Autonomous Shipping Initiative for European Waters

Project type: IA Innovation Action

Start of the project: 01/06/2019 Duration: 42 months

[D7.4] Proposed regulatory, legal and liabilities frameworks amendments

WP n° and title	WP7 - Liability, Regulations and Socio-economic perspective study
Responsible Author(s)	USTRAT
Contributor(s)	BV, PNO, STF, DVW
Dissemination Level	PU

DELIVERABLE INFORMATION

Status (F: final; D: draft; RD: revised draft):	Final
Planned delivery date	30/11/2022 (M42). As per amendment # 3
Actual delivery date	24/11/2022 (M42)
Dissemination level: (PU = Public; PP = Restricted to other program participants; RE = Restricted to a group specified by the consortium; CO = Confidential, only for members of the consortium)	PU
Type: Report, Website, Other, Ethics	Report

DOCUMENT HISTORY

Version	Date (DD/MM/YYYY)	Created/Amended by	Changes
01	09/05/2022	Yaseen Adnan Ahmed	First issue
02	11/07/2022	Yaseen Adnan Ahmed	Several changes
03	08/11/2022	Yaseen Adnan Ahmed	Several changes
Final	24/11/2022	Carolina Salas	Final format check before submission

QUALITY CHECK REVIEW

Reviewer (s)	Main changes
Dag Atle Nesheim	Several comments
Lars Andreas Lien Wennersberg	Several comments
Ilia Maslov	Several comments
Håvard Nordahl	Several comments

DISCLAIMER AND COPYRIGHT

AUTOSHIP has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 815012. The same disclaimers as they apply to the consortium members equally apply to the European Union employees, officers and organisations.

REFERENCES TO THIS DOCUMENT – ACKNOWLEDGEMENTS

The material in this publication can be reproduced provided that a proper reference is made to the title of this publication and to the AUTOSHIP project (https://www.autoship-project.eu/). References to this document should use the following format, modified as appropriate to the publication where the reference appears:

Ahmed Y.A., Theotokatos G.., Maslov I. Andersen P., Wennersberg L.A.L., Nesheim D.A. "AUTOSHIP deliverable D7.4: Proposed regulatory, legal and liabilities frameworks amendments", November 2022.

The authors listed in the above citation have been the main contributors of the material in this report. The editor and contributors also would like to thank all other members of the AUTOSHIP projects for comments and inputs to this document. As discussed in the introduction and as noted in the disclaimer, the content of this publication is to be understood as a "reference architecture" and the authors' organizations may not fully endorse or implement all recommendations and definitions in this publication.

1 LIST OF CONTENTS

2 LIST OF FIGURES

3 LIST OF TABLES

4 LIST OF ABBREVIATIONS AND DEFINITIONS

Abbreviation	Definition
AFS	Automated Facilities Services (AOS + APS)
AOS	Automated Offshore Services
APS	Automated Port Services
ANS	Autonomous Navigation System
ADN	European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways
Ax	Degree of Automation of a system (x from 0 to 4)
BLL	Blue Line Logistics
CCNR	Central Commission for the Navigation of the Rhine
CDNI	Convention on the Collection, Deposit and reception of waste generated during navigation on the Rhine and other waterways
CEMT	European Conference of Transportation Ministry
CEVNI	European Code for Inland Waterways
CESNI	European Committee drawing up Standards in the field of Inland Navigation
CLL	IMO’s International Convention on Load Lines
CLNI	Convention on the Limitation of Liability in Inland Navigation
COLREG	IMO’s International Convention on the International Regulations for Preventing Collisions at Sea
CoP	Code of Practice
CCTV	Closed Circuit TV
ODD	Operational Design Domain
DCy	Degree of Direct Control of a system (y from 0 to 3)
DMA	Danish Maritime Authority
DoA	Description of Action
DVW	De Vlaamse Waterweg
EAS	Eidsvaag AS
EC	European Commission
ESTRIN	European Standard laying down Technical Requirements for Inland Navigation vessels
ECDIS	Electronic Chart Display and Information System
GPS	Global Positioning System
GSM	Global System for Mobile Communications
GAx	Global degree of Automation of a ship (x from 0 to 4)

Abbreviation	Definition
GDCy	Global degree of Direct Control of a ship (y from 0 to 3)
GRCz	Global degree of Remote Control of a ship (z from 0 to 3)
HSG	Hybrid Shaft Generator
H2020	Horizon 2020
ILO	International Labour Organization
IMO	International Maritime Organization
IWT	Inland Water Transport
IWW	Inland Waterways
IMS	Intelligent Machinery System
KOGCM	Kongsberg Maritime CM AS
KOGM	Kongsberg Maritime AS
KET	Key Enabling Technology
LOA	Level of Autonomy
LSS	Local Sensor Systems
LNG	Liquefied Natural Gas
LiDAR	Light Detection and Ranging
MARPOL	IMO's International Convention for the Prevention of Pollution from Ships
MASS	Maritime Autonomous Surface Ship
MEPC	IMO Marine Environment Protection Committee
MLC	ILO's Maritime Labour Convention
MSC	IMO Maritime Safety Committee
MRC	Minimum Risk Conditions
MBR	Maritime Broadband Radio
NGAS	Next-Generation Autonomous Ships
NMA	Norway Maritime Authority
NOVIMAR	Novel IWT and Maritime Transport Concepts
$\boldsymbol{O}$	Operational envelope
$\boldsymbol{O}_{AC}$	AC – Automatic Control part of $\boldsymbol{O}$
$\boldsymbol{O}_{FA}$	FA – Full automation part of $\boldsymbol{O}$
$\boldsymbol{O}_{OA}$	OA - Operator or Automation part of $\boldsymbol{O}$
$\boldsymbol{O}_{OE}$	OE – Operator Exclusive part of $\boldsymbol{O}$
OC	Onboard Control
OSS	On Site Services
ORRC	International Convention on Oil Pollution Preparedness, Response and Co-operation

Abbreviation	Definition
PSC	Port State Control
PTZ	Pan/Tilt/Zoom
PRS	Planned Response Service
PSB	Pallet Shuttle Barge
PTI	Power Take In
PTO	Power Take Off
QoS	Quality of Service (normally for communication)
RTK	Real Time Kinematic
RTI	Requests To Intervene
R&A	Remote & Autonomous
RCC	Remote Control Centre
RCz	Degree of Remote Control of a system (z from 0 to 3)
RSE	Regulatory Scoping Exercise
RPNR	Police Regulations for the Navigation of the Rhine
SOLAS	IMO’s International Convention for the Safety of Life at Sea
SSS	Short Sea Shipping
STCW	IMO's International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
SAR	International Convention on Maritime Search and Rescue
TMC	International on Tonnage Measurements of Ships
T_{DT}	Response deadline
T_{MR}	Maximum response time
UNCLOS	United Nations Convention on the Law of the Sea
UNECE	United Nations Economic Commission for Europe
VDR	Voyage Data Recorder
VDES	VHF Data Exchange System
VSAT	Very Small Aperture Terminal
WP	Work package

4.1 USEFUL DEFINITIONS AND TERMINOLOGIES FOR MASS OPERATION

The terminologies defined in this section are referred from Deliverable 3.1 – Design Standards of AUTOSHIP project [4], which are a set standard for SSS and IWW case demonstration. ISO also publishes the document "ISO/TS23860 Vocabulary related to autonomous ship systems" which to a large extent utilises AUTOSHIP D3.1 as part of their baseline/input with some updates and contains an informative annex that discusses some of the definitions in this document. The definitions in this section do not imply any wider acceptance, except where references to external sources are given.

Terminology	Definition
Automated Facilities Services (AFS)	These are the collection of the Automated Offshore Services and Automated Port Services.
Automatic Onboard Controller (AOC)	This is the control and monitoring system onboard the ship that provides the interface between the operators (Crew or Remote Control Centre) and the lower level control systems onboard.
Automated Offshore Services (AOS)	Fully or partly automated 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. This does not include local sensor systems (LSS) or planned response services (PRS).
Automated Port Services (APS)	APS are services implemented in the port to serve the automated ship. This may be automated mooring systems, automated cargo handling etc. The service may also include digital services, e.g. precision location systems for berthing and similar. In general, one should expect that also automated physical services require digital communication for activation and control.
Autonomous Navigation System (ANS) / Digital Captain	The Autonomous Navigation System (ANS) is a new integrated suite of sensors and technology which replaces the ship navigators onboard by utilising the Situational Awareness System (SAS) to provide the necessary inputs and enable autonomous navigation, perception, path-planning or vehicle-following capabilities for autonomous ship. The ANS can make decisions and determine actions by itself. The navigating operator at RCC can monitor and intervene the operation of the ANS if necessary.
Automatic	Pertaining to a process or equipment that, under specified conditions, can function without human intervention.
Automation	The implementation of processes by automatic means, or as a substantive, the automatic control functions.
Autonomous, Autonomy	In the context of ships, autonomy e.g. as in "autonomous ship system", means that the ship system, under specified conditions, uses automation to perform one or more ship processes without human intervention.

Terminology	Definition
Autonomous Ship	Ship with some degree of independence of human operators. Autonomous ships are definitionally considered the overall term for “ships capable of providing – via automatic processes – decision-support or a possibility of taking over parts of or the entire human control and management of the ship, irrespective of whether the control is exerted from the ship or from somewhere else.” Alternatively, autonomous ships can also be ships that use technology allowing for, inter alia, an occasionally unmanned (physical) bridge/reduced manning or anti-collision systems.
Automatic Remote Controller	Automatic control of autonomous ship system, located on another location than the ship.
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
Company	"*Company*" means the owner of the ship or any other organization or person such as the manager, or the bareboat charterer, who has assumed the responsibility for operation of the ship from the shipowner and who on assuming such responsibility has agreed to take over all the duties and responsibility imposed by the code [1], 195.
Control	Purposeful action on or in a process to meet specified objectives [3].
Control mode	On what abstraction level the human interacts with the automation.
Crew Ship crew	The term crew applies only to the crew on the ship, if any. References to RCC should be just RCC or RCC personnel.
Degree of Automation	The degree of automation represents the degree of decision making (authority) deferred from the human to the system.
Degree of control	The degree of control represents the degree of availability of human operating the ship aboard (crew) or remotely outside the ship from a remote control centre (operators).
Direct control	Low level control mode.
e-navigation	IMO initiative defined as: **"***the harmonized collection, integration, exchange,* presentation *and analysis of marine information on board and ashore by electronic means to enhance berth to berth navigation* and related services for safety *and security at sea and protection of the marine environment."*
Electronic bridge	An electronic bridge is a similar version of a ship bridge, located at RCC which enables the remote operator to control/supervise/monitor the autonomous ships by utilising the Key Enabling Technologies (KETs). It consists of a combination of systems which are interconnected in order to allow centralised remote access to onboard sensor information or command/control of the autonomous ships from RCC.
Electronic lookout	An electronic lookout is a machine-based visual lookout that assembles the available sensory data, processes it and displays the information on digital screens.

Terminology	Definition
Fallback	This is a predefined state, outside the operational envelope, that can be used when it is not possible for the autonomous ship systems to stay within the operational envelope, e.g. due to equipment failure or environmental conditions that exceed the operational envelope's limits. The fallback is implemented as a minimum risk condition (MRC) [4].
Fallback space	The collection of all fallback states.
Function	A subdivision of operation. Can be divided into tasks.
Intelligent Machinery System (IMS) / Digital Chief	Intelligent Machinery System (IMS) is a new system that replaces the engineers on board and makes sure the machinery is automatically set up correctly to accommodate for power requirements in the different parts of the voyage, and to give a system perspective of alarms for other autonomous applications.
Level of Autonomy (LOA)	A form of measurement of "how autonomous" a given system is.
Local sensor systems (LSS)	Sensors placed on another location than the ship, but used by the autonomous ship system.
Maritime Broadband Radio (MBR)	The MBR connects crews and their ships with a high-speed and high capacity digital communication channel with fast track priority options. The system can securely carry a diverse array of operational information, from real-time video to system data, and remotely situated teams can work together seamlessly, coordinating systems and activities for optimal performance, safety and operational success [5].
Maximum response time, T_{MR}	Dependent on the activities of the operators, there should be a maximum response time which is the worst case time it takes for the operator, after being alerted to take control, to regain sufficient situational awareness to act safely on a given situation.
Minimum Risk Condition (MRC)	This is the functional realization of a fallback state.
Mission	One of the defining factors for the operational envelope. For a ship, the mission will normally include a voyage, but also other operations can be included, e.g. search and rescues, offshore supply operations etc.
Mission objectives	This is the operative input to the autonomous ship system and defines the objectives a specific mission, e.g. as a voyage plan.
Mission phase	A temporal sub-division of the mission.
Operation	Highest level of functional sub-division of an autonomous ship system.
Operational envelope ***O***	The specific conditions and scenarios under which a given autonomous ship system is designed to function. The operational envelope needs to consider, e.g. geography, environmental conditions and the different mission phases. *Note: An autonomous ship system may in principle contain more than one ship, but the one should consider how useful it is to define one common operational envelope for all ships.*

Terminology	Definition
O_{AC}	This is the part of the operational envelope where automation is able to handle all situations. There is no need for human assistance or supervision in this area, although the human normally will be allowed to take over control also here (AC – Automatic Control).
O_{FA}	This is the part of the operational envelope where the automation can handle all situations without human assistance (Fully Autonomous).
O_{OA}	This is the part of the operational envelope where the automation can handle most situations, but where it is unknown when human assistance is needed. The human must supervise automation in this area (Operator or Automation).
O_{OE}	This is the part of the operational envelope where operators are needed to handle the situation. Automation may still play an active role, e.g. in certain automated low level functions as in an autopilot, or in providing advice to the operator (OE – Operator Exclusive)
Operator	A common term for ship crew and RCC personnel. Operator can mean either or both.
On Site Services (OSS)	These are usually non-automated services provided to the autonomous ship outside conventional coastal, port and IWW services, e.g. in conjunction with surveys or special cargo deliveries. OSS is not considered part of the autonomous ship system.
Personnel, RCC/ROC Personnel	This is RCC or ROC personnel. Together with crew, these will be referred to as operators. However, personnel can also be used in the meaning of "special personnel" onboard the ship [6].
Planned Response Service (PRS)	A normally non-automated service, not part of the onboard ship functionality, provided physically on board or close to the ship, to assist in the planned tasks for the autonomous ship. This may include, e.g. towage in case of critical sub-system failure on board.
Process	Process will be used as a term to describe individual levels or logical combinations of operations, functions, tasks or sub-tasks.
QoS	Quality of Service (normally for communication)
Remote Control Centre (RCC)	An RCC is a site remote from the ship from which monitoring and/or control of some or all of the ship functions can be executed. *Note: In the context of RCC, the ship will normally be autonomous, but this is not necessarily the case. RCC can also be used to supervise conventional ships.*
Request to intervene (RTI)	An alert from Automation that its capabilities is about to be exceeded and that the human operator needs to intervene.
Response deadline T_{DL}	For certain Ship Control Task (SCT) that requires human intervention, there may be an operator deadline associated with the task. This is the maximum time the operator has available to intervene, after being alerted to the need for intervention.
Ship Control Task (SCT)	This is the functional realization of the operational envelope states. Each state will have one or more SCT associated with it to operate one or more ship functions in the given condition. An SCT can be implemented by Automation and/or by Operators.

Terminology	Definition
Ship management	Services required to operate the autonomous ship systems beyond those provided by the RCC, i.e. technical and administrative management, chartering etc.
Ship operations	Equivalent to Operations.
State variable	Defines the dimensions in the operational envelope sub-divisions, gives input to ship control tasks.
System objectives	High level objectives for autonomous ship system.
Situation awareness system (SAS)	Situation awareness system (SAS) is a system that helps in collecting, visualizing, and analysing information related to the surrounding and remote environment to facilitate surveillance as well as security
Two-way bridge-to-shore communications	Two-way bridge-to-shore communications are telecommunications systems designed to help autonomous ships maintain reliable connectivity with the RCC. These communication systems enable the remote operator at RCC to get the real-time onboard feed to obtain substantial level of situational awareness and intervene if necessary.
Task	Part of a function. Can be sub-divided into sub-tasks.
Unattended	Used for a process control position or the process itself, e.g. an "unattended engine control room" or "unattended engine control", when no operators are attending to the specific process or the corresponding control position.
Uncrewed	A ship with no crew on board. There may be passengers or other categories of personnel on board. *Note*: *The term "crewless" is used in [7], but later ISO submissions points to "uncrewed" as the preferred terminology.*

5 EXECUTIVE SUMMARY

This report utilizes the mapping studies from WP2, the results of WP3, as well the experience acquired so far for the design and building of the two demonstrators in the AUTOSHIP project, the Short Sea Shipping (SSS) general cargo ship and Inland Waterways (IWW) barge in WP4 and WP5, respectively for proposing recommendations or improvements in the existing regulatory, legal and liabilities frameworks.

A comprehensive review of recently published articles on international regulatory framework analysis and other pertinent autonomous ship projects' outcomes has been done and direct interaction with the relevant partners, their networks and authorities have been employed for their invaluable comments to iterate the listed proposals in this report for any prevailing regulations, rules and standards in existing regulatory, legal and liabilities framework. The existing frameworks consist of several regulatory bodies (e.g., Safety of Life At Sea, SOLAS), which provide a number of instruments (e.g., clauses in SOLAS chapters and sub-sections) requiring specific provisions to meet for the operation of ships. This report has adopted the most appropriate way(s) to address the challenging instruments as discussed in Regulatory Scoping Exercise (RSE) [8] by either: interpreting, amending, developing a new instrument or keeping it as it is. To facilitate the process of the amendments, International Maritime Organization (IMO) [8] and Central Commission for the Navigation of the Rhine (CCNR) [9] defined automation levels have been considered for the SSS and IWW use cases, respectively. Severities are also set to address the instruments as high, moderate or low, considering the degree of the human involvement to comply with existing provisions, the need for introducing/proposing appropriate amendments as well as the time-scale for the approval of these amendments in national/international levels.

The AUTOSHIP project use cases are considered to operate in a specific regulatory and legislative environment, one in the inland waterways in Belgium and one in national waters as well as in a route between Norway and Denmark. Considering the routes of operation of these two use cases, this study aims to provide recommendations for the gaps identified in existing regulatory, legal and liabilities frameworks including the international, national and regional regulations, rules and standards for the design, building, testing and operation of the SSS and IWW use cases.

The analysis of the regulatory framework has been limited to the following mandatory regulatory bodies related to maritime safety and security:

SOLAS, CLL, TMC, STCW, COLREG, SAR, MLC, European Directives, National and Local regulations for the SSS use case

RPNR, CEVNI, CLNI, CDNI, European Directives, Regional, National and Local regulations for the IWW use case

IMO Interim Guidelines for MASS trials, IMO Guidelines on maritime cyber risk management and Bureau Veritas Guidelines for Autonomous Shipping have also been considered. However, it should be noted that the land-based regulations for remote control centres located at the shore have not been included in this report.

The legal aspects of the two use cases have been analysed with respect to the current conventions, in particular, the UNCLOS. The jurisdiction restrictions and other provisions, such as manning requirements that create barriers to autonomous ships' operability have been identified and relevant proposals are presented at national and international levels.

Furthermore, the current liabilities and insurance frameworks relating to the use cases operation have been mapped to identify the potential gaps. Anticipated new players with new risks in the context of unscrewed ships and shifting in liabilities towards the new players have been analysed. Increased liability exposure of shipowners and system suppliers and the issues in determining the insurance pricing for new technologies have also been discussed. Proposals are then included to mitigate these potential gaps in the current liabilities and insurance frameworks.

The outcome of this report is expected to be beneficial for the pertinent policy makers and other involved stakeholders of autonomous shipping industry. This will also form the basis for developing a roadmap for autonomous ship adoption and development and a proposal submission to IMO (as planned in WP8).

6 INTRODUCTION

6.1 BACKGROUND

AUTOSHIP [10] project is an initiative that promotes Autonomous Shipping in European Waters to build up a new paradigm of multimodal transport to enhance the sustainability of business and relieve road congestion and related pollution. The main aim of this project is to develop and demonstrate two fully autonomous ships for SSS and IWW, respectively in a real environment and help European coastal SSS and IWW to compete with trucks as they are losing relative market shares to road transport. However, to make this happens, there are potential obstacles and variables which come from social, economic and regulatory perspectives that must be considered and overcome. To address this crucial barrier, WP7 of AUTOSHIP project is designed for investigating the following four topics:

i. Field surveys and results analysis to capture the understanding and positions of all the involved stakeholders
ii. Regulatory, Legal and Liabilities aspects analysis
iii. Social-Environmental-Economic aspects analysis
iv. Supply chain/Logistics analysis

This report complements “Regulatory, Legal and Liabilities aspects analysis“ by fulfilling the D7.4 which is: Proposed regulatory, legal and liabilities frameworks amendments - to cover the autonomous shipping operation

6.2 PURPOSE OF THE REPORT

The present legal, regulatory and liabilities frameworks, which govern the safety and security of conventional ships, have been constructed based on human-centred design, believing the fact that humans are on board for navigating and monitoring purposes. However, in the context of autonomous ships, the onboard crew will be moved from ship to shore through the use of remote and autonomous ship technology. This disruptive shift will lead to new players in maritime industries with new stipulated rules and regulations, which are not explicitly addressed by the current maritime regulations, neither at IMO nor at national and inland waterways regulatory level. The lack of explicitly defined legislation will hinder the maritime industry to reap the full benefits of autonomous shipping. Thus, this report aims to address the potential gaps identified in WP2 in the existing legal, regulatory and liabilities frameworks by doing a comprehensive study of recently published articles on international regulatory framework analysis [11], [12], [13], relevant autonomous ship projects outcomes, such as MUNIN [14], [15] MEGURI 2040 [16] etc. and employing the relevant partners, their networks and authorities for their imperative comments to refine the proposals addressing the gaps in current legal, regulatory and liabilities frameworks for the two use cases.

To address the gaps in the most appropriate manner, this report refers to the outcome of the Regulatory Scoping Exercising (RSE) [8], which was initiated by IMO to assess the degree of acceptability of MASS operations within the existing regulatory framework. RSE proposes 4 alternative ways to address the instruments which are also adopted in this study by either:

i. Developing interpretations or equivalences as provided by the instruments

ii. Amending existing instruments and/or

iii. Developing a new instrument

iv. None of the above as a result of the analysis

To facilitate the process of the amendments, four degrees of autonomy have been considered as identified in RSE [8] for SSS demonstrator case, whilst CCNR [9] autonomy levels have been preferred for IWW demonstrator case. The analysis has captured some instruments that require onboard human/manual intervention to comply with the provisions and identified them as **highly severe** as these need more considerations in getting international acceptance for autonomous ships. Some instruments require human involvement actively or passively but not necessarily onboard presence or system upgradation with KETs. These are considered **moderate** in terms of severity as trusted advanced technology could support the alternative provisions of these instruments. Last but not least, the instruments that require only wording adjusting or inclusion of new/amending definitions are given **less severity**.

This study has been limited to mandatory instruments including international and nationals for the design, building, testing and operations of the SSS and IWW use cases considered in the AUTOSHIP project. IMO Interim Guidelines for MASS trials, IMO Guidelines on maritime cyber risk management and Bureau Veritas Guidelines for Autonomous Shipping have also been considered. It should be noted that it does not include all code and standards relevant for such SSS and IWW use cases. The flag states could also have their own set of legislations, which are not included in this report.

The existing legal framework has also been analysed to identify if any addition or amendment is needed, in specific for UNCLOS. Flag state jurisdiction, port and coastal state jurisdiction and other provisions, such as mandatory manning requirement, masters' obligation to render assistance in distress situations etc. that create barriers to autonomous ships' operability have been identified and relevant proposals are presented in national and international levels.

In addition, a detailed analysis has been carried out of the liabilities and insurance aspects frameworks with regard to shipowners, system suppliers, remote operators, cargo, assets, new technologies, criminal offences, cyber risks and operations with the following subtasks: (a) Assessment of current liabilities and insurance scenarios considering the anticipated autonomous shipping growth; (b) New players with new risk and shifting of risk towards new players; (c) Identify the changes in the distribution of liabilities among current stakeholders and propose amendments to address those changes; (d) Insurance framework considering the autonomous shipping landscape.

6.3 METHODOLOGY

The methodological approach adopted in this study considers the following three stages: (a) Current or Existing stage, (b) the Transition stage, and (c) the stage for Next-Generation Autonomous Ships (NGAS). The existing stage does not consider/allow the operation of MASS. Transition stage considers/allows the operation of MASS (new built or converted/retrofitted conventional ships) keeping the human in the loop (by considering the human operator in the remote control centres). Next generation stage considers MASS to autonomy level 4 according to IMO [8], i.e., no human in the loop.

The existing stage deals with analysing the regulatory, legal and liabilities frameworks and identifying the potential challenges in the view of anticipated autonomous ships growth. The transition stage deals with the amendments or improvements of the existing instruments by utilizing Key Enabling Technologies (KETs), however, keeping humans in the loop for any request to intervene (RTI). After this transition stage, further amendments, possible new instruments or a separate Maritime Autonomous Surface Ship (MASS) code (which is envisaged to enter into force on January 1st, 2028, by IMO) would become necessary for NGAS.

This report analyses the gaps identified in WP2 and includes the recommendations to amend the existing regulatory, legal and liabilities frameworks for SSS and IWW use cases. Therefore, it focuses on the transition stage only, where expert knowledge is always required. The amendments for the NGAS without expecting a human to respond to RTI are out of the scope of this analysis. The three stages mentioned above are illustrated in Figure 1, whereas Figure 2 illustrates the regulatory, legal and liabilities frameworks considered in this report.

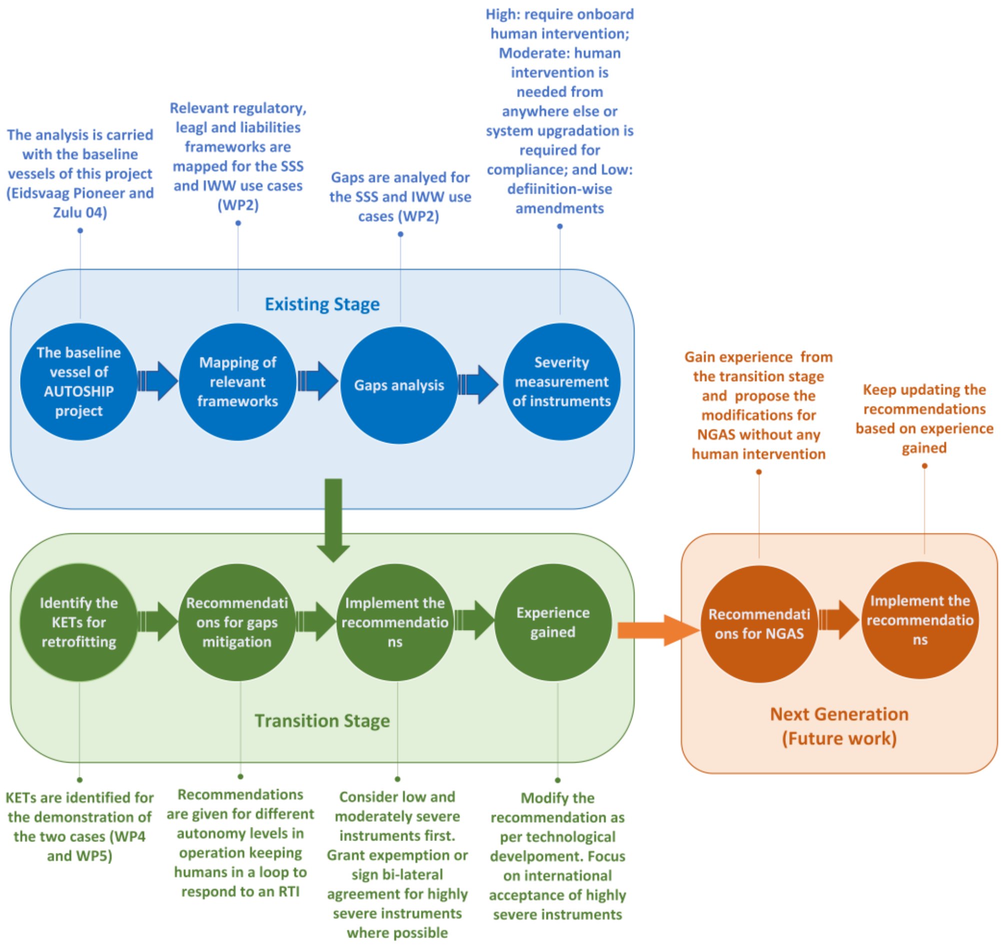

Figure 1 - Methodology flowchart

In regard to Current/Existing stage, the gaps and challenging requirements in the existing regulatory, legal and liabilities frameworks of the SSS and IWW demonstrator cases have already been identified in WP2 Deliverable 2.3 [17] of AUTOSHIP project. This starts with identifying the ship specifications, the operation areas, the work organisations, the operating methods, the autonomy levels of the demonstrator, the maintenance method etc. It is then followed by the mapping of the relevant regulatory bodies and identifying the relevant regulations that could provide hurdles in autonomous ships' operability. As a next step, a comprehensive review has been carried out of those listed regulations and gaps that were identified in the context of autonomous short sea shipping.

Based on these gaps, the severity levels of the analysed instruments' provisions are classified as High, Moderate or Low in this report, considering the degree of the human involvement to comply with existing provisions, the need for introducing or proposing appropriate amendments as well as the time-scale for the approval of these amendments in national and international levels. These severity levels could help the MASS policy makers and other stakeholders to prioritize the instruments which would require amendments before all others while preparing the roadmap for MASS adoption.

The Transition stage is expected to focus on mitigating the gaps in the existing frameworks to allow the testing and operation of autonomous ships at international or national levels and this is the main motive of this report. Currently, IMO is working on preparing goal-based standards for MASS operation [18] where the standards are supposed to be broad, over-arching safety, satisfying the requirements set by classification societies, long-standing and specific enough in order not to be open to differing interpretations. While preparing the road map for developing this goal-based code for MASS, IMO considers implementing a non-mandatory MASS code first for gaining the experience. Once enough experience is gained and feedbacks from different panel members are gathered, the compulsory MASS code will be enforced, which would be based on the non-mandatory code with possible amendments (if necessary) for NGAS. In a similar manner, to support the alternative solutions which could provide an equivalent level of safety and security to that of manned ships, the AUTOSHIP project focuses on developing and utilising the reliable Key Enabling Technologies (KETs) first. It is to be noted that, at this stage of MASS development, expert knowledge is always required to comply with the provisions even in a fully autonomous mode,

It is expected that extensive experience from the commercial operations of constrained autonomous ships (IMO level 3), over several years, is needed before NGAS can be realised. NGAS is thus considered to be decades away from being possible to operate in real world. Furthermore, since the human is not expected to react to any RTI, and there might not even be any remote control centre at all, further refinements or new regulations such as a separate MASS code would be needed to meet the expected level of safety and security. Therefore, due to the immaturity of NGAS and the regulatory framework, this stage is out of the scope of this study and has been left for further study.

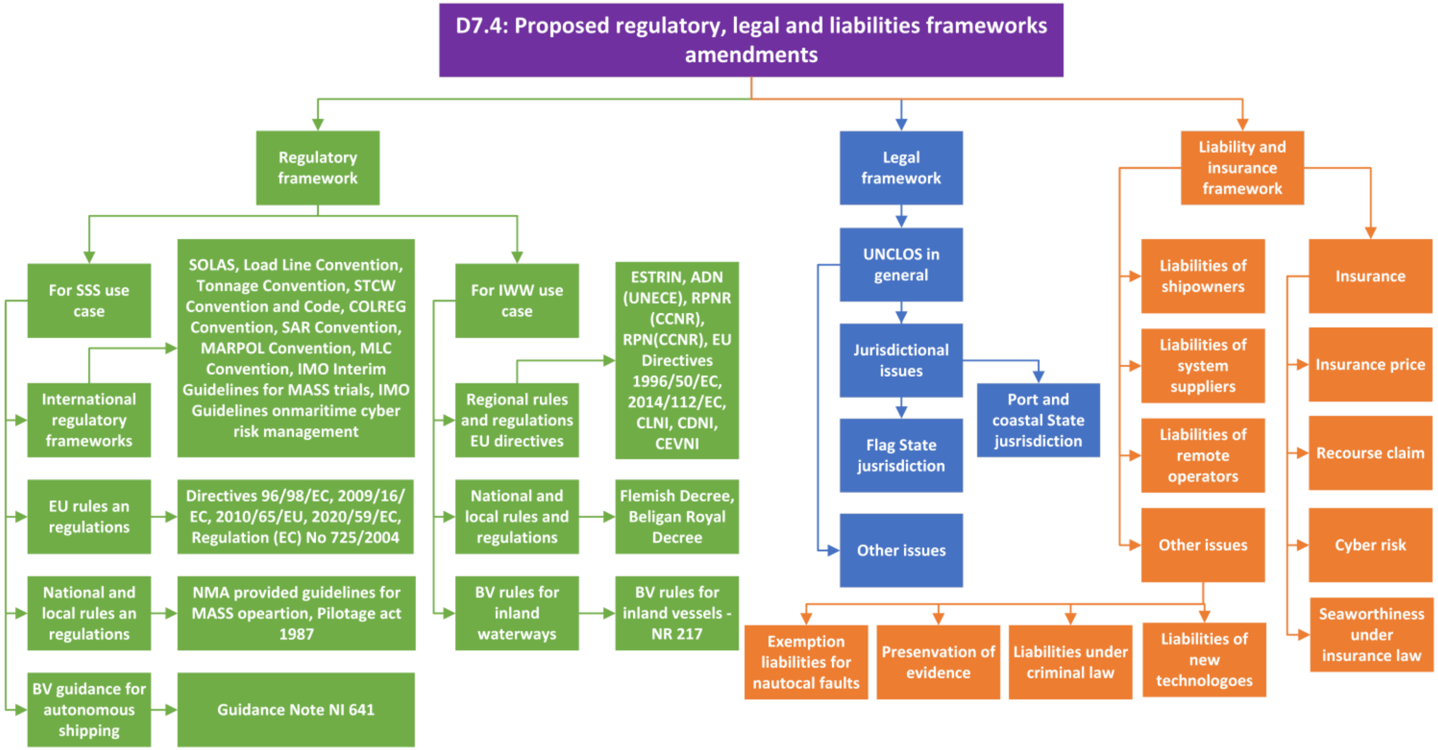

Figure 2 - Regulatory, legal and liabilities frameworks

6.4 RELATION TO OTHER DELIVERABLES

The relationship between this deliverable (Deliverable 7.4) and other tasks and WPs deliverables is provided in Figure 3.

