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A study on rules and regulations regarding autonomous ships

Graduation Thesis

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Kuressaare, 2021

I declare that I have compiled this study independently.

In this study all works, statements and data by other authors has been referenced.

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Abbreviations

MASS – Maritime Autonomous Surface Ship

IMO – International Maritime Organization

MSC – Maritime Safety Committee in IMO

RO - Recognised Organisation

AL – Autonomy Level

DNV GL - Det Norske Veritas Germanischer Lloyd

COLREG – Convention on the International Regulations for Preventing Collisions at Sea

SOLAS – International Convention for the Safety of Life at Sea

STCW – International Convention on Standards of Training, Certification and Watchkeeping for Seafarers

SAR – International Convention on Maritime Search and Rescue

RSE – Regulatory Scoping Exercise

MUNIN - Maritine Unmanned Navigation through Intelligence in Networks

AAWA - Advanced Autonomous Waterborne Applications

UNCLOS - United Nations Convention for the Law of the Sea

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Annotation

Autonomous shipping is the future that will change the maritime industry. Technology to control ships remotely is already here and being tested in different collaboration projects between classification societies and technology industry leaders. International maritime law however needs clarifications and new definitions in the wake of this new era.

In this study international conventions like COLREG, UNCLOS, STCW and SOLAS will be analysed to identify gaps and challenges included in rules and regulations that might pose conflicts in the use of unmanned vessels and suggestions are made on how to address them. In the second part of the study new arising risks are analysed with conclusions about definitions that need clarifications and cyber security threats in terms of international law.

Introduction

Technology is evolving rapidly and changing the world everyday. Autonomous vessels that once were a phenomenon in science fiction today are underway and will fundamentally change the maritime sector. In the last few years there have been many developments in automation and not only in maritime sector. So far most advancement that have been made in the development of autonomous technology have been in aviation and automotive industry.

Autonomous technology is immensely potential and attractive to ship owners because it aims to reduce vessel's operating costs and environmental impact as well to make shipping more safe. It is well known that most maritime incidents are due to human error and potentially lead to damage of the ship, loss of cargo and human lives, damage to the environment. European Maritime Safety Agency has reported that 54% of maritime incidents happened due to human error. [1, p. 9]
Reduced costs externalize mainly in lessened fuel consumption, the salaries of the crew and ship's construction as there would be no need to build and maintain the infrastructure and conditions for the crew on board. In cargo ships this will also increase the possible room for cargo making each voyage more cost efficient. Although with all these benefits building an autonomous ship will be more expensive as it will need very reliable technology with minimum maintenance, in the longer perspective reduced operational costs will still give a clear advantage [2, p. 5].

Moreover partially autonomous vessels are already being tested in seatrials and they aim to make ships more cost-efficient, safe and environmentally cleaner. These rapid developments will pose new unknown challenges to legislation as this is something entirely new to mankind. Never before have there been vessels on the oceans without seafarers on board and this means there are no precedents and no data on how to approach to regulating autonomous ships. All the conventions and regulations that shipowners and builders have to follow have been written in a time when the idea of an autonomous ship wasnt something to be considered. This means that regulators emanate from the traditional view that a ship is at all times controlled by seafarers on board. Maritime legislation is also a quite complex system with many parties like international conventions, class socities, flag states with each of them having their own requirements and their own views on levels of autonomy. What complicates the situation even more is the possibility of different interpretations of most regulations as there are no decicive directives as to what exactly is a autonomous vessel. This poses a great challenge to legislators, shipowners, insurers as for the moment it seems that technology is evolving faster than regulations. It is important to note that much work has already been done by legislators and more is currently underway for regulations to keep up with the development of technology. So far it has also been unclear as to which organization should start working out and approving new regulations. Nevertheless research has been done into this topic by IMO and classification societies such as Lloyds Register of Shipping and DNV GL. IMO has assumed the leading role in researching and creating a new legal framework for autonomous vessels.

When analysing the process of testing autonomous vessels in the seas from technology point of view, it is clear that the challenges of testing and developing a safe system must be done with due diligence and fewer risks. This means that autonomous vessels will be developed starting from small coastal vessels, scaling up to ocean going vessels and along the way testing in different scenarios with gradually increasing the degree of autonomy level of the vessel. From the legal point of view gradual increase of the autonomy level will prove very valuable as it will start forming a data set which will be needed in order to develop and improve the regulations regarding autonomous vessels.

This study will investigate the overall environment where international maritime conventions and regulations are developed, the challenges new conventions will face. First part of this study will elaborate on the current system of international maritime regulatory network. It will research the most important conventions that will be impacted or might pose conflicts or obstructions when developing regulations about autonomous vessels. As there is research done in regulating autonomous vessels around the world, it is also important to elaborate on the most important publications, literature and projects about this topic so far to form a versatile point of view.

The objective of this study is to analyse gaps to identify challenges that will emerge with the use of autonomous vessels. The second part of this study will aim to point out and make suggestions to address these challenges. International regulatory bodies have led research and projects into this novel field but no certain statements have been made so far. This study will conduct qualitative analysis on most important publications, conventions and trade literature to point out challenges regarding autonomous ships. The author analysed documents in the context of autonomous ships and derived conclusions.

In the second part of this study author analyses the definition of autonomy and possible conflicts in conventions. In the last chapter new risks are analysed which will arise with autonomous shipping.

1 Strategic background and overall regulatory framework

Maritime regulations can be divided into international regulations which apply in international waters and national regulations which apply in one state in it’s territorial waters. International traffic at sea is regulated by IMO which acts under the United Nations through international conventions and its amendments which are implemented by the member states. Since IMOs creation in 1958 it has been developing and amending new regulations to keep up to date with the development of shipping and technology and as of 2020 there are 174 member states and over 50 international conventions that IMO governs. [3]

IMO has two main councils The Assembly and Council and four main committees Marine Safety, marine Environment Protection, Legal and Facilitation Committees and most notable work in autonomous shipping is done by the Marine Safety Committee [5, p. 1].
New conventions or amendment proposals can be done by any of the member states or IMO itself when there are clear results of major research or a shipping incident which makes it undesputable that new regulations need to be drafted. When the proposal of a new convention is accepted the committee will forward it to the IMO Assembly or Council which will also have to accept the proposal. That approval gives the authorization to the committee to start drafting the new convention and the first step of adopting a convention begins as seen in Figure 1 . The committe will draft and send the first version of a new convention to the Assembly or Council which will then proceed to bring together a conference with the member states to start the approval process of the new convention. Before the conference, a draft of the new convention will be sent to all member states who are in the position to make comments and suggestions to the committee which will decide wheter the convention will be changed accordingly or not. The conference will include all the member states and the amended draft will be presented after which the member states will vote to agree with the final draft or not. If the majority of the member states vote to accept the new convention will be formally accepted and then sent to the Secretary General of the IMO. At this point the convention needs to go through the ratification process to which the terms will be drafted and agreed upon by the member states in the draft of the convention. [5]

