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Rise of the Machines – A Legal analysis of Seaworthiness in the context of autonomous shipping

JURM02 Graduate Thesis

Graduate Thesis, Master of Laws program
30 higher education credits

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Semester of graduation: Period 1 Spring Semester 2019

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Summary

In recent years, technological developments have been the focal point of the discussion in the shipping industry. The two main topics have been a general discussion on IT security and a discussion about autonomous ships.

Concerning IT security, the discussion has been focused on the industry's knowledge in the field and preparedness for any attacks or mishaps that can affect companies that are heavily dependent on IT technology.

The majority of participants in the discussions agree that the shipping industry has fallen behind concerning IT security, why it has become so is unclear. One possible explanation may be that the industry has not been put under pressure on these issues before. Previously, much of the administration has been done with paper, but with an ever-increasing transition to digital systems, the industry has become increasingly put at risk.

Both industry organisations and IMO have in recent years presented guidelines and increased requirements for IT security. Historically, the shipping industry has emphasized the physical safety of both ship and crew. In today's era, greater demands are being placed on protecting the organization against digital threats. This can also include physical protection for IT facilities and communication and navigation systems.

The discussion on autonomous ships has mainly been focused on three themes, which legal barriers exist, which technical obstacles exist to implement the transition to autonomous ships and what are the advantages with autonomous ships compared to conventional.

The advantages that mainly have been put forward as support of autonomous ships concerns the economy and the environment and safety. The economic advantage for autonomous ships are reduced costs for crew and the possibility of carrying an increased cargo load when the need for crew-related spaces vanishes. However, these reduced costs can be offset by the need for several back-up system when there no longer is any human crew on board who can rectify any errors.

One suggested possibility is for autonomous ships to use an approach called "slow steam", which means that the ship travel at a slower speed than it has the capacity for. This would result in a cut of the cost of fuel, since the ship does not consume as much fuel, and a saving in CO_2 emissions. However, travel at a reduced speed is not something specific for autonomous ships, since all ships can reduce its speed. Also, if the ship has a human crew, the potentials for any savings is lower, as the longer journey results in increased wage for the crew.

The third argument for autonomous ships is that with a greater degree of automation, safety should increase since the number of accidents and incidents would diminish. The reason behind this argument is that there is a widespread notion within the shipping industry that the so-called human factor are behind up to 96% of the accidents in the maritime industry. However, this idea seems to be based on reports and investigations concerning accidents that happened between about 30-50 years ago. Since then e.g. The ISM code has been adopted and there are reports from recent years that indicate that the human factor is significantly lower, 58%

The paper addresses a number of definitions of autonomous ships launched in recent years, including initiatives from the research sector, the maritime industry, the IMO. Furthermore, a selection of projects focused on autonomous ships, both pure research projects and projects that resulted in the construction of autonomous ships, is presented.

The essay has examined whether autonomous ships, according to existing legal frameworks, can be regarded as ships or not. The conclusion that can be drawn is that the significant international conventions in the field and the British legislation that have been examined do not pose any significant obstacles. There are some uncertainties regarding staffing requirements, but since autonomous ships in international shipping probably still are a few years away, there is time to address these ambiguities.

The thesis also examines whether there are any obstacles to autonomous ships concerning seaworthiness, the relevant conventions in the area and the British legislation are examined.

One of the main aspects of the thesis is whether the definition of seaworthiness will be affected by the introduction of autonomous ships, and especially with regard to cyber security. A difference likely change the concept of seaworthiness is that it will stretch far beyond the ship itself and its immediate physical form. Communication systems that handle the data flow between the ship and land based control stations and satellites must be protected. The land-based control stations may be considered as part of the ship, which means that the requirements for these are subject to the same requirements imposed on the ship.

There will be increasing demands on the organization, not only to prevent but also to manage and mitigate the consequences of e.g. IT system intrusion.

There is no established practice in the area, as legal issues related to IT security have not been subject to judicial review. The thesis has to a certain degree examined to what extent settled case law concerning technical issues could be used as guidance for IT-related issues.

Sammanfattning

De senaste åren har den tekniska utvecklingen varit brännpunkten för diskussionen inom sjöfartsindustrin. De två huvudspår som kan skönjas är en generell diskussion om IT-säkerhet och en diskussion kring autonoma skepp.

När det gäller IT-säkerheten har diskussionen varit fokuserad industrins kunskap på område och beredskap på eventuella angrepp eller missöden som kan drabba företag som till betydande del är beroende av IT-teknik.

De allra flesta som deltar i diskussionerna är överens om att sjöfartsindustrin hamnat på efterkälken när det gäller IT-säkerhet, varför det blivit så är oklart. En möjlig förklaring kan vara att branschen inte haft något större utvecklingstryck på sig när det gäller dessa frågor. Tidigare har mycket av den administrativa hanteringen skett med papper men med en allt större övergång till digitala system och hjälpmedel har branschen blivit allt mer riskutsatt.

Både branschorganisationer och IMO har de senaste åren kommit med riktlinjer och skärpta krav på IT-säkerheten. Historiskt sett har sjöfartsindustrin betonat den fysiska säkerheten både avseende skepp och besättning. I dagens tidevarv ställs det större krav på att skydda sin verksamhet även mot digitala hot. Detta också kan inbegripa fysiskt skydd för IT-anläggningar och kommunikations- och navigationssystem.

Diskussionen kring autonoma skepp har varit fokuserad på i huvudsak tre områden, vilka legala barriärer finns, vilka tekniska hinder finns för att genomföra övergången till autonoma skepp och vilka fördelar finns det med autonoma skepp jämfört med konventionella.