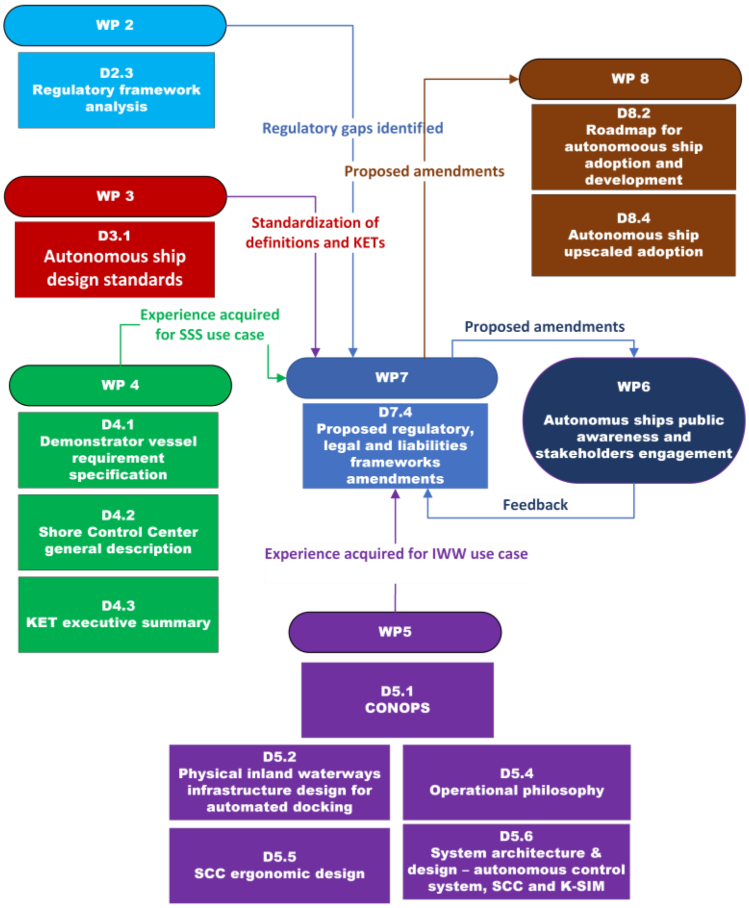

Figure 3 - Relationship of this deliverable (D7.4) with other tasks and WPs

This report utilizes the mapping studies from WP2 [17] to identify the gaps in current regulatory and liabilities frameworks for both Short Sea Shipping (SSS) cargo ship and Inland Waterways (IWW) barge use cases. The results of WP3 [4] have also been considered to standardise the definitions for MASS operations and identify the KETs while proposing the justifications or amendments. In addition, the experience acquired so far for the design and building of the two demonstrators in WP4 and WP5 have been taken into account for possible improvements to the listed proposals. The output of this deliverable will form the basis for developing a roadmap for autonomous ship adoption and development and a proposal for submission to IMO (as planned in WP8). For finalising the proposed changes, iterations are also planned with the advisory group and the industry stakeholders associated with AUTOSHIP in WP6.

6.5 OUTLINE OF THE REPORT

Section 5 includes the characteristic details of the SSS use case cargo ship, MV Eidsvaag Pioner. The system upgradation and the retrofitting of new technologies are briefly discussed in this section including the KETs [4] for its Remote and Autonomous (R&A) operations and the autonomy levels for the planned demonstration in WP4. The regulatory gaps identified in WP2 [17] for SSS use case are also highlighted for their proposed amendments or improvements. Section 6 contains the characteristic details of the IWW use case barge, Zulu 4, levels of autonomy considered for the demonstration in WP5, KETs [4] for its remote and autonomous operations, and the proposals against the regulatory gaps [17] for IWW use case. Current legislative framework is analysed in Section 7 and relevant proposals are drawn at national and international levels. Section 8 discusses a comprehensive study of existing liabilities and insurance framework considering the anticipated autonomous shipping growth. Mapping of the areas requiring changes/amendments in the existing model is done and proposals to reflect on the evolution of the autonomous shipping developments are discussed. Finally, overall conclusions are drawn and the main proposals are summarized in Section 9 for regulatory, legal and liabilities frameworks for the two use cases.

7 USE CASE FOR SHORT SEA SHIPPING

7.1 CASE DESCRIPTION

The following information is extracted from the semi-structured interview conducted with Eidsvaag AS (EAS) (https://eidsvaag.no/) personnel in the scope of the Deliverable 2.1 [19].

7.1.1 SSS use case - MV Eidsvaag Pioner

MV Eidsvaag Pioner is considered as a reference ship for the SSS use case and planned as a demonstrator for demonstrating Remote and Autonomous (R&A) capabilities of the technologies developed within the AUTOSHIP project. The use case ship is a fish feed carrier owned and operated by the Norwegian shipowner Eidsvaag AS (EAS). The ship transports primarily fish feed in bulk from factory to fish farms along the Norwegian coast. During normal operation, the ship will load cargo at the fish feed factory's quay facilities and then sail to the fish farms where the load is discharged while the ship holds position in DP mode. The main particulars of the use case are provided in Table 1, taken from Deliverable 2.1 [19] and Deliverable 2.3 [17]. A picture of MV Eidsvaag Pioner is provided in Figure 4.

Table 1 - Principal Particulars of MV Eidsvaag Pioner

Description	Value	Unit
Length overall	74.7	meters
Length between p.p.	72.9	meters

Description	Value	Unit
Breadth moulded	13.6	meters
Draught max.	5.1	meters
Gross tonnage	2145	tons
Deadweight	1743	tons

Figure 4 - MV Eidsvaag Pioner, the demonstrator ship

In principle, this type of ship is operated by a crew of seven (7) persons on-board working 4-week shifts on 6-hours rotations comprising: Master, Chief officer, Chief engineer, One 1st. engineer/ One trainee (rotates), Two Deckhands and One Cook. The ship has a dedicated Feed Control and Monitoring (FCM) System. There are operator stations for the FCM System at the bridge and on the deck office. The FCM System has a wireless connection that is used to interface the factory automation system when moored at factory quay for loading.

Deliverable 2.3 [17] includes the sailing route for the SSS use case that extends within the Norwegian waters. The ship operating area includes fjords, passages under bridges, strong currents, fog, rain, snow. The daytime and environmental conditions vary strongly with the season of the year. The ship encounters a number of other ships on its way including a number of fishing ships, kayaks, sailboats, small and medium cargo ships, small passenger ships and recreational crafts, with frequency of encounter varying per season. Very rarely military ships or submarines can be observed.

As the study has been limited to mandatory instruments related to the SSS use case sailing route, other relevant but non-mandatory codes and standards are not included herein.

7.1.2 System upgradation for remote and autonomous operations

The use case consists of a mix of Remote and Autonomous (R&A) sequences. In an open sea, the ship is operated at fully autonomous mode, i.e. the operating system of the ship is able to make decisions and determine actions by itself, without human intervention. When it comes close to the shore, port or heavy traffic zone, however, a remote operator takes the control of the operation and the ship starts to sail at remotely operated mode. The remote operation is conducted from a Remote Control Centre (RCC) located onshore for navigating the ship in remote mode, supervision of the ship in autonomous mode, the system health status checks and troubleshooting of possible malfunctions.

No crew, passengers or other persons are considered on board. Some technical personnel could be temporarily embarked on board for the purpose of maintenance or time-limited technical intervention but they have not been taking into account in the scope of this regulatory framework mapping.

In order to facilitate the remote and autonomous operations of the SSS use case, KETs need to be retrofitted to the existing ship. The KETs that are suggested to be included in this study during the retrofitting are: Autonomous Navigation System (ANS), Situational Awareness (SA), Remote Control Centre (RCC), Connectivity and Cyber-Security System (Con/CyS) and Intelligent Machinery System (IMS). A list of the SSS investigated systems could be found in D2.4 [20].

To enable the R&A demonstration of MV Eidsvaag Pioner, the onboard automation, control and navigation systems shall be upgraded and expanded with the new functionalities (SA, ANS and IMS), and integrated with a RCC through a Con/CyS system. The capabilities of SA and ANS, to enable safe autonomous navigation of the ship without the presence of a Chief officer and Master onboard, and of IMS, to enable safe and reliable operation and condition monitoring of equipment without the presence of an onboard Chief engineer, should be confirmed. The RCC and Con/CyS to enable safe and secure remote monitoring and control by an onshore crew at RCC shall also be considered for demonstration.

An overview of ship systems of MV Eidsvaag Pioner and their interconnection in communication is shown in Figure 5.

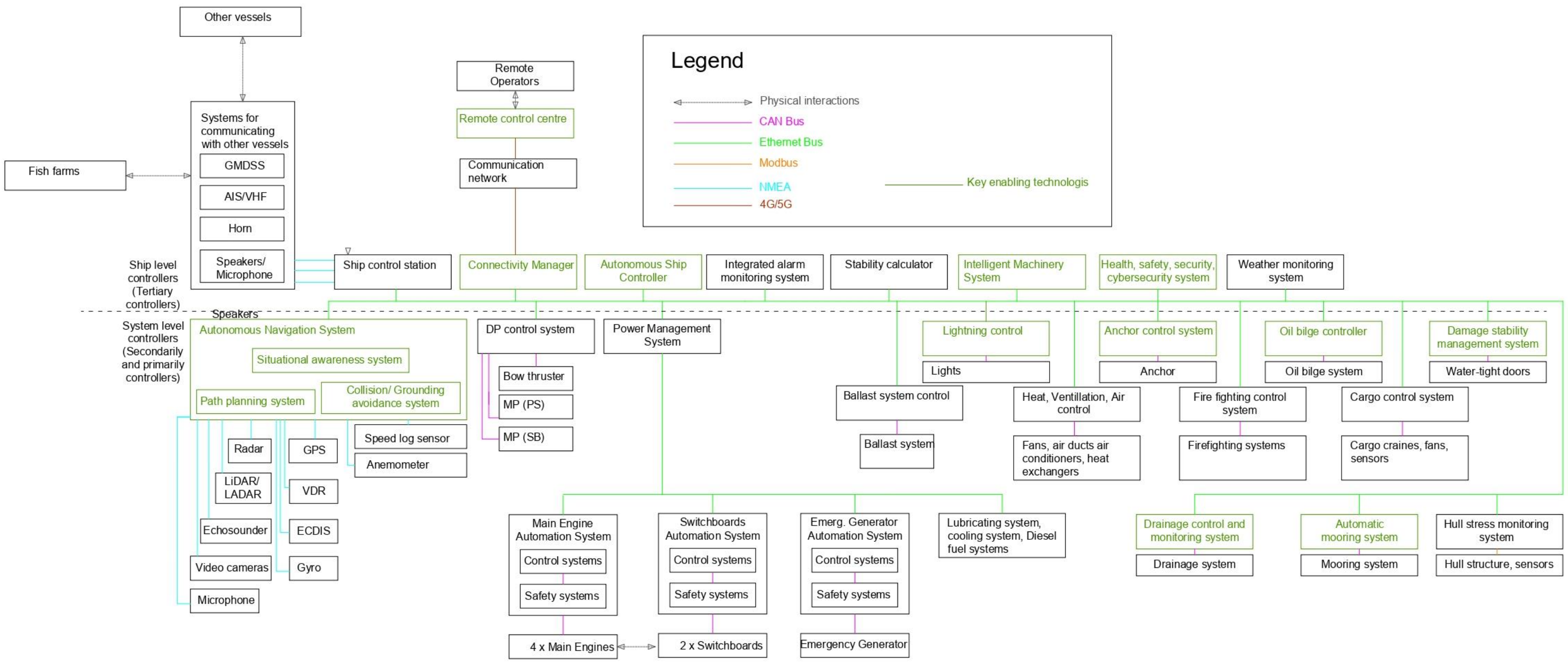

Figure 5 - An overview of the SSS use case ship systems and their communication network [20]

7.1.3 Autonomy levels

Most projects on autonomous ships [15], [16] are planned to change between different autonomy levels (manual steering, remotely controlled, remotely supervised or fully autonomous) in their voyages. Consequently, in reality, the legal barriers will be dynamic and change depending on the levels of autonomy at which the ship is operating. In many cases, it is presumed that complex ship operations (such as port calls or sailing in densely-trafficked areas) will be undertaken at a lower level of autonomy, compared to sailing in open waters.

The AUTOSHIP project Deliverable 3.1 [4] proposes a definition of the term "Degree of Control" based on the definition given in NI-641 [51]. The term 'Degree of Control' defines the operator's ability to reach the control position and to gain sufficient situational awareness to act safely and efficiently within a given time frame. This Degree of Control is denoted from C0 to C3. If there is a need to distinguish between control from an on-board control station by crew, or personnel at an RCC, the prefixes O (Onboard) and R (Remote) will be used, e.g. OC3 or RC2. Conversely, to decide the automation's ability to operate without direct control or supervision from operators, 'Degree of Automation' is defined and denoted from DA0 to DA3. A brief description of these degrees of control and degrees of automation is included in Appendix A. According to Deliverable 3.1 [4], the use case considers constrained automation (DA2) with supervisory control and discontinuous operator control (C2).

In a legal context, compliance with the instruments is possible at lower autonomy levels without any amendments, just by considering the equivalences, whereas amendments or even new regulation might become necessary at higher autonomy levels. Therefore, in this report, we have systematized the approach to tackle the regulatory, legal and liabilities barriers on the basis of IMO defined autonomy levels (see Table 2) used for the Regulatory Scoping Exercise (RSE) [8].

Table 2 - Autonomy Levels in a Regulatory Context

Autonomy levels		**Description**
M	Manual navigation with automated process and decision support	The master is on board to operate and control shipboard systems and functions as per current manning standards. Some operations may be automated and subject to sufficient technical support options and warning systems, the bridge may at times be unmanned with an officer on standby ready to take control.
R	Remotely controlled ship with crew on board	The ship is controlled and operated from shore or from other ship, but trained personnel will be on board for navigational watch and manoeuvring of the ship as it is not known when this assistance is needed. He/she will be on standby ready to take control and operate the shipboard systems and functions, in which case the autonomy level shifts to level M.
RU	Remotely controlled ship without crew on board	The ship is controlled and operated from shore or from another ship, and does not have any crew on board. The human operators can be alerted with an RTI in time before their assistance is needed.
A	Fully autonomous ship	The operating system of the ship is able to make decisions and determine actions by itself with the help of KETs. The operator on shore is only involves in decision making if the system fails or prompts alarm for human intervention, in which the autonomy level will shift to

Autonomy levels		Description
		level R or RU, depending on whether there is a crew on board or not.

In order to understand the degrees of automation and control considered in Deliverable 3.1 against the IMO defined autonomy levels, a mapping is done as shown in Table 3. Here, column represents human control degree and rows automation degrees. The unlabelled cells represent combinations that cannot be sustained. The mapping suggests that the investigated use cases will have an IMO defined autonomy level RU for constrained automation (DA2) with supervisory control and discontinuous operator control (C2).

Table 3 - Mapping of IMO proposed and SSS use case autonomy levels

	CC0	CC1	CC2	CC3
DA0				M
DA1			R	R
DA2		RU	RU	RU
DA3	A	RU	RU	RU

7.2 REGULATORY FRAMEWORKS AMENDMENTS FOR SHORT SEA SHIPPING

7.2.1 International regulatory bodies

The mapping of the International regulatory bodies applicable to the SSS use case is given in Table 4.

Table 4 - SSS - Mapping of International Regulatory Bodies

Regulatory bodies	Purpose
SOLAS Convention [21]	International Convention for the Safety of Life at Sea, 1974, deals with requirements about safety of life at sea. The current SOLAS Convention includes Articles setting out general obligations, amendment procedure and so on, followed by an Annex divided into 14 chapters.
Load Line Convention [22], [23] & [24]	IMO International Convention on Load Lines (CLL), 1966, deals with requirements about Load Lines and its associated Intact Stability Code (Protocol of 1988, Part A), and the IMO Instruments Implementation Code (III Code).
Tonnage Convention [25]	IMO International Convention on Tonnage Measurement of Ships (TMC), 1969, deals with requirements about tonnage measurement.
STCW Convention and Code [26] & [27]	IMO International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978, and Seafarers' Training, Certification and Watchkeeping Code, deal with training, certification and watchkeeping requirements.
COLREG Convention [28]	IMO Convention on the International Regulations for Preventing Collisions at Sea, 1972, deals with requirements for preventing collisions at sea.
SAR Convention [29]	International Convention on Maritime Search and Rescue 1979, deals with maritime search and rescue requirements.
MARPOL Convention [30]	IMO International Convention for the Prevention of Pollution from Ships, 1973, deals with requirements for the prevention of pollution of the marine environment by ships from operational or accidental causes.
MLC Convention [31]	ILO Maritime Labour Convention, 2006, embodies all up-to-date standards of existing international maritime labour conventions and recommendations.

Regulatory bodies	Purpose
IMO Interim Guidelines for MASS trials [32]	IMO Interim Guidelines for MASS trials MSC.1/Circ.1604, 14 June 2019, assist relevant authorities and relevant stakeholders with ensuring that the trials of MASS related systems and infrastructure are conducted safely, securely and with due regard for protection of the environment.
IMO Guidelines on maritime cyber risk management [33]	IMO Guidelines on maritime cyber risk management MSC-FAL.1/Circ.3, 5 July 2017, provide high-level recommendations on maritime cyber risk management to safeguard shipping from current and emerging cyber threats and vulnerabilities.

7.2.1.1 Regulatory Scoping Exercise

The Outcome of the Regulatory Scoping Exercise (RSE) [8] was approved by the Maritime Safety Committee (MSC), at its 103rd session (5 to 14 May, 2021). The objective of this scoping exercise is to access the degree to which the existing regulatory framework under purview of the MSC might be affected in order to address MASS operations. It further provides the guidance to MSC and other interested parties (shipowners, operators, academia, etc.) to identify, select and decide on the future work on MASS, facilitate the preparation of requests for, and consideration and arrival of new outputs.

An exploratory research has been conducted in this scoping exercise and finally the outcome includes: a)Information for all degrees of autonomy for every instrument expected to be affected by MASS operations, b)The most appropriate way(s) of addressing those to mitigate any barrier for MASS operability, c)The potential gaps that require addressing, possible links between instruments and d) The priorities for future works, including terminology and the order in which instruments could be addressed.

Referring to RSE, this report considers the gaps identified in AUTOSHIP WP2 Deliverable 2.3 and other relevant pertinent articles on regulatory gaps analysis and treats the gaps as dynamic for different autonomy levels to comply with the instruments. Later, the instruments are classified as high, moderate or less severe on the basis of the consideration of modern technologies to replace human intervention in compliance with the rules and regulations and getting worldwide acceptance. High severity is given to those instruments which explicitly require human intervention onboard and which are very troublesome to justify the same safety level without direct human involvement, such as pilotage or rendering assistance in distress situations. Moderate severity is given to those which require implicit human intervention (not necessarily onboard), or system upgradation with KETs (for remote or autonomous operation) would be sufficient to ensure equivalent safety levels while defining alternative ways to meet the provisions. And, low severity is given to those which require wording adjusting, such as inclusion of new or amending definitions.

7.2.1.2 Identified gaps and proposals for international regulatory bodies

This part of the report addresses the gaps identified in Deliverable 2.3 [17] in compliance with international instruments for the SSS use case. Recommendations, amendments or new developments have been proposed as shown in Table 5 to minimize the hurdle of autonomous ships' operability. The regulatory bodies mapped in Table 4 have been considered at this stage of the analysis, which are sufficient to cover major international governing bodies of SSS operation. The proposals have been considered dynamic wherever possible on the basis of different levels of autonomy and the instruments have been addressed by either developing interpretations, equivalences, amending existing instruments, developing a new instrument or do nothing as it does not hinder MASS operation. The proposals have also been prioritized based on the urgency of the required adjustment before all others to ensure the sailing of autonomous ships on international routes.

Table 5 – Proposals for International Regulatory Bodies for SSS Use Case

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
SOLAS Chapter I	General provisions	I. Definitions should be added for MASS operations	R, AU and A	**Recommendation**: Include the list of definitions given in Section 2.2. **Justification:** A list of definitions and terminologies for MASS operations has been added in Section 2.2 of this report.	✓		
SOLAS Chapter II-1	Requirements about structure, subdivision and stability, machinery and electrical installations.	I. Definitions should be added for MASS operations	R, AU and A	Same as above	✓		
		II. Requirements should be added about remote monitoring and remote control (e.g. availability requirements for critical equipment/functionalities).	R, AU and A	**Recommendation:** Include the following requirements to be considered: - A prescriptive requirement of three compulsory blocks which are: ship control system, connectivity and remote control centre with their associated functionalities. - A risk-based approach to identify the minimum redundancy in the ship-shore communication and station-keeping/manoeuvring. **Justification:** To facilitate remote monitoring and remote control of autonomous ships, three main building blocks, which are: ship control system, connectivity and remote operation centre should be formed.		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				The ship control system is based on a traditional package of functionalities for a ship combined with situational awareness technology and autonomous navigation. In addition, there will be a mission manager acting as a digital master on board the ship. The connectivity link is cyber security and a robust communication link between the ship and RCC. The main goal of this link is to ensure a prioritized, encrypted, redundant, safe and high availability link for doing the remote operation. The Remote Control Centre (RCC) has the main goal of planning and monitoring the autonomous operations of one or several ships. The main tasks usually performed at RCC are monitoring and remote controls of ships if needed. It is suggested to include the risk-based approach to understand the minimum redundancy requirement in the ship-shore communication and station-keeping/manoeuvring in the sense of IMO MSC Circ 1580 DP2/3 [34]. This will help to restrict the area of navigation at autonomy levels RU and A based on the ship-shore communication's redundancy and reliability of transmission levels. This report includes the major functional breakdown of these three blocks in Appendix B, which are going to be used in the demonstration cases in the AUTOSHIP project.			

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		III. Regulation 37 on communication between the navigation bridge and the engine room requires at least two independent means of communication between the physical navigational bridge and the machinery space or control room from which the engines are normally controlled. This provision is for communication between navigators and engineers	RU and A	**Recommendation:** Include an alternative provision by establishing the three compulsory building blocks (Appendix B) together with KETs to meet this instrument for an unmanned ship. **Justification:** At autonomy levels RU and A, this provision needs to be met only for inspection purposes as there will be no engineers and navigators on board. In AUTOSHIP SSS use case, to meet this provision, an onboard Intelligent Machinery System / Digital Chief will monitor the real-time onboard engine and other machinery health data during navigation and help operator and engineer at RCC to monitor the order and corresponding responses via electronic lookout to control the speed or direction of thrust.		✓	
		IV. Regulations mentioning indications, alarms, direct reading gauge glass or communication means in the	R, RU and A	**Recommendation:** Include the following requirements to be considered: - A prescriptive requirement of three compulsory building blocks with necessary KETs to provide the alternatives to meet the provisions.		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		bridge, engine-room, centralized control position or engineers' accommodation. Justification is needed considering no crew on board.		- A goal-based requirement with regard to the redundancy. It is to mention that the gaps relevant to the indications, alarms, direct reading gauge glass and communication means can be considered as having non-critical redundancy (beyond the minimum redundancy allowing the ship to perform its critical functions in the event of a single point failure). **Justification:** **Alarm:** To meet the provision mentioned in Regulation 38 (Engineer's Alarm) and Regulation 51-53, at any autonomy levels, ships must be arranged with an alarm for sounding to the person performing/monitoring the officer function at RCC so that he/she can carry out the action required. It is also necessary to establish an extensive alarm system for sounding to the supervisor at RCC if the normal alarm system is not deactivated by a remote operator within a limited time. **Direct reading gauge glass:** To meet the provision mentioning direct reading gauge glass, redundancy of sensors should be included to double-check the reading if any alarm is activated. **Indications, communication means in the bridge, engine room etc:** At autonomy levels R and RU, provisions mentioning indications, communication means in the bridge, engine room etc. could be met by establishing an on board			

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				Intelligent Machinery System (IMS) / Digital Chief to provide an electronic lookout of engine/machinery room to the person-in-charge at RCC (will act as manned central control station) with the aid of technologically advanced cameras, sensors, communication and network systems for his decision making. On contrary, at autonomy level A, Autonomous Navigation System (ANS) / Digital Captain and Intelligent Machinery Systems / Digital Chief will replicate the task of a master/navigator at the physical bridge and engineers at the engine room, respectively. These two systems will be integrated to facilitate the relevant information exchange to navigate the ships without any human intervention, but keeping humans in the loop for continuous monitoring. **Engineers' accommodation:** Provision regarding engineers' accommodation only needs to be met at autonomy level R. At autonomy levels RU and A, this provision would become obsolete as there will be no engineers on board.			
SOLAS Chapter II-1	Requirements about structure, subdivision and stability, machinery and electrical installations.	V. Regulations mentioning information to be available on board	R, RU and A	**Recommendation:** Include the following requirements to be considered: - A goal-based approach for autonomous ships at autonomy level R and RU to determine the minimum lag.		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		or to be supplied to the master.		- At autonomy level A, establish an Autonomous Navigation System (ANS) and Intelligent Machinery System (IMS) acting as a Master and an Engineer onboard, respectively for a subset of operational conditions. **Justification:** To meet the provision, it should be made technically possible to consider an electronic bridge replacing a physical bridge for an autonomous ship somewhere else with the same or improved functionality and feed all real-time onboard information to the person performing/monitoring the master function there via satellite/other means with reasonable lag. For fully autonomous ships, this provision could be met by keeping a correctly functional control loop for the subset and real-time RCC for the rest.			
		VI. Regulations mentioning local control of doors (Reg. 9, Reg. 13) and other devices (Reg. 15) e.g. or manual operation to be done on board	RU and A	**Recommendation:** Include the following requirements to be considered: -A redundancy in the sensors for the status of the manually operated equipment. - An automatic control for the manually operated equipment. - A centralised manual override station is also suggested to be installed onboard. **Justification:** Doors and other devices, which are meant to be manually operated should have the provision to be operated autonomously by an onboard ship control system or remotely from RCC			✓

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				based on different autonomy levels. The opening and closing of such doors and their associated watertight integrity could be ensured by the system/RCC personnel by establishing a precise monitoring system including high-resolution cameras/sensors to detect any leakage and set the alarm if so, to ensure safer operation of these doors for autonomous ships. A redundancy is suggested to be included in the sensors to ensure the status of the manually operated equipment. Additionally, it is also necessary to introduce into SOLAS a requirement for a centralised manual override station located onboard that allows disabling the automatic control of the ship's subsystems by the attending personnel to manual when attending the protected spaces in the engine room, propulsion or preparing an underwater survey of the fully autonomous ships' hull.			
SOLAS Chapter II-1	Requirements about structure, subdivision and stability, machinery and electrical installations.	VII. Regulations mentioning actions to be done by the master and/or the officer of the watch	R, RU and A	**Recommendation:** Include an interpretation that clarifies the delegation of duty to the RCC personnel subject to the KETs utilised in autonomous ships at different autonomy levels. **Justification:** At autonomy levels R and RU, a remote operator at RCC, acting as a master will be responsible to perform all necessary actions to be done by the master/officer of the watch on board. With the aid of technologically advanced cameras, sensors, communication and network systems, it is possible to replace the physical bridge watch with a		✓	

Regulatory body	Description	Gaps identified		Autonomy level	Proposals	Level of severity		
						L	M	H
					proper electronic lookout that could provide similar or even better situational awareness to an operator on watch. In the context of fully autonomous ships, i.e. autonomy level A, an onboard Autonomous Navigation System (ANS) / Digital Captain will do the needful to replace the onboard master/officer on watch. In this regard, the Digital Captain will perform the tasks of a master and a navigator altogether.			
SOLAS Chapter II-1	Requirements about structure, subdivision and stability, machinery and electrical installations.	VIII.	Regulation 3-3 mentioning means to enable the crew to gain safe access to the bow of tanker ship	RU and A	This regulation is only applicable for tanker ship, therefore not applicable to this use case			
		IX.	Regulations taking into account the presence of the crew in the stability calculation (index R and permeability)	R, RU and A	**Recommendation:** No amendment is required to the text of SOLAS. **Justification:** Calculation of Index R and Permeability take into account the actual presence or absence of the weights including the crew. Excluding the crew, while calculating the index R and permeability would be enough to mitigate the gap.	-	-	-
		X.	Regulations mentioning habitable conditions	R, RU and A	**Recommendation:** Grant an exemption from complying with the requirements for habitable conditions for autonomous ships at autonomy levels RU and A.	✓		

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity L	M	H
				Justification: At autonomy level R, this provision must be met if there are crews on board. However, in terms of 'habitability', this provision would become obsolete at autonomy levels RU and A as there will be no crew onboard.			
		XI. Regulations mentioning emergency consumers, lighting, muster and embarkation station related to crew evacuation.	R, RU and A	**Recommendation:** Grant an exemption from complying with the requirements for lighting, muster and embarkation station related to crew evacuation for unmanned autonomous ships, whereas the emergency consumers will be more related to the vital subsystems of autonomous ships, e.g. GMDSS, radar, AIS etc. **Justification:** At autonomy level R, this provision should be met as for conventional ships if there are sufficient crew on board. Conversely, regulations mentioning emergency consumers, lighting for illuminating the part of ships accessible to humans, mustering and embarkation station related to crew evacuation would become obsolete at autonomy levels RU and A as there will be no crew onboard.	✓		
SOLAS Chapter II-1	Requirements about structure, subdivision and stability, machinery and electrical installations.	XII. Regulation 19 mentioning damage control plans are always required to be available to the	R, RU and A	**Recommendation:** Include a provision of keeping the damage control plans both at RCC and onboard ship. **Justification:** It is recommended to make the damage control plans available to the one in control of the ship at RCC and on board as well for inspection purposes. It is to be noted that the	✓		

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		officer of the bridge watch.		damage control plans are also required for the damage control party boarding the ship in the event of a complete loss of control and/or accident. As the onboard power supply may not be available in the emergency situation, a paper version would still be compulsory at the onboard control station.			
		XIII. Regulation mentioning periodically unattended machinery spaces.	R, RU and A	**Recommendation:** No amendment is required for this existing instrument if the autonomous ships could comply with the Reg 46 (2), which indicates "Measures shall be taken to the satisfaction of the Administration to ensure that the equipment is functioning in a reliable manner and that satisfactory arrangements are made for regular inspections and routine tests to ensure continuous reliable operation". However, additional requirements are necessary to be included for autonomous ships, which are: - The detailed requirements for built-to-test/built-in self test features for the machinery used at autonomy levels RU and A. - A risk-based schedule of inspections and tests to be completed by maintenance teams intervening when the ship is in port - E-documentary evidence of its fitness needs to be onboard. **Justification:** At autonomy levels RU and A, it is technically possible for the RCC personnel to carry out thorough remote monitoring of engine	-	-	-

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				room/machinery spaces to check the condition of all running machinery systems and try to anticipate any probable alarms that could occur at night before switching the engine room to Unattended Machinery Spaces (UMS) mode at the end of day's work. In this way, he/she can ensure the safety of the ship in all sailing conditions, including manoeuvring which is equivalent to that of a ship having the machinery spaces manned. In addition, regular inspections and routine tests are to be scheduled by maintenance teams intervening when the ship is in port for the reliable functioning of autonomous ships. Also, E-documentary evidence of its fitness to operate with periodically unattended machinery spaces needs to be had onboard.			
SOLAS Chapter II-1	Requirements about structure, subdivision and stability, machinery and electrical installations.	XIV. The meanings of "master", "crew" and "responsible person" should be clarified considering they are not on board.	R, RU and A	**Recommendation:** Consider the following requirements to be included: - An interpretation considering the remote operator at RCC as "master", "crew" and "responsible person" for autonomous ships at autonomy levels R and RU. - Define the term "Digital Captain" and "Digital Chief" to replicate "master/crew" and "engineers" on board for a fully autonomous ship. - Any relevant definitions from Section 2.2. of this report.	✓		

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				Justification: At autonomy level R, where a regular crew is onboard for monitoring purposes, he/she should be able to establish continuous awareness of the situation making him able to take over the control from the automatic navigation system if he/she finds it necessary. In such circumstances, the crew will be designated as 'master' and 'responsible person'. Alternatively, if he/she is only for monitoring purposes and keeps the operator updated with any abnormalities or assists him in some manner in navigating the ship remotely from RCC, the person onboard will be treated as 'crew'. At autonomy level RU, the 'master' and 'responsible person' will be the remote operator at RCC who will take most of the rights and obligations resting with the master under current regulations, and thus could be thought of as the highest authority considered in charge of that ship. Alternatively, in a broader sense, if an operator is involved in the watch duties of multiple ships/fleets, the supervisor who is back up with personnel from other disciplines will be considered a 'master'. In that case, he/she will be responsible for making sure of all automated systems work properly, and any other RCC personnel who involve in navigating/monitoring autonomous ships follow the regulations.			