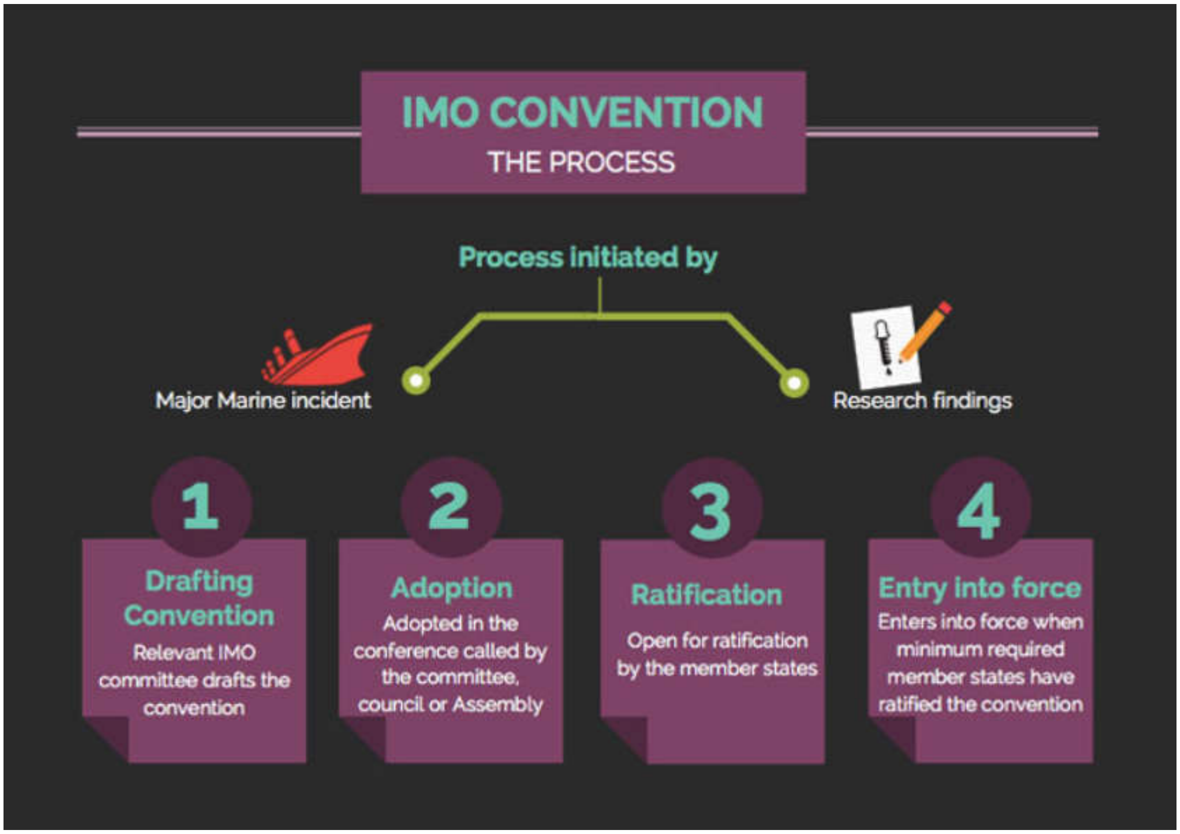

Figure 1. IMO convention process [5]

The proccess of ratification is described in Figure 2. After the terms of ratification are met then the new convention is still not yet binding as member states must accept the convention by signature by a representative or present an instrument of accession to the depository department of IMO which keeps track of conventions and ratification by member states. Until the minimum number of member states have accepted the new convention it will not enter into force after preset time and it is possible that this process could take years to complete. By the time the new convention enters into force it must be included in the law of the member state which means that new regulations will be mandatory to all the vessels sailing under the state's flag. [6]

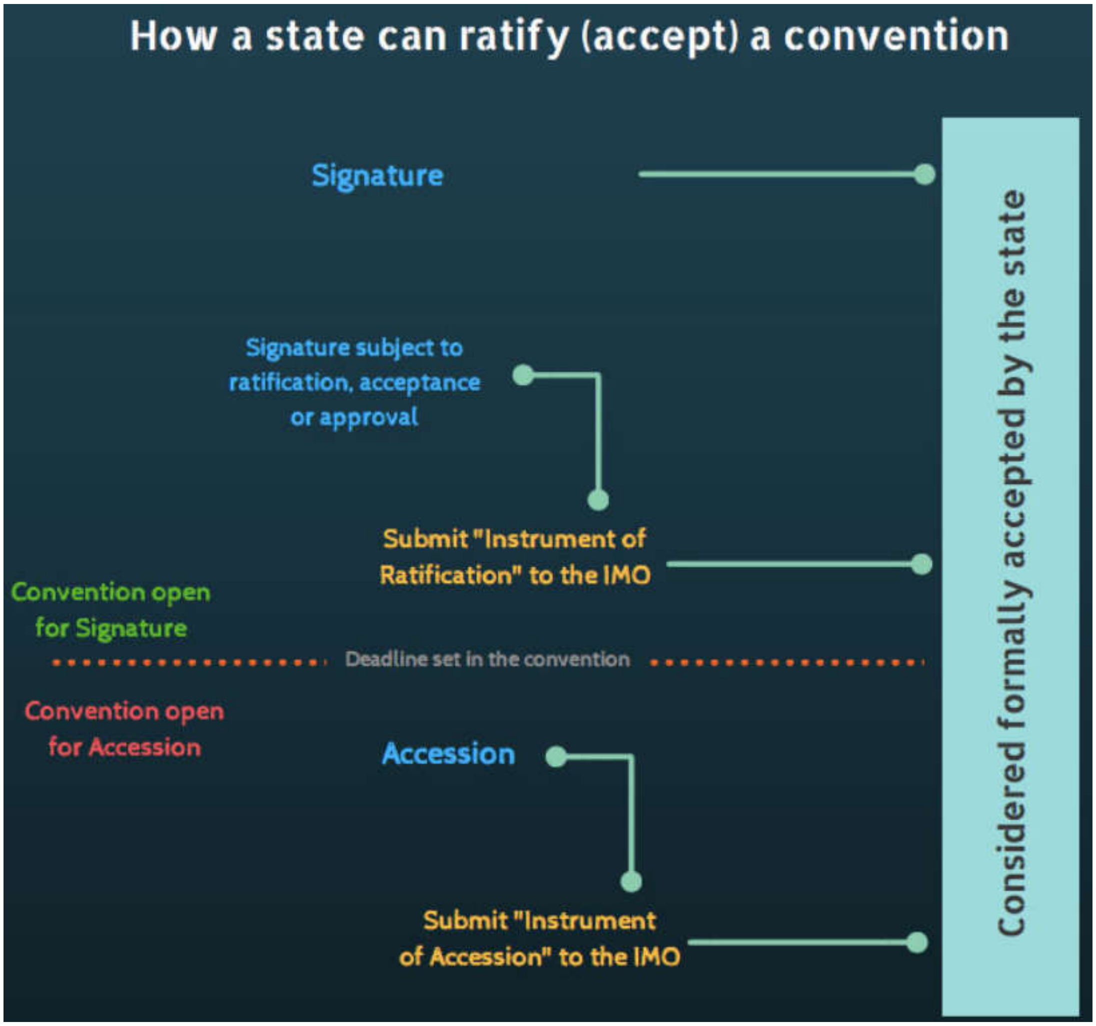

Figure 2. IMO convention ratification process [5]

The process from a proposal to ratifiction can be time consuming and it is well possible that it could take years. One of the challenges IMO faces with regulating autonomous vessels is that knowing all of the above technology is developing faster than new regulations are drafted. Another challenge for legislators is that new conventions or amendments about autonomous vessels must be written in a way that by the time they get ratified they won't already be out of date because of the fast development of new technology. The process of approving new conventions can be a lenghty one since a certain amount of member states must sign the convention and in some cases, the approval process could potentially take years.

For example the International Convention for the Control and Management of Ships's Ballast Water and Sediments was adopted by IMO in 2004 but it entered into force in 2017 after the required tonnage of ships was obtained through ratification from member states [6]. For this convention to enter force it took 13 years and from this example it is evident that a new convention regarding autonomous ships might take years before the required amount of ratification is obtained. If this is the case then faster developing technology without international regulation will bring obstacles and confusion into the shipping industry.

On the other hand it also important to draft the new convention regarding autonomous ships carefully and apply as much due diligence as possible because if not properly thought through the new convention might become an obstacle in innovation. To stop regulation from being restrictive to the innovation of technology international organizations including IMO have adopted goal and performance oriented standards for setting regulations which leave the possibility to employ new technologies so long as the goal is met. Marine Safety Committee (MSC) at IMO has approved guidelines for developing goal-based standards for autonomous vessels. This is an important development from a prescriptive way of writing regulations where the requirements were fixed at the time the regulation was drafted. [7]

In terms of regulating autonomous ships these conventions will be implicated and will need amendments or clarifications on interpretation. Most notably SOLAS, COLREG and STCW will be implicated.