De fördelar som i huvudsak har anförts till stöd för autonoma skepp har avsett ekonomi och miljö samt säkerhet. De ekonomiska fördelar som anföras för autonoma skepp är minskade kostnader för besättning och möjligheten att få plats med mer last på skeppen när behovet för besättningsrelaterade utrymmen försvinner. Dock kan den minskade kostnaden på detta område motverkas av behovet av back-up system när det inte längre finns någon mänsklig besättning ombord som kan åtgärda fel som uppstår.

En möjlighet som föreslagits är att låta autonoma skepp använda sig av ett tillvägagångssätt som kallas ”slow steam”, vilket innebär att skeppet går långsammare än det har kapacitet för. Detta skulle innebära både en besparing i pengar, då skeppet inte drar lika mycket bränsle, och en besparing i CO2-utsläpp. Men att låta skepp gå med reducerade hastighet är inte något som är specifikt för autonoma skepp utan det kan alla skepp

tillämpa. Har skeppet en mänsklig besättning är besparingspotentialen dock lägre, då en längre resa resulterar i ökade lönekostnader för besättningen.

Det tredje argumentet för autonoma skepp är med en större grad av automatisering av skeppen så ökar säkerheten genom att antalet olyckor och tillbud minskar. Bakgrunden till detta argument är att det finns en förhärskande uppfattning inom sjöfartsindustrin att den så kallande mänskliga faktorn ligger bakom de allra flesta olyckor inom sjöfartsindustrin, upp till 96%. Dock förefaller den uppfattningen vara baserad på rapporter och undersökningar som avser olyckor som skedde mellan 30-50 år sedan. Sedan dess har t.ex. ISM koden tillkommit och det finns undersökningar från senare år som indikerar på att den mänskliga faktorn är väsentligt lägre, 58%

Uppsatsen tar upp ett antal definitioner av autonoma skepp som lanserats de senaste åren, här återfinns initiativ från forskningssektorn, sjöfartsindustrin, IMO. Vidare presenteras ett urval av projekt fokuserade på autonoma skepp, både rena forskningsprojekt och projekt som resulterat i konstruktion av autonoma skepp.

Uppsatsen har undersökt om autonoma skepp, enligt existerande legala ramverk, kan betraktas som skepp eller inte. Slutsatsen som kan dras är att de betydande internationella konventionerna på området och den undersökta brittiska lagstiftningen inte lägger några avsevärda hinder i vägen. Det finns några oklarheter kring bemanningskrav men då autonoma skepp i internationell sjöfart troligen ännu ligger några år bort finns det tid att uppdatera dessa tvetydigheter.

Uppsatsen undersöker också om det finns några hinder för autonoma skepp med hänvisning till sjövärdighet och här undersöks relevanta konventioner på området samt den brittiska lagstiftningen.

En huvudaspekt av uppsatsen är frågan om definitionen av sjövärdighet kommer att påverkas till följd av introduktionen av autonoma skepp och då särskilt med hänseende på IT-säkerhet. En trolig skillnad avseende den förändrade sjövärdigheten är att den kommer att sträckas långt bortom själva skeppet och dess omedelbara fysiska form. Kommunikationssystem som hanterar dataflödet mellan skeppet och landbaserade kontrollstationer och satelliter måste skyddas. De landbaserade kontrollstationerna kan komma att anses utgöra en del av skeppet vilket gör att kraven på dessa omfattas av samma krav som ställs på skeppet.

Det kommer att ställas allt större krav på organisationen, inte bara att förebygga men också kunna hantera och mildra konsekvenserna av t.ex. intrång i IT-system.

Det finns inte någon etablerad praxis på området då rättsfrågor kopplade till IT-säkerhet inte varit föremål för prövning i domstol. Uppsatsen har till viss del i vilken grad existerande praxis kring skeppstekniska frågor skulle kunna användas som vägledning för IT-relaterade frågor.

Preface

This is it! The end of a long and winding road, that began a long time ago in the dim and distant past. It started out in that last Millennium and carried on into this one and I doubted many a times that I would reach the end of the road or find the pot of gold at the end of the rainbow. But thanks to my own stubbornness and support from others, I'm finally here at the gates of tomorrow.

I've spent some great times at the Faculty of Law and I chose to remember the great teachers that inspired and pushed and instilled confidence in us students.

I would like to thank Olena for delivering such interesting courses in maritime and transport law that gave me inspiration to write my graduate thesis in maritime law and also for being my supervisor for this thesis.

A special shout-out to Henrik who was there both in the beginning and in the end. Thanks for lunches, feedback and general encouragement along the way.

Last and most importantly I would like to thank my family, my fantastic wife Linnea, my wonderful children Eliott and Elvira, and my incredible in-laws, Inger and Åke. Their unfaltering support and help made it possible for me to achieve my goal and get my law degree. I will be ever in debt for all their support and help.