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				For fully autonomous ships, i.e. at autonomy level A, an onboard control system will be responsible for having the overview, taking decisions, executing minimum risk conditions and so forth. Fully autonomous ships replace the crew on board by establishing an onboard Intelligent Machinery System (IMS) / Digital Chief and Autonomous Navigation System (ANS) / Digital Captain with the aid of technologically advanced sensors, cameras and communication and network systems. These systems will enable the remote operator at RCC to monitor/control the ships if necessary by providing a proper electronic lookout in the vicinity of the ship and machinery spaces.			
SOLAS Chapter II-2	Fire protection, fire detection and fire extinction	I. The meanings of "master", "crew" or "responsible person" should be clarified taking account that they are not on board.	R, RU and A	Same as above	✓		
		II. The definitions of "control stations" should be amended to introduce the Remote Control Centre and remote locations for supervision. The	R, RU and A	**Recommendation:** Include the following requirements to be considered: - A provision of having two "control stations", one located at RCC to facilitate the remote operation and one onboard. Both of the control stations should have identical sub-systems/functionalities and the details of those should be included.	✓		

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		definitions of "manned spaces" should also be amended.		- A centralised manual override station which is designed for the damage control and maintenance teams and prevents inadvertent activation of the ship's systems by automatic control. **Justification:** For autonomous ships, at any autonomy levels, there will be two distinguished control stations: an onshore control station located at Remote Control Centre (RCC) and an onboard ship control station or Automatic Onboard Controller (AOC). Each of these two control stations should have six different functionalities, namely, manoeuvre ship, navigate ship, sense and analyse environment, sense and analyse equipment, operate equipment and manage the mission. Details of each functionality could be found in Appendix B. At autonomy levels R and RU, both will be used for different functionalities from time to time, whereas at autonomy level A, only the onboard ship control station will be used. Hence, the word "control stations" should be amended to introduce this new provision of Remote Control Centre (RCC), from which monitoring and/or control of some or all of the ship functions can be executed. In the context of RCC, the ship will normally be autonomous, but this is not necessarily the case. RCC can also be used to supervise conventional ships. In addition, it is also necessary to have a centralised manual override station located			

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				onboard that allows disabling the automatic control of the ship's subsystems by the attending personnel to manual if needed and prevents inadvertent activation of the ship's systems by automatic control.			
SOLAS Chapter II-2	Fire protection, fire detection and fire extinction	III. Since the decision making could be done remotely, autonomously or automatically, additional functional requirements may be needed to demonstrate that the shipboard systems can detect fire, convey the information in a timely manner to the Remote Control Centre and automatically activate means to recover a safe situation.	R, RU and A	**Recommendation:** Include the following requirements to be considered: - A detailed functionalities of three major building blocks (Appendix B) to demonstrate the capability of the shipboard systems to meet the provision. - Conduct risk-based assessments for the whole system and specify the types and the number of sensors to be carried in each compartment. - Specify the response deadline for the time-bound decision taken for the activation of the fire fighting system at autonomy levels R and RU. **Justification:** To meet this provision, autonomous ships should be equipped with a fire alarm system (consisting of fire detectors, indicator devices and a control panel). The activation of a fire detector should be followed by audible and visual signals at the control panel. The control panel itself should be located at RCC for autonomous ships. Since the rules do not specify the position of the control panel any further, thus making possible the remote monitoring of fire detection. However, the risk-based assessment should be carried out periodically for the whole system and a		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				number of sensors need to be installed in each compartment, such as redundant sensors, atmosphere testing, CCTV infrared cameras of different types e.g. one smoke and one heat etc., where on a conventional ship a smoke detector is only required. In addition, to activate the fire fighting system right on time for autonomous ships at autonomy levels R and RU, the response deadline must be set in advance.			
		IV. Many provisions requiring manual operations and other actions by personnel on board, for example in cases of fire, spillage, cargo management or maintenance, and some provisions regarding accommodations, accessibility and alarms should be amended. The risks should be identified, and appropriate alternative safety	R, RU and A	**Recommendation:** Include the requirement to the system architecture as a goal-based approach. If the ALARP (as low as reasonably possible) can be set as a goal for autonomous ships, then the framework of Safety Integrity Levels can be potentially used as in IEC 61508. **Justification:** With the aid of technologically advanced sensors, high-definition surveillance cameras and communication and networks system, it is possible to carry out automatic fire detection and mitigation, automatic spillage/flooding detection and shut down of safety doors, if necessary, remote cargo monitoring etc. for autonomous ships. However, a safety system for independent shut down of equipment in case of incidents, fire, flooding, security issues, etc. should be ensured. If any alternative safety measures have to be adopted for autonomous ships, these must demonstrate the same safety level as that of			✓

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity L	M	H
		measures (including redundancy) should be adopted to reduce the risks to as low as reasonably practicable and acceptable.		manned ships. In this regard, as provided in D2.4 [20] the ALARP likelihood can be set as a goal to achieve as a result of a design of autonomous ships at autonomy levels RU and A. In addition, it is possible to sort out the findings from D2.4 into several short examples of barrier combinations that allow an acceptable likelihood and to use these examples as a justification and proof of feasibility. Provisions regarding accommodations would become obsolete except for the passenger ships as there will be no crew/human on board at autonomy levels RU and A.			
SOLAS Chapter III and the LSA Code	Life-saving appliances and arrangements	I. For remote operations, the concept of “navigation bridge” should be clarified for certain provisions, such as Personal life-saving appliances (Reg. III/7), Survival craft launching and recovery arrangements (III/16) and Decision support system for masters	R, RU and A	**Recommendation:** Include the following requirements to be considered: - The definition of "electronic bridge" to understand its functionalities. - Adapt the LSA code to the number of personnel boarding for pilotage or the damage control intervention when the ship lost the communication link. - A design that would allow helicopter winching and landing operations. **Justification:** The concept of a "navigational bridge" needs to be replaced by an "electronic bridge" for remotely operated and autonomous ships. Personal life-saving appliances: Even with zero crewing, autonomous ships should maintain a		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		of passenger ships (III/29).		minimum number of life-saving appliances for anyone temporary on board like repair workers, pilots, PSC inspectors etc. or the damage control intervention when the ship lost the communication link. **Survival craft launching and recovery arrangements:** The provision of survival craft launching and recovery arrangements could be taken as a blueprint for arranging an automated launching and recovery system for the survival craft that will be controlled remotely by RCC personnel. It is recommended to consider a design that would allow helicopter winching and landing operations to allow boarding by aircraft for the damage control team restoring a ship following a major failure in the communication link. This in turn provides another evacuation possibility. **Decision support system for masters of passenger ships:** For autonomous passenger ships, the provision of a decision support system could be met by providing an electronic version of the emergency plan onboard and a printed version at RCC.			
SOLAS Chapter III and the LSA Code	Life-saving appliances and arrangements	II. The relevance of the following requirements could be discussed for ships without seafarers on board:	RU and A	**Recommendation:** Include the following requirements to be considered: - An exemption that the survival craft requirements and the requirements for the recovery from water are limited for unmanned autonomous ships (autonomy levels RU and A). They can be engaged			✓

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		• Manning of survival craft and supervision (Reg. III/10). • Rescue boat (Reg. III/21 and III/31) • Line-throwing appliance (Regulation III/18) • Ship-specific plans and procedures for recovery of persons from the water (Reg. III/17-1)		in a sweep search, but not in the recovery of the persons in water or driving survival craft unless the onboard equipment allows them. - Possible scenario of the line throwing device at autonomy levels RU and A. - A fixed boatlanding instead of the manila rope embarkation ladders. **Justification:** For autonomous ships at autonomy levels RU and A, the relevance of the survival craft requirements and the requirements for the recovery of persons from water is limited to the available equipment. For unmanned autonomous ships, compatible equipment is not yet available. Therefore, the exemption should be granted to these provisions at autonomy levels RU and A, and there will be no need for any trained person on board for supervision as it is needed for manned ships. However, the RCC personnel can relay the information of any accident/collision captured by the ships' cameras/sensors to other nearby ships/ports to arrange further distress assistance and participate in sweep search. The line throwing device is needed for passing line, e.g. for emergency towing, which is a possible scenario at autonomy levels RU and A. When the pull towing is required by a damage control team boarding the autonomous ships for intervention, it may require sending lines. This may also be used by an aircraft for personnel transfer. As the line			

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				throwing device contains pyrotechnics, it shall be stored onboard and not delivered by the damage control team. Carriage of pyrotechnics is generally restricted and it may impact emergency response activities. The same applies to the rocket parachute flares, buoyant smoke signals and hand flares. It is suggested to consider the benefits by addressing LSA code's 6.1.6 Embarkation ladders for autonomous ships. At autonomy levels RU and A, a fixed boatlanding is preferred to the manila rope embarkation ladders.			
SOLAS Chapter IV	Requirements for radio communications	I. The absence of the requirements for the remote-control stations (including geo-redundancy of communication links) appears to be a major gap.	R, RU and A	**Recommendation:** Include the following requirements to be considered: - Insert the essentials of the 'Connectivity' block mentioned in Appendix B. - Definition of 'Two-way bridge-to-shore communication' in Reg 2. - Establish the geo-redundant ship-shore communication systems. - A risk-based approach to identify the minimum redundancy in the ship-shore communication and station-keeping/manoeuvring - The process of Fallback. **Justification:** Regulation 2 should define the term 'Two-way bridge-to-shore communication' which is an essential part of the autonomous ships' communication system.		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				Geo-redundant ship-shore communication system also needs to be established to make sure the communication is available in the event of any unexpected outages, whether this is hardware or software failures, emergency maintenance, antenna blocked or natural disasters [36]. If such an unforeseen event occurs, the geo-redundant solution can guarantee communication availability by activating the secondary site from a passive to active mode in a fully automated procedure. In addition, it is suggested to consider a risk-based approach to identify the minimum redundancy in the ship-shore communication and station-keeping/manoeuvring and restrict the area of navigation of unmanned autonomous ships based on the ship-shore communication's redundancy and reliability of transmission levels. An approach similar to GMDSS is suggested with A1,2,3,4 areas that depend on the distance of radio transmission via different independent links. The process of fallback is to be clarified and ensured that the fallbacks are sufficiently executed to allow the autonomous ships at any given time to enter so-called “minimum risk conditions” (MRC), which is a safe state to enter in case of technical failures and/or human error prevents the ship from maintaining normal operations. The following MRCs are considered relevant for the demonstrator cases at autonomy levels RU and A.			

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				1. Continue operation (no changes to control responsibility) 2. Station keeping (using virtual anchoring – provided the ship is equipped with propulsion/ thrusters for this capability) 3. Proceed to safe location 4. Emergency anchoring 5. Await and follow instructions from RCC			
SOLAS Chapter IV	Requirements for radio communications	II. Technical issues such as link quality and quantity would be necessary to be identified and specified in detail.	R, RU and A	**Recommendation:** Include the following requirements to be considered: - Essential details regarding 4G, 5G and MRB. - A risk-based approach to identify the minimum redundancy in the ship-shore communication and station-keeping/manoeuvring. - ECDIS mapping of the communication coverage zones **Justification:** For Short Sea Shipping (SSS), the primary ship-to-shore two-way communication network with predictable latency and sufficient capacity for transmission of live video for remote control of the ship is likely to be GSM 5G. The alternative is 4G/4G+ which works for many services offered to the operation of conventional ships. However, the minimum transmission speed for live video coverage must be defined and regulated. Other alternatives are VHF in certain areas or VDES.		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				Satellite (VSAT) is an alternative but is more expensive and may have longer latency. In real ship operation, the communication quality of satellite (VSAT) varies widely. However, this is the only option available while sailing on the high sea. Broadband radio (such as MBR) may be set up in certain areas if needed. It is suggested to consider a risk-based approach to identify the minimum redundancy in the ship-shore communication and station-keeping/manoeuvring and maintain a geographic mapping of the coverage zones per communication carrier as a shipboard procedure with regular updates. This should be similar to the nautical chart updates and transmitted in the ENC-compatible IHO format. Overlaps offering the required redundancy in communication can then be established. Prohibit passage beyond the areas, where the redundancy in ship-shore comm is not guaranteed. An approach similar to GMDSS could be used with A1, A2, A3, A4 areas that depend on the distance of radio transmission via different independent links.			
SOLAS Chapter IV	Requirements for radio communications	III. New requirements and frequencies would be required because the actual bandwidth available may not	R, RU and A	**Recommendation:** Include the provision of considering private network coverage if the required bandwidth is not adequate. In addition, maintain the essential communications in case of limited bandwidth.		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		be enough to enable maritime communication to operate MASS.		**Justification:** The bandwidth requirement is situation-dependent, with an estimated higher requirement when leaving/entering port and/or when transfer to a Minimum Risk Condition (MRC) takes place. A high-definition video channel requires 3-5 MB/s. With the planned ship/shore communication, the continuously available bandwidth for an aggregated up-and-down link is a minimum of 15 MB/s. It is believed that the existing frequency bands would be enough to establish the communication between MASS and RCC [37]. However, private network coverage could be set up if the required bandwidth is not adequate. In case of low bandwidth, prioritization must be given for maintaining communications, contributing to the provision of functions essential for propulsion, steering and safety of the ship. IEEE has defined standard letters for different frequency bands [35] that are relevant for radar and satellite transmissions. These bands are typically in the centimetre to the millimetre wavelength range. The most common bands codes are listed in Appendix C.			
SOLAS Chapter IV	Requirements for radio communications	IV. Further consideration should be given to the requirement of transmitting	R, RU and A	**Recommendation:** Include the following requirements to be considered: - EPIRB to transmit the distress alert regardless of manning.		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		distress alerts when there are no persons on board the ship.		- An audio transmission of a corresponding pre-recorded distress message on VHF, MF, HF, Inm-C (GMDSS links) etc. where applicable, at regular intervals. - Transmission of alert by AIS and by commercial communication to the nearest Maritime Rescue and Coordination Centres (MRCCs). - A mapping of the MRC to the distress cases for unmanned autonomous ships **Justification:** An automatic distress transmitter on board, EPIRB (Emergency Position Indicating Radio beacon) transmits distress alerts when a ship sinks. For autonomous ships, a similar arrangement is necessary regardless of any person on board, to locate the ship if it sinks. It is also suggested to consider the audio transmission of a corresponding pre-recorded distress message on VHF, MF, HF, Inm-C (GMDSS links) etc. where applicable, at regular intervals. In addition, autonomous ships should be technically capable of detecting distress signals from other ships with the aid of onboard situational awareness technology and transmitting the alert by AIS and by commercial communication to the nearest Maritime Rescue and Coordination Centres (MRCCs). It is also recommended to prepare a mapping of the MRC to the distress cases at autonomy levels RU and A.			

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
SOLAS Chapter V	Safety of navigation.	I. The scope of the duty of the ship Master should be extended/amended .	R, RU and A	**Recommendation:** Include the following requirements to be considered: - An interpretation considering the stipulated duty of the ship Master to be delegated by the remote operator at RCC for autonomous ships. - An amendment into "Regulation 34-1 - Master's Discretion" to include the RCC operator as an overriding authority, when the bridge control station is unmanned. If the ship (autonomy levels RU and A) is temporarily boarded by the damage control team or a pilot, the overriding authority should be transferred to them. **Justification:** An autonomous ship can utilize highly innovative communications technology to enable it to manoeuvre from an RCC as responsively as when under the command of a conventional onboard crew and assist the remote operator/RCC personnel to comply with all provisions required for the ship Master. It is expected the RCC personnel should have a good understanding of navigational matters, as with seafarers; but given that they are not expected to go onboard, some provisions relevant to traditional master's duty may be able to be omitted. Conversely, however, some further qualifications may well be necessary: notably, a good technical knowledge of the relevant computer and communication systems, how to deal with an		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				emergency within the RCC and how to respond to an emergency condition on board the ship. For an instance, SOLAS chapter V, regulation 31, obliges the master to report situations that may present a navigation risk, especially hazardous weather, to all ships in the vicinity and the relevant competent authorities. Such reports do not have to have a specific form. The provision will not present a barrier to autonomous ships to the extent that they are technically capable of detecting dangerous situations and notifying ships in the vicinity hereof. Considering the purpose of the provision, the obligation will have to be met by the remote operator/ RCC personnel for ships at different autonomy levels. It is also suggested to consider a clarification on the overriding authority as in "Regulation 34-1 - Master's Discretion ". This authority should be delegated to the RCC operator at autonomy levels RU and A, when the bridge control station is unmanned. If a damage control team or a pilot takes control of the bridge interface locally, then it is suggested to transfer this overriding authority to the person in local control, if alone, or to the person in charge of the team operating the ship locally, if the unmanned ship is temporarily boarded. Delegation of the overriding authority requires additional consideration bearing in mind that pilots have strong local knowledge and are trained to			

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				prevent manoeuvring incidents with timely intervention.			
SOLAS Chapter V	Safety of navigation.	II. There are several provisions (e.g. Reg 14) that require sufficient and efficient manning. Contracting States are required to do this through the establishment of a transparent documentary procedure, i.e. ships' manning documentation. So, it can be questioned whether a requirement of manning adequacy necessarily prohibits unmanned operability, since an unmanned ship is not at all manned, by definition.	R, RU and A	**Recommendation:** Include the following requirements to be considered: - A prescriptive requirement of three compulsory blocks which are: ship control system, connectivity and remote control centre with their associated functionalities that enable an unmanned ship to manoeuvre as responsively as when under the command of a conventional onboard crew. - Grant a manning exemption by the administration once the high-level technical requirements are specified for autonomous ships at autonomy levels RU and A. - Specify a maximum duration of autonomy for the unmanned operation. **Justification:** If an autonomous ship utilises highly innovative communications technology enabling it to manoeuvre as responsively as when under the command of a conventional onboard crew, an onboard crew numbering zero may be technically adequate. The regulation's aim is to establish a mean by which the relevant administration may satisfy itself in terms of the ship's compliance with the safety credentials rather than calling for any particular mode of operability. However, gaining the approval of maritime administrations may prove very difficult, particularly			✓

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				in the early phases of unmanned operability and in the absence of bespoke and codified regulations for particular operations. Once the high-level technical requirements are clearly specified, administrations can issue a manning exemption for autonomous ships at autonomy levels RU and A and allow the unmanned operation with a maximum duration of autonomy.			
SOLAS Chapter V	Safety of navigation.	III. Due to the ship's remote-control functions, requirements for remote control locations should be included.	R, RU and A	**Recommendation:** Include the requirements for RCC locations as a place that ensures good connectivity to the ships. It should be accessed 24/7 and has the capability of accommodating a single or a fleet of ships. **Justification:** The location for Remote Control Centre (RCC) should be in a place that ensures a good connectivity to the ships. In addition, the RCC should be an environment that has the capability to operate 24/7 and that provides tools to perform both remote (direct control) and autonomous operations to a single ship or a fleet of ships.		✓	
		IV. Amendments should also be considered for requirements about: a. Bridge design	R, RU and A	**Recommendation:** Include the following requirements to be considered: - Definition of "electronic bridge". - Requirements for the design and location of the workstations on the bridge to enable the ship to be navigated and manoeuvred safely and efficiently by one navigator.		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		(Regulation 15 prescribes principles in relation to bridge design)		**Justification:** In an autonomous shipping context, navigation will be performed remotely from the shore or autonomously by the system. Therefore, a "physical bridge" needs to be changed with an “electronic bridge” but any substitute of such an "electronic bridge" will need to comply with safety standards and satisfy at least the spirit of the provisions, which means the electronic bridge would have to comply with the bridge design requirements. The definition of "electronic bridge" is included in Section 2.2. The requirements for the design and location of the workstations are described in D5.5 - RCC Ergonomic Design, however, kept confidential for this project.			
SOLAS Chapter V	Safety of navigation.	b. Carriage of equipment	R, RU and A	**Recommendation:** Include the following requirements to be considered: - For retrofitted ships, no amendment is needed, whereas for new buildings and NGAS, new designs are expected without the same ship systems and equipments. - ECDIS mapping of the communication coverage zones. **Justification:** If a conventional ship is retrofitted for autonomous and remote operations, the same shipborne navigational systems and equipment could be kept as these are already installed and expected to be used at a low autonomy level with some crews on board in certain cases. However, the existing software needs extensive updates to be		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				able to integrate to the autonomous technologies. Later on, these equipments could be removed if the ship is planned to sail on fully autonomous mode as a NGAS. It is also suggested to include into the voyage plan of "Regulation 34 - Safe Navigation and Avoidance of Dangerous Situations" an item for geographic mapping of the coverage zones per communication carrier as a shipboard procedure with regular updates same as for the nautical chart updates and transmit in the ENC compatible IHO format. Overlaps offering the required redundancy in communication can then be established. Prohibit passage beyond the areas, where the redundancy in ship-shore communication is not guaranteed. .			
		c. VDR performance (To assist in casualty investigations, ships, when engaged on international voyages shall be fitted with	R, RU and A	**Recommendation:** Include the following requirements to be considered: - VDR to store all necessary information if the shore data storage is limited. - Include the command log and transmission log for the ship-shore communication into the data replicated to the shore. - Specify the minimum duration of storage. **Justification:** For autonomous ships, logging of ships' operation data must be made compulsory. As autonomous ships need to undergo continuous information sharing with the shore, the operational data must be stored in more than one place so as		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		VDR. However, administrations may exempt ships from being fitted with VDR if interfacing a VDR with existing equipment on the ship is unreasonable and impracticable)		to access it in case of incidents. Consideration must be given to include the command log and transmission log for the ship-shore communication into the data replicated to the shore. The minimum duration of storage data should also be defined to follow. This would be a major improvement compared to a VDR (Voyage Data Recorder) in conventional ships. In addition, voice data, CCTV footages and videos etc. should be recorded at RCC. The operational data generated by MASS will play an imperative role in clarifying circumstances and determining fault in the event of marine casualties. Presumably, insurers will, as part of the insurance terms and conditions, require access to operational data in connection with claims handling. Furthermore, it is essential to ensure who is in control of the ship in relation to the placing of responsibilities as well as a change of autonomy levels. This could be done by issuing electronic certificates to the ones responsible when changing the watching/taking over control of the ship.			
SOLAS Chapter V	Safety of navigation.	d. Visibility	R, RU and A	**Recommendation:** Include the following requirements to be considered: - A provision to consider necessary advanced onboard situational awareness technologies.		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				- An exemption should be granted for navigational bridge window design for autonomous ships at autonomy levels RU and A as there will be no crew to utilize the design. - No action is required for Regulation 3 mentioning the alternative arrangements for any unconventional ship. **Justification:** It is arguable that the advanced onboard situational awareness sensors/cameras/radar/LiDAR is sufficient to meet all provisions mentioned in Regulation 22-1(1-8) for autonomous ships. To ensure the proper functioning of the sensors/radar units, as well as non-obstructed visibility, the minimum height of the sensors/cameras and the maximum height of the cargo should be set. For navigational bridge window design, requirements mentioned Regulation 22-1(9), might become obsolete for autonomous ships at higher autonomy levels, RU and A as there will be no crew onboard to utilize such window design. Regulation 3 mentions alternative arrangements for any unconventional ship shall be provided to achieve a level of visibility that is as near as practical to that prescribed in this regulation. Thus, this rule provides no barrier to autonomous ships' operability.			

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
SOLAS Chapter V SOLAS Chapter V	Safety of navigation. Safety of navigation.	V. Certain duties cannot be conducted on board due to the lack of crew on board. Amendments should be considered in particular about minimum safe manning, crew duties (e.g. engine control including Chief Engineer and Chief Electrician role, Pilot transfer arrangements etc.), priority of control and operation, autonomous navigation function during specific conditions (e.g. night, fog, storm, failure in systems),	R, RU and A	**Recommendation:** Include the following requirements to be considered: - Essential KETs to replace the onboard crew for remote or autonomous operation. - A pilotage exemption for autonomous ships unless they could be supervised remotely by an RCC operator. - Defining the fallback functions to execute in case of unforeseen situations. **Justification:** Autonomous ships could replace the crews on board by establishing Intelligent Machinery Systems (IMS) / Digital Chief with the aid of technologically advanced sensors, cameras and communication and network systems. This will enable the remote operator at RCC to get a proper electronic lookout of the engine/machinery room while navigating. For autonomous ships, it is expected to get pilotage exemption. However, if pilotage becomes necessary, Pilot embarkation (Reg. 23/2.2) shall be supervised remotely by a remote operator at RCC unless there are any crew on board. In case of distress/unforeseen situation (e.g. night, fog, storm, failure in systems), fully autonomous ships must execute its fallback functions and alert a remote operator to take control of the ships. The duty of the RCC personnel may be discharged by ensuring that any distress signals/ danger		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				messages received at RCC are relayed either directly or through the communication hub to the Maritime Rescue and Coordination Centres (MRCCs). Most importantly, Regulation 3 mentions that the marine administration may grant exemptions and equivalence when there is an absence of potential navigational hazards and no elements affecting the safety. Thus exemptions could be granted for certain cases for autonomous ships. However, the potentiality of unmanned ship operators to convince relevant authorities matters a lot.			
SOLAS Chapter VI & VII	Carriage of cargoes, oil fuels and dangerous goods	I. In general, the meanings of "master", "crew", "responsible person", etc. should be clarified, taking account that they are not on board.	R, RU and A	Same as mentioned in SOLAS Chapter II-1, No. XIV	✓		
		II. Some provisions require manual operations and other actions by personnel on board, e.g. inspection, cargo management and emergency	R, RU and A	**Recommendation:** Include the following requirements to be considered: - The cargo-operations-related obligations for autonomous ships at port. - Essential KETs to facilitate the automatic fire detection/mitigation, spillage detection/containment and operation of safety doors.			✓

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		conditions/procedures to deal with conditions of leakage, spillage or fire involving cargoes. Therefore, appropriate alternative safety measures should be adopted to achieve the functionalities intended by the existing regulations, including for example the cargo management performed from the Remote Control Centre.		- A centralised manual override station located onboard. - The fallback state management with MRCs defined. - The requirement to system architecture as a goal-based approach. - Introduce the term "temporary intervention personnel" for the persons boarding to complete routine operational scope. **Justification:** The cargo-related operations which require human intervention should be conducted at port for autonomous ships when the inspection/preparation will be carried out for the next trip. In this regard, the condition before departure/arrival must be legislated to prevent accidents and pollution. On the other hand, with the aid of technologically advanced sensors, high-definition surveillance cameras and communication and networks system, it is possible to carry out automatic fire detection and mitigation, automatic spillage/flooding detection and shut down of safety doors if necessary, remote cargo monitoring etc. However, the manual control of the extinguishing media release for the CO_2 fire extinguishing fixed system in the engine room as described in the FSS code within SOLAS is in conflict with the automatic control proposal. Due to the fact that it may lead to fatalities for the personnel accessing the engine			

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				room for maintenance, alternatives should be thought of. One of the solutions for unmanned ships is to introduce into SOLAS a requirement for a centralised manual override station located onboard that allows disabling the automatic control of the ship's subsystems by the attending personnel, e.g. CO_2 to manual when attending the protected spaces in the engine room, preparing an underwater survey of the fully autonomous ships etc. It is also essential to specify the fallback state management with MRCs defined. This will allow initiating the fallback functions to maintain pre-defined Minimum Risk Conditions (MRC) if the system or communication to ship fails at some point. If any alternative safety measures have to be adopted for autonomous ships, these must demonstrate the same safety level as that of manned ships. In this regard, as provided in D2.4 [20], the ALARP (as low as reasonably possible) likelihood can be set as a goal to achieve as a result of a design of autonomous ships at autonomy levels RU and A. If the ALARP can be set as a goal for autonomous ships, then the framework of Safety Integrity Levels can be potentially used as in IEC 61508. In addition, it is possible to sort out the findings from D2.4 into several short examples of barrier combinations that allow an acceptable			

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				likelihood and to use these examples as a justification and proof of feasibility. Consider introducing the term "temporary intervention personnel" for the persons boarding to complete routine operational scope, not to be confused with the damage control team.			
SOLAS Chapter VIII	Nuclear ships	Out of Scope					
SOLAS Chapter IX and the ISM Code	Management for the safe operation of ships	I. Requirements presuppose that ships are operated by a crew on board, and certain activities will be carried out remotely from the ship. These requirements should be amended and requirements about remote monitoring and remote control should be added, including among others:	R, RU and A	**Recommendation:** Include the definition of RCC, RCC personnel and different levels of autonomy in Reg 1. In addition, ship handover management should be included once the autonomous ships are intended for an international voyage. **Justification:** All necessary activities mentioned in this chapter should be carried out remotely from RCC with proper compliance. A remote operator controlling the ship remotely at RCC will be responsible to comply with all duties rested on the master on board. **Ship handover management:** If autonomous ships are intended for an international voyage, one must think of ship handover management from one RCC to another as a part of the ship safety management system, and it must be a part of ISM code.		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		a. ship handover management from one Remote Control Centre to another		However, involving autonomous ships in an international voyage would take time. For the time being, Short Sea Shipping and Inland Waterways (as considered in the AUTOSHIP project) could be thought of for their initial operability. In such cases, operating from one RCC would be enough to ensure its safe operation.			
SOLAS Chapter IX and the ISM Code	Management for the safe operation of ships	b. maintenance management	R, RU and A	**Recommendation:** Include the following requirement to be considered: - The details of maintenance management considering the fact that the maintenance/repair works of autonomous ships are conducted at port or in moored condition only. - The necessity of certifying the RCC for both Document of Compliance (DOC), Safety Management Certificate (SMC). **Justification:** Maintenance and repair work on board will be performed when the ship is moored. A system for the administration of work permits will be organised by RCC, possible in cooperation with human resources at the destinations. The ship and equipment onboard will be arranged for unattended operation. Condition monitoring and self-diagnostics together with planned preventive		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				maintenance routines will be prepared for the expected ship availability and reliability. Software maintenance will only take place when the ship is moored and idle. It is also suggested to have Document of Compliance, Shore fleet Management Certificate, Safety Management Certificate, Onboard Ship Management Certificate etc. for the RCC.			
		II. The ISM Code would affect not only the personnel on board but also personnel onshore involved in MASS operations.	R, RU and A	**Recommendation:** Include an interpretation considering the RCC personnel as a responsible authority to comply with the ISM Code. **Justification:** The remote operator and other RCC personnel who involve in MASS operations must comply with the responsibilities and authority mentioned for the manned ships in ISM Code. In this regard, the ISM Code could include any special provision relevant to safe management of remote/autonomous operation of ships.		✓	
		III. Requirements associated with the safety of persons on board only apply when such persons are present on board. Conversely, such requirements naturally not apply where no persons	R, RU and A	**Recommendation:** Include the following requirements to be considered: - A provision to cover the manned and unmanned operation of autonomous ships and transfer of control in case of emergencies in the Safety Management System (SMS) manual. - Conducting an assessment on operational risk management as a part of the shipowner's Safety Management System.		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		are intended to be on board.		**Justification:** As maintenance and repair work will be performed on board when the ship is moored, a minimum safety standard for persons on board must be maintained for autonomous ships. Additionally, a special assessment on operational risk management for autonomous ships should be included as a part of the shipowner's Safety Management System. It is also suggested to explicitly indicate the requirement for the SMS manual to cover the manned and unmanned operation, transfer of control and emergencies, however, the present wording of ISM code does not prevent compliance.			
SOLAS Chapter X	High-speed craft	Out of scope					
SOLAS Chapter XI-1 and the Casualty Investigation Code	Special measures to enhance maritime safety	I. Functions, rights and responsibilities of Remote Control Centre, including qualification of personnel, should be defined.	R, RU and A	**Recommendation:** Include the functions, rights, responsibilities and qualifications of RCC personnel. **Justification**: The functions, rights and responsibilities of an RCC for SSS and IWW would be the same. Appendixes B and E include the information regarding the RCC functionalities and responsibilities, respectively. The qualification of RCC personnel could be found in AUTOSHIP Deliverable 7.2 [40] (Training framework for crew, operator and designer) Table 27 and Table 28. In regard to the training period,		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				tables in Chapter 7 of D7.2 provide useful information. Examples of proposed requirements for the remote operator are: 1) Remote operators will, as a minimum, be required to have completed ordinary education and training as a navigating officer and to meet the relevant requirements under the STCW Convention. 2) He/she should have other competencies necessary to steer an autonomous ship, i.e. especially education, training and qualifications within operational technology ("OT") and other relevant technology of importance to the steering of autonomous ships.			
SOLAS Chapter XI-1 and the Casualty Investigation Code	Special measures to enhance maritime safety	II. The regulation concerning Continuous Synopsis Record (SOLAS Reg. XI-5) should be amended considering that the Continuous Synopsis Record would be done in the Remote Control Centre.	R, RU and A	**Recommendation**: Include a provision to facilitate both RCC and onboard ship with the CSR record. **Justification:** Continuous Synopsis Record should be done at RCC, and to meet the provisions of this regulation, an electronic/printed version of it needs to be readily available onboard for inspection purposes. The administration of autonomous ships should issue this CSR containing the information listed in Regulation XI-5.	✓		

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
SOLAS Chapter XI-1 and the Casualty Investigation Code	Special measures to enhance maritime safety	III. The regulation concerning Port State Control procedures for controlling that the master or crew are familiar with essential shipboard procedures relating to the safety of ships (SOLAS Reg. XI-1/4.1.) should be amended considering that the master and crew are not on board.	RU and A	**Recommendation:** Include the following requirements to be considered: - The requirement of the Shipowner/Company to provide the technical means of communication between the PSC inspectors and the RCC operators including communication while the PSC inspectors are onboard at autonomy levels RU and A. - Consider the training for the RCC personnel in the essential shipborne procedures. **Justification:** In the context of unmanned autonomous ships, this provision could be met if the authorized port officers could get access to the ship and interview the operator at RCC regarding essential shipboard procedures. This authority of access should be both physically (to enter the ship) and remotely (to communicate with RCC). Due to this reason, the remote operators at RCC should be trained in the essential shipborne procedures. This will be the shipowner/Company's responsibility to provide the technical means of communication between the PSC inspectors and the RCC operators including communication while the PSC inspectors are on board.		✓	
		IV. Chapter 12 of the Casualty Investigation Code concerning	R, RU and A	**Recommendation:** Include an interpretation to consider the RCC operator as a master of autonomous ships, and therefore, involve him/her in any marine casualty investigation.	✓		

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		evidence obtained from seafarers and Chapter 8 concerning the powers of investigations should be amended to include also the Remote Control Centre and personnel.		**Justification:** Chapter 12 of the Casualty Investigation Code concerning evidence obtained from seafarers needs to consider remote operator as a master for autonomous ship and other relevant personnel as crews while investigating as there are no seafarers on board an autonomous ship at higher autonomy levels. Chapter 8 should also be amended to include the rights to investigate the RCC personnel and acquire evidential materials from RCC in any safety investigation.			
		V. The requirements of having certificates and manuals on board should be amended.	R, RU and A	**Recommendation:** Include a provision of making the copies of certificates or transmitted those electronically as it is not acceptable to provide originals of the certificates onboard of autonomous ships. Facilitate both RCC and onboard with the necessary certificates. **Justification:** Manuals are necessary to be kept at RCC, whereas the electronic/printed version of certificates could be kept on board for inspection purposes. The manuals related to the emergency response onboard a ship shall be kept in a paper format including all drawings. The locker with drawing could be accessed for inspection and emergency with RCC notified when its lock is operated.	✓		

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
SOLAS Chapter XI-2 and the ISPS Code	Special measures to enhance maritime security	I. The regulations concerning the definitions (SOLAS Reg. XI-1/1 and ISPS Code Section A/2) should be amended.	R, RU and A	**Recommendation:** Include the following requirements to be considered: - Define RCC Security Plan and RCC Security Officer. - Consider the RCC Security Officer as a separate identity who is responsible only for the RCC premises and not for the ships as assets. - Consider Ship Security Officer to inspect the autonomous ships periodically. - Define the critical functionalities for RCC Security Officer and a Plan, such as how to access the RCC premises ashore, how it is controlled and how access to the system is gained to prevent hijacking the ships from the RCC control station. **Justification:** Some definitions need to be added in ISPS Code Section A/2, such as RCC security plan, and RCC security officer. **RCC security plan** means a plan developed to ensure the application of measures at RCC designed to protect cargo, cargo transport units, ship's stores or the ship from the risks of a security incident. **RCC security officer** means the person at RCC, designated by the Company as responsible for the security of the ship, including implementation and maintenance of the ship security plan and for liaison with the company security officer and port facility security officers.	✓		

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				Some other definitions could be added in SOLAS Reg. XI-1/1 from Section 2.2 of this report which are relevant to the MASS operation. It is recommended to avoid any changes to the term Ship Security Officer and Company Security Officer as the duty of performing regular inspections cannot be removed in principle. It is necessary for Ship Security Officer to periodically board the autonomous ship for inspection or designated it to the trusted personnel of a port facility and employ the remote survey techniques as given in IACS UR Z29 [38]. For RCC Security Officer and a Plan, it is critical to put focus on the access to the RCC premises ashore, how it is controlled and how access to the system is gained to prevent hijacking the autonomous ships from the RCC control station. RCC Security Officer shall be responsible only for the RCC premises and not for the ships as assets.			
SOLAS Chapter XI-2 and the ISPS Code	Special measures to enhance maritime security	II. The regulations concerning the alternative security agreements (SOLAS Reg. XI-2/11) and the equivalent security arrangements (SOLAS Reg. XI-2/12) could allow	R, RU and A	**Recommendation:** Include any special shipboard plans and arrangements if necessary. Otherwise, no action is required. **Justification:** In an autonomous shipping context, there must be a similar ship-to-shore alert mechanism in place to alert those at the shore-based facility as to when the ship's physical or cyber-security has been compromised. To consolidate this alert mechanism system, alternative security agreements (SOLAS Reg. XI-		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		for creating special shipboard plans and arrangements for crewless ships.		2/11) and the equivalent security arrangements (SOLAS Reg. XI-2/12) could be enforced to create special shipboard plans and arrangements.			
		III. Functions, rights and responsibilities of Remote Control Centre should be defined in the ship security plan.	R, RU and A	**Recommendation:** Include the following contents in form of amendments within the Ship Security Plan for unmanned autonomous ships. - Procedures for granting access for pilots, maintenance personnel and damage control party - Procedures for response to unauthorised access - Measures to counter hijacking by direct boarding - Measures to remotely disable the ship to prevent its use for terrorist threats - Measures to organise remote security inspections when the ship is in port - Measures to control the movement inside the ship and detect a breach by redundant means **Justification:** The regulations concerning the ship security plan (ISPS Code Section 9) could allow for establishing the relevant roles and obligations for the functions required when no persons are on board. Indeed, the ship might be protected and secured by dedicated electronic surveillance, protection and alarm system, as any industrial and/or financially important facility onshore and would not be relying on human presence. Such a system could be remotely supervised and controlled. However, amendments are necessary		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				to include some additional contents (mentioned above) within the ship security plan as a safeguard of any physical threats of unmanned ships.			
SOLAS Chapter XI-2 and the ISPS Code	Special measures to enhance maritime security	IV. It should be clarified: a. How to respond without undue delay to any changes in security levels.	R, RU and A	**Recommendation:** Design an autonomous ship sailing at autonomy levels RU and A for Security Level 3 by default with a single controlled access point where a single person can only enter after a remote authorisation from RCC. **Justification:** Security Level 3 should be considered for autonomous ships at autonomy levels RU and A. With Security Level 3, the ship will be accepted at any facility with lower levels The following measures should be put in place with the highest degree of vigilance and detail: [39] Limiting access to a single, controlled access point Granting access strictly to authorised personnel or those responding to any security incident Suspension of embarkation and disembarkation Suspension of cargo operations and stores etc. If needed, the evacuation of the ship Close monitoring of the movement of the people on board Preparing for a full or partial search of the ship With the aid of technologically advanced sensors, cameras, and communication and network systems, autonomous ships can enhance security awareness and vigilance onboard. They can also		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity L	Level of severity M	Level of severity H
				provide an electronic lookout of the vicinity of the ship to the remote operator at RCC, continuously monitoring those, triggering alarm to the operator if necessary to Request to Intervene (RTI), and initiating the fallback functions, such as sending text messages to the appropriate authority if the alarm is unattended for a certain time. The will definitely help to respond to any changes in security levels without any undue delay and report all security incidents to the Administration or Contracting Government.			
		b. How to notify the appropriate authority prior to ship-to-ship interface or prior to entry into port.	R, RU and A	**Recommendation:** No action is needed **Explanation:** Autonomous ships should follow the current ISPS reporting requirements to notify the appropriate authority, which is usually by Email. It is the remote operator's responsibilities to notify the appropriate authority prior to the ship-to-ship interface or entry into port, whichever occurs earlier if they are not in compliance with the ISPS codes or requirements of the security level.	-	-	-
		c. How to comply with threats to ship where a risk of	R, RU and A	**Recommendation:** Include the following requirements to be considered: - A provision considering ✓advanced situational awareness technologies onboard to facilitate the remote monitoring of autonomous ships.		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		attack has been identified, whether it is under threat or security has been compromised		- The responsibilities while/after detecting any threat should be delegated and situated to the remote operator at RCC. - A provision of automatic activation of Ship Security Alert system (SSAS) if the local control is taken over while the ship is a mode precluding the presence of personnel on board. **Justification:** High-tech sensors, cameras, and communication and network systems will be utilized to establish an advanced remote monitoring system to detect any risk of attack on the ship. If any threat is detected, a remote operator at RCC should ask for assistance or advice or report the security concern to a point of contact provided by the contracting authorities. In this regard, the Contracting Government should have the responsibility to set and ensure the provision of security level information to autonomous ships operating or having the intention to operate in their territorial sea (Ref. Chapter XI-2, Regulation 7). Activation of an automatic Ship Security Alert System (SSAS) should be ensured if the local control is taken over while the ship is a mode precluding the presence of personnel onboard.			
		d. How to initiate and transmit a ship-to-shore	R, RU and A	**Recommendation:** Insert the following wording into SOLAS: "If the RCC personnel fail to respond to the alarm system in due time, the Ship Security Alert System (SSAS) shall be activated automatically and		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		security alert		predefined fallback functions shall be executed to ensure the ships within a corresponding Minimum Risk Conditions (MRCs)." **Justification:** Autonomous ships could utilize technologically advanced CCTVs and other surveillance devices to establish an enhanced security awareness system to detect any abnormalities or physical threats. If so, the onboard awareness system will trigger an alarm via an uninterrupted and secure communication system (as mentioned in SOLAS Chapter IV, No II) to the operator at RCC and request to intervene, i.e. to identify any changes in security levels and report all security incidents without any undue delay to the Administration or Contracting Government. If somehow the RCC personnel fail to respond to the alarm system in due time, the pre-defined fallback functions will be executed to ensure the ships are within Minimum Risk Conditions (MRC).			
		e. How to comply with alternative security agreements for any ship-to-ship activities	R, RU and A	**Recommendation:** No action is required. Follow the same procedure as for conventional ships. **Justification:** Alternative agreements are bilateral or multilateral agreements that the Contracting Governments sign with other Contracting Governments to enforce part A of ISPS code and consider alternative security arrangements covering short international voyages on fixed routes between port facilities located within their territories. This agreement is mandatory for any ship-to-ship	-	-	-