SOLAS – is one of the most important international conventions regarding maritime safety. Since it's first version in 1914 there have been later versions in 1929, 1948, 1960, 1974 and numerous amendments. SOLAS conventions specifies the main requirements for ship construction, equipment and safe operation. As with other conventions in IMO it is the responsibility of the Flag states to ensure that all vessels under it's flag are compliant with the requirements. SOLAS consists of 14 Chapters:

- Chapter I – General Provision
- Chaper II-1 – Construction - Subdivision and stability, machinery and electrical installations
- Chapter II-2 - Fire protection, fire detection and fire extinction
- Chapter III - Life-saving appliances and arrangements
- Chapter IV – Radiocommunications
- Chapter V - Safety of navigation
- Chapter VI - Carriage of Cargoes
- Chapter VIII - Nuclear ships
- Chapter IX - Management for the Safe Operation of Ships

- Chapter X - Safety measures for high-speed craft
- Chapter XI-1 - Special measures to enhance maritime safety
- Chapter XII - Additional safety measures for bulk carriers
- Chapter XIII - Verification of compliance
- Chapter XIV - Safety measures for ships operating in polar waters. [8]

COLREGs – the International Convention for Preventing Collisions at Sea which came into effect in 1972 is one of the most important maritime conventions and it is governed by IMO. It's most recognised innovations is the adoption of traffic separation schemes but it also specifies navigational rules for vessels to prevent collisions at sea. [9]

STCW – International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, adopted by IMO in 1978 and has been amended after that several times. It establishes international qualification and training standards for the crew working onboard ships. STCW consists of part A and part B from which part A is mandatory and part B recommended. STCW certificate is mandatory for crew working on board seagoing ships. [10]
With the development of new technology for ships, the requirements for seafarers will have to change accordingly and a new skillset will be needed to operate advanced technologies from land-based control centres.

According to IMO, vessels in international voyages are required by SOLAS Chapter II-1 to be constructed and maintained in compliance with the requirement of a classification society, in other words a classification society certificate is needed for a vessel in international voyages. Vessels in domestic voyages are subject to coastal state regulations and laws. Flag administrators may recognize organisations to carry out inspections of a vessel on their behalf and issue certificates of compliance with regulations in the role of recognised organisation (RO). [3]

Although drafting and enforcing a new convention is a long process, regional regulatory states are free to support and regulate autonomous technology in their territorial waters. Vessels in route only in the jurisdiction of one coastal state are not subject to IMO international regulations, however COLREG must be applied even in coastal waters. Before remote and autonomous technologies can be used in international shipping a regulatory framework by IMO must be achieved. Since autonomous concepts are new and only with limited data at the moment it is not optimal to develop detailed international regulations yet.

1.1 Existing literature and projects on autonomous ships

Several international organizations have also been working on issues regarding autonomous ships and launched research projects including ship classification societies, universities, technology companies. Research into autonomous marine industry is a fast growing development area around the world and most productive reasearch has been done in collaboration projects between classification societies and technology development leaders like Rolls Royce, Deltamarin.

1.1.1 Lloyd's Register of Shipping autonomous ship procedures

One of the most innovative project in regulation and technology is the collaboration between Lloyd's Register of Shipping, Rolls Royce and Svitzer (global towage company) where Lloyd's worked out a safe framework for testing, approving and regulating using it's cyber-enabled ShipRight procedure, Rolls Royce has developed technology to allow unmanned operations on the water and Svitzer used it's operational experience and expertise in towage. The milestone project where Svitzer's ship Hermod performed safely remotely controlled manoeuvres in the Copenhagen harbour as seen in Figure 3, is considered a historic moment for the shipping industry with the expectation that remotely controlled vessels might get in the water even sooner than was anticipated. [13]

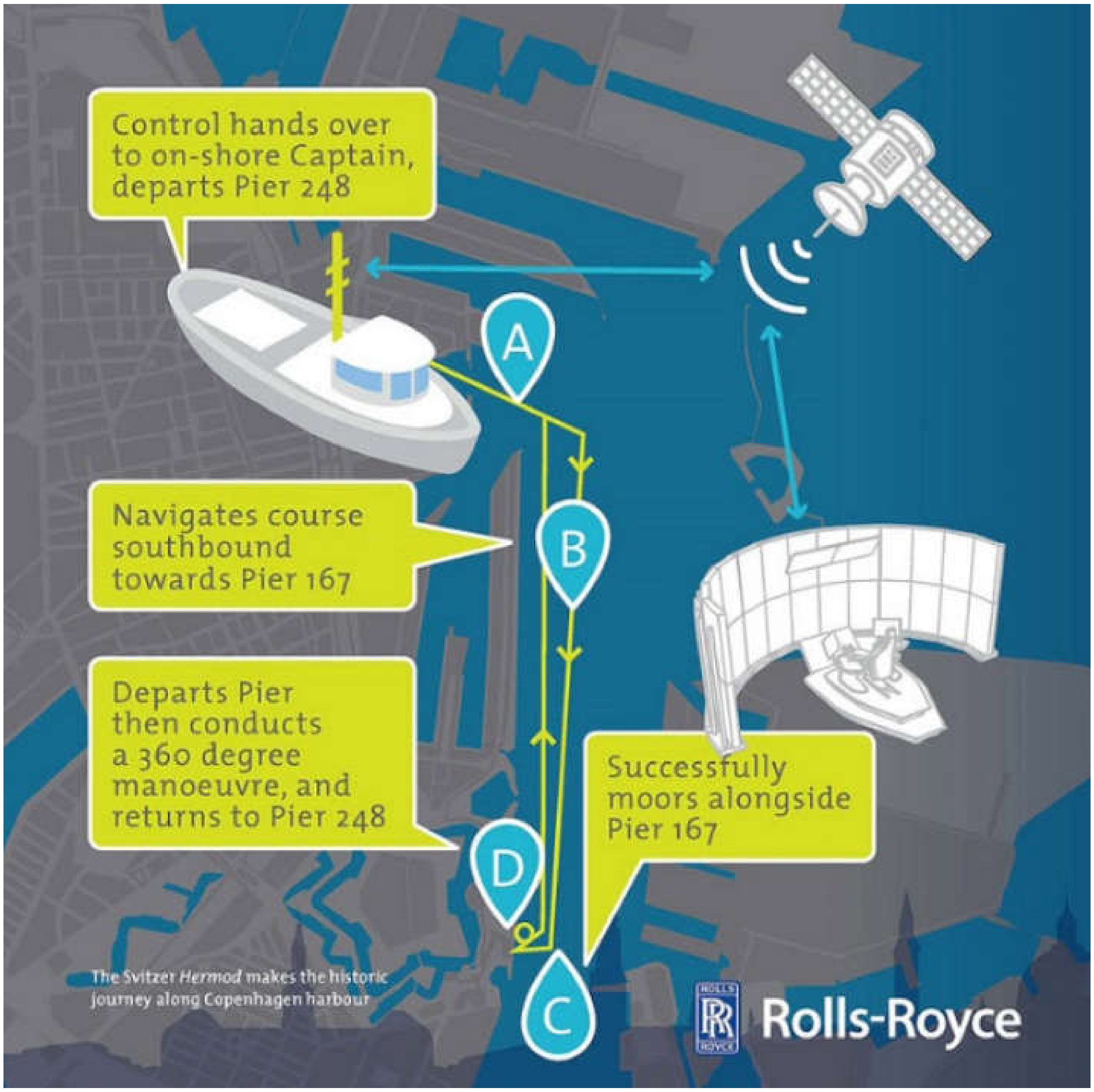

Figure 3. Svitzer Hermod in Copenhagen [13]

In 2017 Lloyd's Register of Shipping was the first to define autonomy levels in it's ShipRight procedure guidance which divides autonomy level (AL for short) ranging from AL0 to AL6 [13], see Table 1. These level will provide the shipping industry with guidelines about design, construction and operations to make autonomous ship projects meet the required levels of safety and classification and are also meant to support international regulations by IMO.