Lund May 2019

Anders

Abbreviations

AAWA	Advanced autonomous waterborne applications initiative
ABS	American Bureau of Shipping
AIS	Automatic identification system
BIMCO	Baltic and International Maritime Council
BNWAS	Bridge Navigational Watch Alarm System
CLIA	Cruise Lines International Association
CMI	Comité Maritime International
COLREGs	International Regulations for Preventing Collisions at Sea, 1972
ECDIS	Electronic Chart Display and Information System
EMSA	European Maritime Safety Agency
ETO	Electro Technical Officer
GDPR	General Data Protection Regulation
GT	Gross Tonnage
HVR	Hague-Visby Rules
HR	Hamburg Rules
ICS	International Chamber of Shipping
IMO	International Maritime Organization
Intercargo	International Association of Dry Cargo Shipowners
INTERTANKO	International Association of Independent Tanker Owners
ISM Code	International Safety Management Code
IUMI	International Union of Marine Insurance
LIDAR	Light Detection and Ranging
NFAS	Norwegian Forum for Autonomous Ships
NUC	Not under command
NTNU	Norwegian University of Science and Technology
MARPOL 73/78	International Convention for the Prevention of Pollution from Ships, 1973/78
MASS	Maritime Autonomous Surface Ship
MIA 1906	Marine Insurance Act 1906
MIF	Maritime Industries Forum
MLC	Maritime Labour Convention, 2006
MUNIN	Maritime unmanned navigation through intelligence in networks
MaCRA	Maritime Cyber-Risk Assessment
MSA	Marine Shipping Act 1995
OCIMF	Oil Companies International Marine Forum
RADAR	Radio Detection and Ranging
UNCLOS	United Nations Convention on the Law of the Sea, 1982

UNCTAD	United Nations Conference on Trade and Development
UNCITRAL	United Nations Commission on International Trade Law
UAV	Unmanned aerial vehicle
WSC	World Shipping Council
P&I Club	Protection and Indemnity Club
RR	Rotterdam Rules
SDR	Special Drawing Right
SOLAS	International convention for the Safety of Life at Sea, 1974
STCW	Standards of Training, Certification and Watchkeeping for Seafarers convention, 1978
SSC	Shore control centre
TEU	Twenty-foot equivalent unit

1 Introduction

1.1 History and background

Since the dawn of mankind transportation by the way of water has been an important part of society and this is also reflected in ancient legislation.

One of the oldest known legislation in maritime law is the *Lex Rhodia*, from 800 BC. Unfortunately, no copy of the law has survived to the present day. Our knowledge of the law stems from references in Roman legislation. During the Byzantine era the maritime law developed and become known as *Nomos Rhodion Nautikós*.[1]

No specific regulation in *Nomos Rhodion Nautikós* explicitly mentions an obligation for the ship-owner to provide a seaworthy ship. However, it recommends the merchants to make certain inquiries. The merchant should check that the ship has a complete tackle and is watertight and that the master and crew have the necessary experience. The merchant should also make sure that the crew are sufficient in numbers regarding the size of the ship.[2]

The meaning of seaworthiness has changed over time with the development of the shipping industry. However, the ship's physical appearance have been important in deciding whether a ship has been seaworthy or not.

With the increasing dependence on technology and diminishing crews manning the vessels it has become more and more important that the ship's technological systems are up to date and that the remaining crews training includes knowledge on cyber risks.

The cyber security issue is sometimes described as a "wicked problem". This refers to a situation that in reality is not possible to solve. A company can pour a lot of resources into preventing a security breach but "because of incomplete, contradictory, and changing requirements" the goal is hard to reach.[3] Even if the "wicked problem" might be difficult so solve, or even impossible, its consequences can be reduced. They have to be handled properly through measures of resilience.[4]

Over the last few years, there have been a number of high profile cyber attacks, affecting the shipping industry. Maersk was affected by a cyber

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[1] Ferrándiz (2017) pp. 41-42.
[2] Ashburner (1909) pp. clxxxii- clxxxiii.
[3] Mileski et. al. (2018) pp. 415-416.
[4] Mileski et. al. (2018) p. 421.

attack in 2017 which more or less shut down the company for ten days.[5] Also in 2017 a number of ships in the Black Sea were exposed for a GPS spoofing attack, which resulted in that the GPS lost position or displayed a very inaccurate position. Some GPS devices showed the position to be up to 32 kilometres inland.[6] Had the crew relied totally upon the GPS navigation they might have encountered problems and the crew, ship and cargo would have been in danger.

However, there is an unwillingness in the shipping industry to reveal or make it publicly known that the company has been a target of a cyber attack, whether it was successful or not.[7] This makes it difficult to determine the scale of the cyber intrusions aimed at the shipping industry.

It is important to understand that it is not just the ships that might be affected. Between 2011-2013 the port of Antwerp was under a cyber attack by criminals that gained access to the port IT-systems.[8] This kind of attacks could have the consequence that the port would no longer be considered as a safe port.

IMO has recognised an urgent need to raise awareness regarding cyber risks and adopted a Resolution MSC.428 (98) that encourages companies to appropriately address these issues in safety management systems. Initiative from the industry has also addressed the cyber risk and several guidelines have been developed in order to provide help in an area of growing importance.

The consequence of the constant development of technology has led to a greater dependence of automated systems on ships, and perhaps culminating in a fully autonomous ship. There are a number of competing civilian projects aimed at developing autonomous vessels. In general, these projects focus on cargo ships or other non-passenger ships e.g. YARA Birkeland, a container ship in Norway [9] and Svitzer Hermod, a tugboat trafficking the

[5] Andy Greenberg ‘The Untold Story of NotPetya, the Most Devastating Cyberattack in History’ (Wired, 22 August 2018) <https://www.wired.com/story/notpetya-cyberattack-ukraine-russia-code-crashed-the-world/> Accessed 15 February 2019.
[6] ‘Mass GPS Spoofing Attack in Black Sea?’ (Galileo GNSS 21 September 2017) <https://galileognss.eu/mass-gps-spoofing-attack-in-black-sea/> Accessed 6 February 2019.
[7] Tam et al.(2019) p. 130.
[8] Tom Bateman, ‘Police warning after drug traffickers' cyber-attack’ (BBC News16 October 2013) <https://www.bbc.com/news/world-europe-24539417> Accessed 6 February 2019.
[9] ‘Kongsberg, Autonomous ship project, key facts about YARA Birkeland’ <https://kmdoc.kongsberg.com/ks/web/nokbg0240.nsf/AllWeb/4B8113B707A50A4FC125811D00407045?OpenDocument> Accessed 6 February 2019.