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				activities. In the context of autonomous ships, a remote operator at RCC or any onboard crew (at autonomy level R) could engage in necessary ship-to-ship activities without an issue, therefore, autonomous ships could be considered within the scopes of the agreements.			
SOLAS Chapter XII	Additional safety measures for bulk carriers	Out of scope					
SOLAS Chapter XIII	Requirements about verification of compliance	No amendments, new required developments or other relevant findings have been identified			-	-	-
SOLAS Chapter XIV	Requirements about safety measures for ships operating in polar waters	Out of scope					
ISM Code		See SOLAS Chapter IX.					
ISPS Code		See SOLAS Chapter XI-2.					
Load Line Convention	Refer to Table 4	I. In the context of autonomous ships, the equivalent person who will perform the duties/responsibilities of the master should be	R, RU and A	Refer to SOLAS Chapter II-1, No XIV	✓		

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		identified. It should be clarified in the relevant provisions.					
		II. There are numerous instances of provisions which presume/require manual intervention for their application (e.g. valves, windows, side scuttles, skylights, deadlights and storm covers operation). Considering no seafarer on board, such provisions should be amended where manual intervention/presence of crew on board is required/presumed.	RU and A	**Recommendation:** Include a paragraph on the autonomous ships at autonomous levels RU and A requiring to have: - Automatic closing devices and closure status sensors for the internal watertight bulkheads and ventilation - A plan for closing the other external openings by port services if it is delegated - A plan for closing devices for the external openings where the port services cannot be delegated with a task of closing - Specify the need for the manual local override where an automatic closing device is installed to prevent injuries for the attending personnel **Justification:** The provisions which require manual intervention for their application should have the option to be operated autonomously by an onboard ship control system or remotely by an operator at RCC for autonomous ships at different autonomy levels. In this regard, the opening and closing of valves, windows, side scuttles, skylights, deadlights etc. could be ensured by the system/RCC personnel by establishing a precise monitoring		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				system including high-resolution cameras/sensors to detect any abnormalities and set the alarm if so. However, some of these equipments might fail to close fully. Therefore, if the equipment is crucial for safety (eg. Oily water overboard valve), redundancy must be ensured. Monitoring the valve pressure while opening/closing any valve remotely could enhance the safety level too. A separate plan is also needed for closing the other external openings by port services if it is delegated and where the port services cannot be delegated with the task of closing. It is also necessary to specify the need for the manual local override where an automatic closing device is installed to prevent injuries for the attending personnel			
Load Line Convention	Refer to Table 4	III. In the same way, there are explicit/implicit assumptions in the ICLL 'General notes' that certain pre-departure functions have to be accomplished by master and crew, such as safe loading and ballasting of the ship with respect to	RU and A	**Recommendation:** Include an interpretation to consider an RCC operator to be responsible for accomplishing the pre-departure functions of autonomous ships at autonomy levels RU and A. **Justification:** If the master is not on board the ship, it must be presumed that the obligation can still be met by the steering/monitoring officer at the remote control centre when the ship is at port. The essential must be that the relevant information from the sensors/cameras is available to him as the basis for this decision competence in relation to the operation of the ship.		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		LL marks, stability and bending stresses. Considering no seafarer on board, responsibility for these pre-departure functions should be addressed.					
Load Line Convention	Refer to Table 4	IV. The ICLL contains several provisions for the protection of the crew (i.e. guard rails elevated walkways, etc.). Considering no seafarer on board, these features could be not necessary.	RU and A	**Recommendation:** No action is required. **Justification:** The provisions that are relevant to general human safety should not be compromised for autonomous ships. This is because people for different reasons, such as inspectors from classification societies to do periodic inspections, pilots for port state navigation, PSC inspectors for security reasons or any repair workers need to be onboard when the ships are moored at port.	-	-	-
Tonnage Convention	Refer to Table 4	I. The regulation referring to the crew and the master while defining a passenger (Annex I, Reg. 2(6)) should be amended. The definition of the	R, RU and A	**Recommendation:** Include the following amendment for Annex 1, Reg. 2(6). Also, include the designation of an RCC operator as a master of autonomous ships at autonomy levels RU and A. Annex 1, Reg. 2(6) could be modified as: A passenger is every person other than:	✓		

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		master should be clarified.		(a) the master or remote operator and the members of the crew or RCC personnel or other persons employed or engaged in any capacity onboard on the business of that ship; and (b) a child under one year of age Definition of 'master' could be added by referring to SOLAS Chapter II-1, No XIV			
STCW Convention and Code	Refer to Table 4	I. As a rule, the STCW convention does not apply because there are no trained and qualified seafarers on board the ship to perform the operational functions.	R, RU and A	**Recommendation:** Include the texts clarifying the training frameworks used for RCC operators and their qualification from the D7.2 of AUTOSHIP project. In addition, include the minimum amount of hours under supervision and simulator training necessary for RCC operator to be certificated. **Justification:** Every seafarer/watchkeeper needs to go through the training in accordance with the STCW convention and it has no connection with a change of the bridge watch to either an electronic bridge at RCC or below deck. However, unmanned operability introduces an entirely new range of personnel changes into the maritime domain. During such changes, a new training framework needs to be developed. Since human operators are not removed but shifted from onboard to the onshore control centre in the present autonomous ship concept, the STCW convention is still useful to train and certify human operators. However, in order to reflect the changed circumstance, modification of the STCW is		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				required. Table 27 and Table 28 of D7.2 [40] of AUTOSHIP project list the recommendations which reflect the characteristics of autonomous shipping. In regard to the training period, tables in Chapter 7 of D7.2 provide useful information. Chapter VIII, Regulation 2(2)(1) needs to be amended so as to allow the watchkeeping navigational officers periodically be somewhere else than onboard the ship as well as other arrangements, such as supervision of first line RCC operators.			
STCW Convention and Code	Refer to Table 4	II. The definition of seafarers should be clarified in order to distinguish between those individuals with operational responsibilities and those with other duties.	RU and A	**Recommendation:** Include an interpretation considering an RCC operator steering/monitoring autonomous ships at autonomy levels RU and A as a master who can be from a seafarer background, whereas the maintenance and repair work on board will be performed when the ship is moored by local personnel. **Justification:** In the context of an unmanned ship, the remote operator at RCC who can be from a seafarer background, will take most of the rights and obligations resting with the master under current regulations, such as navigational obligation, ship's/shipowner's representative in regard to the authorities and, to some extent, the obligation to take care of the cargo after it has been loaded. On the other hand, maintenance and repair work onboard will be performed when the ship is moored by local personnel. In this regard, a system for the	✓		

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				administration of work permits will be organised by RCC, possible in cooperation with human resources at the destinations.			
STCW Convention and Code	Refer to Table 4	III. There is a need to establish if the remote operator is a seafarer.	R, RU and A	**Recommendation:** Include the texts clarifying the training frameworks used for RCC operators and their qualification from the D7.2 of AUTOSHIP project. In addition, include the minimum amount of hours under supervision and simulator training necessary for RCC operator to be certificated. **Justification:** One would expect the remote operator/RCC personnel to have a good understanding of navigational matters, as with seafarers; but given that they are not expected to go onboard, some matters relevant to traditional seafarers' qualifications may be able to be omitted. Conversely, however, some further qualifications may well be necessary: notably, a good technical knowledge of the relevant computer and communication systems how to deal with an emergency within the RCC and how to respond to an emergency condition onboard the ship or in respect of an maritime search and rescue (SAR) request. Requirements in relation to qualification, education, training, certification and watchkeeping schemes and watchkeeping principles for remote operators are developed within the scope of AUTOSHIP project for D7.2 (Training framework for crew,		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				operator and designer). Table 27 and Table 28 of D7.2 [40] list the recommendations which reflect the characteristics of autonomous shipping. In regard to the training period, tables in Chapter 7 of D7.2 provide useful information. Some of the proposed requirements are: 1) Remote operator will, as a minimum, be required to have completed ordinary education and training as a navigating officer and to meet the relevant requirements under the STCW Convention. 2) He/she should have other competencies necessary to steer an autonomous ship, i.e. especially education, training and qualifications within operational technology (”OT”) and other relevant technology of importance to the steering of autonomous ships.			
STCW Convention and Code	Refer to Table 4	IV. There are gaps throughout the requirements with respect to the introduction of the remote operator, including training, certification and medical requirements, control procedures, the standard of competence, hours	R, RU and A	**Recommendation:** Include the texts clarifying the training frameworks used for RCC operators and their qualification from the D7.2 of AUTOSHIP project. In addition, include the minimum amount of hours under supervision and simulator training necessary for RCC operator to be certificated. **Justification:** All these gaps could be mitigated by the development of a training framework for RCC personnel and considering the STWC convention in the arrangement where relevant. Since human operators are not removed but shifted from onboard to the onshore control centre in the present		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		of rest, prevention of drug and alcohol abuse, watchkeeping provisions etc.		autonomous ship concept, the STCW convention is still useful to train and certify human operators. However, in order to reflect the changed circumstance, modification of the STCW is required. Table 27 and Table 28 of D7.2 [40] of AUTOSHIP project list the recommendations which reflect the characteristics of autonomous shipping. In regard to the training period, tables in Chapter 7 of D7.2 provide useful information. The same provision regarding drug and alcohol abuse would apply for the RCC as for the ship.			
STCW Convention and Code	Refer to Table 4	V. It should also be considered that systems on board will incorporate functions that crew currently conducts. All tasks will be not moved from crew to remote operators. Some tasks will be performed by systems on board.	R, RU and A	**Recommendation:** Include the provision considering the KETs to facilitate the remote steering/monitoring of autonomous ships. In addition, include the four different types of tasks for RCC personnel namely, monitoring, supervision, intervention and direct control which may vary from time to time depending on the complexity and scope of the operation. **Justification:** Autonomous ships will replace the onboard crews by establishing an onboard Intelligent Machinery System (IMS) / Digital Chief and Autonomous Navigation System (ANS) / Digital Captain. These systems will enable the remote operator at RCC to monitor/control the ships if necessary by providing a proper electronic lookout in the vicinity of the ship and machinery spaces. However, the tasks defined by the RCC operator will vary depending on the complexity and scope of		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				the operation. In general, four different types of tasks could be identified for RCC personnel, namely, monitoring, supervision, intervention and direct control. A detail of these tasks could be found in Appendix D of this report.			
COLREG Convention	Refer to Table 4	I. A crewless ship could be constructed differently from a conventional ship. As a result, a separate section could be required within the annexes similarly to Annex I (/13 with High-Speed Craft which defines positioning and technical details of lights and shapes.	R, RU and A	**Recommendation:** Include special regulations about navigational signs (a part of discussion) that are required to distinguish between manned and unmanned ships. **Justification:** Navigational lights and shapes are useful to convey various information to other ships at night. Hence, autonomous ships must meet the provisions mentioned on lights and shape in COLREG. However, special regulations about navigational signs are required to distinguish between manned and unmanned ships. It should be noted, however, Governments may accept “closest possible compliance” with the requirements of Parts C and D in respect of “number, position, range or arc of visibility of lights and shapes as well as the … characteristics of sound signalling appliances” in respect of ships of “special construction or purpose” (Part A, Rule 1(e)).		✓	
COLREG Convention	Refer to Table 4	II. It should be clarified how to demonstrate the ability of a	R, RU and A	**Recommendation:** No action is required. **Justification:** For autonomous ships, a remote operator at RCC could initiate the aural, visual,	-	-	-

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		crewless ship to indicate distress using the signals (Annex IV)		radiotelephonic, radiotelegraphic or EPIRB signals remotely to indicate distress signals. As there are a number of options available in Annex IV to use or exhibit either together or separately, this provision will not provide any barrier to autonomous ships' operability.			
		III. It also should be clarified on how to demonstrate the ability of a remote operator or automated ship control systems:	R, RU and A	**Recommendation:** Include the following requirements to be considered: - A perspective requirement of the three major building blocks for the autonomous ships with their associated functionalities and KETs.. - the key requirements to the testing procedure of the algorithm, including the data sets for the simulation environments, pass/ fail rate etc. for the fully automatic collision avoidance or ship berthing system,. Otherwise, it is already mentioned in the SOLAS amendments to consider three compulsory blocks in the architecture. These SOLAS requirements can be expanded with the performance criteria into "Regulation 18 - Approval, Surveys and Performance Standards of Navigational Systems and Equipment and Voyage Data Recorder ". **Justification:** To demonstrate the ability of a remote operator or automated ship control systems, the major functionalities of the three building blocks and the key enabling technologies (KETs) should be successfully developed. For the AUTOSHIP		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				project, the two main groups of key enabling technologies (KETs) identified are given below: Autonomous navigation systems / Digital Captain: 1. Situational Awareness system (perception system); 2. Automated Navigation System (collision avoidance, routing, etc.); 3. All-speed Dynamic Positioning System; 4. Connectivity and Cyber Security System; 5. Remote Control; 6. Operators stations; and 7. Logistics systems. Intelligent machinery systems / Digital Chief: 8. High availability machinery & Intelligent Asset Management Systems; 9. Hierarchical Alert & Energy Management; and 10. Predictive Condition Monitoring & Preventive Maintenance Support This report includes the major functional breakdown of these three blocks in Appendix B, which are going to be used in the demonstration cases in the AUTOSHIP project. For the fully automatic collision avoidance or ship berthing system, it would be required to specify key requirements to the testing procedure of the algorithm, including the data sets for the simulation			

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				environments, pass/ fail rate. These are available in the Autoship K-Sim validator D5.8 and can be reworked into a recap of the principles to follow in the performance testing. However, due to confidentiality issue, these are not disclosed in this report.			
COLREG Convention	Refer to Table 4	IV. How to assume the role of "Master or crew" (Rule 2 a). Rule 2 requires simultaneous human judgement in deciding COLREG prescribed manoeuvre, when it is required or alternatively, something potentially completely different.	R, RU and A	**Recommendation:** Include an interpretation to consider the distribution of the role of "Master or crew" between the means of the algorithm-based collision avoidance control and the RCC operator for autonomous ships at different autonomy levels. The following text could be inserted: "For remotely controlled/operated ships, RCC operator will be delegated and stipulated to perform the duty of a master. At higher autonomy levels, some of the duties, such as navigation will be transferred to the onboard ship control system which is pre-programmed to navigate the ships based on COLREGs-compliant collision avoidance algorithm with a possibility to intervene to remote operator at RCC." **Justification:** At autonomy levels R and RU, this judgement will be provided remotely by a remote operator at RCC who will act as a master of that ship. However, its compliance with the existing rules depends on the sophistication of the relevant communication technology.		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				Alternatively, Autonomous Navigation System (ANS) / Digital Captain will be pre-programmed with COLREGs compliant collision avoidance algorithm for fully autonomous ships to navigate without any human intervention.			
COLREG Convention	Refer to Table 4	V. How to reach the same standards required of those as a lookout on board (Rule 5), with particular reference made to difficult weather conditions and sea state and the ability to detect smaller ships that perhaps radar would struggle to identify. Referring to "sight and hearing", Rule 5 clearly requires human input in surveying and assessing the situation and collision risk.	RU and A	**Recommendation:** Include the following requirement to be considered: -An exemption for autonomous ships allowing the use of automatic visual and audio recognition equipments to facilitate the remote lookout onboard, which in turn, can be defined via SOLAS "Regulation 18 - Approval, Surveys and Performance Standards of Navigational Systems and Equipment and Voyage Data Recorder ". - Minimum requirements (still a part of discussion) for the coverage angles around the hull, resolution of camera and fallbacks for the cases where ambiguity in the object classification is encountered and requires human intervention. **Justification:** The use of sufficient aural and camera sensors in unmanned craft to project the ship's vicinity to the shore-based remote controller could satisfy the requirement of Rule 5. However, the use of electronic aids and shore-based orientation need to be clarified. It is also necessary to maintain the minimum requirements to the coverage angles around the hull, resolution of the camera and fallbacks for the cases where		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				ambiguity in the object classification is encountered and the system can request human intervention.			
		VI. How to ensure a safe speed to take proper and effective action to avoid collision and be stopped within a distance appropriate to the prevailing circumstances and conditions (Rule 6). This rule requires any foreseeable delay in communications or human-automation interaction should be factored into the safe speed calculation.	R, RU and A	**Recommendation:** No amendment is suggested for COLREG. However, include a performance criterion on the reactivity into the requirements to the collision avoidance algorithm. This insertion is also necessary into SOLAS "Regulation 18 - Approval, Surveys and Performance Standards of Navigational Systems and Equipment and Voyage Data Recorder **Justification:** The transfer of data to the shore-based remote controller and transfer back of orders to the ship inevitably will involve a delay of some duration, known as latency and it depends on the strength of network and communication systems. This consideration must be taken into account to meet the required provision. Furthermore, in most cases, it should be possible to organize the onboard crew or the personnel at the RCC so that they can get the maximum time after being alerted for a collision to reach the control position, gain situational awareness and are ready to perform actions to maintain safety and security. This time is called the maximum response time or T_{MR}. This T_{MR} will vary with how work is arranged on board and on shore and also with the degree of autonomy.		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				On the other hand, in many cases, it is also possible to determine a maximum time during which the automation can continue to operate safely when it is in a collision path without human assistance. This time is called the response deadline or T_{DL} This time will vary with the external situation, such as different Operation Envelopes, O. This T_{DL}, together with T_{MR} can be used to define the time constraints for interaction between humans and automation and to respond properly to avoid a collision. A minimum requirement for safe autonomous operation will be that T_{DL} is longer than T_{MR}. Automation needs to alert the responsible crew or personnel once T_{DL} becomes equal to T_{MR} [41]			
COLREG Convention	Refer to Table 4	VII. Rule 7 describes the "Risk of Collision" and Rule 8, "Action to Avoid Collision". Both of these rules require human intervention.	R, RU and A	**Recommendation:** Include an interpretation considering both RCC operator and the algorithm-based collision avoidance controller to evaluate the risk of collision and take avoiding action for autonomous ships at different autonomy levels. **Justification:** At autonomy levels R and RU, a remote operator at RCC will be obliged to meet the fundamental principle of human control, and simultaneous decision making stipulated in COLREG. In this regard, a proper electronic lookout in the vicinity of the ship with the aid of sufficient cameras/sensors will assist the RCC operator to take the appropriate avoiding actions. However, the reliability and redundancy must be ensured by use		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				of several and different types of object detection systems, independent of each other (redundant). It is also necessary to choose a combination of object detection systems based on careful consideration about each technology's relative capabilities, as well as how they support RCC operators' ability to assist in object detection. Fully autonomous ships that are pre-programmed to navigate could meet the provisions by installing a COLREG compliant autonomous collision avoiding system. In this regard, the following risk control measures (RCMs) could be considered: 1) When programming a fully autonomous ship, prioritisation of protective considerations on the basis of ethical considerations. 2) Indications on what types of decision making could be left to human beings or define criteria (to set notifications/ alarms) for when assistance from RCC operators is required to maintain normal operations. 3) Use sensors and cameras designed to withstand possible impairments due to environmental conditions (snow, salt, rain etc). 4) Perform comprehensive testing of software to confirm reliability both as part of commissioning (e.g. hardware-in-the loop testing) as well as after			

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				updates, to verify functionality and absence of failures. 5) Provision on using harmonized collision avoiding system at sea for a fully autonomous ship need to be coded for an international agreement.			
COLREG Convention	Refer to Table 4	VIII. Rule 9 to 17 on navigational rules.	R, RU and A	**Recommendation:** Include an interpretation considering both RCC operator and the algorithm-based Automatic Onboard Controller (AOC) to navigate the autonomous ships at different autonomy levels. **Justification:** At autonomy levels R and RU, a remote operator at RCC will be obliged to meet the fundamental principle of human control and meet all navigation rules, whereas, an onboard Autonomous Navigation Systems / Artificial Caption will be utilized for fully autonomous ships to meet these provisions. However, in case of any unforeseen situation or sailing through congested waterways, the human operators will be alerted with an RTI in time before their assistance is needed.		✓	
COLREG Convention	Refer to Table 4	IX. Rule 18 on "Responsibilities between ships" Rule 18 gives navigational priority to ships "not under	R, RU and A	**Recommendation:** No amendment is suggested for COLREG. **Justification:** "Not under command" status is feasible for an unmanned ship that has lost communications and initiated fallback functions for MRC. In such a case, alerting proximate sea users about this status is critical. However, the reference to "exceptional circumstances" clearly refers to	✓		

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		command" defined in Rule 3(f).		circumstances other than a ship's ordinary operational arrangements, and thus could be used to justify the circumstances of lost connection.			
		X. Another issue identified relates to the connection between the remote operator and the ship itself. Any disturbances or losses of connection may directly prevent the remote operator from maintaining "a proper lookout" (Rule 19). The systems on board should be able to perform certain tasks during temporarily loss of connection and would have an active role for maintaining this required "proper lookout".	R, RU and A	**Recommendation:** No amendment is suggested for COLREG. However, the performance criteria for the lost connection should be written into SOLAS "Regulation 18 - Approval, Surveys and Performance Standards of Navigational Systems and Equipment and Voyage Data Recorder ". **Justification:** A redundant solution for ship-shore communication needs to be established to guarantee the availability of communication in the event of any unexpected outages, emergency maintenance or natural disasters. The carriers and associated external networks are to be redundant in the area of the autonomous operation. If such an unforeseen event occurs, the geo-redundant solution can guarantee communication availability by activating the secondary site from a passive to active mode in a fully automated procedure. In addition, the process of fallback is to be clarified and ensured that the fallbacks are sufficiently executed to allow the autonomous ships at any given time to enter so-called "minimum risk conditions" (MRC), which is a safe state to enter in case of technical failures and/or human error prevents the ship from maintaining normal operations.		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				Also, the navigation system for the autonomous operation could be redundant with dual processors. Connected sensors for navigation and situation awareness could be duplicated or chosen so that the same essential parameter can be observed or derived from more than one unit. A separate communication link could be used to control the ship by a boarding team to facilitate entry to the ship in case of loss of communication or during normal boarding and disembarkation procedures. This needs to be highly reliable and secure.			
SAR Convention	Refer to Table 4	I. The consistency between the concept of "rescue" and "distress" should be closely considered with a view to clarifying if the term "ship and other craft" would include ships without seafarers, workers or passengers on board. Definitions might need to be amended accordingly.	RU and A	**Recommendation:** Include the exemption that the duty to render assistance is limited for any unmanned autonomous ships. Autonomous ships at autonomy levels RU and A can be engaged in a sweep search and relaying the distress alert, but not in the recovery of the persons in water unless the onboard equipment allows them. **Justification:** In the context of unmanned ships, the personnel at RCC in charge of controlling or supervising will ensure that any distress signals received are relayed either directly or through communication hub to the Maritime Rescue and Coordination Centres (MRCCs). The requirement that persons taken on board be treated with humanity is qualified by the reasonable capabilities and limitations of the ship, therefore autonomous ships could request for an exemption			✓

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		SOLAS V/33 reiterates the obligation for the master onboard, if in a position to do so, to proceed with all speed to the assistance of persons in distress at sea.		to distress assistance from the Contracting Government.			
SAR Convention	Refer to Table 4	II. The global SAR system would be activated only to render assistance to persons in distress. The Global SAR Plan is a necessary and practical tool for SAR operations.	RU and A	**Recommendation:** Include the exemption that the duty to render assistance is limited for any unmanned autonomous ships. Autonomous ships at autonomy levels RU and A can be engaged in a sweep search and relaying the distress alert, but not in the recovery of the persons in water unless the onboard equipment allows them. **Justification:** The requirement that persons taken on board be treated with humanity is qualified by the reasonable capabilities and limitations of the ship. If a remote controller at RCC were to discover persons in distress and does nothing at all to inform appropriate authorities, he/she should be considered in breach of the duty and such conduct would not be treated well for unmanned ship integration into the more conventional maritime community. On the other hand, Global Maritime Distress and Safety System Master plan of Shore Based Facilities (GMDSS Master Plan) is also developed, which is based on both satellite and terrestrial radio services, and has changed international distress communications from being primarily ship-to-ship			✓

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				to primarily ship-to-shore. In such a case, the Rescue Coordination Centres could play a major role in the communication and coordination.			
SAR Convention	Refer to Table 4	III. A ship without seafarers, workers or passengers on board: o Would not require rescue but recovery, o could not be considered in distress, o could not carry distress notification equipment (e.g. EPIRBs) that would be used for the express purpose of indicating a person is in distress,	RU and A	**Recommendation:** Include the following requirements to be considered: - An interpretation into the SAR Convention to clarify the fact that the unmanned autonomous ships in distress can use GMDSS for alerting about a distressed status onboard to the Maritime Rescue Co-ordination Centres (MRCC). - Consider the salvage procedure given in International Convention on Salvage, 1989 [42] for an autonomous ship in distress - According to the SOLAS IV, an Emergency Position Indicating Radio Beacon (EPIRB) is compulsory for any ship and it should not be an exclusion for autonomous ships. **Justification:** Some of the provisions mentioning recuse requirements and consideration in distress might be irrelevant for uncrewed MASS. However, according to the SOLAS IV, EPIRB is compulsory for any ship to transmit distress alerts and it should not be exclusion for autonomous ships. Unmanned autonomous ships in distress can create significant damage to the environment and other ships if drifting uncontrolled. A salvage procedure would then apply as given in the International Convention on Salvage, 1989, where		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				the role of master is taken by the RCC operator signing a salvage contract with the nearest coastal service. The term distress can be applicable as SAR specifies the "Distress phase" which is "A situation wherein there is a reasonable certainty that a person, a ship or other craft is threatened by grave and imminent danger and requires immediate assistance". It is suggested to include into SAR Convention a paragraph clarifying the fact that the unmanned autonomous ships in distress can use GMDSS for alerting about a distressed status onboard and that it is the decision of the Maritime Rescue Co-ordination Centres (MRCC) to decide about the necessary intervention and actions for the ships in the vicinity. In this regard, the local MRCC must be always informed.			
MARPOL Convention	Refer to Table 4	I. Reporting Obligation in MARPOL, Protocol 1	R, RU and A	**Recommendation:** Include an interpretation considering the stipulated duty of Reporting Obligation in MARPOL, Protocol 1 to be delegated by the remote operator at RCC for autonomous ships. **Justification:** The obligations rested with the master under MARPOL Protocol I and Article 4 of the OPRC Convention could be met by a remote operator for autonomous ships to the extent that it will be technically possible to collect the necessary information about pollution of the sea. This is supported by MARPOL, Protocol 1, article 1, as well as article 4 of the OPRC Convention which imposes		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				the reporting obligation on ”The master or other person having charge of any ship involved in an incident”.			
		II. Emergency preparedness on board ships which includes: MARPOL Annex 1, chapter VIII, regulation 41 (STS Operations Plan) MARPOL Annex 1, chapter V, regulation 37 (Shipboard Oil Pollution Emergency Plan) MARPOL Annex II, chapter VII (Prevention of pollution arising from an incident involving noxious liquid substances) Article 3 of the OPRC Convention (Oil pollution emergency plans)	R, RU and A	**Recommendation:** Include a provision of keeping the emergency preparedness plan both at RCC and onboard ship. **Justification:** In case of autonomous ships, an emergency preparedness plan should be kept at RCC as required by and in accordance with the provisions adopted by the organization. In addition, a printed form of the plans should be kept on board while in a port or at an offshore terminal under the jurisdiction of a party.		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
MLC Convention	Refer to Table 4	I. Safe manning document (The purpose of Reg. 2.7 is to ensure that seafarers work on board ships with sufficient personnel for the safe, efficient and secure operation of the ship)	RU and A	**Recommendation:** Include a provision specifying the limits of the workload for the RCC operators as well as medical examinations as a special case. The following text could be inserted: "The manager/ administration of Remote Control Centre (RCC) should prepare the workload for the RCC operators with hours of work and rest based on their exposure to the electronic screens. Any special criteria that require medication examinations also need to be well-mentioned." **Justification:** To the extent that unmanned autonomous ships are safe without a crew on board in relation to UNCLOS Article 94(4)(b) and SOLAS chapter V, regulation 14(1), MLC regulation 2.7 will not present a barrier to ships at higher autonomy levels. However, it is recommended to consider specifying the limits of the workload for the RCC operators with hours of work and rest as well as medical examinations as a special case.	✓		
IMO Interim Guidelines for MASS trials	Refer to Table 4	I. The Committee agreed to keep the Interim Guidelines under review and to amend them in view of the experience gained with their application and/or as and when the	R, RU and A	**Recommendation:** No amendment is suggested. **Justification:** 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. The circular details the following 10 main objectives to guide relevant authorities and stakeholders when planning, authorizing and conducting trials of MASS-related systems and infrastructure:	✓		

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		circumstances so warrant.		i. Risk management ii. Compliance with mandatory instruments iii. Manning and qualifications of personnel iv. Human element v. Infrastructure vi. Trial awareness vii. Communications and data exchange viii. Reporting requirements and information sharing ix. Scope and objective for each individual trial x. Cyber risk management			
IMO Guidelines on maritime cyber risk management	Refer to Table 4	I. This Resolution encourages administrations to ensure that cyber risks are appropriately addressed as other risks in existing safety management systems (as defined in the ISM Code) no later than the first annual verification of the company's	R, RU and A	**Recommendation:** No amendment is needed. However, it is necessary to include the provision to issue the cyber security compliance certificate for the cloud infrastructure used in autonomous ships. **Justification:** Following additional rules, standards and guidelines may also be considered: i. Bureau Veritas Rule Note on Cybersecurity for the Classification of Marine Units NR 659 DT R00 [31]. ii. ISO/IEC 27001 standard on Information technology – Security techniques – Information security management systems – Requirements. Published jointly by the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC).	✓		

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		Document of Compliance after 1 January 2021. These guidelines could be applied for the SSS & IWW use cases. Additional rules, standards and guidelines may also be considered.		iii. The Guidelines on Cyber Security on board Ships produced and supported by BIMCO, CLIA, ICS, INTERCARGO, INTERTANKO, OCIMF and IUMI. iv. United States National Institute of Standards and Technology's Framework for Improving Critical Infrastructure Cybersecurity (the NIST Framework). In addition, it is necessary to discuss on the cyber security certification of the cloud infrastructure to draw the attention of the international workgroups.			

7.2.2 European Union regulatory bodies

A mapping of the European Union Rules and Regulations applicable to the SSS use case and covered by the investigation is given in Table 6.

Table 6 - SSS - Mapping of European Union regulatory bodies

Regulatory bodies	Purpose
Directive 96/98/EC [43]	Council Directive 96/98/EC of 20 December 1996 on marine equipment, deals with the uniform application of the relevant international instruments relating to marine equipment to be placed on board EU ships and to ensure the free movement of such equipment within the Union.
Directive 2009/16/EC [44]	Directive 2009/16/EC of the European Parliament and the Council of 23 April 2009 on Port State Control, deals with common criteria for control of ships by the port State and harmonising procedures on inspection and detention.
Directive 2010/65/EU [45]	Directive 2010/65/EU of the European Parliament and of the Council of 20 October 2010 on reporting formalities for ships arriving in and/or departing from ports of the Member States and repealing directive 2002/6/EC, deals with the simplification and harmonisation of administrative procedures applied to maritime transport by making the electronic transmission of information standard and by rationalising reporting formalities.
Directive 2002/59/EC [46]	Directive 2002/59/EC of the European Parliament and of the Council of 27 June 2002 establishing a Community ship traffic monitoring and information system, deals with enhancing the safety and efficiency of maritime traffic, improving the response of authorities to incidents, accidents or potentially dangerous situations at sea, including search and rescue operations, and contributing to better prevention and detection of pollution by ships.
Regulation (EC) No 725/2004 [47]	Regulation (EC) No 725/2004 of the European Parliament and of the Council of 31 March 2004 on enhancing ship and port facility security, latest consolidated version: 20/04/2009, deals with enhancing the security of ships used in international trade and domestic shipping and associated port facilities in the face of threats of intentional unlawful acts.

7.2.2.1 Identified gaps and proposals for European Union regulatory bodies

This part of the report addresses the gaps identified in Deliverable 2.3 [17] in compliance with European Union rules and regulations for SSS use cases. Recommendations/amendments or new developments have been proposed as shown in Table 7 to minimize the hurdle of autonomous ships' operability in European waterways. The regulatory bodies mapped in Table 5 have been considered at this stage of analysis, which are sufficient to cover the European governing bodies for SSS operation. The proposals have been considered dynamic as mentioned before and addressed in any of the four ways mentioned in the RSE [8].