Table 1. Ship autonomy levels according to Lloyds Register of Shipping [16]

Autonomy Level	Description	Operator's role
AL0: Manual controlled	Navigation controls or waypoints for course are handled manually.	The operator is on board or controls the vessel remotely through radio link.
AL 1: Decision support on board	Automatic navigation according to set references and schedule. Course and speed measured by onboard sensors.	The operator sets course as waypoints and determines desired speed. The operator monitors and changes course and speed if necessary.
AL 2: Decision support on board or from shore	Course navigation through a sequence of waypoints. Course is calculated according to a planned schedule. An external system can upload a new schedule.	The operator monitors operation and surroundings. Changes course and speed if needed. Suggestions for interventions may be provided by algorithms.
AL 3: Execution by operator who monitors and authorises actions	System recommends navigational actions on the basis of sensor information from the ship and its surroundings.	The operator monitors the system's functions and actions, and authorises actions before they are carried out.
AL 4: Execution by operator who monitors and is able to intervene.	Decisions on navigation and operational actions are calculated by the system that executes on the basis of its calculations following approval from the operator.	The operator monitors the system's actions, and takes correctional actions as needed. Monitoring may take place from shore.
AL 5: Monitored autonomy	Overall decisions regarding navigation and operation are made by the system, also assessing consequences and risks. Sensors capture relevant information of the surroundings, and the system interprets the current situation. The system	The system performs calculated actions. The operator is alerted unless the system is very certain of its interpretation of the surroundings, its own state and of the following calculated actions. General goals are determined by

	calculates its actions and executes these. The operator is alerted in case of uncertainty.	the operator. Monitoring may take place from shore.
AL 6: Full autonomy	Overall decisions regarding navigation and operation are made by the system, also assessing consequences and risks. The system acts on the basis of analysis and calculations of both own actions and the surroundings' response. Knowledge on surroundings and of past and typical situations are factored in via machine learning.	The system makes its own decisions and actions, calculating own capability and prediction of the behavior of surrounding traffic. The operator is alerted in case the system fails to determine action. General goals may be determined by the system. Monitoring from shore.

Most ships today are under categories from AL0 to AL2 where all operations assume the presence of the seafarer at all times. From level AL3 to AL4 partly unmanned and remotely controlled ships are possible.

1.1.2 DNV GL Guidelines

Classification Society DNV GL has also developed guidelines for autonomous ships and offers guidance on concept and technology qualification where the flag state will give final approval as seen in Figure 4. In 2018 DNV GL published it's class guidelines document „Autonomous and remotely operated ships" which aims to provide guidance for safe implementation of autonomous marine functions, recommended work process to obtain approval of novel concepts challenging existing classification regulations [14]. Technology guidance is set to guide arrangement of systems to support remote operations like safe navigation, remote control centres, communication functions, vessel engineering functions.

DNV GL's guidance document divides concepts similar to IMO's scoping exercise MASS autonomy degrees and it covers four types of concepts:

- Decicion supported navigational watch
  This concept is based on enhanced decision support systems supporting an on-board officer in charge of the navigational watch in performing tasks for the navigation function. The incentive for such a concept may be to cover tasks conventionally done by the crew with advanced technology, or it may be for the purpose to enhance the safety and facilitate the officer in performing the navigation function.
- Remote navigational watch
  This concept is based on the tasks, duties and responsibilities of an officer in charge of the navigational watch being covered by personnel in an off-ship remote control centre. This concept assumes that no crew is available on board to support the remote personnel in performing the navigation function and the radio communication function as defined in the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) code.
- Remote engineering watch assisted by personnel on board
  This concept is based on the tasks, duties and responsibilities of an officer in charge of the engineering watch being covered by personnel in an off-ship remote control centre. For this concept, it is assumed that crew is available on board to perform certain defined tasks and assist the remote personnel as needed.
- Remote engineering watch
  This concept is based on the tasks, duties and responsibilities of an officer in charge of the engineering watch being covered by personnel in an off-ship remote control centre. This concept assumes that no crew is available on board to support the remote personnel in performing the marine engineering function. [14]

DNV GL guidance is planned to be developed further as more data, technology and tests are being gathered in research and establish class notations but in it's guidelines the basic framework for classifying novel vessel concept is established.

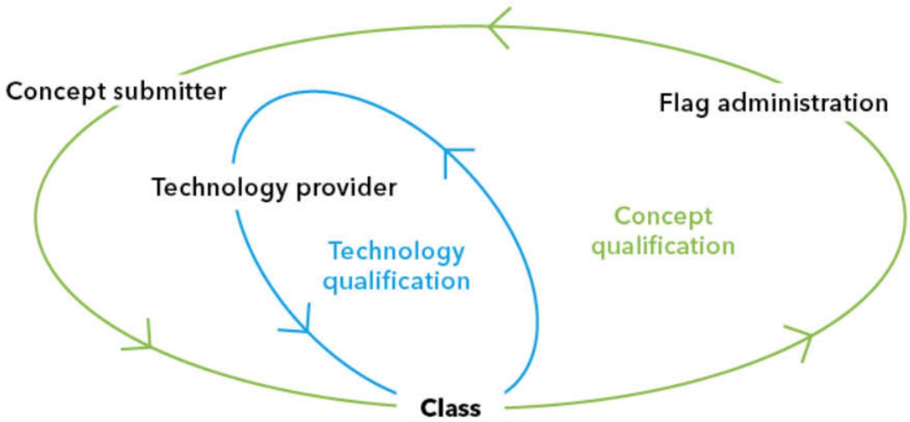

Figure 4. DNV GL autonomous concept qualification interactions [17].

1.1.3 IMO Regulatory Scoping Exercise

IMO launched in 2017 a Regulatory Scoping Exercise (RSE) to develop safe operations of MASS [2]. RSE aims to analyse the existing regulatory framework in terms of MASS operations and for this MSC divided autonomy into 4 degrees as seen in Table 2. In the first part on RSE 14 international legal instruments were investigated and in the second part consisted of an analysis how MASS operations should be addressed and what instruments should be amended. As one of the results of RSE it is clear that new understanding is needed regarding the terminology, tasks of ship's crew wheter they are on board the ship or not, new standards for seafarers with a clear definition of responsibilities. It has been stipulated that the STCW convention in it's existing form might only apply to ships where there are seafarers on board. [15]

Table 2. IMO approved autonomy degrees [20]

MASS Degree 1	Ship with automated process and decision support.	Some operations automated and at times unsupervised with seafarers ready to control. Seafarers on board.

Table 3. IMO approved autonomy degrees		
MASS Degree 2	Remotely controlled ship with seafarers on board.	Controlled and operated from another location. Seafarers available on board to take control and operate.
Table 2. IMO approved autonomy degrees		
MASS Degree 3	Remotely controlled ship without seafarers on board.	Controlled and operated from another location. No seafarers on board.
MASS Degree 4	Fully autonomous ship.	The operating system on MASS is able to make decision and determine actions by itself.

1.1.4 Project MUNIN

Maritine Unmanned Navigation through Intelligence in Networks is a collaboration research project co-funded by the European Commissions from 2012-2015 to develop a technical concept for an autonomous cargo ship [16]. The aim was to develop technology that could operate independently for at least some part of the voyage without seafarers on board. The concept was developed for a dry bulk carrier and objective was that the ship would operate unmanned during the uninterrupted deep-sea voyage but seafarers would take control of the ship in restricted waters. During the deep-sea voyage the ship would be controlled from a Shore Control Centre and for this they adopted various new technologies like Advanced Sensor Module, Autonomous Navigation System, Autonomous Engine and Monitoring Control System. From the Shore Control Centre the vessel would be monitored and controlled after the seafarers leave the ship and the centre would encompany several positions like Shore Control Centre Operator, Shore Control Centre Situation Room team, and Shore Control Centre Engineer. Different operational modes would be used as seen in Figure 5 and the operator would monitor and control the vessel with commandments and updates when needed. The Situation Room team would be on stand-by and take over the vessel in certain unintended situations. [16]