Copenhagen port.[10] There has also been a test with an autonomous ferry, the Falco, in Finland.[11]

The most bold predictions prophecy that remotely controlled autonomous ships will be in coastal traffic by 2020 and that autonomous and unmanned ships will navigate the oceans by 2030.[12] Other commentators, like the CEO of Maersk, remain a bit more sceptical and doubt that there will be any autonomous and unmanned ocean going ships during his lifetime.[13] It is most likely that conventional manned ships and fully autonomous ships and everything in between will traffic the ocean side by side for a long time to come. Therefore, it will be important to take into account the legal implications for both fully autonomous vessels and the ships that have some manual override.

In the first instance, it could be considered as moving into uncharted legal waters even if the existing regulations and case law partially could be seen as to cover the rise of the machine age. For the latter case, analogies can be drawn upon from the existing regulations and case law.

1.2 Purpose and problem

There has been a rather large discussion concerning on how to consider an autonomous vessel, should it be considered as an ordinary ship or something completely new? There has also been a rather large debate over the practical and legal aspects of vessels that are not having any human crews on-board. One aspect that has been discussed is if there are any advantages to gain from removing the crew from the ships.

The discussion concerning cyber security and questions concerning IT in general, have been less prevalent but have gained momentum during the last few years. There is a lack of relevant case law for cyber security, which means that there is an uncertainty concerning the importance of this for the concept of seaworthiness.

I will address and analyse the following questions:

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[10] 'Maersk, The road to autonomous vessel tech' (14 December 2017) <https://www.maersk.com/en/news/2018/06/29/the-road-to-autonomous-vessel-tech> Accessed 6 February 2019.

[11] 'Finferries' Falco world's first fully autonomous ferry' (3 December 2018) (Finferries) <https://www.finferries.fi/en/news/press-releases/finferries-falco-worlds-first-fully-autonomous-ferry.html> Accessed 6 February 2019.

[12] In Depth: Smart Ships Are Coming! (World Maritime News, April 24 2017) <https://worldmaritimenews.com/archives/218365/interview-smart-ships-are-coming/> Accessed 23 April 2019.

[13] Christian Wienberg, 'Maersk's CEO Can't Imagine Self-Sailing Box Ships in His Lifetime' (Bloomberg, 15 februari 2018) <https://www.bloomberg.com/news/articles/2018-02-15/maersk-ceo-can-t-imagine-self-sailing-box-ships-in-his-lifetime> Accessed 23 April 2019.

- Does there exist a universal definition of what an autonomous surface vessel is?
- Can autonomous vessel be considered as a ship or is it a new type of entity?
- Will there be any need for an amended legislation framework or is the present legislation broad enough to include autonomous vessels?
- Will the introduction of autonomous vessels affect the understanding and definitions of seaworthiness especially regarding cyber security?

1.3 Delimitations

This thesis will be restricted to civilian surface vessels intended for commercial use and carrying goods but not passengers. Vessels, of any kind, intended for military use will not be included in this thesis. Likewise underwater vehicles of any kind will also be outside the scope of this thesis.

The chosen conventions and legislation have a pivotal role within maritime law. Among the selected conventions there are some that regulates the usage and access to the ocean and rules for navigation. Other conventions concern safety, for both seamen and environment, and finally the central conventions for carriage of goods by sea. Apart from the Hamburg Rules and the Rotterdam Rules, the selected conventions have been ratified by a large number of states and cover almost the entire world tonnage. The UK legislation has, over the Swedish legislation, been selected due to the importance it holds within the maritime industry. The chosen conventions and legislation therefore have a great relevance for the topic of this thesis.

1.4 Method, material and state of research

The source material I have used for this thesis stems from a variety of sources. It includes national legislation, international conventions and case law as well as legal doctrine and guidelines issued by international organisations, industry organisations and individual companies. Reports issued by governmental agencies and industry organisations have also been used. For background information and technical descriptions, I utilised online sources, trade publications and non-legal scientific publications. I also used an interview to gain information concerning an autonomous ship project.

I have chosen to write about cyber security in relation to seaworthiness since it seems to be a topic less explored than e.g. cyber security and insurance issues.

I chose to explore seaworthiness firstly with an overreaching perspective and secondly in discussing it in relation to relevant conventions and legislation.

Seaworthiness will be presented taking its start in settled case law, which concerns common law and international conventions on carriage of goods, such as HVR. Other international conventions of interest are SOLAS, STCW and UNCLOS. When insurance issues could serve as illuminating or clarifying they will be addressed briefly.

In order to make the thesis coherent I chose to use a similar approach when presenting the material for the definitions of ships and the definitions of autonomous ships. The material will be presented through the focal point of the conventions and legislation and the guidelines instead of a more thematic approach. This will make it easier to compare the information from different sources.

I have chosen to give a, perhaps more extensive than necessary, background information on autonomous ships in chapter 2. The reason behind this is to provide a background on some of the important non-legal issues concerning autonomous ship that might have an important impact.