Table 7 – Proposals for EU Regulatory Bodies for SSS Use Case

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
Directive 96/98/EC	Refer to Table 6	Marine equipment that is placed on board an EU ship shall meet the design, construction and performance requirements of the international instruments as applicable at the time when that equipment is placed on board. The international instruments for autonomous ships are yet to develop.	R, RU and A	**Recommendation:** Sign a bilateral agreement among the EU member states to list down the marine equipment to be placed on autonomous ships to meet the commonly agreed design, construction and performance requirements. **Justification:** Apart from developing international instruments, which is time-consuming, a bilateral agreement could be set up among the EU member states to list down the marine equipment to be placed on autonomous ships to meet the commonly agreed design, construction and performance requirements. This will be supported by Article 30, that contains exemptions provisions based on technical innovation: "a flag state can allow marine equipment not compliant with the procedures under the marine equipment directive if it has been found, through testing or in some other manner to the satisfaction of the flag state, that such equipment meets the purpose of the marine equipment directive." In addition, Article 31 contains exemptions provisions for testing or evaluation: "a flag state may permit marine equipment which does not comply with the conformity assessment procedures for reasons of testing or evaluation."	✓		
Directive 2009/16/EC	Refer to Table 6	I. The terms "master"/"crew" appear in numerous instances throughout	RU and A	**Recommendation:** Include the following requirements to be considered.	✓		

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		the directive. Their meanings should be specified, taking account that they are not on board. Such as: Article 3 – Scope, Article 9 – Notification of arrival of ships, Article 14 – Expanded inspections, Article 17 – Report of inspection to the master, Article 18 – Complaints, Article 20 – Right of appeal, Article 21 – Follow-up to inspections and detentions.		- An interpretation considering an RCC operator to be responsible for complying with the rights and obligations rested on a master of a conventional ship. - The definition of “autonomous ships”, "remote control centre" and “remote operator”. **Justification:** It must be presumed that most of the rights and obligations resting with the master under current regulations will be performed by a remote operator at RCC for unmanned autonomous ships. Thus, the member states must rely on the remote operator at RCC who will be duly authorised to comply with all necessary provisions stipulated up on master on board. Therefore, the first intermediate goal in terms of preparing these regulations could be to adopt the definition of the concept of the “master” and to lay down new definitions of the concepts “autonomous ships” and “remote operator” and to clarify which rights/obligations should rest with a “remote operator”.			
		II. Generic parameters considered for the determination of the ship risk profile should be specified for MASS operations. Annexes I and II should be amended. Annex 1-1 (Ship risk profile) is for	R, RU and A	**Recommendation:** Consider to include the following amendments. **Amendment in Annex 1-1:** The generic parameters considered for the determination of the MASS risk profile are: (a) Type of ship At an initial stage, before the reliability of autonomous ships' operation is assured, it is necessary to establish a benchmark regarding acceptable risk levels and then work		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		distinguishing the high-risk ships and giving a guideline for an inspection at port. Annex 2 is for design of ship risk profile.		on how to define probability for systems without access to historical data. (b) Age of ship No amendment is required as autonomous ships could be treated as other conventional ships in terms of evaluating risk over ages. (c) Flag State performance No amendment is needed as it depends on the flag of state that ships flying with high/low detention or for which an audit has been completed. (d) Recognised organisations No amendment is needed as it depends on the organisation that issues the certificates. (e) Company performance No amendment is needed as it depends on company performance **Amendment in Annex 2:** Similar amendment for 'Type of ship' and 'Age of ship' No amendments for 'Flag State performance', 'Recognised organisations', 'Company performance'.			
Directive 2010/65/EU	Refer to Table 6	The meaning of “master” and “person duly authorised” should be specified taking account that they are not on board, see Article 4 –	R, RU and A	Refer to Directive 2009/16/EC	✓		

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		Notification prior to arrival into ports: ”(…) Member States shall ensure that the master or any other person duly authorised by the operator of the ship provides notification (…)”. In a broader sense, the legal role of the master should be clarified.					
Directive 2002/59/EC	Refer to Table 6	I. The term "master" appears in numerous instances throughout the directive. The meaning of this term should be specified, taking account that the master is not on board. Such as: Article 4 – Notification prior to entry into ports of the Member States, Article 17 – Reporting of incidents and accidents at sea, Article 18 – Measures in the event of exceptionally bad weather, Article 18a – Measures in the event of risks posed	R, RU and A	Refer to Directive 2009/16/EC	✓		

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		by the presence of ice, Article 19 – Measures relating to incidents or accidents at sea.					
		II. Article 16 – Transmission of information concerning certain ships: it should be specified whether MASS operations should be considered in the scope of this article dealing with ships posing a potential hazard to shipping.	R, RU and A	**Recommendation:** Include an interpretation considering the word "ships" to include the provision of autonomous ships' operability. **Justification:** In all aspects, MASS could comply with the operational need mentioned in the scope of this article for not being considered as ships posing a potential hazard to shipping. Thus, the word "ships" in this article should include the provision of autonomous ships' operability.	✓		
Regulation (EC) No 725/2004	Refer to Table 6	Concerning all references to ISPS Code.	R, RU and A	Refer to SOLAS Chapter XI-2 and the ISPS Code		✓	

7.2.3 National and local regulatory bodies

The scope of this section is limited to the analysis of the Norwegian Maritime Authority (NMA) provided guidelines for the design, building, testing and operating of the Short Sea Shipping (SSS) use case considered in the AUTOSHIP project and pilotage act 1987.

7.2.3.1 NMA provided guidelines for MASS operation

The Norwegian government promotes autonomous shipping to such a large extent that they have developed their own rule and regulations. So far, the Norwegian Maritime Authority (NMA) has provided some guidance on how to handle MASS projects in the document "*Veiledning ved reduksjon av bemanning*" [48] (in Norwegian only), based on the IMO MSC.1/Circ.1455 [49] process.

Following regulations are referred to in the Section 3 of this NMA document:

i. Ship Safety and Security Act ("*skipssikerhetsloven*")
ii. Reg. n°.1072 on construction of ships ("*om bygging av skip*")
iii. Reg. n°.666 on the manning of Norwegian ships (manning Reg. 09) ("*bemanningsforskriften*")
iv. Reg. n°.537 on watchkeeping on passenger and cargo ships ("*Vaktholdforskriften*")

In addition, the Norwegian Coastal administration is conducting the Act relating to the Pilot Services.

7.2.3.2 Pilotage act 1987

Pilotage is subject to various national regulations in each coastal and port State, where an authorised or licensed pilot needs to manoeuvre the ships through dangerous or congested waters, such as harbours or river mouths. Pilots are higher skilled professionals in navigation as they are required to know immense details of waterways as well as displaying expertise in navigating ships of all types and size.

Pilotage Act 1987 is an Act of Parliament that governs the operation of maritime pilotage in United Kingdom. The act requires the authority to keep under consideration what pilotage services are needed to secure the safety of ships and gives them powers to: a) make pilotage compulsory within their pilotage district and levy charges for the use of a pilot; b) grant pilotage exemption certificates (PEC) to any bona fide master or first mate who has the skill, experience or local knowledge to pilot their own ship in a compulsory pilotage area, and, c) authorise pilots within their district.

Table 8 shows how pilotage act should deal with unmanned autonomous ships.

Table 8 – Proposals for National and Local Regulatory Bodies for SSS Use Case

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
Pilotage Act 1987	The United Kingdom's Pilotage Act 1987 [50] is an Act of Parliament that governs the operation of maritime pilotage. The Act repealed the previous pilotage legislation in its entirety, the Pilotage Act 1983, which itself had repealed the Pilotage Act 1913.	Pilotage is subject to various national regulations in each coastal and port State. In many ports, pilotage is made compulsory to accept ships' operability in their territories.	R, RU and A	**Recommendation:** Pilotage act 1987 should be exempted by local government by the local government for the trials of autonomous ships. However, in the long run, if a shore-based pilotage is planned, include the following provisions to be considered into the pilotage act: -Pilot boarding arrangement as a fixed boatlanding -Control transfer to Pilot at the ship control panel on the bridge to allow a quick local override in the course of the pilotage - Additional requirements for the communication connection's redundancy and security -Training for pilots aimed at raising awareness with regard to unmanned ships **Justification:** This provision will presumably not present any barrier for ships at lower autonomy level R as the onboard crew could perform the navigational obligation in connection with port calls and could act according to a local pilot's advice in case of mandatory pilotage. For unmanned autonomous ships (at autonomy levels RU and A), the pilotage could be exempted by local government for trial purposes. However, in the long run, a shore-based pilotage could be the only option where a remote operator~~/port~~			✓

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				~~personnel~~ who is specialised in sailing in those particular areas and aware of local rules and regulations will take the control of ships as a pilot. If the shore-based pilotage is planned from a port by port personnel, the requirements for the pilot's access to the ship's electronic bridge by allowing the computer systems to switch over to allow input from a remote pilot and the requirements for the communication connection's redundancy and security must be defined. In this regard, the remote operator retains ultimate control and needs to intervene to retake the control of any inappropriate pilot's action which involves risks. Alternatively, a specially trained remote operator at the RCC could perform the task of a pilot by applying for a pilotage exemption certificate. However, this matter needs to be addressed explicitly in any relevant regulation.			

7.2.4 Bureau Veritas guideline for autonomous shipping

This Guidance Note (Bureau Veritas Marine & Offshore, NI 641, Guidelines for Autonomous Shipping, October 2019 [51]) set out the main recommendations for the design or the operation of systems which may be used to enhance automation in shipping.

7.2.4.1 Guidance Note NI 641

The Guidance Note includes recommendations related to the design and operations of ships equipped with automation systems capable, to varying degrees, of making decisions and performing actions with or without human intervention, and the associated Remote Control Centre if any. The recommendations also include the statutory requirements deemed applicable. These recommendations are intended as a reference for designers, shipyards, manufacturers, shipowners and administration in order to help in the definition of the applicable statutory framework. It also presents the structured approach to risk and reliability for autonomous ships, which could be followed for the development of a MASS project, subject to agreement to the administrations.

Table 9 includes the proposal to utilize Guidance Note NI 641 for SSS use case.

Table 9 – Proposals utilizing the BV guideline for SSS Use Case

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity L	Level of severity M	Level of severity H
BV Guidance Note NI 641	Refer to 5.2.4.1	The application of this Guidance Note does not relieve the Interested Party from compliance with all relevant regulations from applicable international conventions, national regulations or local legislation, if any	R, RU and A	**Recommendation:** No amendment is required **Justification:** Where appropriate, exemptions or equivalent solutions should be explicitly approved by the flag state and/or the state under whose authority the ship is operating. So it is crucial to establish a close dialog with the administrations as early as possible for MASS projects.		✓	
		How to utilize the structured approach to risk and reliability for MASS as presented in the NI 641 Guidance Note.	R, RU and A	**Recommendation:** No action is required. The approaches and methods of NI 641 are sufficient and fully in line with MASS operations. **Justification:** Depends on the agreement to the administrations, the development of a MASS project could follow the structured approach to risk and reliability for autonomous ships as presented in the NI 641 Guidance Note, including the following three main areas: i. A risk and technology assessment including identification and analysis of risks and how they could be mitigated ii. The functionality of autonomous systems, defining minimum levels for essential systems and providing goal-based recommendations iii. Reliability of autonomous systems, including recommendations on design and performance levels.	-	-	-

8 USE CASE INLAND WATERWAYS

8.1 CASE DESCRIPTION

The following information is extracted from the semi-structured interview conducted with Blue Line Logistics (BLL) personnel in the scope of the Deliverable 2.1 [19].

8.1.1 IWW use case – Zulu 4

Blue Line Logistics has established a concept for short and medium range transport of palletized goods based on hubs in combination with short range road distribution. The concept allows door to door service, and the size and design of the ships allows them to navigate even small waterways, often closer to the cargo destination. The concept is already successfully implemented with four barges in operation (Zulu 01/02/03/04). The barges are operated by one man during transit, with additional hands available for loading and discharging cargo or other operations when necessary at the quay.

The ship considered for the IWW demonstration is the BLL owned barge Zulu 4. Zulu 4 is a second-generation (mono-hull) Pallet Shuttle Barge (PSB) which has a flat cargo deck above the waterline. The control cabin is installed at the ship bow. The ship uses a deck crane that can reach the entire deck. The barge has one rear and one bow thruster. The Class 2 PSB, as the name suggests, is specially designed for transportation of palletized goods/cargo. It is also designed to carry 20-feet wheel containers (containers with wheels on one end), and goods in big-bags. The main particulars of the IWW use-case are provided in Table 10, taken from Deliverable 2.1 [19]. A picture of the demonstrator (original ship) is provided in Figure 6.

Table 10 - Principal Particulars of Zulu 4

Property	Value / Reference	Unit
Name of the ship	Zulu 4	-
MMSI	205574990	-
Length	50	m
Breadth	6.6	m
Sailing speed	17	km/h
Draft - fully loaded	1.9	m
Carrying Capacity design	300	tons
Carrying Capacity actual	240 tons	No. of pallets / big bags / other

Property	Value / Reference	Unit
Deck space for goods	40 m x 6.6 m = 264	m^2
Maximum stable height of compact goods	Gravity point: 0.8	m
Class	Register Holland	-

Figure 6 - Zulu 4 picture [52]

The existing ship is designed to be operated by a single person crew who needs to have necessary qualifications to navigate the barge and operate the crane for loading and unloading, whilst the demonstrator is planned to be operated unmanned with a backup crew on board only for monitoring purpose. The barges (today) are primarily operated at inland waterways within Belgium and the Netherlands. Future operation is considered in all waterways of member states of the European Union, including Switzerland, the UK (after Brexit) and Norway. The operating limitations to this type of ship are imposed by tidal waves level, current speed, canals depth and breadth, bridges height and lock dimensions.

As the study has been limited to mandatory instruments related to the IWW use-case sailing route, it does not include all codes and standards relevant for such IWW in general.

8.1.2 System upgradation for remote and autonomous operations

The IWW use case ship, PSB 2.0, is not designed for unmanned and autonomous operations. Consequently, it is necessary to focus on the coordination of shore control, communication and ship systems to facilitate the operation of the unmanned, autonomous barge. There are no modifications planned for the technical systems (machinery) already installed onboard, and at this stage it is foreseen that demonstration of unmanned operations will take place with backup personnel on board.

An overview of ship systems of Zulu 4 and their interconnection in communication is given in Figure 7. A list of the IWW ship functions and related inputs is given in Deliverable 2.4 [20]. This Deliverable 2.4 also contains the details of the systems, with their functionalities and responsibilities. The classification of functions is based on the Deliverable 3.1 [4].

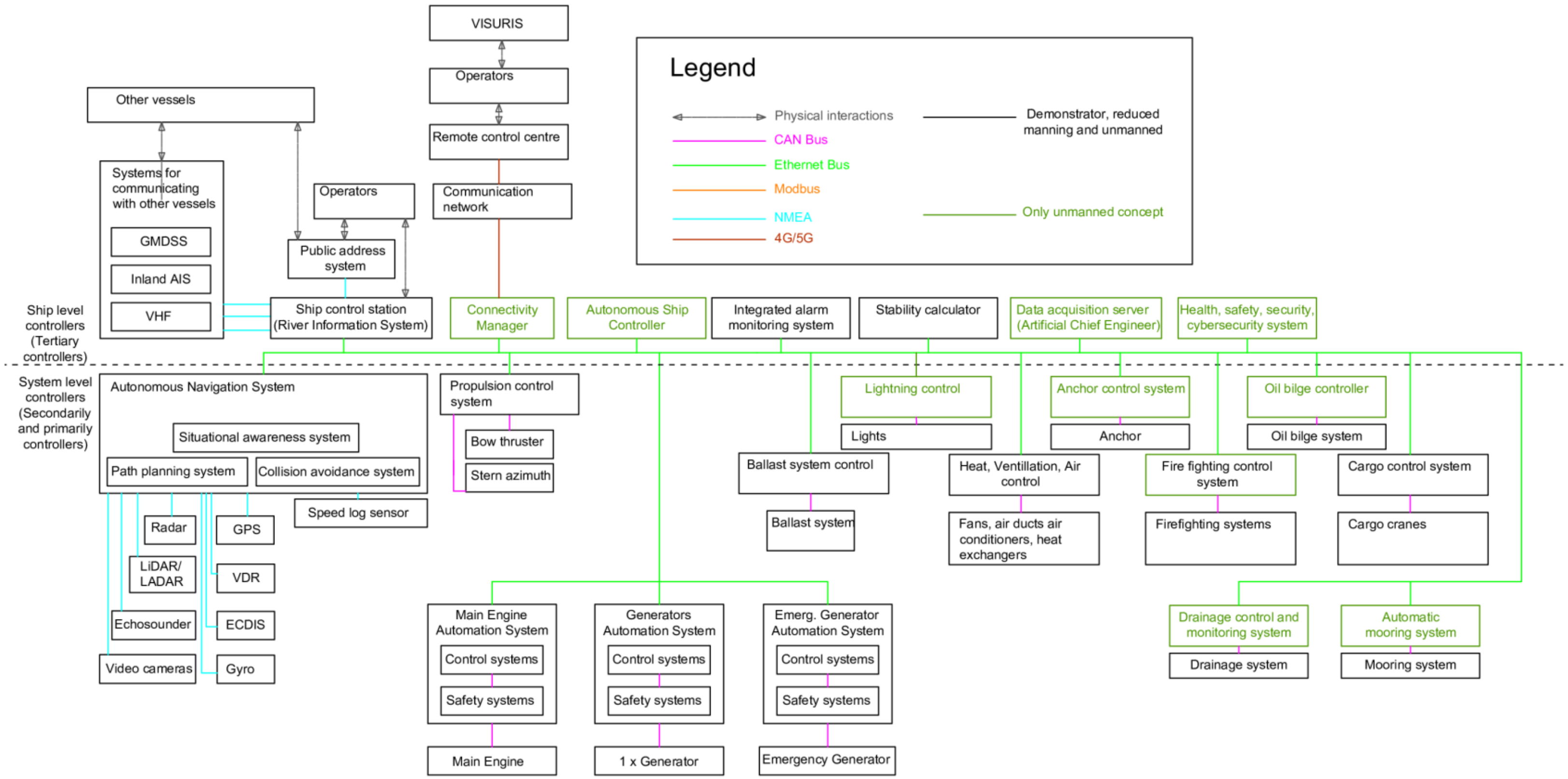

Figure 7 - An overview of the IWW use case ship systems and their communication network [20]

8.1.3 Autonomy levels

The IWW demonstration will consist of a mix of the following Remote and Autonomous (R&A) sequences as mentioned in Deliverable 2.3 [17]:

i. Automatic bridge operations, crew on the bridge:
   - the barge is operated autonomously with a crew/captain on the bridge

ii. Constrained autonomous operations, crewless bridge, crew on board:
   - the barge is operated autonomously with a crew/captain on board, but not on the bridge
   - in certain situations, the crew/captain regains control such as when approaching locks, berths or in close quarters situations.
   - control is supervised at a distance from a Remote Control Centre (RCC)

iii. Constrained autonomous operations, crewless, no crew on board:
   - the barge is operated autonomously without a crew/captain on board
   - the remote operator may take control for specific tasks outside the capabilities of the ship or when the operator wants.

The levels of automation, i.e. the degrees of decision making (authority) deferred from the human to the system, considered for the IWW demonstrator refer to those defined by the Central Commission for the Navigation of the Rhine (CCNR) about the various forms of automated navigation [9].

The R&A operations considered in the IWW demonstration case may be classified as follows according to the CCNR levels (see **Figure 8**).

i. Automatic bridge operations, crew on the bridge ≅ **CCNR level 2**

ii. Constrained autonomous operations, crewless bridge, crew on board ≅ **CCNR level 3**

iii. Constrained autonomous operations, crewless bridge, no crew on board ≅ **CCNR level 4**

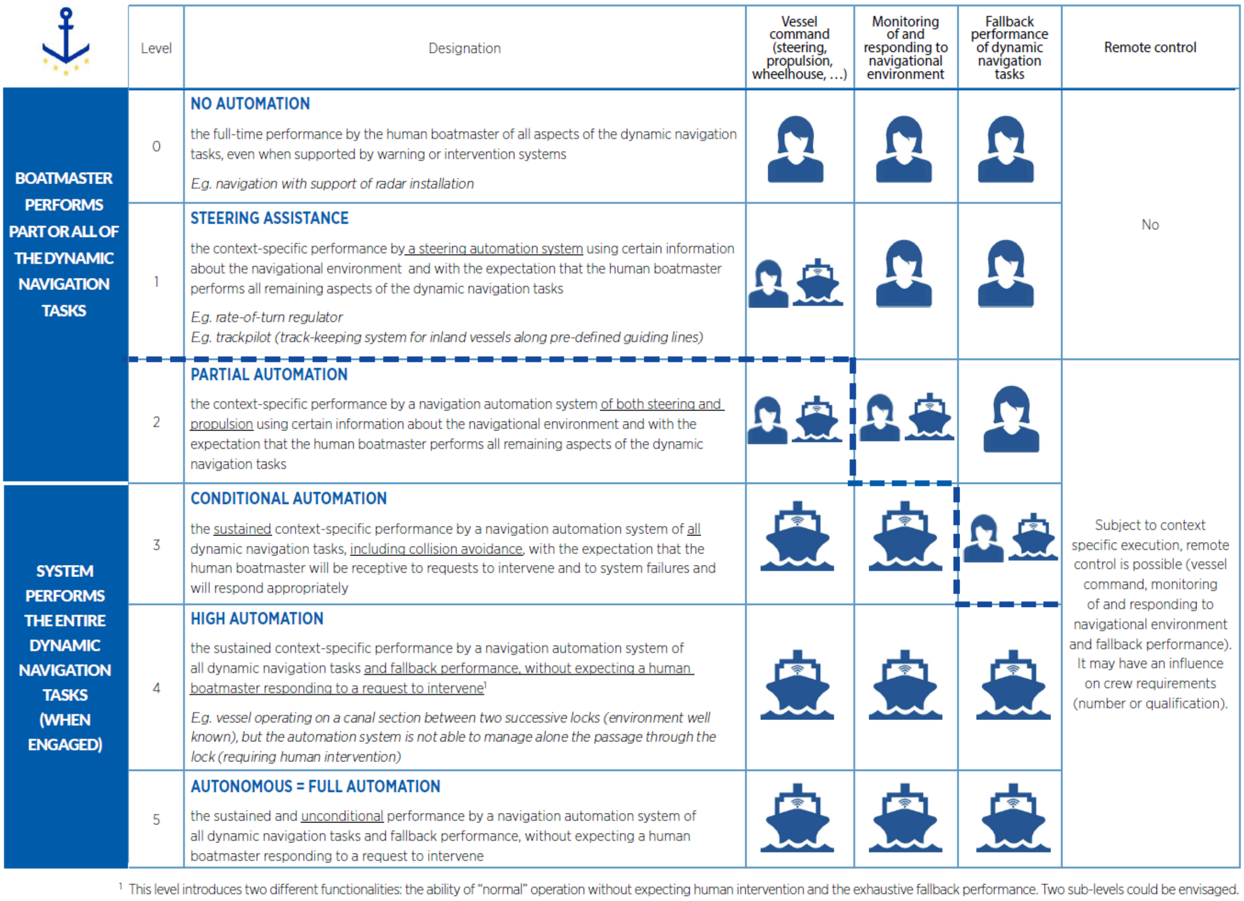

Figure 8 - IWW – Levels of automation in inland navigation [17]

8.2 REGULATORY FRAMEWORKS AMENDMENTS FOR INLAND WATERWAYS

This section provides recommendations for the existing regulatory framework including the regulations, rules and standards (Regional and National) for the design, building, testing and operating of the Inland Waterways (IWW) use case.

8.2.1 Regional rules & regulations European Directives

The analysis is organised as follows: a mapping of the Rules and Regulations covered by the investigation is provided. Then, for each regulation, the main issues and gaps are identified and areas requiring further development or amendments are highlighted from Deliverable 2.3 [17]. The recommendations are then drawn to address each regulation by either developing interpretations or equivalences, amending existing instruments, developing new instruments or do nothing as it does not hinder MASS operation. The proposals have also been prioritised based on the urgency that requires adjustment before all others to ensure the sailing of autonomous ships in inland waterways.

A mapping of the Rules and Regulations applicable to the IWW use case that are covered by the investigation is given in Table 11.

Table 11 - IWW – Mapping of regulatory bodies

Regulatory bodies	Purpose
European Directive 2016/1629/EC [53]	European Standard laying down Technical Requirements for Inland Navigation ships – ESTRIN (CESNI)
European Directive 2008/68/EC [54]	Annexed Regulations of the European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways – ADN (UNECE)
Rhine convention	Police Regulations for the Navigation of the Rhine – RPNR (CCNR)
	Regulations for the Rhine Navigation Personnel – RPN (CCNR)
European Directive 1996/50/EC [55]	On the harmonization of the conditions for obtaining national boat masters' certificates for the carriage of goods and passengers by inland waterway in the Community
European Directive 2014/112/EC [56]	Implementing the European Agreement concerning certain aspects of the organisation of working time in inland waterway transport
CLNI – Strasbourg convention of 2012 [57]	Convention on the limitation of liability in inland navigation- CLNI 2012 (CCNR)
CDNI – Strasbourg convention of 1996 [58]	Convention on the collection, deposit and reception of waste generated during navigation of the Rhine and other inland waterways – CDNI (CCNR)
Resolution N° 24 – European Code for Inland Waterways (CEVNI) [59]	European Code for Inland Waterways – CEVNI (UNECE) adopted on 15/11/ 1985

8.2.1.1 Identified gaps and proposals for European Union regulatory bodies

This part of the report addresses the gaps identified in Deliverable 2.3 [17] in compliance with EU directives for the IWW use case. Amendments or new developments have been proposed as shown in Table 12 to minimize the hurdle of autonomous ships' operability. The regulatory bodies mapped in Table 11 have been considered at this stage of the analysis, which are sufficient to cover major EU regulatory bodies of

IWW operation. Like the SSS use case, the proposals have been considered dynamic wherever possible on the basis of different levels of autonomy and the instruments have been addressed by either developing interpretations or equivalences, amending existing instruments, developing new instruments or do nothing as it does not hinder MASS operation. The severity levels have been set as High, Moderate and Low to the instruments and the proposals are priorities based on the urgency that requires adjustment before all others to ensure the sailing of autonomous ships on European waterways.

Table 12 – Proposals for European Union Directives for IWW Use Case

Regulatory bodies	Ref	Gaps identified	Autonomy level	Proposals	Level of severity L	M	H
European Directive 2016/1629 (ESTRIN)	3.03(5)	Doors in the aft-peak bulkhead shall be permitted only if it can be determined by remote monitoring in the wheelhouse whether they are open or closed and shall bear the following readily legible instruction on both sides: 'Door to be closed immediately after use'. This requirement foresees the remote monitoring of doors in aft-peak bulkhead but does not prescribe any means of remote control of such doors. It is arguable that the doors are to be operated by a human; otherwise, the risk of flooding will be increased.	CCNR level 3 and above	**Recommendation:** Include the following requirements to be considered: - A provision considering an automatic control for operating the doors in the aft-peak bulkhead. - Provide a watertight integrity plan to the shore personnel attending the ship for the cargo operation. - The openings to be closed by the 3rd party should be at least equipped with the sensors for the closure status. **Justification:** Doors in the aft-peak bulkhead should have the provision to be operated autonomously by an onboard ship control system or remotely from RCC based on different autonomy levels. The opening and closing of such doors and their associated watertight integrity could be ensured by the system/RCC personnel by establishing a precise monitoring system including high-resolution cameras/sensors to detect any leakage and set the alarm if so, to ensure safer operation of these doors. At autonomy levels RU and A, it is also recommended to consider providing a watertight integrity plan to the shore personnel attending the ship for the cargo operation, e.g. stevedores. The plan could include the list of the openings to be			✓

Regulatory bodies	Ref	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				checked and closed before the departure of autonomous ships. Legible instruction on both sides: 'Door to be closed immediately after use' should be kept as it is as the doors are also expected to be operated manually by onboard personnel during an inspection. The openings to be closed by the 3rd party should be at least equipped with the sensors for the closure status. Such arrangements can permit the RCC operator to provide effective control of the watertight integrity before the ships' departure. It is important to highlight that the existence of article 25 of these Regulations promotes the use of new technologies and derogations for specific ships in order to encourage innovation. Therefore, there will be no issue accepting the proposed changeover for autonomous ships.			
European Directive 2016/1629 (ESTRIN)	3.04(3)	All openings in walls, ceilings, and doors of engine rooms, boiler rooms, and bunker rooms shall be such that they can be closed from outside the room in order to prevent the spreading of fire from these rooms. This provision does not explicitly require remote control of openings in walls, ceilings, and doors of engine rooms, boiler rooms, and bunker rooms. So, it is arguable that	CCNR level 3 and above	**Recommendation:** Include a paragraph on the unmanned autonomous ships requiring to have: - Automatic closing devices and closure status sensors for the internal watertight bulkheads and ventilation - A plan for closing the other external openings by port services if it is delegated - Closing devices for the external openings where the port services cannot be delegated with a task of closing			✓

Regulatory bodies	Ref	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		the doors are to be operated by a human. The entire concept of fire safety is considered in the presence of human operators who are responsible for both detection and extinguishing of the fire.		- Specify the need for the manual local override where an automatic closing device is installed to prevent injuries for the attending personnel - When prescribing the automatic extinguishing systems a manual override needs to be added to prevent the release of fire extinguishing media during the periods of maintenance when the protected space is manned - Establish two separate communication systems to prepare for any communication breakdown due to fire damage to one system. **Justification:** In case of unmanned autonomous ships (autonomy levels RU and A), this function should be specifically assigned by design to a remote operator/ship control system to reduce the risk of fire in machinery space spreading outside the place. With the aid of technologically advanced sensors, high-definition surveillance cameras and communication and networks system, it is possible to carry out automatic fire detection and mitigation, automatic spillage/flooding detection and shut down of safety doors if necessary etc. In this regard, automatic closing devices and closure status sensors for the internal watertight bulkheads and ventilation must be ensured. A plan for closing the other external openings is also necessary to have it by port services if it is delegated, otherwise closing devices for the external openings must be provided. It is essential to have the provision of manual local override			

Regulatory bodies	Ref	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				where an automatic closing device is installed to prevent injuries for the attending personnel. When prescribing the automatic extinguishing systems, a manual override needs to be added to prevent the release of fire extinguishing media during the periods of maintenance when the protected space is manned. Additionally, it is recommended to establish two separate communication systems to prepare for any communication breakdown due to fire damage to one system.			
European Directive 2016/1629 (ESTRIN)	4.04	Ships shall have at least three pairs of draught marks, of which one pair shall be at ½ of length L and the two others located, respectively, at a distance from the bow and stern that is equal to roughly 1/6 of the length L. This regulation makes provision to determine the draught and trim of the ship by seeing draught marks and draught scales.	CCNR level 3 and above	**Recommendation:** Include a provision to have an Automatic Draught Indicator System, ADIS for inland autonomous ships. **Justification:** This provision is unlike the safety regulations for seagoing ships that require an automatic way of reading the draught marks (an Automatic Draught Indicator System, ADIS). However, the same technology could be implemented in contemporary manned/unmanned inland ships to meet this provision.		✓	
European Directive 2016/1629 (ESTRIN)	7.01.1	Wheelhouses shall be arranged in such a way that the helmsman may at all times perform his task while the ship is underway. Ships are operated by a human from the wheelhouse, whose	CCNR level 3 and above	**Recommendation:** Include a prescriptive requirement of three compulsory blocks which are: ship control system, connectivity and remote control centre with their associated functionalities. In addition, include the requirements of the workstation at RCC that promotes excellent ergonomics and safe operations.		✓	

Regulatory bodies	Ref	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		design needs to include ergonomics.		**Justification:** This report includes the major functional breakdown of these three blocks in Appendix B, which need to be inserted into 2016/1629 to understand the KETs to be used in autonomous ships. This provision could be met by designing an electronic wheelhouse at RCC for the operator to access all of the controls needed for the operation of the ship comfortably while the ship is underway without leaving his position or losing sight of the display screen. In short, RCC should be arranged in a manner that promotes excellent ergonomics and safe operations.			
	7.02.1	There shall be an adequately unobstructed view in all directions from the steering position. This requirement implies an attended steering position on board.	CCNR level 3 and above	**Recommendation:** Include a provision considering camera-based monitoring equivalency to the human watchkeeping by sight by utilizing Infrared/PTZ/CCTV/omnidirectional cameras and uninterrupted communication and network system. **Justification:** With the aid of carefully positioned multiple camera sensors, such as Infrared/PTZ/CCTV/omnidirectional cameras and uninterrupted communication and network system, the onboard control system could project the video streams of a full 360° view of the ship's vicinity to the shore-based remote controller and comply with the equivalency of this provision.		✓	
	7.02.2	The area of obstructed vision for the helmsman ahead of the ship in an unladen state with	CCNR level 3 and above	**Recommendation**: Include a provision considering camera-based monitoring equivalency to the human watchkeeping by sight by utilizing		✓	

Regulatory bodies	Ref	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
European Directive 2016/1629 (ESTRIN)		half of its supplies but without ballast shall not exceed 250 m. To further reduce any area of obstructed vision, only appropriate auxiliary means shall be used. This rule implies that sufficient visibility from the wheelhouse should be attained primarily by design adapted to human perception.		Infrared/PTZ/CCTV/omnidirectional cameras and uninterrupted communication and network system. In addition, include a risk-based approach to identify the minimum redundancy in the ship-shore communication. **Justification:** An analogous monitoring system for different load conditions could be set up for autonomous ships with the aid of technologically advanced Infrared/PTZ/CCTV/omnidirectional cameras and uninterrupted communication and network system. However, the positions and heights for installing the cameras should be decided carefully to meet the provision. A geo-redundant solution for ship-shore communication could be established to make sure the communication is available in the event of any unexpected outages, whether this is hardware or software failures, emergency maintenance or natural disasters, and thus guarantee unobstructed vision for different load conditions. In this regard, it is suggested to include the risk-based approach to understand the minimum redundancy requirement in the ship-shore communication in the sense of IMO MSC Circ 1580 DP2/3 [34]. This will help to restrict the area of navigation at autonomy levels RU and A based on the ship-shore communication's redundancy and reliability of transmission levels.			