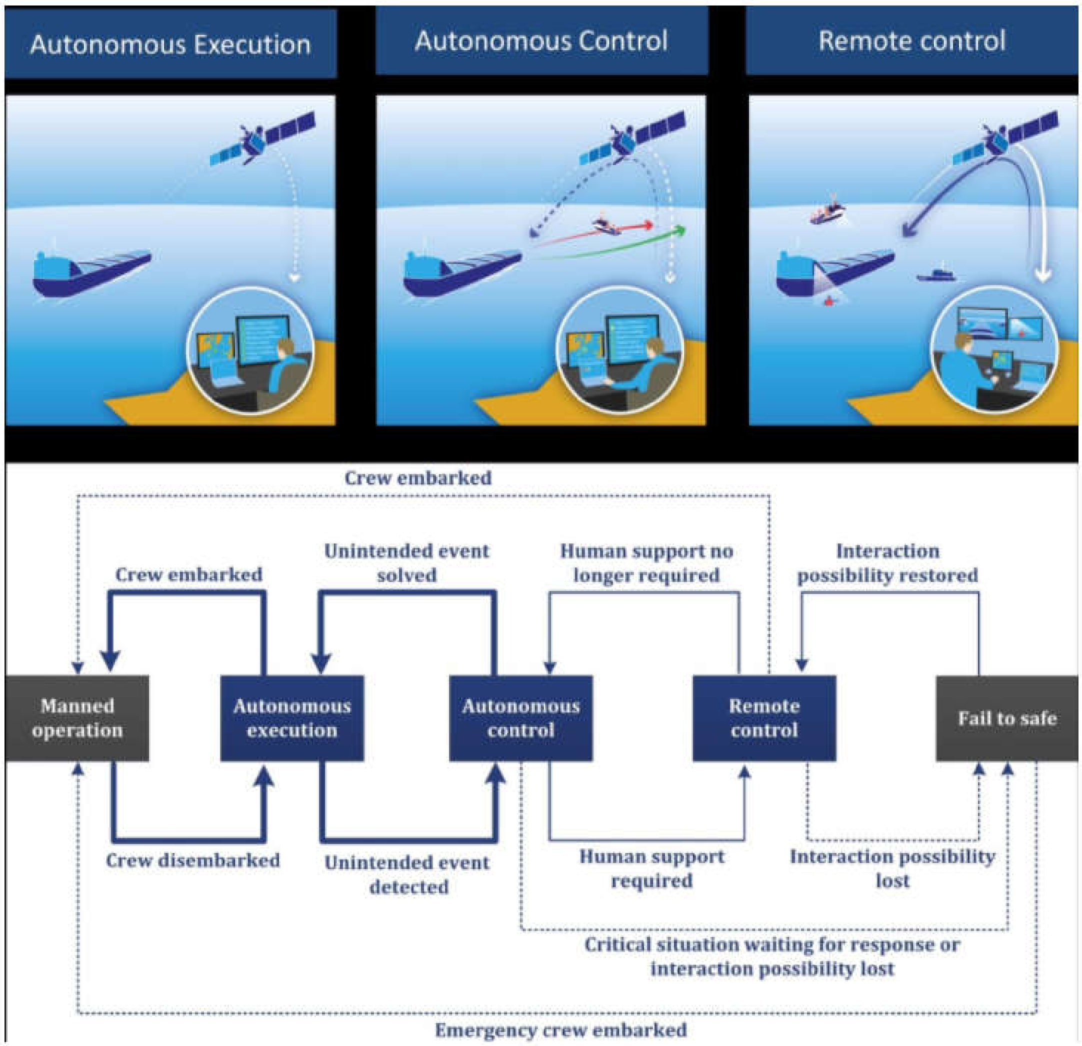

Figure 5. Project MUNIN Operational modes [22].

1.1.5 Project AAWA

Advanced Autonomous Waterborne Applications Initiative was a project launched in 2015 by technology company Rolls-Royce and many other partners which brought together ship designers, classifications societies, universities, equipment manufacturers to develop a concept for an autonomous vessel with a special attention on technical specification and classification. AAWA project was carried out in collaboration with Finnish ferry company Finferries who carried out a series of tests of sensor tenchnology in operating conditions aboard it's 65 metres ferry Stella [23]. Classification society DNV GL participated in AAWA and is working on developing requirements for autonomous vessels to be able to test and classify the future ships. For these results several questions needed to be addressed in the project:

- What technology is need and how can it be best combined to allow a vessel to operate autonomously and miles from shore
- How can an autonomous vessel be made at least as safe as existing ships, what new risks will it face and how can the be mitigated
- What will be the incentive for ship owners and operator to invest in autonomous vessels
- Are autonomous ships legal and who is liable in the event of an accident ?

AAWA project concluded that technology to make autonomous ships already existis but needs solutions for an optimal combination, autonomous ships will be at least as safe as manually operated vessels but with new types of risks, issues with liability need to be investigated and clearly defined on all regulatory levels. [17]

2 Existing gaps and challenges

Autonomous ships will change the whole shipping industry as we know it. Some international conventions might lose some of their effect because the traditional human factor is missing from ship operations or is situated somewhere else than on board the ship. Many aspects in safety regulations, ship design, equipment, rescue have been developed to preserve the safety of human life but if there are no humans on board to begin with, these regulations will be rendered obsolete. This will also mean the end on the traditional seafarer career. Not too far in the future it will be possible that ships are controlled from anywhere around the world by specialists that have never set foot on the ship itself.

The objective of this study is to analyise the framework for autonomous shipping but the term „autonomous“ hasn't been defined internationally, moreover even the term „ship“ and „captain“ are differently interpreted in different legal instruments. Questions arise wheter an unmanned vessel is even considered to be a „ship“ in terms of international conventions and if so, then who is considered to be a „captain“ of that vessel ? One of the gaps that will arise is that the international maritime legal organisations with their complicated approval procedures will be slower than the development of technolgy. Although the international law needs more time, then it is still possible for each state to regulate unmanned shipping in their territorial waters.

2.1 Safety

Safety issues is one of the main considerations in all marine operations no matter if the ship is manned or unmanned. Although with an unmanned vessel there will be less consideration for human life on board, safety issues will become even more important than before. The safety focus points will change towards technology, cargo and environment. From Figure 6, it can be seen that the main contributing factor to marine incidents has been the human factor. European Safety Management reported in its Annual Overview of Marine Casualties and Incidents that 54% of total accidents were attributed to human action [1].

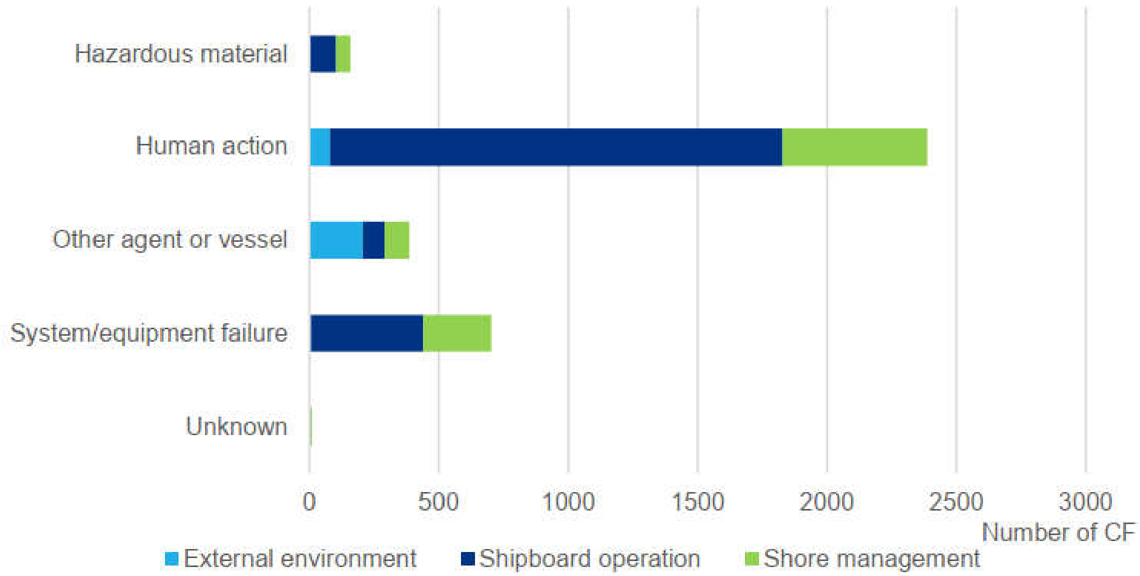

Figure 6. Marine Incidents by causal factors [1]

Marine autonomous technology has the potential to reduce incidents in marine environment due to human error and make shipping much more safe. Even with the rise of unmanned technology the human factor will still have to be considered in the future. When ships are controlled from shore based control centres, it is still very possible to make a mistake by the ship's operator. Also since technology is never independent from humans, the risk to error will remain. Even when ships are fully autonomous, the algorithms that control the ship's behaviour, are still developed by humans.

In the coming era of unmanned vessels the main safety concerns according to AAWA project have been:

- Ability of automation to reliably detect small vessels and floating objects on route
- Ability of automation to avoid collisions in case of encounters of multiple ships
- Ability of automation to navigate safely on coastal fairways
- Reductions on preventative and corrective maintenance that are currently largely carried out during voyages
- Ability to handle emergencies, such as firefighting or failure recovery and repairs at sea
- Errors and malfunctions in software
- Disturbances, malfunctions and vulnerabilities in data communication connections

- Undue trust on the capability and flawlessness of information and communication technologies. [18, pp. 59-60]

The use of new technology might bring risks that are not yet identified. In other words, the risk of the unknown could be the largest risk of them all. These safety concerns are all speculation because there is no data set about the use of unmanned technology in marine environment. These risks could be mitigated with thorough testing starting with small coastal vessels and scaling up to bigger vessels with more complicated tasks and longer voyages.