The usual method for all kind of legal "works", such as articles, essays and various other publication formats is the legal dogmatic method (*rättsdogmatisk metod*). It is a theory know to all legal scholars and students alike but not one that lends itself to an easy description or definition.

These descriptions can define the legal dogmatic method from the viewpoint of purpose, function, the activity that are being studied.[14]

Even books that deal with the topic are a bit elusive in their description of said method.[15] If one goes to the core of the meaning of the word dogmatic it will be traced back to medieval theology and the concept to reveal a hidden truth.[16] In a more colloquial sense the word "dogma" has acquired a negative connotation rather referring to an unwillingness to reflect and take into account new information. It has come to represent a rigid point of view, a point of view presented with no or little facts to support it.[17]

One thing most legal scholars tend to agree on is that there cannot be only one true answer to a legal problem. Some scholars argue that there cannot be any genuine true answer to a legal problem, just more or less well supported suggestions.[18]

The definitions that do exist are sufficiently broad as to include the methodological approach of this thesis that will use current legislation, settled case law, legal doctrine in order to answer questions concerning *de lege lata*.[19] The method will comprise of weighting arguments for and

[14] Sandgren (2005) p. 649.
[15] Kleineman (2018) p. 21.
[16] Sandgren (2005) p. 648.
[17] Ibid. (2005) p. 648.
[18] Ibid. (2005) p. 653.
[19] Kleineman (2018) p. 21.

against before reaching a, hopefully, well-grounded conclusion on issues concerning *de lege lata* but also extend to issues regarding *de lege ferenda*.[20]

Since I use different legal documents and sources as material for my thesis, the legal dogmatic method seems to be the best suited method.

1.5 Outline

Following this introduction, the second chapter gives a brief description of a few but relevant projects related to autonomous shipping and addresses the perceived advantages with autonomous shipping.

The third chapter presents the most common definitions of autonomous ship and that an autonomous ship can truly be considered a ship in the legal sense. When addressing the issue if an autonomous vessel is a ship international conventions and relevant legislation and case law will be the focal point.

The fourth chapter concerns the concept of seaworthiness in maritime law and how it might be affected by the technological developments. The fifth chapter concerns cyber security and IT aspects of importance for the shipping industry.

The sixth and final chapter summarises the findings and provides some recommendations on possible future development.

[20] Kleineman (2018) p. 36.

2 Autonomous ships: evolution and selected projects

2.1 Introduction

Apart from the ever-evolving technological development, a number of factors have been presented to make the case for autonomous ships.

The perhaps most prominent factor would be the economical factor. The possibility to save on crew salary, fuel consumption and construction cost would be a strong incentive for the shipping industry. Dwindling demand for shipping combined with an overcapacity in tonnage, have put it under collective pressure the last decade.[21]

A secondary effect of reducing the on-board crew on the ships relates to safety. There is a strong belief in the shipping industry that the reduced crew will result in significant less accidents, caused by human errors. The reducing of human errors will have positive environmental effects, less accidents and incidents, less risk of pollution by oil spill or the loss of dangerous cargo. The environment could be affected in a positive manner if goods transported by trucks instead were transported by ships.

A consequence of totally removing an on-board crew would result in eliminated need for crew quarters and other human related spaces. This will lower the construction cost and reduce the electrical power consumption.[22] However, reducing or eliminating the on-board crew most likely will call for an increase in back-up systems and the demand for redundancy concerning crucial systems. A consequence could be that a reduction in costs related to the crew would be offset by an increased cost for equipment.

In order to get an understanding on the technological aspects of autonomous shipping a few significant projects will be presented in this chapter. There is a plethora of projects that are exploring autonomous shipping in some form. The selection presented below is based on available information and how far along the project has come and its scope. The projects range from the existing ship, Svitzer Hermod, to pure research projects such as MUNIN.

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[21] Andreas Illmer, 'Hanjin: Final curtain falls on shipping saga', 17 February 2017 <https://www.bbc.com/news/business-38953144> Accessed 16 April 2019.
[22] Kretschmann et al. (2017) p. 82.

2.2 Autonomous vessel projects

2.2.1 Svitzer Hermod

This tugboat project is a collaboration between the Danish shipping company Maersk and Rolls Royce. When it was launched in November 2017 it was labelled as the world's first remotely operated commercial vessel.[23]

It operates in the port of Copenhagen and can be remotely operated from a ROC (Remote Operating Centre), also located in the harbour. The ambition with the project is to evaluate the technology and to explore the possible potential commercial and operational benefits.[24] The tests with the ship have been carried out with crew on-board and have therefore been deemed to comply with existing conventions and regulations. Since the project is still under evaluation, it is for the time being when the next step will be taken or what the next step will be.[25]

2.2.2 YARA Birkeland

The project regarding cargo ships that has made most progress is the YARA Birkeland. This is a container ship that is currently under construction and is expected to begin testing under 2019. If the plans follow the proposed timeline the ship is expected to move into fully autonomous operation by 2022. The project is a collaboration between Yara and Kongsberg.[26]

YARA Birkeland is not just intended to be an autonomous vessel but it will also be fully electric and a zero emissions ship. It will traffic a route along the coast in southern Norway and it is estimated to replace around 40,000 diesel-powered truck transports a year.[27] It will transport fertilizers from the YARA plant in Porsgrunn to ports in Brevik and Larvik for further shipping to customers.[28]

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[23] 'Maersk, The road to autonomous vessel tech' (14 December 2017) <https://www.maersk.com/en/news/2018/06/29/the-road-to-autonomous-vessel-tech> Accessed 6 February 2019.
[24] Ibid.
[25] Interview Svitzer
[26] 'Kongsberg, Autonomous ship project, key facts about YARA Birkeland' <https://kmdoc.kongsberg.com/ks/web/nokbg0240.nsf/AllWeb/4B8113B707A50A4FC125811D00407045?OpenDocument> Accessed 6 February 2019.
[27] Ibid.
[28] 'YARA and KONGSBERG enter into partnership to build world's first autonomous and zero emissions ship' (May 9 2017) Press release <https://www.km.kongsberg.com/ks/web/nokbg0238.nsf/AllWeb/98A8C576AEFC85AFC125811A0037F6C4?OpenDocument> Accessed 9 February 2019.