Regulatory bodies	Ref	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
	7.04.1	It shall be possible to control and monitor the main engines and steering systems from the steering position. This steering position is located in the ship wheelhouse.	CCNR level 3 and above	**Recommendation:** Include the following requirements to be considered: - A prescriptive requirement of three compulsory blocks which are: ship control system, connectivity and remote control centre with their associated functionalities. - A risk-based approach to identify the minimum redundancy in the ship-shore communication and station-keeping/manoeuvring. - Update the inland ECDIS for the communication coverage zones. **Justification:** This report includes the major functional breakdown of these three blocks in Appendix B, which need to be inserted into 2016/1629 to understand the KETs to be used in autonomous ships. It is technically possible to consider an electronic bridge replacing a physical bridge for autonomous ships somewhere else with the same or improved functionality and feed all real-time onboard information to the person performing/monitoring the master function there via satellite/other means. In this regard, an onboard Intelligent Machinery System (IMS) / Digital Chief will monitor the engines / other machinery and alert the remote operator at RCC if any unforeseen situation arises. On the other hand, an onboard Autonomous Navigation System (ANS) / Digital Captain or a remote		✓	

Regulatory bodies	Ref	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				operator will navigate the ships based on different autonomy levels. With regard to the technical requirements for the continuous control of unmanned autonomous ships, It is recommended to consider a risk-based approach to identify the minimum redundancy in the ship-shore communication and station-keeping/manoeuvring and maintain a geographic mapping of the coverage zones per communication carrier with regular updates in the Inland ECDIS. Overlaps offering the required redundancy in communication can then be established. Prohibit passage beyond the areas, where the redundancy in ship-shore communication is not guaranteed.			
European Directive 2016/1629 (ESTRIN)	7.06.5a)	In wheelhouses designed for radar navigation by one person: the radar screen shall not be shifted significantly out of the helmsman's axis of view in its normal position;	CCNR level 3 and above	**Recommendation:** Include the requirements of the workstation at RCC that promotes excellent ergonomics and safe operations. **Justification:** This provision could be met by ensuring a High Attention View of the electronic lookout of the radar screen at RCC that gathers all real-time radar information and feeds those to the person performing/monitoring the master function.		✓	
	13.03.1	There shall be at least one portable fire extinguisher in accordance with the European Standards EN 3-7: 2007 and EN 3-8: 2007 at each of the following places: (…)	CCNR level 2 and above	**Recommendation:** No action is required. **Justification:** A minimum number of portable fire extinguishers need to be carried for those onboard like repair workers, pilots, PSC inspectors etc.	-	-	-

Regulatory bodies	Ref	Gaps identified	Autonomy level	Proposals	Level of severity L	Level of severity M	Level of severity H
		This provision implies the presence of crew on-board.					
European Directive 2016/1629 (ESTRIN)	27.01(2)	Stability documents shall provide the boat master with comprehensible information on ship stability for each loading condition. In conventional ships, stability calculation is computed by a software programme for a given loading condition and confirmed by C/O and boat master.	CCNR level 3 and above	**Recommendation:** Include an interpretation considering the stipulated duty of the Boat Master to be delegated by the remote operator at RCC for autonomous ships. **Justification:** If the master is not on board the ship, it must be presumed that the obligation can still be met by the steering/monitoring officer at the remote control centre by performing the stability assessment prior to departure. The essential must be that stability information is available to him as the basis for this decision competence in relation to the operation of the ship.		✓	
	27.04	The procedure for assessing stability may be determined by the documents referred to in Article 27.01(2).	CCNR level 3 and above	Same as above		✓	
	28.03(3)	For diversified cargo, the stability calculation shall be performed for the most unfavourable loading condition. This stability calculation shall be carried on board. The stability assessment procedure implies the involvement of the boat master (or another crew member).	CCNR level 3 and above	**Recommendation:** Include an interpretation considering the stipulated duty of the Boat Master to be delegated by the remote operator at RCC for autonomous ships. In addition, include the delegation of the visual draught check to the shore personnel or require use of the draught sensors, such as Automatic Draught Indicator System, ADIS. **Justification:** Stability assessment results will be the same if the load data and draft measurements		✓	

Regulatory bodies	Ref	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
European Directive 2016/1629 (ESTRIN)				are correct. It can be argued that stability assessment from RCC would be equivalently reliable if the required data are readily available to the operator/RCC personnel as the basis for this decision competence. Calibration of the draft measurements for autonomous ships will be done at port by confirming the hull side-draft mark during mooring from local personnel. This will a part of port maintenance work.			
	30.03	A safety rota shall be provided onboard craft equipped with propulsion or auxiliary systems operating on fuel with a flashpoint equal to or lower than 55 °C. The rules imply that the safety organization onboard ships using low-flashpoint fuels rely upon the human operators.	CCNR level 2 and above	**Recommendation**: Include the following requirements to be considered: - A provision to facilitate both RCC and on board ship with a safety rota. - Consider the system architecture as a goal-based approach for low flashpoint fuels. If the ALARP (as low as reasonably possible) can be set as a goal for autonomous ships, the framework of Safety Integrity Levels can be potentially used as in IEC 61508. **Justification:** In the context of an autonomous ship, this provision would become obsolete if it is not operated with any fuel with a flashpoint equal to or lower than 55 °C. However, in any distress situation meeting this provision by providing a safety rota at RCC and a digital version of it onboard could be worthwhile for others. If any alternative safety measures have to be adopted for autonomous ships equipped with		✓	

Regulatory bodies	Ref	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				propulsion or auxiliary systems operating on fuel with a flashpoint equal to or lower than 55 °C, these must demonstrate the same safety level as that of manned ships. In this regard, as provided in D2.4 [20] the ALARP likelihood can be set as a goal to achieve as a result of a design of autonomous ships at autonomy levels RU and A. In addition, it is possible to sort out the findings from D2.4 into several short examples of barrier combinations that allow an acceptable likelihood and to use these examples as a justification and proof of feasibility.			
European Directive 2008/68/EC (AND)		The IWW use case does not include the carriage of dangerous goods. The European Directive 2008/68/EC has therefore not been considered.		Out of Scope			
Police Regulations for the navigation of the Rhine – RPNR	1.02	Boat master: This provision explicitly requires the presence of a person on board the ship with the necessary qualifications. This person is also responsible for making sure that everybody follows the regulation.	CCNR level 3 and above	**Recommendation:** Include the following requirements to be considered: - an interpretation considering a remote operator at RCC as a "Boat Master" for autonomous ships at autonomy level RU and when the local control on the bridge has been taken by a damage control team or by a pilot during pilotage. - Define the term "Digital Captain" and "Digital Chief" to replicate "master/crew" and "engineers" on board for a fully autonomous ship.	✓		

Regulatory bodies	Ref	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				- Include the relevant definitions from Section 2.2. of this report. **Justification:** If a regular crew is onboard for monitoring purposes, he/she should be able to establish continuous awareness of the situation making him able to take over the control from the automatic navigation system if he/she finds it necessary. In this regard, he/she will be designated as Boat master. On the other hand, in the context of an unmanned ship, a remote operator at RCC with equivalent qualifications taking full authority of one particular ship could be considered a Boat master. Alternatively, in a broader sense, if an operator is involved in the watch duties of multiple ships/fleets, the supervisor who is back up with personnel from other disciplines will be considered a Boat master. In that case, he/she will be responsible for making sure of all automated systems work properly, and any other RCC personnel who involve in navigating/monitoring autonomous ships follow the regulations. At high automation level (CCNR level 4), an onboard control system will be responsible for having the overview, taking decisions, executing minimum risk conditions and so forth. Fully autonomous ships replace the crew on board by establishing an onboard Intelligent Machinery System (IMS) / Digital Chief and Autonomous Navigation System (ANS) / Digital Captain with the aid of technologically advanced sensors, cameras			

Regulatory bodies	Ref	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				and communication and network systems. These systems will enable the remote operator at RCC to monitor/control the ships if necessary by providing a proper electronic lookout in the vicinity of the ship and machinery spaces. It is to be noted that, the RCC operator will always be in charge of the damage control team leader if intervention is in progress and the local control on the bridge has been taken. The same goes for any planned shore-based pilotage.			
Police Regulations for the navigation of the Rhine – RPNR	1.03	Duties of other people on board This provision refers to the duties of crew and other people on board of the ship.	CCNR level 3 and above	**Recommendation:** Include an interpretation considering all the stipulated duties and responsibilities rested on the master to be delegated by the RCC operator at autonomy levels RU, whereas the onboard ship control system will be responsible at autonomy level A for meeting the provision. **Justification:** At CCNR level 3, similar duties could be imposed upon the remote operator and other personnel at RCC in compliance with the provision. However, at CCNR level 4, the duties will be distributed among onboard digital master, digital navigator and digital chief, keeping a human in the loop to RTI. In this regard, the onboard control system could execute the fallbacks if the human responding to an RTI exceeds the set threshold waiting time.		✓	

Regulatory bodies	Ref	Gaps identified	Autonomy level	Proposals	Level of severity L	Level of severity M	Level of severity H
Police Regulations for the navigation of the Rhine – RPNR	1.04	General duty of vigilance Presence of crew on board is required to exercise vigilance	CCNR level 3 and above	**Recommendation:** Include a provision considering camera-based monitoring equivalency to the human watchkeeping by sight by utilizing Infrared/PTZ/CCTV/omnidirectional cameras and uninterrupted communication and network system. **Justification:** At CCNR level 3, a remote operator and other personnel at RCC could meet this provision by exercising vigilance and good navigational practice with the aid of onboard situational awareness technology that could provide a proper electronic lookout of the vicinity of the ship. At high automation level (CCNR level 4), an onboard Digital Captain will be responsible for that keeping human in the loop for RTI and could execute the fallbacks if necessary.		✓	
	1.08	Crew This provision explicitly requires the presence of enough crew on board to ensure the safety of those on board and safe navigation.	CCNR level 3 and above	**Recommendation:** Include a prescriptive requirement of three compulsory blocks which are: ship control system, connectivity and remote control centre with their associated functionalities for the safe navigation of unmanned ships. **Justification:** Autonomous ships could replace the crews onboard by establishing an onboard Intelligent Machinery System (IMS) / Digital Chief and Autonomous Navigation System (ANS) / Digital Captain with the aid of technologically advanced sensors, cameras and communication and network systems. These systems will enable the remote operator at RCC to monitor/control the ships if		✓	

Regulatory bodies	Ref	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				necessary by providing a proper electronic lookout in the vicinity of the ship and machinery spaces. However, a part of this provision, which mentions the safety of onboard passengers/crews would become obsolete for uncrewed autonomous ships as there will be no humans on board.			
Police Regulations for the navigation of the Rhine – RPNR	1.09.1	On board of any ship underway, the helm must be held by at least one person This provision explicitly requires the presence of a person.	CCNR level 3 and above	**Recommendation:** Include the texts clarifying the training frameworks used for RCC operators and their qualification from the D7.2 of AUTOSHIP project. Include the minimum amount of hours under supervision and simulator training necessary for RCC operators to be certificated. **Justification:** It is arguable that a remote operator at RCC with similar/equivalent qualification, capable of steering/monitoring unmanned ship would meet this provision. However, the use of electronic aids and shore-based orientation need to be clarified. In addition, appropriate age, education, qualification and certification requirements etc. for operators (navigating officers) of electronic bridges should be identified. Since human operators are not removed but shifted from onboard to the onshore control centre in the present autonomous ship concept, the STCW convention is still useful to train and certify human operators. However, in order to reflect the changed circumstance, modification of the STCW is required. Table 27 and Table 28 of D7.2 [40] of		✓	

Regulatory bodies	Ref	Gaps identified	Autonomy level	Proposals	Level of severity L	M	H
				AUTOSHIP project list the recommendations which reflect the characteristics of autonomous shipping. In regard to the training period, tables in Chapter 7 of D7.2 provide useful information.			
Police Regulations for the navigation of the Rhine – RPNR	1.09.3	The helmsman must be able to receive and give all information and orders that arrive at the wheelhouse or depart from it. This provision presumes a physical bridge and implies an attended wheelhouse.	CCNR level 3 and above	**Recommendation:** Include a prescriptive requirement of three compulsory blocks which are: ship control system, connectivity and remote control centre with their associated functionalities for the safe navigation of unmanned ships. **Justification:** It is technically possible to consider an electronic bridge replacing a physical bridge for autonomous ships somewhere else with the same or improved functionality and feed all real-time onboard information to the person performing/monitoring the master function there via satellite/other means. In this regard, onboard Intelligent Machinery System (IMS) / Digital Chief will monitor the engines / other machinery irrespective of autonomy levels as there will be no engineers on board or at RCC. If any unforeseen situation arises, the system alerts the remote operator and initiates the fallbacks to ensure MRC. On the other hand, a remote operator at RCC or an onboard Artificial Navigation System (ANS) / Digital Captain will navigate the ships at CCNR level 3 and 4, respectively.		✓	
	4.06	Use of radar: the ships can only navigate on the radar as long as there is permanently a person	CCNR level 3 and above	**Recommendation:** Include a provision to issue an approved driving certificate to an RCC operator		✓	

Regulatory bodies	Ref	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
		holding an approved driving certificate. This provision implies the presence of a crew on board.		responsible for steering/monitoring an autonomous ship. **Justification:** In the context of an unmanned ship, it could be argued that the permanent person holding an approved driving certificate at RCC will perform or monitor the function of the master and navigate the autonomous ships on radar.			
Police Regulations for the navigation of the Rhine – RPNR	6.13.2	If the proposed manoeuver can or must force other ships to deviate from or change their speed, the ship that wants to turn must, before turning, announce its manoeuver in useful time, emitting: (a) "an extended sound followed by a short sound" if he/she wishes to turn to starboard or b) "a prolonged sound followed by two short sounds", if he/she wants to turn to port. This provision presumes a physical bridge and implies the presence of crew onboard to alert other ships while manoeuvring.	CCNR level 3 and above	**Recommendation:** Include a prescriptive requirement of three compulsory blocks which are: ship control system, connectivity and remote control centre with their associated functionalities to facilitate the automatic or remotely controlled horn activation. **Justification:** For remotely operated ships (CCNR level 3), the operator at RCC will be obliged to meet this provision with the aid of onboard situation awareness technology. At high autonomy level (CCNR level 4), this provision could be met by establishing an onboard control system with 'Sense and Analyze Environment' functionality to emit the sound as per requirement to alert other ships while manoeuvring.		✓	

Regulatory bodies	Ref	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
Police Regulations for the navigation of the Rhine – RPNR	6.32.1	The ships can only navigate on the radar as long as there is permanently a person holding a Rhine license or an approved driving certificate or recognized as equivalent under the Rhine Navigation Staff Regulations for the sector to be covered, and a certificate of proficiency for radar operation issued or recognized equivalent under his Regulation, as well as a second person who knows how to use the radar. This provision implies the presence of a crew on board.	CCNR level 3 and above	**Recommendation:** Include a provision considering issuing relevant certificates to the RCC operator upon fulfilling all the requirements. **Justification:** This provision could be met by a shore-based controller at RCC by fulfilling all the requirements regarding licensing/certification/recognition under the Rhine Navigation Staff Regulations.		✓	
	7.08.1	An efficient on board watch keeping is necessary.	CCNR level 3 and above	**Recommendation:** Include a prescriptive requirement of three compulsory blocks which are: ship control system, connectivity and remote control centre with their associated functionalities to facilitate a remote and efficient on board watch. **Justification:** In the context of remotely operated ships with/with crew onboard (CCNR level 3), technically it is possible to construct an electronic bridge with the aid of onboard technically advanced cameras, sensors and communication and network systems and feed all real-time onboard information to the person performing/monitoring the master		✓	

Regulatory bodies	Ref	Gaps identified	Autonomy level	Proposals	Level of severity L	Level of severity M	Level of severity H
				function there via satellite/other means for watchkeeping. At high autonomy level (CCNR level 4), an onboard ship control system with 'Sense and Analyze Environment' and 'Sense and Analyze Equipment' functionalities could meet this provision.			
Regulations for the Rhine navigation personnel (RPN)	3.15	A minimum crew of self-propelled and pushers. The minimum crew may not be reduced to zero.	CCNR level 3 and above	**Recommendation:** Include a minimum manning requirement at RCC in compliance with any of the given equipment standards. **Justification:** In the context of unmanned ships, shore-based personnel will be responsible for controlling/monitoring the ship. Thus, a minimum crew number to operate/monitor an autonomous ship should be maintained at RCC in compliance with any of the given equipment standards.		✓	
	4.01	On board ships carrying dangerous goods, a person must hold an expert attestation in accordance with model 8.6.2 of the ADN, under 7.1.3.15 and 7.2.3.15 of ADN. An ADN expert should be on board the ship.	CCNR level 2 and above	**Recommendation:** Include a provision considering the system architecture in a goal based format for the carriage of dangerous goods. **Justification:** At CCNR level 2, no amendment is needed as there will be a person onboard holding an expert attestation (ADN expert). At CCNR level 3 and above, this provision will create a barrier for an unmanned ship carrying dangerous goods only. A dedicated personal holding expert attestation could be on board to meet this provision. However, a common agreement is needed within the			✓

Regulatory bodies	Ref	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				contracting authorities in relation to meeting this provision. In this regard, the requirements to the system architecture can be suggested in a goal based format. As provided in D2.4 of AUTOSHIP, the ALARP likelihood can be set as a goal to achieve as a result of a design of unmanned ships. If ALARP is considered, then the framework of Safety Integrity Levels can be potentially used as in IEC 61508.			
European Code for Inland Waterways – CEVNI	-	The problems raised by the applicability of the CEVNI Code to the autonomous ships concept are similar to those related to the applicability of the RPNR.	CCNR level 3 and above	Refer to RPNR		✓	
European Directive 1996/50/EC	Article 2	For the purposes of this Directive: 'Boatmaster' shall mean the person who has the necessary aptitude and qualifications to sail a ship on the Member States' waterways and who has nautical responsibility on board; The definition needs to be modified in the context of autonomous ships.	CCNR level 3 and above	**Recommendation:** Same as in Police Regulations for the navigation of the Rhine – RPNR (Ref. 1.02) In addition, consider the following definition of "Boatmaster". 'Boatmaster' shall mean the person who has the necessary aptitude and qualifications to sail a ship onboard or remotely on the Member States' waterways and who has nautical responsibility irrespective of the control exerted from the ship or somewhere else. OR	✓		

Regulatory bodies	Ref	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				'Boatmaster' shall mean the person who has the necessary aptitude and qualifications to sail a ship onboard or remotely on the Member States' waterways and who has nautical responsibility irrespective of his physical presence on board. **Justification:** Same as in Police Regulations for the navigation of the Rhine – RPNR (Ref. 1.02)			
European Directive 1996/50/EC	Article 2	For the purposes of this Directive: "Member of the deck crew' shall mean a person who has regularly participated in sailing a ship in inland navigation, including manning the tiller." These regulations need to be adapted for ships at level 3 and above of automation.	CCNR level 3 and above	**Recommendation**: Include an interpretation considering the RCC personnel as 'Member of the deck crew' in terms of complying the rested duties and responsibilities. Proposed definition: "Member of the onboard or electronic deck crew shall mean a person who has regularly participated in sailing a ship onboard or remotely in inland navigation, including manning the tiller or remote control system and receptive to the requests to intervene and to system failures and respond accordingly."	✓		
	Article 7	An applicant must provide proof of at least four years' professional experience as a member of the deck crew on an inland waterway ship. A revision is needed to count the experience of RCC personnel in context of autonomous ships.	CCNR level 3 and above	**Recommendation:** Include a provision to count the experience of RCC personnel as professional experience of a member of the deck crew. Proposed revised text: An applicant must provide proof of at least four years' professional experience as a member of the deck crew or as a remote operator at RCC on an inland waterway ship.	✓		

Regulatory bodies	Ref	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
European Directive 2014/112/EC	-	If people work in an RCC, this directive might not be relevant for them as they work on land.	CCNR level 3 and above	**Recommendation:** Include a provision considering the work time regulations for people who work on land for RCC personnel. **Justification:** If people work in an RCC, they will fall under the work time regulations for people who work on land.	✓		
CLNI – Strasbourg Convention 2012	-	The purpose is this Convention is to allow shipowners and crew members of inland ships and their salvors to set a maximum amount to limit their liability in respect of claims made in connection with a single incident.		**Recommendation:** No action is required **Justification:** The application of the CLNI convention to the autonomous ships seems to raise no problem regardless of the level of automation.	-	-	-
CDNI – Strasbourg convention of 1996	-	The main objective of this Convention is to protect the environment and to improve safety in inland navigation. To achieve this objective, the Convention aims at improved checking of any waste which relies mainly on the boat master.		**Recommendation:** Include the delegation of the duty to manage waste to the RCC operator together with the delegation of the waste direct handling onboard by the maintenance personnel boarding the ship at regular intervals in port or to stevedores, if the waste is related to the cargo handling (dunnage). In addition, a requirement to issue such a shipboard plan could be beneficial. **Justification:** Within the scope of the CDNI convention, “boat master” means the person under whose authority the ship is placed. As there is no further specification about the location from where the authority is exercised, a remote operator at RCC could take the charge of boat master for monitoring/navigating so that the application of the		✓	

Regulatory bodies	Ref	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				CDNI Convention may not raise problems at CCNR level 3 and above. It is also necessary to include the delegation of the waste direct handling onboard by the maintenance personnel boarding the ship at regular intervals in port or to stevedores if the waste is related to the cargo handling (dunnage). In this regard, issuing a shipboard plan could be beneficial.			
Other Rules and Regulations			CCNR level 3 and above	The autonomous ship concept needs to be accounted for in all upcoming Rules and Regulations, as applicable. For instance, the recommendations to regulatory bodies developed within the project need to be made available to the EU committee drawing up the new European Directive on crew requirements.		✓	

8.2.2 National and local rules & regulations

The scope of this section is limited to the analysis of the Flemish Decree which mentions temporary exemption for experiments and the Belgian Royal Decree which regulates the navigation of ships on island waterways network in Belgium.

Table 13 includes the analysis results in terms of identifying the gaps and relevant proposals to mitigate those in the context of autonomous ships.

Table 13 – Proposals for National and Local Rules and Regulations for IWW Use Case

Regulatory body	Description	Gaps identified	Autonomy level	Proposal	Level of severity L	Level of severity M	Level of severity H
Regional regulation on temporary exemption for experiments	Flemish Decree containing various provisions on mobility policy, public works and transport, traffic safety policy and VVM - De Lijn was published on June 24th 2019 and contains a chapter on innovation (chapter 3). Article 50 and 51 of Chapter 3 describe the possibility of Flemish waterway authorities giving temporary exemptions on certain rules and regulations to enable tests with innovative concepts.	Article 50 and 51 of Chapter 3 describe the possibility of Flemish waterway authorities giving temporary exemptions on certain rules and regulations to enable tests with innovative concepts. The extent of these exemptions in context of autonomous ships needs to be discussed.	CCNR level 3 and above	**Recommendation:** Grant an exemption by fulfilling the requirement of the Flemish Decree for AUTOSHIP IWW case demonstration. **Justification:** The innovative concepts may include automated systems on board of a ship or on the shore. The temporary exemptions concern rules and regulations about the crew, the navigation of the ship, the technical aspects or the equipment of the ship, the regulation of shipping traffic and the regulations with regard to the activities on board and ashore. The deviations cannot relate to provisions on supervision and enforcement and to provisions of a criminal nature. When admitting for the experiments or pilot projects, the following matters must in any case be determined: i. what the purpose of the experiments or pilot projects is ii. on which waterways, waterway sections or parts of the port area the experiments or pilot projects are carried out iii. for which period the admission applies iv. which rules can be deviated from and, where relevant, under which conditions deviations are permitted v. which safety measures are taken for the implementation of the experiments or the pilot projects. It is to be noted that AUTOSHIP project IWW case demonstration possesses full compliance with the		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposal	Level of severity		
					L	M	H
				perimeter of the information required to apply for the exemption.			
Belgian Royal Decree of 24/09/2006	Belgian Royal Decree of 24/09/2006 regulates the navigation of ships on inland waterways network in Belgium.	The problems raised by the applicability of the Belgian Decree to the autonomous ship concept are similar to those related to the applicability of the RPNR.	CCNR level 3 and above	Refer to RPNR		✓	

8.2.3 Bureau Veritas classification rules

NR 217 – Bureau Veritas Rules for the Classification of inland vessels [60] gives the requirements for the assignment and maintenance of Class applicable to inland navigation ships as well as to ships operated in restricted maritime stretches of water.

Examples of requirements to be adapted for autonomous ship concept are given in Table 14.

Table 14 - Proposals utilising the BV guideline for IWW Use Case

Ref	Gaps identified	Autonomy level	Proposal/Recommendation	Level of severity L	M	H
Pt A, Ch 1, Sec 1, [3.3.1]	Operation and maintenance of ships – The classification of a ship is based on the understanding that the ship is loaded and operated in a proper manner by the competent and qualified crew or operating personnel according to the environmental, loading, operating and other criteria on which classification is based.	CCNR level 3 and above	**Recommendation:** Include an interpretation considering the maintenance/repair works of autonomous ships to be conducted at port or in moored conditions only, whereas the ship operation is carried out remotely or autonomously at different autonomy levels. **Justification:** Maintenance and repair work on board will be performed when the ship is moored. A system for the administration of work permits will be organised by RCC, possible in cooperation with human resources at the destinations. In regard to ship operation, safety of operation is not necessarily associated with the presence of humans on board (crew). It can be argued that if a ship utilises highly innovative communications technology enabling it to manoeuvre as responsively as when under the command of a conventional onboard crew, an onboard crew numbering zero may be technically adequate. The main aim of this regulation is to establish a mean by which the relevant administration can ensure a ship's compliance to the safety credentials rather than calling for any particular mode of operability.		✓	

Ref	Gaps identified	Autonomy level	Proposal/Recommendation	Level of severity		
				L	M	H
Pt A, C2, S4, [3]	Documentation to be carried on board	CCNR level 3 and above	**Recommendation:** Include a provision to facilitate both RCC and onboard ship with necessary documents. **Justification:** Both physical and electronic bridges should facilitate with necessary documents. One could prefer carrying digital documentation on board and keeping the printed one at RCC or vice versa. However, it is recommended to maintain a set of onboard documentation related to the emergency response in a paper format, as these may be needed by the damage control team boarding the ship.	✓		
Pt B, C2, S1, [1.7.4]	Watertight doors required to be open during navigation are to be of the sliding type and capable of being operated both at the door itself, on both sides, and from an accessible position above the bulkhead deck. Means are to be provided at the latter position to indicate whether the door is open or closed, as well as arrows indicating the direction in which the operating	CCNR level 3 and above	**Recommendation:** Include a paragraph on the autonomous ships at autonomous levels RU and A requiring to have: - automatic closing devices and closure status sensors for the internal watertight bulkheads and ventilation - a plan for closing the other external openings by port services if it is delegated - a plan for closing devices for the external openings where the port services cannot be delegated with a task of closing - specify the need for the manual local override where an automatic closing device is installed to prevent injuries for the attending personnel **Justification:** To meet this provision, watertight doors need to be operated autonomously by onboard ship control system or remotely by an operator at RCC at different autonomy levels. The opening and closing of such doors and their associated watertight integrity could be ensured by the system/RCC personnel by establishing a precise monitoring system including high-resolution cameras/sensors to detect any leakage and set the alarm if so, to ensure safer operation of these doors. A separate plan is also needed for closing the other external openings by port services if it is delegated and where the port services cannot be delegated with the task of closing. It is also necessary to specify the need for the manual local override			✓

Ref	Gaps identified	Autonomy level	Proposal/Recommendation	Level of severity		
				L	M	H
	gear is to be operated. The above requirement implies the presence of crew on board.		where an automatic closing device is installed to prevent injuries for the attending personnel. Other instructions on having the sliding type of watertight door, the possibility of being operated at both sides, providing arrows indicating the direction in which the operating gear is to be operated etc. could be kept as it is to operate those manually for inspection purposes or in the course of an emergency intervention.			
Pt B, C2, S1, [1.7.5]	Watertight doors may be of the hinged type if they are always intended to be closed during navigation. Such doors are to be framed and capable of being secured watertight by handle-operated wedges which are suitably spaced and operable at both sides. This requirement implies the presence of crew on board.	CCNR level 3 and above	**Recommendation:** Same as above (Ref. Pt B, C2, S1, [1.7.4]) **Justification:** Manually operated watertight doors that are always intended to be closed during navigation, should have the provision to be operated autonomously by onboard ship control system or remotely by an operator at RCC for autonomous ships at different autonomy levels. In this regard, a precise monitoring system including high-resolution cameras/sensors to detect any leakage and set the alarm if so, could be established to ensure safer operation of these doors. A separate plan is also needed for closing the other external openings by port services if it is delegated and where the port services cannot be delegated with the task of closing. It is also necessary to specify the need for the manual local override where an automatic closing device is installed to prevent injuries for the attending personnel. However, consideration must be given to comply with existing provisions on this type of watertight door to operate those manually for inspection purposes or in the course of an emergency intervention.			✓

Ref	Gaps identified	Autonomy level	Proposal/Recommendation	Level of severity		
				L	M	H
Pt C, C1, S2, [2.7.1]	Diesel engines – Control and monitoring The alarms are to be visual and audible. The indicators are to be fitted at a normally attended position (on the engine or at the local control station). This requirement implies the presence of crew on board for surveying and accessing the situation.	CCNR level 3 and above	**Recommendation:** Include a provision transmitting the alarm data to the RCC operator's interface and make the relevant information available at the central control panel on the Bridge. **Justification:** With the aid of technologically advanced sensors and AI, onboard Intelligent Machinery System (IMS) / Digital Chief will be established to do diagnostic and prognostic of engine/machinery health based on the ship's operational condition. If any unforeseen situation arises, the system will detect it with its 'Sense and Analyse Equipment' functionality and send visual and audible alarms to RCC to alert the operator/RCC personnel. It is also necessary to make sure the availability of the relevant information at the central control panel on the Bridge, e.g. as given in the SYS-NEQ-OSV [61] notation. The provision on providing indicators at a normally attended position could be kept for onboard personnel doing a manual inspection.		✓	
Pt C, C1, S10, [2.7.2]	Piping systems - Shutoff devices Hand-operated shutoff devices are to be closed by turning in the clockwise direction.	CCNR level 3 and above	**Recommendation:** Include a provision considering the remote/autonomous operation of all hand-operated shutoff devices for autonomous ships. In addition, consider redundancy in the sensors/shut-off devices to prepare for the leakage issues. All hand-operated shutoff devices should be controlled autonomously by onboard ship control system or remotely by an operator at RCC at different autonomy levels during navigation. **Justification:** All hand-operated shutoff devices should be controlled autonomously by the onboard ship control system or remotely by an operator at		✓	

Ref	Gaps identified	Autonomy level	Proposal/Recommendation	Level of severity		
				L	M	H
	This requirement implies the presence of crew on board.		RCC at different autonomy levels during navigation. Unmanned machinery piping systems must have backup shutoff devices to prepare for leaking issues.			
Pt C, C1, S10, [2.7.3]	Indicators are to be provided showing the open/closed position of valves unless their position is shown by other means. This requirement implies the presence of crew on board.	CCNR level 3 and above	**Recommendation:** Include a provision considering to send the digital signals relevant to opening/closing of valves from the onboard computers to RCC **Justification:** Digital signals need to be sent from onboard computers to RCC to ensure the status (open/close) of operating value in addition to the provided visual indicators. Alternatively, onboard camera sensors could be utilised for visual illustrations of the opening/closing of certain types of valves to the operator at RCC.		✓	
Pt C, C1, S10, [2.9.2]	Piping systems – Remote controlled valves Construction – Remote controlled bilge valves and valves important to the safety of the ship are to be equipped with an emergency operating arrangement.	CCNR level 3 and above	**Recommendation:** Include a provision considering the autonomous operation of all remote-controlled valves with minimum redundancy. **Justification:** All remote controlled valves should have the provision to be operated autonomously by onboard ship control system or remotely by an operator at RCC for autonomous ships at different autonomy levels. If the equipment is crucial for safety (eg. bilge valve), redundancy must be ensured as there will be no crew in an emergency situation to operate the valves for uncrewed ships.		✓	

Ref	Gaps identified	Autonomy level	Proposal/Recommendation	Level of severity		
				L	M	H
	This requirement implies remote operation of hydraulic, pneumatically or electrically operated valves in piping systems and sanitary discharge pipes.					
Pt C, C4, S4, [1] and Pt D, C3, S7, [5.4]	Firefighting – Water supply systems This requirement implies the presence of crew on board.	CCNR level 3 and above	**Recommendation**: The following provisions need to be included for unmanned autonomous ships: - automatic and remote control of onboard firefighting systems - A centralised manual override station should be installed onboard. - An exemption that the duty to render assistance is limited for any unmanned autonomous ships. - The requirement for the system architecture to be considered as a goal-based approach **Justification:** With the aid of technologically advanced sensors, high definition surveillance cameras and communication and networks system, it is possible to establish an onboard ship control system with 'Sense and Analyze Equipment' functionality for automatic fire detection and mitigation including automatic spillage/flooding detection and shut down of fire doors if necessary. The system will include the existing fire fighting and fire protection arrangements for manual operation. However, the number of portable fire extinguishers could be reduced as there will be no crew onboard during the ship operation and could be kept only for repair workers, pilots, PSC inspectors etc. Means of the emergency escape may be		✓	
Pt C, C4, S4, [2] and Pt D, C3, S7, [5.3]	Firefighting – Portable fire extinguishers This requirement implies the presence of crew on board.					
Pt C, C4, S4, [4] and Pt D, C3, S7, [5.5]	Firefighting – Fixed fire extinguishing systems					

Ref	Gaps identified	Autonomy level	Proposal/Recommendation	Level of severity L	M	H
	This requirement is developed and organised around the presence of crew on board.		still required for the compartments with machinery and mainly intended for the personnel which is temporary boarding for maintenance or inspection.			
Pt C, C4, S5	Fire protection – Escape This requirement implies a manned ship		The manual control of the extinguishing media release for the CO_2 fire extinguishing fixed system in the engine room as described in the FSS code within SOLAS is in conflict with the automatic control proposal. Due to the fact that it may lead to fatalities for the personnel accessing the engine room for maintenance, alternatives should be thought of. One of the solutions for unmanned ships is to introduce a centralised manual override station located onboard that allows disabling the automatic control of the ship's subsystems by the attending personnel, e.g. CO_2 to manual when attending the protected spaces in the engine room, preparing an underwater survey of the fully autonomous ships etc. In case of an emergency situation, the duty may be discharged by ensuring that any distress signals received at RCC are relayed to the Maritime Rescue and Coordination Centres (MRCCs). This means Autonomous ships at autonomy levels RU and A can be engaged in a sweep search and relaying the distress alert, but not in the recovery of the persons in water unless the onboard equipment allows them. Last but not the least, all the stipulated new provisions on fire safety for autonomous ships will need to be demonstrated that the technical solutions meet these requirements. In this regard, as provided in D2.4 [20], the ALARP (as low as reasonably possible) likelihood can be set as a goal to achieve as a result of a design of autonomous ships at autonomy levels RU and A. If the ALARP can be set as a goal for autonomous ships, then the framework of Safety Integrity Levels can be potentially used as in IEC 61508. In addition, it is possible to sort out the findings from D2.4 into several short examples of barrier combinations that allow an acceptable likelihood and to use these examples as a justification and proof of feasibility.			

9 LEGAL FRAMEWORKS

Legal frameworks include the jurisdiction rules, which lay down the states' rights and obligations to take measure with respect to ships. These are laid down in the 1982 UN Convention on the Law Of the Sea (UNCLOS). This convention has been ratified by 168 parties, which includes 167 states and the European Union. This section discusses UNCLOS in general and different jurisdictional issues to identify the hurdles in autonomous ships' operability and associated recommendations to curve those in national or international levels.

9.1 CONSTITUTION FOR OCEANS, UNCLOS IN GENERAL

UNCLOS defines the rights and obligations of states over the seas. The key issues addressed by this body of law include: to what extent ships can navigate in different sea areas; what obligations do states have over ships flying their flags; and what rights do other states have to interfere in the navigation of ships in different sea areas.

UNCLOS enjoys a widespread acceptance worldwide and its provisions regarding navigational rights and duties are widely accepted. The convention lay down the rules on establishment and delimitation of maritime zones and includes details rules for each zone with respect to states' rights and obligations.

A first and fundamental question in the context of autonomous ships to be resolved in UNCLOS is whether ships without a crew on board are 'ships' or 'vessel' within the meaning of the convention at all. The two terms are used interchangeably in UNCLOS, but neither is defined. Article 91 (Nationality of Ships) provides that each state shall fix the conditions for the grant of its nationality to ships, which implies that the national law of the flag state will be critical for the definitions used.

9.2 JURISDICTIONAL ISSUES

9.2.1 Flag State jurisdiction

Flag state's jurisdiction applies irrespective of the ship's location. UNCLOS establishes that all states have a right to the sail ships flying their flag and to fix the conditions for granting nationality to ships (Article 90 and 91(1)). It also includes the detailed duties for flag states. Generally, UNCLOS avoids 'freezing' the requirements of flag states at a given point in time or technical level by not providing any precise obligations, and keeping it to an abstract, while still preserving the international character of rules in question.

Every state has the obligation to "effectively exercise its jurisdiction and control in administrative, technical and social matters over ships flying its flag" (Article 94(1)), including to "assume jurisdiction under its internal law over each ship flying its flag and its master, officers and crew in respect of administrative, technical and social matters concerning the ship" (Article 94(2)(b)). Moreover, the flag state shall "take such measures … as are necessary to ensure safety at sea with regard, inter alia, to … the manning of ships, labour conditions and the training of crews, taking into account the applicable international instruments" (Article 94(3)(b)), including measures necessary to ensure "that each ship is in the charge of a master and officers who possess appropriate qualifications, in particular in seamanship, navigation, communications and marine engineering, and that the crew is appropriate in qualification and numbers for the type, size, machinery and equipment of the ship" (Article 94(4)(b)). When adopting these measures each flag state is required "to conform to generally accepted international regulations, procedures and practices and to take any steps which may be necessary to secure their observance" (Article 94(5)).