2.2 Definition of autonomy

In all the research projects that have been launched, the term „autonomy" is utilised differently and that has lead to competing concepts in marine autonomous vessels. As this industry field is immature and fast developing basic terms that are understood the same way around the world should be agreed upon. When the term „autonomous" is being used freely in different concepts and research documents it will bring misunderstanding and to avoid this several classification and international regulatory bodies have agreed upon their own autonomy levels or degrees but they also stress the need for internationally defined framework of terms in autonomous marine technology.

Oxford Languages has defined „autonomous" as follows: having the freedom to govern itself or control its own affairs [18]. By this definition most research right now is being done in remotely controlled or unmanned ships and autonomous means that a ship can make it's own decision without human interference.

It its important to note that not all automation technology will make the ship „autonomous" since automatic systems have been in use on ships for a long time now.

In his article „Regulating Autonomous Ships Concepts Challenges and Precedents" Henrik Ringbom presented a simple two axis figure to simplify how a ship's manning level and autonomy are connected. In reality it is probable that a ship's manning level will change during a voyage so the ship will be acting in different degrees of autonomy during a single voyage [19]. Figure 7 is an example why it might be more accurate to analyse from the point of view of „remotely controlled" or „unmanned" not autonomous.

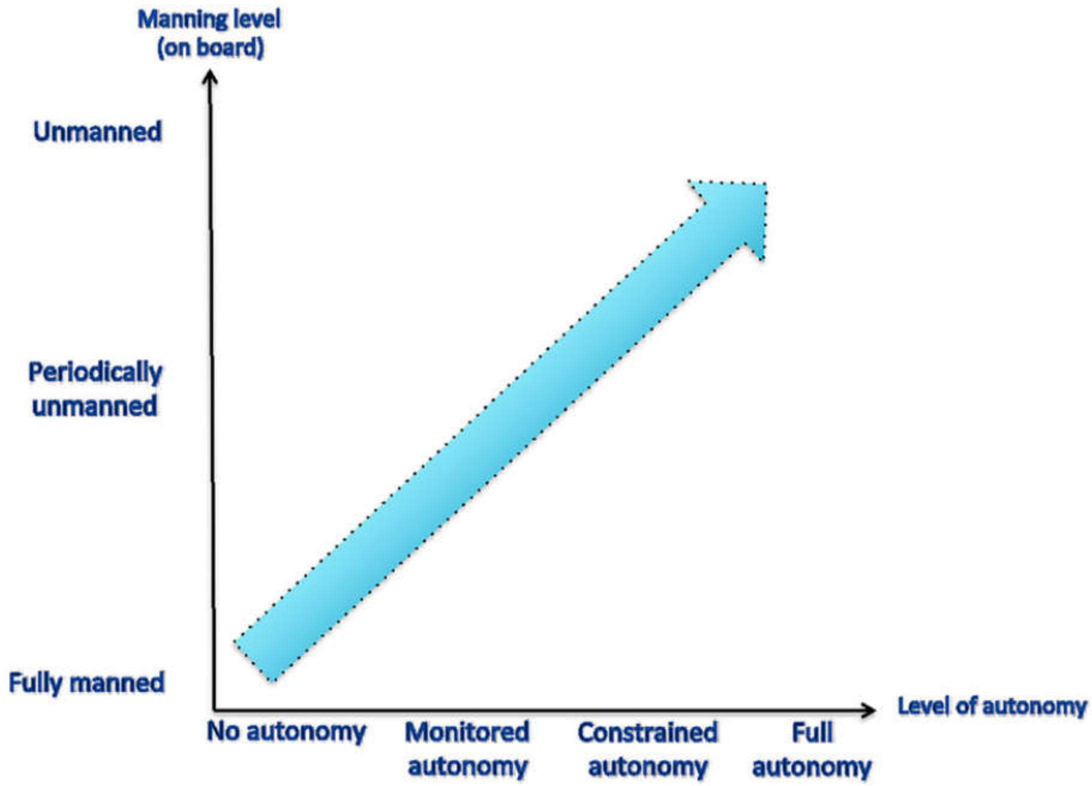

Figure 7. Separating the two key aspects of ship automation [24, p. 5].

If the term „autonomous" by definition means having the freedom to govern itself, then the only vessels that could be considered autonomous are vessels driven by the ships system that makes its own decision. All other vessels then cannot be considered autonomous but remotely controlled or unmanned to different degrees.

2.2.1 Analysis of possible obstructions in most important international marine conventions

In this chapter the most important international conventions are analysed in terms of unmanned ships.

SOLAS main purpose is to govern the safety of life at sea and although on remotely controlled ships there are no seafarers on board, safety features must still be followed. The responsibility of enforcing SOLAS regulations on ships is with the flag state. SOLAS regulations do not have any concept of unmanned or autonomous vessels in its regulations but it does have an exemption for a vessel of novel features. In Regulations 4, Exemptions (b) it is stated „The Administration may exempt any ship which embodies features of a novel kind from any of the provisions of Chapters II-1, II-2, III and IV of these Regulations the application of which might seriously impede research into the development of such features and their incorporation in ships engaged on international voyages.“ [12]

The Administration meaning the flag state can decide upon inspection what kind of regulations must be enforced on a novel ship and which regulations will be deemed unnecessary from chapters II-1, II-2, III ja IV [12]. All constructional safety must still be granted according to the rules of SOLAS but for example the requirements of lifeboats might be obsolete since there are no humans on board the ship.

Most problematic regulations for unmanned ships are the requirements for minimum safe manning which can be found in SOLAS chapter 5. [12] However the regulations do not specifically state in numbers how many seafarers must be on board to be considered safe, it still poses a possible conflict for the use of unmanned ships. The decision if safe manning requirements are met must be done by the flag state and it it up to the owner of the ship to prove that operating its ship is safe. Some countries in the world specifically require a certain number of seafarers onboard and in those countries it would not be possible right now to legally operate an unmanned vessel.

UNCLOS as the United Nations Law of the Seas article 98 Duty to render assistance states:

Every State shall require the master of a ship flying its flag, in so far as he can do so without serious danger to the ship, the crew or the passengers: (a) to render assistance to any person found at sea in danger of being lost; (b) to proceed with all possible speed to the rescue of persons in distress, if informed of their need of assistance, in so far as such action may reasonably be expected of him; (c) after a collision, to render assistance to the other ship, its crew and its passengers and, where possible, to inform the other ship of the name of his own ship, its port of registry and the nearest port at which it will call. [26]

Even when unmanned vessels will start to be seen on seas, there will still be vessels with seafarers on board. This article will bring both legal and technological questions. If indeed an unmanned vessel is obliged to render assistance to a vessel in danger with seafarers on board, what kind of technology should be there on the vessel for a rescue mission ? Firstly an unmanned vessel will have to be taught to recognise this situation at sea but secondly there will still have to be accomodation and infrastructure built for possible humans on board. If this requirement will be applied to unmanned vessels, then these ships must be built with a possible rescue mission in mind. That means building accomodation for possible persons on board even on unmanned ships.

COLREG provides regulation to avoid vessel collisions and in Rule 3 it is stated that „(a) The word 'vessel includes every description of water craft, including nondisplacement craft, WIG craft and seaplanes, used or capable of being used as a means of transportation on water'." [25]
With this definition it is clear that an unmanned vessel is also a watercraft of every description which concludes then that COLREG regulations are as obligatory for unmanned vessels as they are to vessels with seafarers on board.
In COLREG Rule 5 it is stated that „Every vessel shall at all times maintain a proper look-out by sight and hearing as well as by all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision" [21].
The interpretation of Rule 5 may pose some conflicts regarding unmanned vessels. When traditionally look-out duties were carried out by seafarers then with new technology the seafarers will be replaced by sensors and cameras. Look-out duties carried out by seafarers are prone to human errors and thus sensor technology has the potential to avoid these kinds of errors or negligence. However the question remains – could sensors be considered equivalent to „hearing" and cameras to „sight" ? This will require clarification from IMO but the author thinks that sensors can be considered equivalent if the risk of malfunction is mitigated.