The intention is that both loading and discharging will be handled automatically and it will have an automatic mooring system and berthing and un-berthing will also be handled automatically.[29]

The cost for YARA Birkeland have been reported to be somewhere between $ 25,000,000[30] and $ 30,000,000.[31] This would make the ship at least three times as expensive as conventional ship of the same size.[32]

2.2.3 Falco

The project is a collaboration between Finferries, a Finnish state-owned company, and Rolls Royce.[33]

This project is still in its early stages and its first public test with invited guests took place on the 3rd December 2018.[34] There is no timeframe for when Falco could be put into commercial traffic.

What separates this project from most other projects regarding autonomous ships is that Falco is not a specially designed and built as an autonomous ship. It is a refitted ferry built in 1993 which has been equipped with state of the art technology. The Falco can run either wholly autonomous or be remotely controlled.[35] This means that Falco can run autonomously from one port to another and berth automatically without any involvement from the crew.

2.2.4 ReVolt

ReVolt is a collaboration between DNV GL and NTNU.[36]

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29 'Kongsberg, Autonomous ship project, key facts about YARA Birkeland' <https://kmdoc.kongsberg.com/ks/web/nokbg0240.nsf/AllWeb/4B8113B707A50A4FC125811D00407045?OpenDocument> Accessed 6 February 2019.

30 Heidi Vella, 'Unmanned ships set to sail the seas', (Raconteur, 7 December 2017) <https://www.raconteur.net/business-innovation/unmanned-ships-set-to-sail-the-seas> Accessed 23 April 2019.

31 Vincent Wee 'Vard scoops $30m deal to build Yara Birkeland' (Seatrade Maritime News, 16 August 2018) <http://www.seatrade-maritime.com/news/europe/vard-scoops-30m-deal-to-build-yara-birkeland.html> Accessed 23 April 2019.

32 Heidi Vella, 'Unmanned ships set to sail the seas', (Raconteur, 7 December 2017) <https://www.raconteur.net/business-innovation/unmanned-ships-set-to-sail-the-seas> Accessed 23 April 2019.

33 Ibid.

34 'Finferries' Falco world's first fully autonomous ferry' (3 December 2018) <https://www.finferries.fi/en/news/press-releases/finferries-falco-worlds-first-fully-autonomous-ferry.html> Accessed 6 February 2019.

35 Ibid.

36 'The ReVolt - A new inspirational ship concept' <https://www.dnvgl.com/technology-innovation/revolt/index.html> Accessed 6 February 2019.

The company behind ReVolt is not a shipping company or technology giant but a quality assurance and risk management company.[37] This project is still in a development phase and with only a 1:20 scale model built for testing purpose. The vessel will not have diesel engines; it will be battery powered. ReVolt will be 60 metres long and having a cargo capacity of 100 TEU. It is developed with an aim for the short-sea routes, in order to replace road transport and transport in coastal areas.[38]

The company states that ReVolt will not see commercial use for quite some time and that it should serve more as an inspiration for the shipping industry.[39]

2.2.5 MUNIN

MUNIN[40] was a collaboration consisting of eight partners, both universities and private companies.[41]

MUNIN was a three-year research project co-funded by the European Commission Seventh Framework Programme and ended in 2015. A part of the project was to develop a ship that would be completely unmanned for parts of the voyage.[42]

The project focused on dry bulk carriers, which provides some commercial advantages. The voyage is usually long and uninterrupted, going from the loading port to discharge port and the cargo requires a minimum of monitoring.

2.2.6 Mitsui and Nippon Yusen project

A project with the aim to introduce self-navigating ships by 2025 has been initiated in Japan. It is a collaboration between several large Japanese shipping companies like Mitsui O.S.K. Lines and Nippon Yusen and the Japanese government. The project involves collecting and analysing data about the weather, conditions at sea, shipping information. This information will then be utilised to plot the most fuel-efficient routes.[43]

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[37] 'DNV GL in brief' <https://www.dnvgl.com/about/index.html> Accessed 6 February 2019.
[38] 'The ReVolt - A new inspirational ship concept' <https://www.dnvgl.com/technology-innovation/revolt/index.html> Accessed 6 February 2019.
[39] Ibid.
[40] Munin is one of the two ravens associated with the Norse god of wisdom, Odin, the other one being Hugin. They fly all over Midgard and tell him everything they see and hear.
[41] 'The MUNIN Consortium' <http://www.unmanned-ship.org/munin/partner/marintek/> Accessed 13 February 2019
[42] 'MUNIN Brochure 2013' <http://www.unmanned-ship.org/munin/wp-content/uploads/2013/01/MUNIN-Brochure.pdf> Accessed 13 February 2019.
[43] 'Japan aims to launch self-piloting ships by 2025' (8 June 2017) <https://asia.nikkei.com/Tech-Science/Tech/Japan-aims-to-launch-self-piloting-ships-by-2025> Accessed 9 February 2019.