In the context of autonomous ships, requirements for the manning (Article 94(2)(b)) need to be handled. Additionally, lack of harmonized rules (Article 94(5)) could provide a general barrier to the autonomous ship for its wide acceptance.

9.2.2 Port and coastal state jurisdiction

Port and coastal states' jurisdiction defines other states' parallel jurisdiction over the same ship depending on the maritime zone concerned. The coastal state's authority over a foreign ship increases with the proximity of the ship to its shores.

If a ship is present in one of its **ports or internal waters**, the coastal/port state has broad jurisdiction over foreign ships. With respect to ships passing through its **territorial sea**, which may extend up to 12 nautical miles from the coastline, the right of coastal states is more limited. Under a longstanding principle of the law of the sea, all ships enjoy a right of 'innocent passage' through other states' territorial seas as long as it is not "prejudicial to the peace, good order or security of the coastal state" (Article 19(1)). The areas of a coastal state's territorial sea which form part of a '**strait used for international navigation**' are subject to even more limitations for coastal states. With respect to ships sailing in the **exclusive economic zone** (EEZ), which may extend up to 200 nautical miles from the coastline, the jurisdiction to prescribe national requirements is even more limited. Considering the **high seas**, which lie beyond the jurisdiction of any coastal state, is the starting point where the flag state alone has jurisdiction over the ship.

Autonomous ships' access could be refused by a port state to its **port or internal water**, provide that the refusal complies with certain criteria of reasonableness that exist in general international law, such as non-discrimination, proportionality between the measure and its objective and that the prohibition does not constitute an abuse of right (Article 300 of UNCLOS). In addition, for the **territorial sea**, autonomous ships' right of 'innocent passage' through other states' territorial seas is not defined. For other sea areas which lie beyond the jurisdiction of any coastal state, the flag state alone has jurisdiction over the ship. A number of exemptions to this main rule exist, but none of those is relevant to the question of navigational rights of autonomous ships.

9.3 OTHER PROVISIONS

Apart from the jurisdiction issues, there are certain other UNCLOS provisions that may turn out to be problematic for autonomous ships' operability. The obligation set out in Article 94(4)(b) that each ship needs to have a (properly qualified) master and a crew has been mentioned above. Another UNCLOS provision presumes that every state shall require the master of a ship flying its flag and it is his obligation to render assistance to persons in danger or distress (Article 98(1)). These rules might have a limited applicability in the context of autonomous ships as there will be no master on board.

9.4 IDENTIFIED GAPS AND PROPOSALS FOR UNCLOS

This part of the report addresses the gaps identified in compliance with UNCLOS. Recommendations or amendments or new developments have been proposed as shown in Table 15 to minimize the hurdle of autonomous ships' operability in European waterways.

Table 15 - Analysis of UNCLOS and proposals in context of autonomous ships

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
UNCLOS	General	Proper definition of 'ships' / 'vessel' is needed to ensure autonomous ships' operability.	R, RU and A or CCNR level 3 & above	**Recommendation:** Include the term "autonomous ship" as a special type of 'ships' / 'vessel' into UNCLOS. **Justification:** Existing international conventions that define the term 'ship' do not include references to crewing and at a national level, too, the definition of a ship is usually disconnected from the question of whether or not the ship is manned. However, introducing the term "autonomous ship" as a special case of a ship into UNCLOS is necessary in particular due to its wide scope of application. Once it is defined, autonomous ships could be regarded as vessels/ships by the virtue of their size, features and functions, and like other conventional ships, the jurisdictional rules are also applicable to autonomus ships.	✓		
UNCLOS	Flag State Jurisdiction:	There is a lack of well-established rules or regulations for autonomous ships. That could hinder the wide acceptability of autonomous ships.	R, RU and A or CCNR level 3 & above	**Recommendation:** Sign a bilateral agreement between two contracting parties or agreement between states in a broader geographical area as a temporary solution to mitigate this gap. In addition, include the definition of "autonomous ship" into UNCLOS. **Justification:** A bilateral agreement between two contracting governments/ flag states or agreement between states in a broader geographical area (e.g. Basic Sea, North Sea, Mediterranean Sea) could be a solution where two parties/states consider autonomous ships as ordinary ships by the virtue of their size, features and functions, and temporarily set commonly agreed rules for autonomous ships' operability to mitigate this gap. This consideration can be achieved by introducing the term "autonomous ship" as a special case of a		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				ship into UNCLOS in particular due to its wide scope of application. Alternatively, a set of regulations could be enforced to ensure the general acceptability of autonomous ships amongst different nations. However, it would take a long time to establish such international rules.			
	Port and Coastal State Jurisdiction	Due to not having any commonly agreed rules and regulations, a port state might not feel safe to give access to autonomous ships. This will turn out to be a significant limitation of autonomous ships' freedom of movement.	R, RU and A CCNR level 3 & above	**Recommendation:** Include the acceptance criteria in general terms for the unmanned autonomous ships to grant admission into harbours. Also, include the role of the Port and Coastal States in the recovery of unmanned autonomous ships in case of complete loss of control. **Justification**: Commonly agreed rules and regulations for coastal waterways need to be defined for autonomous ships which might result in Coastal States and Port States not banning autonomous ships from their inner waters. It is also suggested to consider specifying in general terms into UNCLOS the role of the Port and Coastal States in the recovery of unmanned autonomous ships in the event of a complete loss of control (either drifting, not-under-command dead ship, anchored or still underway). As the uncontrolled unmanned autonomous ships may trespass the territorial and other waters restricted for passage while "receiving the order to stop", it is important to explicitly present the scenario within the framework of UNCLOS as a distress situation instead of a case prompting for a hot pursuit. The role and authorisation of the boarding damage control party not directly linked to the owner can also be specified.		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity L	M	H
UNCLOS	Port and Coastal State Jurisdiction	For the territorial sea, autonomous ships' right of 'innocent passage' through other states' territorial seas is not defined.	R, RU and A CCNR level 3 & above	**Recommendation:** No action is required. **Justification:** There will not be an issue with the ship's manning requirement to enjoy the right of innocent passage as far as autonomous ships are considered as ships, and they are not engaged in the activities mentioned in Article 19 (2).There will not be an issue with the ship's manning requirement to enjoy the right of innocent passage as far as autonomous ships are considered as ships, and they are not engaged in the activities mentioned in Article 19 (2).	-	-	-
		The obligation set out in Article 94(4)(b) that each ship needs to have a (properly qualified) master and a crew.	R, RU and A CCNR level 3 & above	**Recommendation:** Include an interpretation considering a remote operator at RCC as a master of an autonomous ship at autonomy levels R and RU. In addition, include a manning exemption for autonomous ships at autonomy level A in the text of UNCLOS. **Justification:** This requirement could arguably be met in the case of remotely operated ships as long as a qualified person (remote operator) can always be identified as the one in command of the ship, while a supervisor and a backup team are available for consultations. Thus, a shift in the command cannot be presumed to be contrary to the obligations of UNCLOS, article 94(4)(b). Fully autonomous ships without human involvement in navigation and steering, on the other hand, will not be in accordance with UNCLOS Art. 94(4)(b). However, in relation to "safe manning levels", it can be argued that UNCLOS, article 94(4)(b) will not present barriers to fully autonomous ships provided that it can be validated that autonomous ships are capable of operating without being		✓	

Regulatory body	Description	Gaps identified	Autonomy level	Proposals	Level of severity		
					L	M	H
				manned according to the ship's type, size, machinery, equipment and voyage plan.			
	Other relevant provisions	UNCLOS provision, Article 98(1) presumes that every state shall require the master of a ship flying its flag and it is his obligation to render assistance to persons in danger or distress. (Also specified in SOLAS Regulation V/33). The duties include qualifications by reference to "in so far as he/she can do so without serious danger to the ship" or "in so far as such action can be reasonably expected of him" which will probably reduce the extent of obligations for unmanned ships, as the available options will be fewer.	R, RU and A CCNR level 3 & above	**Recommendation:** Include an exemption that the duty to render assistance is limited for any unmanned autonomous ships. Autonomous ships at autonomy levels RU and A can be engaged in a sweep search and relaying the distress alert, but not in the recovery of the persons in water unless the onboard equipment allows them. **Justification:** At autonomy level R, this responsibility should be delegated and stipulated to the crew onboard and the operator at RCC who will act as master of remotely controlled ships. In case of zero crewing at autonomy level RU, it could be argued that a remote operator's obligation to physically provide assistance at sea is limited. In case of an emergency situation, the duty may be discharged by ensuring that any distress signals received at RCC are relayed to the Maritime Rescue and Coordination Centres (MRCCs). For fully autonomous ships, a remote operator at RCC will be notified of any distress situation by an onboard ship control system and request to intervene to relay the distress signals to Maritime Rescue and Coordination Centres (MRCCs) to meet this provision at its most. Autonomous ships could be assisted with technologically advanced remotely operated lifesaving appliances/devices/boats to provide a satisfactory level of distress assistance that is equivalent to that on fully manned ships. However, it will seriously affect the potential cost efficiency of unmanned ships if we need to equip them with Hi-Tec lifesaving devices.			✓

10 LIABILITY AND INSURANCE FRAMEWORKS

10.1 CURRENT LIABILITIES AND INSURANCE FRAMEWORKS ANALYSIS

Unfortunately, we need to consider the scenario where something goes wrong. The current legal framework, when it comes to third party liability is generally based on negligence and the fact that someone is on board and can be blamed for any incidence that occurred. Therefore, if the cause of an accident is an error in navigational algorithms for an unmanned autonomous ship, it is quite challenging to blame someone who is responsible for the incident. The maritime industry is well known for its high rate of fatal injuries and high consequences of maritime disasters [62], [63]. The investigations of underlying causes for marine causalities mostly point to the 'human errors' as the single greatest contributor, which is 75-96% of all accidents [64]. In this regard, automation could bring down these numbers by reducing explicit human intervention and enhancing the overall safety as shown in the comparisons of yearly safety reports [65]. However, from the legal point of view, the risk perspective will change. Although the overall risk level might be reduced by increased autonomy, there will be new risks introduced, such as failure in technology, limitation in technology, etc. This change in the risk picture will affect not only the existing stakeholders but also new players, such as system suppliers (hardware and software) and the remote operators.

Under the current liabilities framework, the shipowners normally require the crew or some other parties to be negligent for claiming the third party insurance. That means that if there is a cause in the area of navigational algorithms, at the starting point, there is no liability. However, the shipowners may be held liable for negligence by the onshore control room operators or the system suppliers. If it is not possible to hold the owners liable based on negligence, that does not necessarily mean that the owners are off the hook. It is possible for example that the cause might impose strict liability, which means liability irrespective of fault. Strict liability is quite common in land-based hazardous activities, and that might also be seen at the sea although it is not currently the law. Also, there might be international or national legislation provided for strict liability.

When it comes to liability to the cargo interest, the current liability regime is also based on fault and the human element. As long as the shipowners reputed all the systems and the ship is seaworthy, it would be difficult to hold them liable.

When it comes to insurance, it is believed that the insurance will generally be available and that it is a question of the pricing of risk. There will also be some questions concerning the cyber risk and the maintenance of systems, which will be crucial for the safe operation of autonomous ships. Classification societies' guidelines or rules could be referred to in this regard, for instance, DNV GL class notation Cyber secure [66] addresses cyber security by providing requirements and verification of technical barriers, processes and people awareness based on management of cyber risks on board. On the other hand, BIMCO [67] guidelines incorporate elements from the NIST framework and relevant IMO guidance on the management. They also incorporate International Association of Classification Societies (IACS) guidance on the cyber resilience. Their main focus is the cyber risk management and cyber risk assessment.

10.2 ANTICIPATED NEW PLAYERS WITH NEW RISK IN CONTEXT OF UNMANNED SHIPS

From a global perspective, the increased automation and introduction of MASS are expected to reduce the level of risks and marine casualties, whereas, at the same time, new risks due to implementing new technologies could also be introduced which have not been quantified or insured previously. Historically, the legal systems and the insurance industry can absorb such risks without the need for fundamental changes to the basic principles. For MASS, it is also applicable; however, it could take time. Therefore, one must think of the gradual implementation of automation and MASS at different autonomy levels, which will allow the industry to weigh the newly introduced risks over expected benefits.

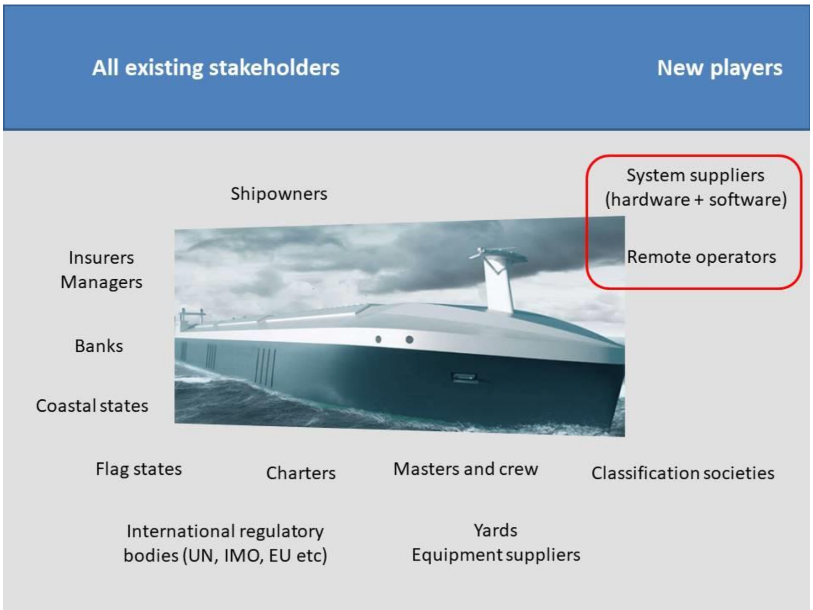

Figure 9 - Existing and new players in autonomous shipping

Apart from the technological risk, there will be risks associated with new players, such as remote operators, system suppliers and technology providers (see Figure 9), who make the remote operation and monitoring of autonomous ships possible. Causalities due to a fault in navigation algorithms, hardware failure, or negligence of the operator would be new in this field and possible liable parties must be defined and widely agreed upon before such occurs. These new players will also share some liabilities with shipowners and other stakeholders, which mean a gradual shifting in liabilities towards the new player is expected. The system suppliers and remote operators are expected to have an increased liability exposure, partly depending on the negotiations of the contract with the shipowners and yards, and also the applicable laws.

On the other hand, the shipowners will be vicariously liable for the acts and omissions of the remote operators. However, it is unlikely that the manufacturer of the navigation system, or the programmer of an algorithm, will be considered a master with the shipowners being vicariously liable for any shortcomings.

10.3 CHANGE IN THE DISTRIBUTION OF LIABILITIES AMONG CURRENT STAKEHOLDERS

In order to ensure a sustainable autonomous shipping industry, it is crucial to identify the changes in the liabilities distribution among the current stakeholders, and the gradual shifting of risks towards the new players. The following subsections discuss the liabilities of shipowners, system suppliers and remote operators considering the autonomous shipping landscape and propose amendments to curb those. Additionally, issues such as exemption from liability for nautical faults, preservation of evidence for any marine casualty, liable parties under criminal law, and liability of new technology are analysed in the context of autonomous ships.

10.3.1 Liability of Shipowners

The shipowners are the overall liable party within commercial civil shipping. Their liability is regulated nationally and depends, inter alia, on the flag state of the ship and the territorial waters it lies in. In addition, they have secondary liability for their employees and those performing tasks in the ship's service (employer liability) under section 151(1) of the merchant shipping act, which has the following wording: “The shipowners shall be liable for damage caused through fault or negligence in their service by the master, crew members, pilot or others who carry out work in the service of the ship.” Additional complexity is expected in relation to jurisdiction and enforcement against the remote operators.

Regarding showing obligation to care for cargo, the Hague and Hague-Visby rules, Art. 3 (2) mentions that: "Subject to the provisions of Article IV, the carrier shall properly and carefully load, handle, stow, carry, keep, care for, and discharge the goods car." On the other hand, section 262(1) of the merchant shipping act mentions that "The carrier shall perform the carriage with appropriate care and dispatch, take care of the goods and otherwise safeguard the interests of the owner from receipt to delivery of the goods." Since the current liability regime is also based on fault and the human element, it would be difficult to hold the shipowners liable if he/she already ensured all systems working properly and that the ship is seaworthy.

Table 16 identifies the challenges associated with the shipowners’ third-party civil liability, liability for collision, liability to show care for cargo and the right to limitation of liability in view of autonomous shipping industry and addresses those accordingly.

Table 16 - Shipowners' liabilities in context of autonomous ships

Issues	Regulatory bodies	Gaps identified	Proposals
Liability of Shipowners for third party claim (Civil Liability)	Merchant shipping act	In most jurisdictions, shipowners are vicariously liable for the acts and omissions of their crew. In regard to RCC personnel, their liability needs to be defined.	**Recommendation:** Include an interpretation considering a remote operator as a master of an autonomous ship, and therefore, the shipowners will be vicariously liable for the acts and omissions of the remote operator. **Justification:** In the context of autonomous ships, the remote operator will discharge the navigational/operational duties placed with the master under the current regulatory framework. Hence, the shipowners will be vicariously liable for the acts and omissions of the remote operator.
		Most jurisdictions impose a fault-based regime linking liability to a ship's proportion of fault in the case of an accident. In the context of autonomous ships, it will not make sense to refer to the fault-based liability of the shipowners to the extent that navigation is performed and decisions are taken by the system without any human interference.	**Recommendation:** Include a provision considering the strict liability of shipowners. **Justification:** It is quite difficult to find room for assessment of fault on part of a shipowners unless they have failed to exercise due diligence in its operation and use of the MASS or in relation to maintenance or software updates. Thus, it is necessary to change the liability norm in the long run to strict liability at least in connection with collisions on behalf of the shipowner. This gives rise to distributions of principles in case of collisions or causation of damage in regard to third parties of two or more ships with strict liability. Strict liability at sea can be developed by courts - as for hazardous activities on land. Also, there might be national or international legislation providing for the strict liability. Though the liability norm

Issues	Regulatory bodies	Gaps identified	Proposals
			may change over time, the overall liability for ships causing damage will still rest with the shipowners.
Liability of Shipowners for collisions	1910 Collision Convention [68]	In relation to collisions, the notion of "fault" needs to be addressed in the context of MASS.	**Recommendation:** Include an interpretation considering the technical and programming-based fault for MASS operation. In addition, consider a contractual regime to list down the scope of services, warranties and obligations of any third party responsible for the fault. **Justification:** In the context of autonomous ships, the interpretation of the convention's wording "fault of a vessel" should be expanded to encompass the fact that collisions could happen due to technical failure or inadequate programming where no humans have been involved in the navigation. It also remains to be clarified if the concept of "fault of the vessel" only covers fault demonstrated by the crew or members of ship owners' organisations or if it could also capture faults from other third parties such as equipment and system suppliers and software programmers. If any third party is responsible for the fault, the contractual regime should be referred that lists down the scope of services, warranties and obligations.
Cargo liability of shipowners / Obligation to show care for the cargo	The Hague and Hague-Visby rules, Art. 3 (2) [69] &	The current cargo liability regime is based on fault and the human element. As long as the shipowners have reputed all the systems and the ship is seaworthy, it would be difficult to hold him liable.	**Recommendation:** Include an interpretation to lay out the responsibilities of the shipowners towards the cargo carried on board while issuing the bill of lading. **Justification:** The bill of lading issued by the carrier will serve as a contract for the carriage of goods to lay out the responsibilities of the shipowners toward the cargo carried on board. The shipowners

Issues	Regulatory bodies	Gaps identified	Proposals
	Section 262(1) of the merchant shipping act	Thus, the stakeholders have requested clarification in relation to obligations to care for the cargo in the context of unmanned MASS. It is expected that cargo insurers will also push for clarification on the application of the current regulatory framework and standard contracts for the carriage of cargo in relation to MASS, if and when a market for MASS cargo transport emerges.	are therefore liable for the cargo damage as pursuant to the contract of carriage issued. It is expected that wordings of charter parties will be adapted to the use of MASS for cargo carriage as demand rises and that this will not present a challenge as charter parties in most jurisdictions are subject to the principle of freedom of contract.
Right to limitation of liability of shipowner	Article 1 of the 1976 Liability Limitation Convention [70]	It must be presumed that like shipowner, the remote operators, manufacturers and programmers of autonomous ships' navigation systems will also be covered by the right to limitation of liability under this convention.	**Recommendation:** Include an interpretation to cover the remote operator by the right to limitation of liability as a representative of the shipowner. An amendment is also required to consider the knock-for-knock agreement as a common liability limitation instrument. On the other hand, the limitation of liability for manufacturers and programmers of autonomous ships' navigation systems is quite hard to define. **Justification:** Remote operators of autonomous ships will be covered by the right to limitation of liability under section 171(2) of the merchant shipping act since he/she is performing a work function on behalf of the shipowner. Although he/she is working remotely, this convention does not provide any restriction on the provision of the working location. However, if the remote operator has not been hired by the shipowner, but works in an independent company who serves several shipowners by providing operators, it creates uncertainty.

Issues	Regulatory bodies	Gaps identified	Proposals
			Additionally, It is suggested to consider the knock-for-knock clauses for the agreements of the shipowners with the offshore site facility operators and with the port facility operators. This is a common liability limitation instrument used in the offshore sector. A knock-for-knock clause offers certainty and clarity to the parties and their insurers. It is an agreement between the parties to contract out of remedies to which they would otherwise be entitled and it clearly establishes where liability lies. Because there is no requirement to show cause, fault or blame there is less scope for dispute. This reduces the chance of litigation or arbitration and also promotes transparency. Knock-for-knock clauses may also reduce duplication in the parties' respective insurance policies, by removing the need to consider (or pay for) insurance in respect of other parties' property. This leads to cost savings. On the other hand, it is quite hard to provide access to limitation of liability for manufacturers and programmers of autonomous ships' navigation systems since they are not the considered persons for whom the shipowners are liable.

10.3.2 Liability of system suppliers

In conventional shipping, there are system suppliers related to navigation, such as ECDIS, radar, SAT etc. However, in the context of autonomous ships, there will be new system suppliers including manufacturers and programmers of navigation and communication equipment. The liability of the new system suppliers will be based on current liabilities of suppliers of navigational equipment of conventional ships, but as the new technologies and algorithms are planned to be used for the first time, the liability clauses might be different than what we have now for well-established navigational systems at the initial stage. This study considers the system suppliers' liabilities as contractual liability, third party (product) liability and professional liability. Table 17 includes the details of those.

10.3.3 Liability of remote operators

Stakeholders generally assume that the duties and responsibilities of the master will be allocated to the remote operator in the context of MASS, and therefore, they will be in the very centre of future autonomous ship operations and management. It is obvious that the remote operators would attract liability and should be considered as independent liability subjects. Even in the context of fully autonomous ships, it is expected that designation of a remote responsible operator will be required to anchor liabilities. The remote operators are expected to have contractual liability towards the shipowners which will be similar to that of current technical and commercial managers. On the other hand, shipowners will be vicariously liable for the acts and omission of the remote operator. Table 18 explains the liability of remote operators in details.

10.3.4 Other issues

In regard to exemption from liability for nautical faults, the Hague and Hague-Visby rules, Art. 4 (2)(a) states that: "Neither the carrier nor the ship shall be responsible for loss or damage arising or resulting from (a) Act, neglect, or default of the master, mariner, pilot, or the servants of the carrier in the navigation or in the management of the ship". In addition, section 276(1) of the merchant shipping act states that "The carrier shall not be liable if he/she can prove that loss or damage arose or resulted from: (1) fault or neglect in the navigation or management of the ship by the master, crew, pilot or others who work in the service of the ship and (2) fire, unless caused by fault or neglect of the carrier himself."

However, the claiming exemption from liability for nautical faults for autonomous ships has yet to be defined. Other issues, such as preservation of evidence in any marine casualty, liable parties under criminal law, and liability of new technology are also needed to be discussed anticipating the growth of autonomous ships. Table 19 addresses these challenges in the context of autonomous ships.

Table 17 - System suppliers' liabilities in context of autonomous ships

Issues	Regulatory bodies	Gaps identified	Proposals
The liability of system suppliers (manufacturers and programmers of navigation and communication equipment)	-	The liability of manufacturers and programmers of navigation and communication equipment for autonomous ships needs to be defined as new players in autonomous shipping.	**Recommendation:** Include a provision defining the following liabilities of new system suppliers. **Contractual liability:** The contract between the manufacturers/programmers and the yard/shipowners will remain the decisive instrument when establishing the allocation of risks and liabilities. Yards are in general not likely to take on additional liability or warranty obligations as a system and equipment integrator in relation to the construction of MASS. Shipowners will have to rely on obligations and warranties extended by suppliers. **Third Party (Product) Liability:** The defects in supplies that do not impose damage on other things or persons cannot be covered through insurance according to the law of obligations. Thus, this will be considered the manufacturer's or programmer's business risk. Furthermore, if their products and services cause injuries to persons or damage to objects, they could be liable pursuant to the regulations on third party (product) liability. **Professional liability:** Manufacturers and programmers could be subject to the professional liability of advisers to the extent that they could provide independent advice in addition to their product or service.

Table 18 -Remote operators' liabilities in context of autonomous ships

Issues	Regulatory bodies	Gaps identified	Proposals
Liability of remote operator	-	Remote operators are expected to attract liability and to be considered as independent liability subjects.	**Recommendation:** Include a provision defining the following liabilities of remote operator. **Contractual liability towards shipowner:** To the extent remote operators are established as third-party service providers, it is expected that the contractual regime will be similar to that of current technical and commercial managers. This includes a clearly defined scope of services, warranties and obligations. Remote operators could be covered by shipowners' insurance as managers. **Third-party liability:** In relation to third party liability, it is generally assumed that shipowners will remain vicariously liable for the acts and omission of the remote operator.

Table 19 - Other liabilities issues and proposals in context of autonomous ships

Issues	Regulatory bodies	Gaps identified	Proposals
Exemption from liability for nautical faults	The Hague and Hague-Visby rules, Art. 4 (2)(a) [62] & Section 276(1) of the merchant shipping act	Claiming exemption from liability for nautical faults for autonomous ships	**Recommendation:** Include an amendment to consider the term RCC operator at autonomy levels R and RU, whereas there is hardly any possibility of claiming exemption from liability for navigation faults for fully autonomous ships. **Justification:** For ships at lower autonomy levels, the remote operator will be considered the ”master” in relation to the ship’s navigation. Thus, he/she will be responsible for any loss or damage due to his act/negligence during navigation, and the carrier can claim its exemption from liability for nautical faults. In this regard, to protect the shipowners it is suggested to include the term "RCC operator" into Hague-Visby rules, Article IV, rule 2(a) and Section 276(1) of the merchant shipping act as follows: The Hague and Hague-Visby rules, Art. IV (2)(a) : "Neither the carrier nor the ship shall be responsible for loss or damage arising or resulting from (a) Act, neglect, or default of the master, mariner, pilot, RCC operator or the servants of the carrier in the navigation or in the management of the ship". Section 276(1) of the merchant shipping act: "The carrier shall not be liable if he/she can prove that loss or damage arose or resulted from 1) fault or neglect in the navigation or management of the ship by the master, crew, pilot, RCC operator or others who work in the service of the ship. 2) fire, unless caused by fault or neglect of the carrier himself. "

Issues	Regulatory bodies	Gaps identified	Proposals
			Since Hague-Visby rules, Article I, defines the ship as any ship used for the carriage of goods by sea, it is needless to define the MASS separately as the existing definition of "ship" could support the operation of MASS. In the context of a fully autonomous ship, there is hardly any possibility of claiming exemption from liability for navigation faults, considering the fact that the fully autonomous ships run on pre-programmed algorithms, rather than navigation decisions. In addition, faults committed in ”the management of the ship” by other shore-based personnel in the shipowners' organisation or among the partners will not necessarily fall within the scope of application of the provision.
Preservation of evidence	Part 18 of the merchant shipping act on ship logs, marine enquiries & SOLAS, Chapter V, regulation 20	Preservation of evidence to explain liabilities in case of civil law or marine casualty	**Recommendation:** Include the following requirements to be considered: - A provision considering an onboard VDR to store all necessary information if the shore data storage is limited. - Consider the command log and transmission log for the ship-shore communication into the data replicated to the shore. - Specify the minimum duration of storage. **Justification:** For autonomous ships, logging of ships' operation data must be made compulsory. As autonomous ships need to undergo continuous information sharing with the shore, the operational data must be stored in more than one place so as to access it in case of incidents. Consideration must be given to include the command log and transmission log for the ship-shore communication into the data replicated to the shore. The minimum duration of storage data should

Issues	Regulatory bodies	Gaps identified	Proposals
			also be defined to follow. This would be a major improvement compared to a VDR (Voyage Data Recorder) in conventional ships. The operational data generated by MASS will play an imperative role in clarifying circumstances and determining fault in the event of marine casualties. Presumably, insurers will, as part of the insurance terms and conditions, require access to operational data in connection with claims handling. Furthermore, it is essential to ensure who is in control of the ship in relation to the placing of responsibilities as well as a change of autonomy levels. This could be done by issuing electronic certificates to the ones responsible when changing the watching/taking over control of the ship.
Liable parties under criminal law	Merchant Shipping Act 1995	Liable parties under criminal law should be clearly defined for autonomous ships. It is noted that for conventional ships, master and the shipowner are the liable parties under criminal law for compliance with regulatory requirements aimed at shipping industries.	**Recommendation:** Include an interpretation of the current legal basis to make the remote operator liable to prosecution as a master of autonomous ships. **Justification:** For autonomous ships, the remote operator will be liable to criminal law sanctions to the extent that he/she assumes the obligations that rest with the master under current law. Therefore, it will be necessary to amend the current legal basis where the master is the party liable to punishment if it is to be able to make the remote operator liable to punishment.
Liability of new technology	-	Shipowners are responsible for covering the risk and exposure to liability for commercial shipping. In the context of autonomous ships, the new risk associated with using new technology will be imposed.	**Recommendation:** Include a provision to account for the inclusion of additional autonomous aspects such as sensors, software and communications for MASS operation. In this regard, the Classification Societies could be considered as third parties to repute the equipments as seaworthy.

Issues	Regulatory bodies	Gaps identified	Proposals
			Justification: Given the novelty of the technology and the operational structure, it is assumed that insurers may require additional independent third-party assurance and due diligence investigations prior to underwriting MASS risks. Classification Societies as third parties to repute the ship and the equipment as seaworthy could be considered suitable in this regard. Moreover, as the claims history and the risk profile connected with insuring MASS are not available, particular insurance terms and conditions for MASS might be required. Additional consideration of the increasingly common cyber risks will also be required. At present, hull coverage usually excludes cyber risks explicitly whilst liability insurance usually does not contain any explicit provision apart from the exclusion of events arising from war and terrorism.

10.4 INSURANCE

It is believed that insurance coverage will be available for MASS operation, as the insurance market will adapt to the demand from shipowners and technological developments. A clear international regulatory framework will act as a catalyst for maturing the insurance market for MASS. Until such framework is in place, stakeholders expect insurers to rely on flag state requirements and statutory certificate as well as verification from classification societies as a prerequisite for insuring MASS.

Risks associated with data exchange and dependency are not new to MASS operation. As any other industry, shipping industry is also exposed to cyber risks. However, with the implementation of MASS, the cyber risk is expected to increase significantly. Traditional types of marine insurance, especially P&I and Machinery insurances, normally do not cover cyber risks since they will typically contain a so-called "institute cyber-attack exclusion clause (CL 380)", which implies that there is no insurance cover for damage "caused by or contributed to or arising from the use or operation, as a means for inflicting harm, of any computer, computer system, computer software programme, malicious code, computer virus or process or any other electronic system". On the other hand, Baltic and International Maritime Council (BIMCO) cyber security clause [67] has been developed for contracts by a team comprised of owners, charterers, P&I clubs and legal experts. The clause mainly focuses on three important functions, which are raising the risk awareness of each party, providing a mechanism to help minimise the risk of a cyber incident happening in the first place and ensuring that the parties mitigate and resolve the effects of an incident when it occurs, while also cooperating to assist each other. In this regard, each party shall use reasonable endeavours to ensure that any third party providing services on its behalf in connection with this Contract complies with the cyber security clauses. However, the insurance companies still believe that there is a huge gap between the actual cyber risk and the limited insurance taken out in the maritime field, thus, a major non-insured risk. Hence, the insurance instruments are often limited by a buy back [67] for the limited range of the related risks in the cyber domain. The situation may further improve as the classification societies consistently develop and apply standardised cyber security requirements, e.g. unified requirements (UR) E26 [71] and UR E27 [72] from IACS based on IEC 62443.

The section addresses the issues in the existing insurance framework to ease the MASS operation. It includes insurance pricing, recourse claims, seaworthiness under insurance law and the insurance of cyber risks. Table 20 includes the details of those.

Table 20 - Insurance framework analysis and proposals in context of autonomous ships

Issues	Regulatory bodies	Gaps identified	Proposals
New/unknown risks without any precedents and claims record could raise the issue of Insurance pricing	-	New and unknown risks without any precedents and claims records could result in uncertainty in determining the extent of coverage and the size of the insurance premium. A too expensive or non-transparent insurance market could present a considerable systemic barrier to autonomous ships.	**Recommendation:** Include a new instrument considering the provision of risk assessments of new technologies. In addition, the new technologies must be certified by the IACS members and IEC recognised third parties. **Justification:** A new risk assessment needs to be carried out for the new technologies adopted in autonomous ships to understand the coverage required by the insurer and associated insurance premium. For instance, a novel risk assessment process has been proposed for autonomous inland waterways ship in AUTOSHIP project [35] that integrates the operational and functional hazard identification approaches, whilst considering the safety, security and cyber security hazards. Another newly developed threat likelihood estimation approach mentioned in [73] could support risk managements under potential cyber threats. In this regard, a clearly coded international regulatory framework will be a necessary precondition to set a standard for the equipments/technologies used in autonomous ships, and consequently a well-functioned and effective insurance market for autonomous ships. However, it will be a time-consuming job. There is also a need for the certification of the new technology by IACS members and by the International Electrotechnical Commission (IEC) recognised third parties. A number of operational monitoring services have emerged and some of them already provide the metrics for the risk of collision on conventional ships. Creation of global databases with metrics for the conventional and MASS ships should support benchmarking

Issues	Regulatory bodies	Gaps identified	Proposals
			of the technical solutions and assessing the risks and estimating the corresponding premiums. Creation of global databases on the safety performance metrics would require action at an international level to encourage the sharing of the anonymised data, and instruments at the level of IMO and EU Commission. On contrary, insurers can add or amend clauses using specific wording without having to base themselves on regulations or can rely on flag state requirements and statutory certificates as well as verification from classification societies as a prerequisite for insuring MASS. In this way, the insurance framework will be able to adapt faster than the regulatory framework.
Recourse claims		P&I (Protection and Indemnity insurance) and Hull & Machinery insurance companies need to take a stance on the actual value of recourse claims against manufacturers and programmers of navigation and communication equipment (hardware and software) in case of major damage.	**Recommendation:** Include an interpretation to understand the actual value of recourse claims against the manufacturers and programmers of navigation and communication equipment. **Justification:** In this connection, the extent of the coverage and the limit of cover in the manufacturers' and programmers' liability insurance and product liability insurance will be central so that the P&I and Hull & Machinery insurance companies are not left with the recourse claims that are uncovered by insurance and cannot be collected from the manufacturers and programmers. To the extent that MASS will operate on different autonomy levels with inherent variations of associated risks, it is expected that insurers will introduce "change of risk/alternate risk clauses" in MASS insurance policies.
Seaworthiness under insurance law	-	A ship will be considered not seaworthy under insurance law if it is not in such a condition – in terms of manning and	**Recommendation:** Include an interpretation to consider an autonomous ship seaworthy based on Class notation.

