by three attributes: the surrounding conditions, the operational situation and time margins in which any change in these conditions and situations occurs. In basic navigational situations or simple operational conditions, an automated system can perform safely and for a varying amount of time, depending on its level of automation, without continuous human attention/attendance. The time margins are longer in good conditions and at open sea. In narrow fairways and dense traffic situations, where the tolerances are smaller and the time requirement is much more demanding, more active human attendance or a higher level of automation is required.

Levels of automation

8 One Sea members have considered that the taxonomy regarding maritime automation and autonomy levels should consider, as far as practicable, the SAE levels of automation developed and adapted by the car industry. The SAE levels of automation and terminology are globally accepted and used. Although the maritime traffic and situational conditions differ profoundly from road and car traffic conditions and requirements, One Sea members regard it beneficial to use the same vocabulary and definitions. It is to be expected that automation technology will advance in all traffic modes. Agreeing on some basic definitions and vocabulary would enable developers and designers to have a mutual understanding of the technology and features developed. The alignment of some basic vocabulary and definitions would enable a broader discussion and could greatly benefit the maritime sector by removing barriers of cross-sectional use of new technology.

9 The levels of automation for maritime could be defined as follows:

.1 Basic operation – human operator;

.2 Assisted operations – the system supports the human operator;

.3 Partial automation – a human controls the system;

.4 Conditional automation – a human supervises the system;

.5 High automation – a human is alerted if needed, and;

.6 Autonomous – un-attended by humans.

Human interaction with the automation levels is further explained in detail hereunder.

10 All levels of automation, except autonomous, would need some level of attendance by a human. The level of automation should be defined according to which degree human attendance is required. The level of involvement may be operating, controlling, supervision of or supporting the system.

11 For the purpose of explaining the levels of automation, navigation is used as an example. Navigation and collision avoidance is one of the most central functions performed on board and can be best used to describe functions and complex situations. It needs to be acknowledged that a vessel is a system of a multitude of systems, and automation may be applied to any of the onboard systems.

12 For the purpose of these explanations these attributes are used:

.1 **automation** describes a wide range of technologies that reduce human intervention in processes. Human intervention is reduced by predetermining decision criteria, sub-process relationships and related actions – and embodying those predeterminations in self-functioning machines or systems. Industrial automation usually includes using computers to control machines and processes.

.2 **attended** is understood to be the action or state of going regularly to or being present at a place or event.

Basic operation – Human controls the vessel

13 In its simplest form, automation is used to control a process according to set points controlling a variable. A human controls the vessel manually or sets the desired setpoint and the automation performs the actions to achieve that denomination. The automation analyses the deviation between the desired setpoint and actual received information and acts by adjusting the variables until the received information corresponds to the setpoint. This closed-loop control is an application of negative feedback to a system.

14 In this case, the officer of the navigational watch (OOW) sets the desired heading on the autopilot. The automation controls the rudder angles until the ships heading corresponds to the setpoint. The automation performs a function of adjusting the vessels heading, based on information received from a compass to match the setpoint entered into the autopilot, by operating the rudder. The automation keeps the setpoint until a human enters a new setpoint. The automation cannot change the setpoint based on the surrounding conditions or according to changes in those. This reflects the current state of play and regulations in force.

Assisted operations – Hands-on, eyes-on, mind-on.

15 A human operates the functions performed, assesses and combines the information, and enters or adjusts the setpoints. The system automation assists the human operator by providing observations and/or control of basic simple unit-automation.

16 A typical example of such functions is the Dynamic Positioning (DP) system[2], providing automatic and manual position and heading control and which is used, e.g. in offshore operations. The operator controls or manoeuvres the vessel manually using a joystick for position and heading control or the system automatically maintains the required position and heading. The operator may select automatic control of either one or two of the surge, sway, and yaw axes. This reflects the current state of play of system automation and regulations in force.

Partial automation – Hands-off (sometimes), eyes-on, mind-on.

17 In this level of automation, the operation of at least one full function/operational mode is automated. The system monitors the actual situation and might perform actions to achieve the setpoint or result required. The system informs the human operator of relevant observations and actions intended to be performed. The action to be performed by the system may need to be confirmed beforehand by the human operator.

18 One example of such a system is a Track Control system[3] (also referred to as "Track steering") which combines an Electronic Chart Display and Information System (ECDIS) with the Autopilot. The officer of the navigational watch (OOW) can programme a voyage plan into the ECDIS that contains one or more tracks. The autopilot system receives its orders from the ECDIS and transmits steering commands to the steering system. The Track Control may perform actions under the control of the OOW or the system may alert of approaching action to be taken and may ask for confirmation of execution. The OOW takes control to deviate from the programmed track, e.g. to avoid objects or collisions.