STCW
Standards of Training, Certification and Watchkeeping convention establishes the minimum requirements for seafarers but flag states are allowed to impose their own stricter rules for training and qualifications. In the context of autonomous ships, it is questionable wheter STCW or to what extent it can be applied. For example in Article III it states that it applies to „The Convention shall apply to seafarers serving on board sea-going ships entitled to fly the flag of a Party" [30]. When a ship is operated from a shore control centre, then strictly speaking the seafarer isn't on board a seagoing ship. For now, its remains unclear if STCW convention in it's current form will be applicable to unmanned vessels and clarification from IMO is needed.
When unmanned vessels are operated from ashore, new skillset will be needed. Possible solution could be that a new category will be created in STCW that will regulate training and certificate requirements for the operator.

2.2.2 New risks

Cybersecurity and piracy

Ships operating over networks will pose a new type of risk that could affect negatively the vessel, its cargo, data, crew ashore and on the vessel and even pose a threat to the surroundings of the ship.

As technology advances, it is to be expected that so will piracy. Traditionally piracy has always been an act of violence on board a vessel at sea. But when ships use more technology over networks it will change piracy as we know it. When a remotely controlled vessel does not have any crew on board, the main objective of piracy will be directed against the cargo or the vessel itself. This also means that unmanned vessels must be designed and built in such a way that entry to the ship will be restricted with well-guarded systems.

UNCLOS Article 101 defines piracy as follows:

(a) any illegal acts of violence or detention, or any act of depredation, committed for private ends by the crew or the passengers of a private ship or a private aircraft, and directed: (i) on the high seas, against another ship or aircraft, or against persons or property on board such ship or aircraft; (ii) against a ship, aircraft, persons or property in a place outside the jurisdiction of any State;

(b) any act of voluntary participation in the operation of a ship or of an aircraft with knowledge of facts making it a pirate ship or aircraft. [22]

This definition states that for the act of violence to be considered piracy, it must be carried out by a crew member or a passenger of a private vessel on the sea. When a vessel is controlled remotely, it operates over networks and satellite connections which could be possibly attacked from land with a laptop. With this possibility, a new kind of piracy will emerge and according to the UNCLOS definition for example, hijacking a ship via internet connections would most probably not be considered as piracy right now. With the development of law and classification of remotely controlled and autonomous ship, the author thinks that it is paramount to include cybersecurity guidelines for ships and shipping companies as well as failsafe procedures if indeed the security measures are breached. In 2017 IMO recognised the urgent need to raise awareness on cyber risks and it’s Facilitation Committee and Maritime Safety Committee approved the Guidelines on Maritime Cyber Risk Management [23].

Captain/master or the operator of a remotely controlled ship

One of important questions in terms of unmanned ships is the role of the captain or the master. If there are no seafarers on board who then is considered the captain ? Traditionally the captain has always been aboard the ship and is responsible for the safe passage of the ship and crew and the cargo. With new technology when ships are controlled remotely who then is the captain or master of the ship? UNCLOS article 94 states that each ship must be in charge of a master and officers who possess appropriate qualifications [26]. However it does not state the whereabouts of the master. The main character of a master is command of the vessel, so it then could be followed that whoever has command of the vessel, should be considered the master. For example if the ship is controlled remotely, then it could be expected that the shore operator will assume the responsibilities of the master.

Summary

In this thesis the complex process of international maritime law was investigated and the aim was to identify gaps and challenges in the contect of autonomous vessels. As this technology is novel especially in the maritime industry, there have not been any certain statements from international law organisations on how to approach this new tenchnology and allow their use in international waters. Work on this subject is ongoing in classification societies like Lloyd's Register of Shipping and DNV GL, technology innovators like Rolls Royce, law bodies like International Maritime Organisation. Most notable innovative collaboration projects have been MUNIN, AAWA, IMO Regulatory Scoping Exercise for MASS. Classification societies have also published their own levels of autonomy systems and preliminary guidelines for the design, safety and construction of autonomous vessels with the possibility of developing an approved classification procedure for such ships in the near future. One of the most important milestone projects has been Svitzer's (global towage company) ship Hermod where it performed unmanned operations in Copenhagen harbour. The success of this project brought the expectation that unmanned vessels might be in wider operation sooner than anticipated.

If so, then the gaps and challenges in regulations for ships will become more urgent for possible solutions so not to stand in the way of innovation. In reality it is probable that technology will be developed faster than new regulations in international maritime law. One way to address this is that states have the possibility to regulate unmanned operations in their own territorial waters.

For investigating the new regulatory framework needed, IMO has launched it's Regulatory Scoping Exercise where several aspects will be investigated and suggestions for changes be made. With autonomous ships new challenges arise like regulatory obstructions in widely accepted conventions and new risks like definitions of certain terms like „ship" and „captain" and cyber security risks. In this study most notable international conventions like UNCLOS, SOLAS, STCW, COLREG were analysed and some possible conflicts identified.

In UNCLOS the main conclusion derived was the the definition of piracy should be amended. When ships will be controlled remotely via satellite connections, act of piracy in the future might not be done on the seas by a member of the crew or a passenger. When technology changes, so must the law to keep up with innovation. UNCLOS requirement Duty to render assistance will also be subject to change. Duty to render assistance means that a ship must assist other vessels at sea in danger. As there will always be ships in the sea with seafarers on board even in the future when autonomous vessels are an ordinary thing, this requirement will need clarification. One

possible solution is that there will still be infrastructure built even on unmanned vessels for the possible accomodation of rescued persons at sea.

SOLAS will need clarification on minimum safe manning level on ships. As there will not be crew on board a ship that is controlled remotely, this rule should be amended with the possibility of shore based control centres.

STCW conventions applicability on unmanned vessels has been a question because its definition that it shall apply to seafarers serving on board sea-going ships. One possible solution is that a new category for unmanned ships could be created that specifies the training and certification requirements for crew and operator working in a shore based control centre.

COLREG requirement for look should be clarified as the convention states proper look-out by sight and hearing. Traditionally this has been the duty of seafarers on board but in the future, they will be replaced by cameras and recognition software. Given that risk of software malfunction is mitigated, COLREG should be amended to make technology equivalent to human look-out.

New risks also arise with autonomous vessels. Cyber security has not given much attention in the past but it will become extremely important when ships will be controlled remotely. As a conclusion, cyber security requirements should be included in regulations along with failsafe procedures.

One of the new risks identified in this study is the confusion with definitions and different competing concepts of autonomy degrees. If the term „autonomous“ by definition means having the freedom to govern itself, then the only vessels that could be considered autonomous are vessels driven by the ships system that makes its own decision and all other vessels should be reffered to as unmanned vessels.

The definition of a captain or master will need clarification in international maritime legal instruments. As stated in UNCLOS „each ship must be in charge of a master“ then in the context of unmanned vessels, the operator in a shore based control centre should be made equivalent to a master.

Lühikokkuvõte

Autonoomsed laevad merel osutub lähitulevikus võimalikuks isegi kiiremini kui algselt oodati. Kuna tehnoloogia areng on väga kiire, siis reaalsuses jääb vajalik rahvusvaheline seadusandlik pool liiga aeglaseks, et töötada välja uued standardid ja regulatsioonid, et lubada mehitamata laevad merele. Siiski on võimalik igal riigil töötada välja enda seadusandlus, et lubada mehitamata laevad sõitma enda territoriaalvetesse.

Rahvusvahelised konventsioonid nagu COLREG ehk Rahvusvahelise laevakokkupõrgete vältimise eeskirja konventsioon, SOLAS ehk Rahvusvaheline konventsioon inimelude ohutusest merel, STCW ehk Meremeeste väljaõppe, diplomeerimise ja vahiteenistuse aluste rahvusvaheline konventsioon, UNCLOS ehk Ühinenud Rahvaste Organisatsiooni mereõiguse konventsioon on põhilised konventsioonid, mida analüüsiti käesolevas töös ning tehti järeldusi, kuidas võiks mõningaid potensiaalselt probleeme tekitavaid punkte muuta.