In line with the project, Nippon Yusen will carry out tests with an autonomous container ship during the latter part of 2019. The ship will be remotely controlled and have a crew on standby. The intended voyage will be a cross Pacific voyage from Japan to a, yet unnamed, North American port.[44] The intended voyage seems to be the most ambitious test of an autonomous ship ever performed.

2.2.7 Shone

Shone is an American start up that aims to retrofit existing ships with autonomous technology. The founders of the company have a background in developing self-driving cars.[45] Shone intends to use artificial intelligence and focus mainly on providing navigation support to the crew by analyse data collected by multiple systems and sensors. Shone has entered into a collaboration with CMA CGM to develop it further and with a special focus on COLREGs.[46]

This collaboration is in line with CMA CGMs strategy of operating navigation command centre that provides navigational assistance to the company fleet and keep track of weather changes around the clock.[47]

2.2.8 Waterborne TP

Waterborne is a research project and technology platform that was initiated in 2005 as an industry initiative, MIF, and have since received funding from the EU. At present, the project has several partners from the industry as well as universities and government agencies.[48]

Waterborne have developed a research agenda and work towards establishing consensus on how to allocate research funds. Additionally, they focus on clean and safe waterborne transports.[49]

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[44] NYK to Test Autonomous Boxship in 2019 (World Maritime News, 25 August 2017) <https://worldmaritimenews.com/archives/228202/nyk-to-test-autonomous-boxship-in-2019/> Accessed 9 February 2019.
[45] 'About us' <https://www.shone.com/about-us> Accessed 9 February 2019
[46] 'CMA CGM collaborates with a startup, Shone, to embed artificial intelligence on board ships' (4 June 2018) <https://www.cmacgm-group.com/en/news-medias/cma-cgm-collaborates-with-a-startup-shone-to-embed-artificial-intelligence-on-board-ships> Accessed 9 February 2019.
[47] 'CMA CGM Links Up with AI Startup for Navigation Safety' (The Maritime Executive, 4 June 2018) <https://www.maritime-executive.com/article/cma-cgm-links-up-with-ai-startup-for-navigation-safety> Accessed 9 February 2019.
[48] 'About Waterborne' <https://www.waterborne.eu/about/about-waterborne/> Accessed 7 May 2019.
[49] 'Waterborne Technology Platform' <https://www.waterborne.eu/> Accessed 12 May 2019.

2.3 Factors impacting autonomous vessels

2.3.1 Economy

The economic factors will have an affect both during the investment phase, when ordering and building a ship and during the day-to-day operations of the ship.

The examples used in this chapter will be based on a ~~dry~~ bulk carrier.[50] The construction of such a ship represents a significant investment; it has an average price of $ 26,000,000.[51] The total cost over its lifetime is estimated to reach $ 129,000,000.[52] The calculated operational lifetime for a dry bulk carrier is 25 years, but it varies depending on the current market situation, with a downturn in demand the scrapping can increase and the average lifetime of a ship can drop.[53]

If the ship is constructed as a truly autonomous ship with no designated living quarters for the crew or other human related spaces it has been estimated that model Panamax[54] ship would be 7.6% lighter. There would also be no need for a traditional bridge on the ship, which would alter the design and reduce the air resistance. These changes could result in a 6% reduction of the fuel consumption.[55]

It is difficult to get a precise number on how much of the total operating cost consists of fuel cost. It depends on what kind of ship and at what speed it is traveling and of course the current market price of the fuel. Estimates puts the fuel cost somewhere between 60%[56] and 75%[57] of the total operating cost. A reduction of the on-board crew can increase the fuel cost in relation to the total operating cost. This means that a reduction of the fuel cost will be important for the shipping industry.

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[50] Kretschmann et al. (2017) p. 78.
[51] Angelica Kemene 'Newbuildings & Yards', (Optima Shipping Services, 20 June 2018), <https://www.marinemoney.com/system/files/media/2018-06/06202018_915_Kemene.pdf> Accessed 10 May 2019.
[52] Kretschmann et al. (2017) p. 80.
[53] Peter Sand 'Demolition age drops as the dry bulk market enters another challenging year' (BIMCO, 5 February 2016) <https://www.bimco.org/news/market_analysis /2016/0205_demo_age_story> Accessed 9 May 2019.
[54] Panamax is the term for ships that could pass through the previous locks of the Panama Canal.
[55] Kretschmann et al. (2017) pp. 81-82.
[56] John Kemp, 'Cheaper fuel to boost container shipping' (Reuters, 22 April 2015) <https://www.reuters.com/article/us-shipping-fuel-kemp-idUSKBN0NC22L20150422> Accessed 10 May 2019.
[57] Ronen (2011) p. 211.

Coupled with reduced or eliminated costs for crew, both salary and other costs connected with the crew, it seems that the costs for an autonomous ship could be cut, compared to a non-autonomous ship.