Conditional automation – Hands-off, eyes-off (sometimes), mind-on.

19 Also in this level of automation the operation of at least one full functional/operational mode is automated. When certain operational conditions are fulfilled, the system monitors the process according to the setpoints and performs automatically actions controlling the variables to keep the process proceeding according to the setpoints. The task performed may be left without human control for a limited time determined by the surrounding operational or geographical conditions.

20 An automated docking system is a typical example of such a conditional automation combining and utilizing systems mentioned above. Upon the master's command, the ship undocks and departs from the quay, manoeuvres out of the harbour, sails to the next port, manoeuvres into the harbour and docks alongside the quay, under the supervision but without human intervention. The system mitigates potential human errors resulting from humans having to perform repeated technical manoeuvres and allows the OOW to concentrate on surrounding traffic and situational safety.

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[2] A dynamic positioning system is a system that automatically controls a vessel’s position and heading exclusively by use of active thrust. A DP system consists of active components or systems such as generators, thruster, switchboards, remote controlled valves etc. A single DP control system provides no redundancy. A dual or two-computer system provides redundancy and auto-changeover so that no single fault in an active system will cause the system to fail.

[3] IEC 62065:2014 Maritime navigation and radio-communication equipment and systems – Track control systems – Operational and performance requirements, methods of testing and required test results.

High automation – Hands-off, eyes-off, mind-off (sometimes)

21 This is the highest level of human attended automation. The functional/operational task is performed to a high extent automatically by the system without necessitating human attendance. The system alerts the human operator of need for intervention, if a situation occurs when the system cannot perform the action within the set parameters to achieve the setpoints.

22 A stabilizer and anti-heeling system is a system that may be left unattended to perform its function without continuous monitoring by a human. For roll stabilizing at sea, an automatic control system and a roll-sensing device continuously adapt the oscillating tank-water by operating pumps, valves, or the air pressure above the water surface to counteract the roll. For anti-heeling, a fully automatic inclination equalizing system uses a constant pneumatic air purge and regulating valve system to keep the heel as low as possible when the ship heels owing to an unsymmetrical load.

23 In comparison to a track control or automated docking system, this level of automated navigational system may be left unattended for a certain time defined by the surrounding operational conditions. All navigational watch-related functions and collision avoidance are performed by the system. The system will alert a human of any irregularities or observations that might need attention. The OOW may check the operation of the system at certain intervals and monitor the operation of the system in situations when a heightened level of safety is required.

Autonomous – Hands-off, eyes-off, mind-off = human-off

24 The autonomous level of automation replaces all human supervision and interventions, and human attendance is not required. The goal set for the operation is fulfilled by solving encountered situations, based on gathered information and a profound understanding of the apparent situation. The technology observes, identifies, interprets and solves situations, in a compliant and safe way, by operating the equipment and machinery.

25 A fully autonomous navigation and collision avoidance system would replace all functions of a navigational watch. The autonomous system would keep the vessel on its calculated most efficient route and adjust the route and speed based on information on environmental conditions (e.g. wind, waves and current forecasts along the route) to be just in time at destination. The system observes and identifies objects and vessels in the vicinity, assesses the risks and takes action to solve any close quarter situation by adjusting course and/or speed according to the rules of the road.

26 One Sea members recognize that the definitions and levels of automation presented above might not be directly transferable into regulations, but they may serve as descriptions and clarifications of the functionalities of human interaction with automated systems. The regulations to be developed would need to ensure that the development, design and operation of automated systems are conducted in a safe way.

Remote operation

27 The question regarding onboard or remote operation does not affect this taxonomy. Increased automation will still require qualified operators to be involved. All levels of automation, except autonomous, require a level of human attendance or a human to be alerted for operation or supervision of safe operation. However, the location of where the human operator is in the loop, either on board or remote (workstation), is not relevant when considering the taxonomy of levels of automation.

Minimum safe manning

28 The One Sea members consider that the introduction of more sophisticated automated systems should not be confused with the minimum safe manning principles. Safe manning is a function of the number of qualified and experienced seafarers necessary for the safety and security of the ship, crew, passengers, cargo, and property and for the protection of the marine environment.

29 As explained above, all levels of automation require a different level of attendance by a human. It is only the highest level of automation, the autonomous system that is not requiring human attendance, when it is performing its function. However, even a fully autonomous system can be fully manned. Therefore, the view of One Sea members has been that issues regarding safe manning are not relevant for the discussions on the explanations of technical functionalities or performance at this stage.

Action requested of the Committee

30 The Committee is invited to note the information provided in this document in further work on Maritime Autonomous Surface Ships.

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