Rahvusvahelise laevakokkupõrgete vältimise eeskirja konventsioon on problemaatiline, kuna sätestab vaatluse nõudeks, et laev peab alati pidama vajalikku nägemis- ja kuulmisvaatlust. Mehitamata laevadel asendub nägemismeel ja kuulmismeel tehnoloogiaga ning on küsitav, kas neid on hetkel kehtiva seaduse raames võimalik lugeda võrdseteks vaatluse instrumentideks. See reegel vajab täpsustamist seadusandja poolt ning tehnoloogia lubatavus oleks vaja seadusesse sisse kirjutada, eeldusel, et võimalikud tarkvara ja riistvara rikke riskid oleksid maandatud.

Rahvusvaheline konventsioon inimelude ohutusest merel sätestab miinium meeskonna taseme, et laev oleks turvaliselt mehitatud merereisile minnes. Selle otsuse teeb iga riik ise ning teostab selle üle ka järelvalvet. Kui aga mehitamata laeva juhitakse maal asuvast kontrollkeskusest, siis peaks seda reeglit muutma niimoodi, et kehtsestaks turvaline mehitatuse tase ka kontrollkeskusele.

Meremeeste väljaõppe, diplomeerimise ja vahiteenistuse aluste rahvusvaheline konventsioon praeguses sõnastuses kehtib vaid laeva pardal töötavatele inimestele. Kuna tulevikus juhitakse mehitamata laeva maal asuvast kontrollkeskusest, siis võiks luua maal töötavale meeskonnale täiesti uue kategooria koos uute väljaõppe nõuetega.

Ühinenud Rahvaste Organisatsiooni mereõiguse konventsioonis tuleb defineerida piraatlus niimoodi, et ka küberrünnak oleks käitletav piraatlusena. Samuti vajab nii seadusandlikku kui tehnoloogilist uurimist punkt, mis paneb kohustuse osutada abi teisele merehädas olevale laevale.

Autonoomsete laevadega tekivad ka uued riskikohad, mis vajavad täpsustamist ning reguleerimist. Definitsioonid nagu kapten ja autonoomsuse tase on vaja rahvusvaheliselt kokku leppida üheselt mõistetavas vormis, et vältida segaduste tekkimist erinevate omavahel konkureerivate kontseptsioonide vahel. Ka küberturvalisus, mis seni ei ole suuremat tähelepanu saanud vajab standardiseerimist ja konkreetsete nõuete väljatöötamist koos riskide maandamise plaaniga.

References

[1] European Maritime Safety Agency, "Annual Overview of Marine Casualties and Incidents 2016," 2016. [Online]. Available: http://www.emsa.europa.eu/publications/item/2903-annual-overview-of-marine-casualties-and-incidents-2016.html.

[2] Rolls Royce, "Remote and Autonomous Ships The next steps - AAWA Position Paper," [Online]. Available: https://www.rolls-royce.com/~/media/Files/R/Rolls-Royce/documents/customers/marine/ship-intel/aawa-whitepaper-210616.pdf.

[3] International Maritime Organisation, "Member States, IGOs and NGOs," 2021. [Online]. Available: https://www.imo.org/en/About/Membership/Pages/Default.aspx.

[4] International Maritime Organisation, "Structure of IMO," [Online]. Available: https://www.imo.org/en/About/Pages/Structure.aspx.

[5] R. Jassal, "How an IMO convention enters into force and how it is amended ?," 2017. [Online]. Available: https://www.myseatime.com/blog/detail/imo-convention-amendments#:~:text=The%20convention%20will%20enter%20into,states%20during%20the%20adoption%20process..

[6] International Maritime Organisation, "Conventions," [Online]. Available: https://www.imo.org/en/About/Conventions/Pages/Default.aspx.

[7] International Maritime Organisation, "International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM)," [Online]. Available: https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Control-and-Management-of-Ships%27-Ballast-Water-and-Sediments-(BWM).aspx.

[8] International Maritime Organisation, "IMO Goal-based standards," [Online]. Available: https://www.imo.org/en/OurWork/Safety/Pages/Goal-BasedStandards.aspx.

[9] International Maritime Organisation, "International Convention for the Safety of Life at Sea (SOLAS), 1974".

[10] International Maritime Organisation, "Convention on the International Regulations for Preventing Collisions at Sea, 1972 (COLREGs)".

[11] International Maritime Organisation, "International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW)".

[12] International Maritime Organisation, "SOLAS," 1974.

[13] Rolls Royce, "Rolls-Royce demonstrates world’s first remotely operated commercial vessel," 2017. [Online]. Available: https://www.rolls-royce.com/media/press-releases/2017/20-06-2017-rr-demonstrates-worlds-first-remotely-operated-commercial-vessel.aspx.

[14] The Maritime Executive, "Remotely Operate Tug Sails Copenhagen Harbor," 2017. [Online]. Available: https://www.maritime-executive.com/article/remotely-operate-tug-sails-copenhagen-harbor.

[15] Lloyds Register of Shipping, "LR defines 'autonomy levels' for ship design and operation," 2016. [Online]. Available: https://www.lr.org/en/latest-news/lr-defines-autonomy-levels-for-ship-design-and-operation/.

[16] Lloyds Register of Shipping, "Unmanned Marine Systems Code," 2017. [Online]. Available: https://www.lr.org/en/unmanned-code/.

[17] DNVGL, "Autonomous and remotely operated ships," 2018. [Online]. Available: https://rules.dnv.com/docs/pdf/DNV/cg/2018-09/dnvgl-cg-0264.pdf.

[18] DNVGL, "Autonomous and remotely-operated ships," [Online]. Available: https://www.dnv.com/maritime/autonomous-remotely-operated-ships/class-guideline.html.

[19] International Maritime Organisation, "IMO takes first steps to address autonomous ships," 2018. [Online]. Available: https://www.imo.org/en/MediaCentre/PressBriefings/Pages/08-MSC-99-MASS-scoping.aspx.

[20] K. A., "The Autonomous Shipping Era. Operational, Regulatory, and Quality Challenges," TransNav, vol. 12, p. 341, 2018.

[21] International Maritime Organisation, "Autonomous shipping," [Online]. Available: https://www.imo.org/en/MediaCentre/HotTopics/Pages/Autonomous-shipping.aspx.

[22] M. K, T.-H. J, B. J and H.-S. P, "Autonomous shipping and its impact on regulations, technologies, and industries," Journal of International Maritime Safety, Environmental, vol. 4, no. 2, p. 4, 2020.

[23] Maritime Unmanned Navigation through Intelligence in Networks, "About MUNIN – Maritime Unmanned Navigation through Intelligence in Networks," [Online]. Available: http://www.unmanned-ship.org/munin/about/.

[24] Maritime Unmanned Navigation through Intelligence in Networks, "MUNIN Results," 2016. [Online]. Available: http://www.unmanned-ship.org/munin/about/munin-results-2/.

[25] Rolls Royce, "AAWA project introduces the project’s first commercial ship operators," 2016. [Online]. Available: https://www.rolls-royce.com/media/press-releases/2016/pr-12-04-2016-aawa-project-introduces-projects-first-commercial-operators.aspx.

[26] Cambridge University, "Cambridge Dictionary," [Online]. Available: https://dictionary.cambridge.org/dictionary/english/autonomous.

[27] H. Ringbom, "Regulating Autonomous Ships—Concepts,Challenges and Precedents," Ocean Development & International Law, vol. 50, no. 2-3, 2019.

[28] United Nations, United Nations Convention on the Law of the Sea, 1994.

[29] International Maritime Organisation, Convention on the International Regulations for Preventing Collisions at Sea, 1972.

[30] International Maritime Organisation, "International Convention on Standards of Training Certification and Watchkeeping for Seafarers (STCW)," 1978.

[31] International Maritime Organisation, "Guidelines on maritime cyber risk management," 2017. [Online]. Available: https://wwwcdn.imo.org/localresources/en/OurWork/Security/Documents/MSC-FAL.1-Circ.3%20-%20Guidelines%20On%20Maritime%20Cyber%20Risk%20Management%20(Secretariat).pdf.

[32] International Maritime Organisation, [Online]. Available: https://www.imo.org/en/About/Membership/Pages/Default.aspx.

[33] International Maritime Organisation, "International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM)," [Online]. Available: https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Control-and-Management-of-Ships%27-Ballast-Water-and-Sediments-(BWM).aspx.

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