Issues	Regulatory bodies	Gaps identified	Proposals
		equipment – as it should be according to a seamanlike assessment for the voyage to be undertaken.	**Justification:** It will not put any barrier to autonomous ships' operability as long as they are seaworthy without manning based on the Class status if assigned and maintained.
		In relation to autonomous ships, seaworthiness under insurance law will presumably give rise to uncertainty in many other jurisdictions, especially common law jurisdictions. As a large part of the global insurance market is subject to the law of common law jurisdictions, this would pose a great challenge in relation to the insurance of autonomous ships.	**Recommendation:** Include a set of new technical standards and international regulations to ensure a sustainable insurance market for autonomous ships. **Justification:** Homogeneous technical standards and international regulation will be important to ensure a proper functioning insurance market for the new risk presented by autonomous ships until a representative claims record is available.
Insurance for cyber risks		New insurance products need to be developed in relation to cyber risks.	**Recommendation:** Include new insurance products to ensure the actual coverage of cyber risk for autonomous ships. **Justification:** New insurance products need to be developed to ensure the actual coverage needed for cyber risk and the extent of loss for autonomous ships. This is because the present cyber insurance products have the form of collective agreements (pools), where one shipowner's major loss could exhaust the other insurance-covered shipowners' coverage possibility.

11 CONCLUDING REMARKS

The report addresses the existing regulatory, legal and liabilities gaps identified in WP2 of AUTOSHIP project. A thorough investigation of relevant publications on regulatory framework analysis in the context of autonomous ships has been done in order to prepare the proposals to the regulatory bodies and operators defining needed modifications to current rules and regulations aiming to facilitate the implementation of the autonomous ship's concept. To facilitate the amendments process, four degrees of autonomy have been considered as identified by IMO in Regulatory Scoping Exercise (RSE) and the instruments have been addressed by either: developing interpretations or equivalences, amending the existing one, developing a new or doing nothing at all if the instrument does not create any barrier to autonomous ships' operation. The instruments are also classified as high, moderate or low on the basis of the consideration of modern technologies to replace human intervention in compliance with the rules and regulations and getting worldwide acceptance.

The main amendments in regulatory frameworks that have been identified are as follows:

I. A set of useful definitions and terminologies for MASS operations have been added in Section 2.2 of this report (e.g. master, crew, responsible person, autonomous, autonomy, remote control centre, remote operator, control station, uncrewed etc.)

II. The meanings of "master", "crew" and "responsible person" are clarified at different autonomy levels taking into account that they are not on board and also that several tasks normally carried out manually by the master/crew are managed by the systems on board or remotely by RCC personnel. These types of instruments which require definition wise explanation/amendments are deemed less severe in getting wide acceptance.

III. Some instruments require manual operations or indication/alarm on the bridge. Alternative solutions are proposed in compliance with these provisions with equivalent safety levels, where manual operations are suggested to be done remotely or autonomously at different autonomy levels by deploying the Key Enable Technologies (KETs) for the two use cases. Additionally, the ways to transfer a "physical bridge" to an "electronic bridge" with detailed functionalities of onboard control system, connectivity and remote control system are also included to justify the equivalences of some proposed solutions to the existing instruments. These types of instruments are deemed moderately severe as trusted modern technologies could be utilized to support the alternatives to comply with the existing instruments.

IV. Some instruments explicitly require the presence of humans on board, e.g., render assistance in a distress situation or pilotage requirements. These instruments are suggested to be qualified by the reasonable capabilities and limitations of autonomous ships. Additionally, the provision of getting exemptions from these rules is also highlighted for autonomous ships at regional or national levels. These types of instruments are deemed highly severe as they require more consideration to get acceptance at an international level.

V. There are some instruments that do not require any amendments as they either do not hinder the autonomous operations of ships directly or the provisions contain exemption criteria for innovation or test purposes. For example, Directive 2016/1629/EC and the Bureau Veritas Classification Rules of provisions promoting the use of new technologies and derogations for specific ships in order to encourage innovation.

VI. The minimum redundancy to achieve a satisfactory safety level must be evaluated as a part of a proper risk assessment and cost-benefit analysis. Redundancy is important but extremely costly, and it is recommended to consider only if the safety requirements are too strict. Therefore, if the minimum redundancy has been found to be zero to maintain the minimum safe level, it could be avoided.

VII. Requirements in relation to qualification, education, training, certification and watchkeeping schemes and watchkeeping principles for remote operators are referred to the D7.2 (Training framework for crew, operator and designer) of the AUTOSHIP project.

VIII. The major Classification Societies have issued Guidelines for Autonomous Shipping, e.g., Bureau Veritas Guidance Note NI 641 DT R01 [43] and Rule Note on Cybersecurity for the Classification of Marine Units NR 659 DT R00 [31]. These guidelines and rule note do not include specific requirements for inland navigation ships, which are highlighted and discussed in the context of IWW use case.

The proposals that are put forward to mitigate the gaps identified through the legal framework are as follows:

I. To give autonomous ships a wide acceptability and freedom of movement in different flag and port and coastal states jurisdiction, bilateral agreements among interested parties could be a solution at the initial stage of MASS operation. Alternatively, a set of regulations could be enforced to ensure the general acceptability of MASS amongst different nations. However, it would take a long time to establish such international rules.

II. There will not be an issue with the ship's manning requirement to enjoy the right of innocent passage as far as autonomous ships are considered as ships, and they are not engaged in the activities mentioned in Article 19 (2) of UNCLOS.

III. Apart from the jurisdiction issues, the requirement of having a properly qualified master could be met as long as a qualified person (remote operator) can always be identified as the one in command of the ship for steering and monitoring purposes, while a supervisor and a backup team are available for consultations.

IV. In case of zero crewing, the remote operator's obligation to render physical assistance at sea in a distress situation is limited. They can be engaged in a sweep search, but not in the recovery of the persons in water or driving survival craft unless the onboard equipment allows them.

The main recommendations that are considered through the insurance & liabilities framework are as follows:

I. In the context of autonomous ships, the shipowners will be vicariously liable for the acts and omissions of the remote operator / RCC personnel.
II. Most jurisdictions impose fault-based regimes that require the crew or some other servants to be negligent. However, it does not make sense to refer to the fault-based liability of the shipowners to the extent that navigation is performed, and decisions are taken by the system without any human interference. In such cases, the cause might impose strict liability, which means liability irrespective of fault.
III. In 1910 Collision Convention, the interpretation of the convention's wording "fault of a vessel" should be expanded to encompass the fact that collisions could happen due to technical failure or inadequate programming where no humans have been involved in the navigation.
IV. To justify the cargo caring liability, the responsibilities of the shipowners toward the cargo carried on board should be laid out while issuing the bill of lading.
V. Remote operators of autonomous ships will be covered by the right to limitation of liability; however, it is quite hard to provide access to limitation of liability for manufacturers and programmers of autonomous ships' navigation systems since they are not the considered persons for whom the shipowners are liable.
VI. The liabilities of system suppliers could be classified as Contractual liability, Third party (Product) liability and Professional liability.
VII. The liabilities of remote operators could be classified as Contractual liability towards shipowners, and Third Party liability.
VIII. A new risk assessment needs to be carried out for the new technologies adopted in autonomous ships to understand the coverage required by the insurer and associated insurance premium.
IX. Insurers can add or amend clauses using specific wording without having to base themselves on regulations, hence the Insurance framework will be able to adapt faster than the regulatory framework.
X. New insurance products need to be developed to ensure the actual coverage needed for cyber risk and the extent of loss for autonomous ships.

12 BIBLIOGRAPHY / REFERENCES

[1] International Management Code for the Safe Operation of Ships and for Pollution Prevention, ISM Code, as adopted in 1993.

[2] International Ship and Port Facility Security (ISPS) Code, SOLAS 2002 Conference Resolution.

[3] IEC 60050, International Electrotechnical Vocabulary at http://www.electropedia.org/

[4] Rødseth ØJ, Faivre J, Hjørungnes SR, Andersen P, Bolbot V, Pauwelyn A-S, et al. AUTOSHIP deliverable D3.1 Autonomous ship design standards, Revision 1.1. 2021

[5] Maitime Broadband Radio. Maritime Broadband Radio - MBR - Kongsberg Maritime

[6] IMO Resolution MSC.266(84), (adopted on 13 May 2008), Code of Safety for Special Purpose Ships, 2008.

[7] ISO 23860: Ships and marine technology -- Vocabulary related to autonomous ship systems, Working Draft, Version 1: May 25th 2022. https://www.iso.org/standard/77186.html . The draft is at time of writing not available to the public.

[8] IMO (2020) Regulatory scoping exercise. https://www.imo.org/en/MediaCentre/HotTopics/Pages/Autonomous-shipping.aspx.

[9] Central Commission for the Navigation of the Rhine (CCNR), Definitions on various forms of automated navigation, 2018

[10] AUTOSHIP. Autonomous Shipping Initiative for European Waters 2019 [Available from: https://www.autoship-project.eu/

[11] CMI (2016) CMI International working group position paper on unmanned ships and the international regulatory framework

[12] DMA (2017) Analysis of the regulatory barriers to the use of autonomous ships

[13] Bačkalov I (2020) Safety of autonomous inland vessels: an analysis of regulatory barriers in the present technical standards in Europe Safety Science 128:104763 https://doi.org/10.1016/j.ssci.2020.104763

[14] MUNIN (2013) 7.2: Legal and Liability Analysis for Remote Controlled Vessels

[15] MUNIN (2016) Maritime Unmanned Navigation through Intelligence in Networks. http://www.unmanned-ship.org/munin/. Accessed 12/12/2019 2019

[16] Inoue S, Mori H (2021) Development of Automated Ship Operation Technologies. *Class NK Technical Journal - Special feature: Autonomus Ships*, 3, 59-66.

[17] AUTOSHIP Deliverable 2.3 "Regulatory framework mapping & Identification of gaps and requirements for autonomous ships compliance" downloadable from the AUTOSHIP project website https://www.autoship-project.eu/downloads/

[18] IMO. Generic guidelines for developing IMO goal-based standards. https://www.imo.org/en/OurWork/Safety/Pages/Goal-BasedStandards.aspx

[19] AUTOSHIP Deliverable 2.1 "Complete supply chain mapping & identifications of interactions between SSS and IWW demostrators" downloadable from the AUTOSHIP project website https://www.autoship-project.eu/downloads/

[20] AUTOSHIP Deliverable 2.4 "Risk assessments, fail-safe procedures and acceptance criteria". downloadable from the AUTOSHIP project website https://www.autoship-project.eu/downloads/

[21] International Convention for the Safety of Life at Sea (SOLAS), Consolidated Edition

[22] International Convention on Load Lines (Load Lines), Consolidated Edition, as modified by the revised 88 Protocol, for ships constructed from 2005-01-01

[23] International Code on Intact Stability (2008 IS Code), as adopted in December 2008

[24] IMO Instruments Implementation Code (III Code), Resolution A.1070(28) adopted on 4 December 2013

[25] IMO International Convention on Tonnage Measurement of Ships (TMC), 1969
[26] IMO International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978 (STCW) Consolidated Edition
[27] 2010 Manila Amendments to the Seafarers' Training, Certification and Watchkeeping (STCW) Code
[28] IMO Convention on the International Regulations for Preventing Collisions at Sea (COLREG), 1972, as amended
[29] International Convention on Maritime Search and Rescue (SAR), 1979, Consolidated Edition
[30] IMO International Convention for the Prevention of Pollution from Ships (MARPOL), 1973, Consolidated Edition
[31] ILO Maritime Labour Convention (MLC), 2006, as amended
[32] IMO Circular MSC.1/Circ.1604 Interim Guidelines for MASS trials, 14 June 2019
[33] IMO Circular MSC-FAL.1/Circ.3 Guidelines on maritime cyber risk management, 5 July 2017
[34] IMO MSC.1/Circ.1580. Guidelines for vessels and units with Dynamic Positioning (DP) systems. https://www.register-iri.com/wp-content/uploads/MSC.1-Circ.1580.pdf
[35] IEEE Standard 521-2002 Standard Letter Designations for Radar-Frequency Bands.
[36] Geo-Redundancy: Why Is It So Important? https://www.unitrends.com/blog/geo-redundancy
[37] Frequency Band Review for Fixed Wireless Service. – Ofcom. https://www.ofcom.org.uk/__data/assets/pdf_file/0015/45204/report.pdf
[38] UR Z29 Remote Classification Surveys - New Mar 2022. UR Z - IACS
[39] What Are The Security Levels Under ISPS Code? https://www.marineinsight.com/marine-safety/security-levels-under-isps/
[40] AUTOSHIP Deliverable 7.2 "Training framework for crew, operator and designer"- 1st draft available
[41] Rødseth ØJ, Wennersberg LAL, Nordahl H. Levels of autonomy for ships. Journal of Physics: Conference Series (JPCS). 2022, 2311 1-9. 2022 DOI: 10.1088/1742-6596/2311/1/012018.
[42] International Convention on salvage, 1989. https://www.pravo.unizg.hr/_download/repository/1989_Salvage_convention.pdf
[43] Council Directive 96/98/EC of 20 December 1996 on marine equipment, as amended by Directive 2014/90/EU of the European Parliament and of the Council of 23 July 2014, latest consolidated version: 17/09/2014
[44] Directive 2009/16/EC of the European Parliament and the Council of 23 April 2009 on Port State Control, latest consolidated version: 21/12/2019
[45] Directive 2010/65/EU of the European Parliament and of the Council of 20 October 2010 on reporting formalities for ships arriving in and/or departing from ports of the Member States and repealing directive 2002/6/EC, latest consolidated version: 27/06/2019
[46] Directive 2002/59/EC of the European Parliament and of the Council of 27 June 2002 establishing a Community vessel traffic monitoring and information system, latest consolidated version: 26/07/2019
[47] Regulation (EC) No 725/2004 of the European Parliament and of the Council of 31 March 2004 on enhancing ship and port facility security, latest consolidated version: 20/04/2009
[48] NMA's document "Veiledning ved reduksjon av bemanning", in Norwegian only
[49] IMO Circular MSC.1/Circ.1455 Guidelines for the approval of alternatives and equivalents as provided for in various IMO instruments, 24 June 2013
[50] Pilotage Act 1987. https://www.legislation.gov.uk/ukpga/1987/21/contents
[51] Bureau Veritas Marine & Offshore, NI 641, Guidelines for Autonomous Shipping, October 2019
[52] Blue Lines Logistics. Blue Lines Logistics News. 2015.

[53] European Directive 2016/1629/EC – CESNI, European Standard laying down Technical Requirements (ESTRIN), European Committee for drawing up Standards in the field of Inland Navigation, 2017
[54] European Directive 2008/68/EC – UNECE, European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways (A.D.N), January 2019
[55] Council Directive 96/50/EC of 23 July 1996 on the harmonization of the conditions for obtaining national boat masters' certificates for the carriage of goods and passengers by inland waterway in the Community
[56] [Council Directive 2014/112/EU of 19 December 2014 implementing the European Agreement concerning certain aspects of the organisation of working time in inland waterway transport, concluded by the European Barge Union (EBU), the European Skippers Organisation (ESO) and the European Transport Workers' Federation (ETF)
[57] Central Commission for the Navigation of the Rhine (CCNR), Strasbourg Convention of 2012 on the Limitation of Liability in Inland Navigation, 2012
[58] Central Commission for the Navigation of the Rhine (CCNR), Convention on the collection, deposit and reception of waste generated during navigation on the Rhine and other inland waterways, unofficial version, January 2019
[59] Resolution N° 24 – European Code for Inland Waterways (CEVNI) adopted on 15/11/ 1985
[60] Bureau Veritas Marine & Offshore, NR 217, Rules for the Classification of Inland Navigation Vessels, February 2019
[61] BV: SYS-NEQ-OSV. https://erules.veristar.com/dy/data/bv/pdf/633-NR_2016-03.pdf
[62] Hansen, H.L., Nielsen, D., Frydenberg, M., 2002. Occupational accidents aboard merchant ships. Occup. Environ. Med. 59, 85. https://doi.org/10.1136/ oem.59.2.85.
[63] Hetherington, C., Flin, R., Mearns, K., 2006. Safety in shipping: The human element. J. Saf. Res. 37, 401–411. https://doi.org/10.1016/j.jsr.2006.04.007.
[64] Rothblum, A.M., 2000. Human error and marine safety. Presented at the National Safety Council Congress and Expo, U.S. Coast Guard Research & Development Center, Orlando, FL, USA.
[65] Allianz, 2020. Safety and Shipping Review 2020: An annual review of trends and developments in shipping losses and safety. Allianz Global Corporate & Specialty, Munich, Germany.
[66] DNVGL-CG-0325. Cyber Secure. https://rules.dnv.com/docs/pdf/DNV/CG/2020-10/DNVGL-CG-0325.pdf
[67] BIMCO. The Guidelines on Cyber Security Onboard Ships Version 4.0. https://www.bimco.org/about-us-and-our-members/publications/the-guidelines-on-cyber-security-onboard-ships
[68] Convention for the Unification of Certain Rules of Law with respect to Collisions between Vessels, Brussels, 1910
[69] The Hague-Visby Rules – The Hague Rules as Amended by Brussels Protocol, 1968.
[70] Convention on Limitation of Liability for Maritime Claims (LLMC), London, 1976
[71] IACS UR E26: International Association of Classification Societies, Cyber resilience of ships - Rev.0, April 2016
[72] IACS UR E27: International Association of Classification Societies, Cyber resilience of on-board systems and equipment - Rev.0, April 2016
[73] Per H M, Dag A N, Karin B, Guttorm S (Feb 2022). Assessing cyber threats for storyless systems. Journal of Information Security and Applications, Volume 64, 103050. https://www.sciencedirect.com/science/article/pii/S2214212621002362
[74] AUTOSHIP Deliverable 5.6 “System Architecture & Design – Autonomous Control System, SCC and K-SIM” Confidential report

[75] AUTOSHIP Deliverable 5.1 “CONOPS” Confidential report

13 Appendix A The degrees of automation and control

The excerpts below for the definition of different degrees of autonomy and control have been taken without changes from Deliverable 3.1 [4].

The classification is termed **degree of automation** and will be denoted DA0 to DA4:

- *DA0 - Operator controlled*: Limited automation and decision support is available, as on most of today’s merchant ship. The human is always in charge of operations and needs to be present at the control station and aware of the situation at all times.
- *DA1 – Partial automation*: The degree of automation is higher than for DA0, but there are still limits to the automation’s capabilities. As an example, the system may be able to detect and react safely to one or possibly two obstacles but cannot in general handle more complex obstacle configurations. These limits are not defined or constrained (see DA2), so the human operator must use his or her judgement as to the required degree of control based on the current situation. This makes D1 similar to DA0, but it is assumed that the need for attention is lower.

  Note: Some documents add a fifth level of automation between DA0 and DA1. This level may be called human directed, operator assistance, or similar and represents a level where automation, e.g., can propose actions to the operator, but where the operator stills needs to be at the control position at all times and will need to take actions. This will correspond to DA0 with the definitions used in the above.

- *DA2 – Constrained automation*: The degree of automation is similar to DA1, but system capabilities are now constrained by programmed or otherwise defined limits, e.g. the system can handle one obstacle that is never closer than 200m. The limits are set to enable the system to detect that limits are exceeded and to alert the operator in time before operator intervention is required. This is a necessary prerequisite to enable the analysis of response deadlines versus maximum response times.

- *DA3 – Full automation*: The ship automation can handle all situations that the ship is expected to encounter without any intervention from crew or personnel.

For the degrees 0 to 2 of automation, the system should provide fallback mechanisms in case the designated operator fails to respond in time. Fallback could be provided by a human, e.g., at another control position, but even in this case the system may also require a second fallback, if this second human also fails to react in time. Fallback may be required for all levels in case of technical problems or environmental conditions outside the operational envelope.

In AUTOSHIP Reference Architecture, the following classification for the operator's ability is used to take control within a given time frame. In cases where more than one operator is involved, e.g., in different tiers of control of the same group of processes or in a case where different operators controls different processes, different degrees may apply to the different operators. The levels will be termed degree of control and denoted C0 to C3:

- *(R or O) C0 – No operator control*: There are no operator to monitor and control the systems or ship, nor to take control in case of warning or alert from the system ($T_{MR} \approx \infty$).
- *(R or O) C1 - Available operator control:* The operator is available and can take control in case of warning or alert from the system, but they may be not at the control station. There will be a relatively long latency before the operator can take control. This can vary from a case where the operator is working with other tasks and will need some time to get back to the control station and gain situational awareness, i.e. a delay on the order of a minute or so ($T_{MR} \approx$ minutes) to a case where the operator is off active duty, possibly sleeping, and will need several tens of minutes to reach the control position and to regain safe control (e.g. $T_{MR} \approx$ 10s of minutes).
- *(R or O) C2 - Discontinuous operator control*: The system or ship is monitored by the operator, but the operator is not directly controlling the systems. The operator is close to the control station and needs only a short time to gain situational awareness when actions are needed ($T_{MR} \approx$ 10s of seconds).
- *(R or O) C3 - Full operator control*: The system or ship is actively monitored and controlled at any time by an operator at the control station. The operator is in control of the ship. Response delays are very short ($T_{MR} = 0$).

Letter R in front refers to Remote control whilst letter O refers to Operator on the ship.

There may also be a system of procedure enforced limitations on what the operators are allowed to do. This can be referred to as **control mode**. One example is an RCC where there are two tiers of operators: One first line group of operators monitor the ship and can do simple control tasks, but are required to transfer control to second tier operators in cases where there are more complex problems to be solved. This will normally result in different maximum response times for the two tiers and, hence, different response deadline requirements for the respective functions or tasks the two tiers are expected to handle.

This could also be related to control at different abstraction levels and an example of a possible hierarchy of controls modes from high to low abstraction could be:

- **Monitoring:** Operator is only allowed to monitor operations and not to control any executive function, except adjustments to sensors for human use, e.g. external lights or cameras.
- **Supervisory control:** Operator is allowed to adjust sailing plans on a high abstraction level, e.g., change constraints associated with a waypoint or other sailing strategies.
- **Indirect control:** Operator overrides autonomous ship control and gives instructions, e.g. waypoints or set-points to the automatic control systems, e.g. the autopilot.
- **Direct control:** The operator directly controls, e.g. heading and speed.

14 Appendix B System functional breakdown [74]

Appendix B includes the functional breakdown of the three main building blocks: ship control system, connectivity and remote operation centre of an autonomous control system for ship operation in SSS and IWW use case.

Ship control:

The ship control system can be broken down to the following main functional areas, see **Figure 10**

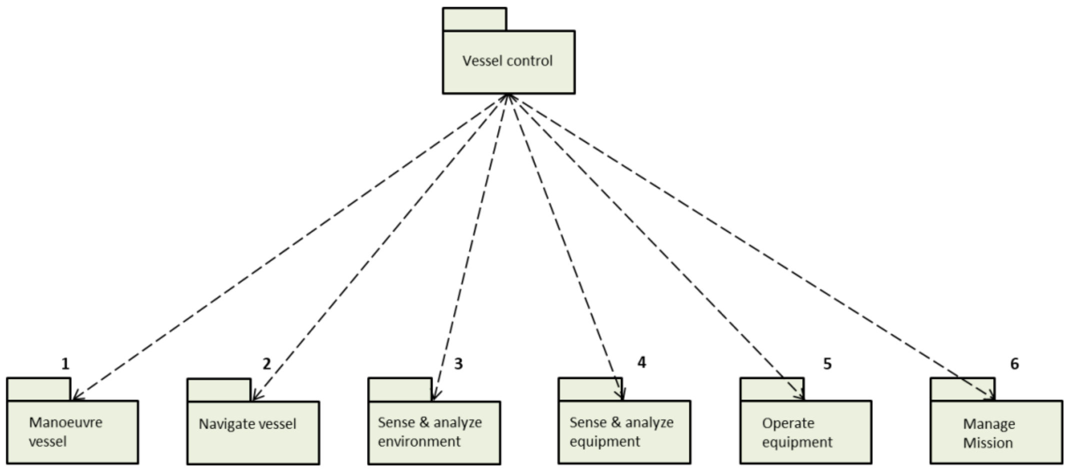

Figure 10 - Main functionalities **of ship control system**

The main description of each function is given in Table 21.

Table 21 - Description of functionalities of ship control system

No	Function	Description
1	Manage mission	This is also called the digital master of the ship. Having the overview, taking decisions, executing minimum risk conditions and so forth.
2	Navigate ship	Tasks like Controlling the voyage, avoiding obstacle and grounding is typical tasks for this function. Normally a task for the navigator.
3	Manoeuvre ship	Tasks like All speed manoeuvring, berthing / unberthing, mode handling (standby, auto-pos, mooring, sailing, etc.). This is also tasks normally done by the navigator.
4	Operate equipment	Tasks like Damage handling, Energy management, propulsion / steering, ballast /

No	Function	Description
		stability, deck machinery control, ship machinery control. This is typical tasks for the chief onboard.
5	Sense and analyse environment	Tasks like object detection and classification, world scene analysis (land contours), weather and sea state detection, own ship pose (the attitude and position of the ship). This is typical tasks for a navigator.
6	Sense and analyse equipment	Tasks like alert management, ship capability, fire and flooding, energy analysis, condition monitoring (health monitoring). These are typical tasks done by the chief.

Connectivity:

The main components of the connectivity link are shown in Figure 11

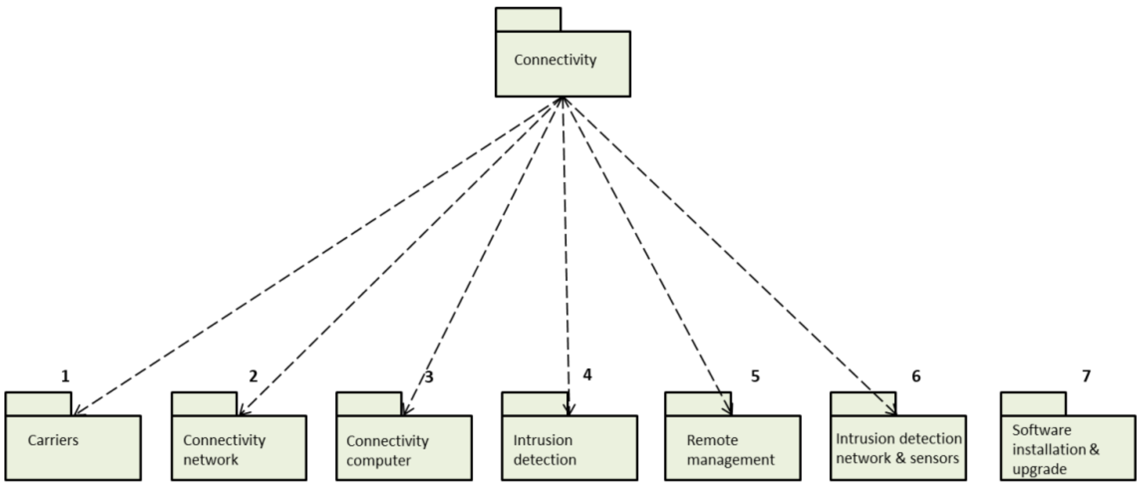

Figure 11 - Main functionalities of connectivity

The main functions of the connectivity components to ensure a safe and secure linking of data between ship and remote centre are described in Table 22.

Table 22 - Description of the functionalities of connectivity

No	Function	Description
1	Carriers	A connectivity link may utilize several carriers and a seamless transfer between carriers is an

No	Function	Description
		important function. The carriers might be satellite, 4G, 5G, MBR, Wi-Fi, etc.
2	Connectivity network	This is the physical switches and routers making the network from the control system to the carriers.
3	Connectivity computer	Routing data from the source to its destination. Muting of carriers, monitoring the carriers (signal strength, data rate, error messages, etc.). Data interchanged between ship and remote centre has different importance. Being able to prioritize these data streams is vital. This ensures that important data is prioritized over non-critical data during the operation.
4	Intrusion detection	Intrusion detection is an important function. Keeping the operation safe from intruders and detecting attacks is vital to have a safe operation. Typical functions are: Capture data from network traffic. Capture data from hosts (administrative activities). Analyze and detect anomalies. Forward to decision making actor. Manual inspection.
5	Remote management	Handling the connectivity system from a remote location and doing the maintenance and managing the system. Also enabling the control systems to be updated and reconfigured from remote.
6	Intrusion detection network & sensors	This is the hardware and network components (instrumentation) added into the network to be able to monitor and detect intrusions in the main connectivity network.
7	Software installation & upgrade	Performing router and switch upgrades. Software will be available on servers to do upgrade on demand.

Remote Control Centre:

The RCC can be broken down to the following main functional areas, see Figure 12

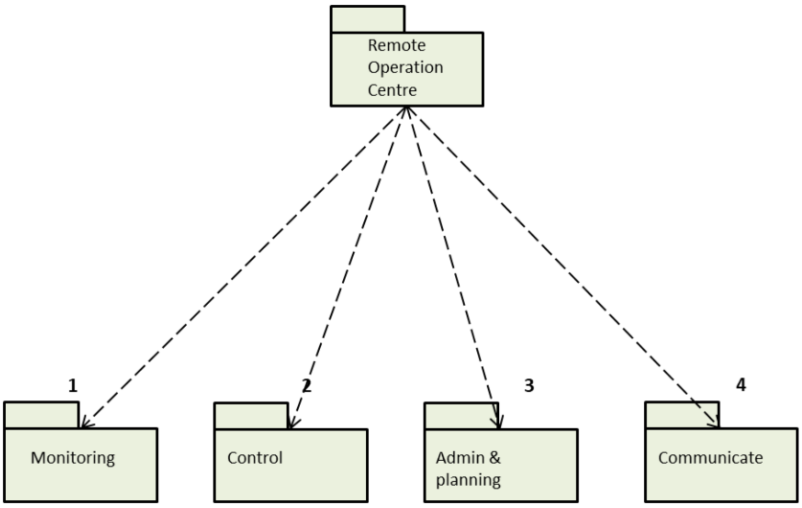

Figure 12 - Main functionalities of RCC

The main functions of the ROC are described in Table 23.

Table 23 - Description of the functionalities of RCC

No	Function	Description
1	Monitoring	To observe information collected by a system on board and observe its operational status. Allows no commands to the system that eventually alters the behaviour of the ship or its equipment. May, however, allow commands to not critical systems such as PTZ commands to search lights or CCTV cameras. Will also allow operation of ship to ship communication from the ROC. Note: The monitoring station will be configured for observation of information from the ship systems. NO COMMANDS to ship systems for any purpose will be possible.
2	Control	There can be several methods of how control is done during an operation. The control can be split in three different methods: 1. Supervise 2. Intervene 3. Direct control
3	Admin and planning	Here the entire mission is planned to include what to do and which ports to enter during the mission. When the mission is sent to the ship, an important part of the mission plan is the quay data giving essential information about the berthing area at the quayside.
4	Communicate	Internal communication inside one ROC, but also intercommunication between RCCs if the operation is split between RCCs

15 Appendix C IEEE radio band codes

The most common band codes, defined by IEEE [35] are listed in Table 24. Additional rows are added for VHF and UHF frequency bands. Note that both L and parts of S band are within the UHF band.

Table 24 - IEEE radio band codes

Band	Frequency	Origin of name
VHF	30 to 300 MHz	Very high frequency (marine 156 to 174 MHz)
UHF	0.3 to 3 GHz	Ultrahigh frequency (marine 457 to 467 MHz)
L band	1 to 2 GHz	Long wave
S band	2 to 4 GHz	Short wave
C band	4 to 8 GHz	Compromise between S and X
X band	8 to 12 GHz	Used in WW II for fire control, X for cross (as in crosshair)
K_u band	12 to 18 GHz	Kurz-under
K band	18 to 27 GHz	German Kurz (short)
K_a band	27 to 40 GHz	Kurz-above

The most relevant bands for satellite communication are L (Inmarsat and Iridium), C (various VSAT providers, normally quite expensive services), Ku (most common VSAT band) and Ka (newer VSAT services including Inmarsat Global Express). Ka is becoming increasingly more popular as demand for bandwidth grows. Note that S (3 GHz) and X (10 GHz) are also used for maritime radars.

16 Appendix D Autonomy related tasks [74]

For autonomous operations, the tasks defined by the RCC operator will vary according to the Table 25.

Table 25 -Autonomy related tasks distribution

No	Task	Description
1	Monitoring	To observe information collected by a system on board and observe its operational status. Allows no commands to the system that eventually alters the behaviour of the ship or its equipment. May, however, allow commands to not critical systems such as PTZ commands to search lights or CCTV cameras. Will also allow operation of ship to ship communication from the RCC. The monitoring station will be configured for observation of information from the ship systems. No commands to ship systems for any purpose will be possible.
2	Supervision	Allows the operator to give commands to control how a system on board behaves. The commands can be given in response to requests, options or ambiguities presented by the system, or they can express the operators' decision for a changed or specific behaviour. Example: The operator watches the traffic situation and decides that the ship should change to an alternative sailing route. (Given that the autonomous functionality is not capable or authorized to make this decision). In practice, when supervising the ship, commands from the operator will alter or influence the basis for decisions made by decision algorithms on board. The commands from the operator does not influence the processing order or flow of commands between systems on board.
3	Intervention	Allows commands to automation systems on board, overriding or substituting control signals from higher level decision algorithms. Example: Bypass decisions from "Navigate ship" and give operator commands directly to "manoeuvre ship" functions (e.g. a course command to the autopilot).
4	Direct control	Allows commands to low level control loops or automation systems, overriding or substituting control signals from higher level control systems/ automation. Example: Bypass the maneuver ship functions and operate thrusters and propulsion by commands from the RCC.

17 Appendix E RCC responsibilities [75]

The primary role of personnel in the RCC is risk management in a wide perspective. They plan operations such as loading/ discharge, voyage and maintenance. They monitor the operation to ascertain that it progresses according to plan and observe that situations with potential hazard do not escalate. The personnel can also intervene and control certain functions on board from the remote location, and they will call upon and coordinate any necessary response in case of an emergency involving the ship.

More precisely, personnel in the remote control centre coordinate the ship operation by doing a wide range of tasks, such as:

Alongside:

- Receive transport assignments from clients
- Establish/Select plan for loading/discharge and stability calculation/monitoring
- Establish cargo manifest
- Check weather forecasts (wind, current, waves, visibility...)
- Establish/select route plan, including lock and bridge passages.
- Respond to alerts from ship systems (particularly during charging and cargo loading/ discharge)
- Confirm ship energy reserve, integrity, communication-, equipment- and system- status before departure
- Coordinate/ communicate with personnel if on board while in port
- Confirm ship cleared (no personnel on board) before departure
- Coordinate and report to VTS before departure (Where relevant)
- Confirm fairway clear before departure
- Confirm ship ready for departure/ Cancel or postpone departure in case of malfunctions/ energy shortage/ weather conditions.

En route:

- Monitor and supervise voyage progress. Intervention when necessary
- Observe ship stability
- Respond to alerts from the ship systems by observation and/ or intervention
- Observe system performance/ Equipment health status
- Observe system and ship/shore communication status
- Condition monitoring of rotating machinery
- Remote operation of maritime VHF

Other tasks handled by personnel in the RCC:

- Online diagnostics of control systems and networks/ ship to shore data link
- Organisation of continuous verification programs
- Complete and distribute recordings and logbooks
- Establish maintenance plans/ administration of work permits
- Organize maintenance
- Organize access to ship for authorized personnel while in port
- Manage access to ship systems/data for other parties (Network security/ management)
- Ship safety and security responsibilities
- Contact with resources outside the ordinary operation (e.g. authorities, locks, ports, emergency services