However, one important factor that needs to be considered is the need for redundancy. Even though it is possible to reduce the expenditures with the possibility of cutting down on crew salaries and other costs connected with a human on-board crew other costs will partly or wholly replace them. The need for a redundancy capacity concerning the electronic equipment, back-up solutions for communication between the ship and the shore and between the ship and e.g. satellites vital for the navigation of the ship, alternate means of propulsion.[58]

Since there is no on-board crew, there is no one to do routine maintenance work during the voyage. Instead, it has to be done during the port stops, which means that the propulsion systems must have a high reliability, which allows for long periods of unsupervised operation. Performing all maintenance during port stops would prolong these and add costs for a maintenance crew. One solution might be to switch from oil engines to electric powered engines, it would eliminate need for installing "scrubbers" [59] or to switch to a more expensive fuel and the effect in case of an accident would be much less devastating. The overall need for maintenance of the engines would drop as well.[60]

All things considered, it seems that the initial investment cost could be higher for an autonomous ship than a non-autonomous ship.[61] A higher initial capital expenditure will make it harder for the ship owner to recuperate the investment cost. In the end, the cost will of course depend on the design choices.

Disruptive events can have a significant effect on the operational lifetime. Just prior to the credit crunch in 2008 the freight rates were extremely high and the ordering of new tonnage for the shipping industry as a whole had risen to exceptional heights, even for the notoriously cyclic business nature of the shipping industry.[62]

When the shipping companies took delivery of the newly built ships, the demand on the world markets had collapsed and left an overcapacity. The problem plagued the shipping industry for years and incurred losses throughout the industry. The pinnacle of the crisis was the bankruptcy of Hanjin Shipping in 2016, which at the time of the failure was the seventh

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[58] Kretschmann et al. (2017) p. 82.
[59] Equipment that removes sulphuric acids from the emissions.
[60] Raunek Kantharia, 'Electric Propulsion System for Ship: Does it have a Future in the Shipping?', (Marine Insight, 11 September 2017) <https://www.marineinsight.com/marine-electrical/electric-propulsion-system-for-ship-does-it-have-a-future-in-the-shipping/> Accessed 2 May 2019.
[61] Kretschmann et al. (2017) p. 83.
[62] Haralambides et al. (2014) p. 9.

largest shipping company in the world. The bankruptcy resulted in a reduced overcapacity.[63]

The daily freight rate for a Panamax dry bulk carrier was $57,000 at the start of 2008 but at the end of the year, the rates had plummeted to $10, 000.[64] Such a drastic decline in rates affects the valuation of the ship and the possibility for the ship-owner to be able to repay loan.

Another recent disruptive event that has happened the last few years was the upgrade of the Panama Canal rendering the Panamax vessels more or less obsolete.

The maximum length for a container ship was 294.13 m[65] and could carry 5,000 TEUs[66]. The increased locks means that the Canal now can handle ships up to 366 m[67] with a capacity of 13,000 TEUs.[68] This new class of ships is known as Neo-Panamax. The upgrade of the Canal meant that the demand for Panamax shrunk and the second-hand value sunk which resulted in that ships that had seen no more than 7-10 years of service were sent to the scrap yard.[69]

With disruptive events of that scale seen the past decade it is perhaps less likely that the shipping industry will venture into another massive shopping spree of an upgraded merchant ships in the coming decade. This could perhaps support the argument of a gradual development of the autonomous era and not a jump.

It is important to keep in mind that if the ship is not constructed as a truly autonomous ship then the possibility for savings will be reduced. If the ship is built with all the rigour of an autonomous ship, with a capacity to work with out a on-board crew, but also incorporates living quarters and other spaces related to a human crew then the savings will be cut.

The reasonable conclusion to draw would be that the introduction of autonomous ships would not drastically reduce the cost for the shipping industry, not yet at least. The question is whether it will save the industry any money at all.

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63 Andreas Illmer, 'Hanjin: Final curtain falls on shipping saga', 17 February 2017 <https://www.bbc.com/news/business-38953144> Accessed 16 April 2019
64 UNCTAD (2009) p. 98
65 ACP (2005) p. 12
66 'Panamax and New Panamax' <http://maritime-connector.com/wiki/panamax/> Accessed 16 April 2019.
67 ACP (2009)
68 'Panamax and New Panamax' <http://maritime-connector.com/wiki/panamax/> Accessed 16 April 2019.
69 Jamie Robertson, 'Shipping slump: Why a vessel worth $60m was sold as scrap', (BBC.com, 1 March 2017) <https://www.bbc.com/news/business-38653546> Accessed 16 April 2019.

The argument for autonomous shipping should perhaps be found elsewhere. If accidents and incidents will see a significant drop then surely this would be the most compelling argument for the autonomous ship. The best scenario promises less risks for the seafarers and the environment.

2.3.2 Safety

An argument for autonomous shipping is that the human error as a cause for maritime accidents is expected to decrease. Accidents caused by the human factor can depend on e.g. fatigue or alcohol consumption. Long working hours and diminishing crew sizes have contributed to accidents.[70]

Within the industry it seems to be an accepted fact that human errors count for a large portion of the accidents and incidents in shipping. The estimate of human related accidents in shipping ranges between 64%-96%.[71] What these numbers are based on are a bit difficult to decipher.

It seems that the most frequently cited source is a conference paper published in 2000 and the findings in this source were based on papers and reports concerning accidents covering the period 1975-1992.[72]

That particular study estimates that the human factor accounted for between 75%-96% of the accidents, the lower figure related to fires and explosions and the higher concerned collisions.[73] Another study was based on accidents that took place between the years of 1982 and 1985 and was heard by the Dutch Shipping Council. The study found that the human error was present in 96 out of the 100 studied accidents.[74] One interesting observation made in the study was that in staggering 93 of the 100 accidents important factors was lack of training, lack of attention and wrong habits.[75] As a side note, it is not clear how the sample of studied cases were made. It is unclear if the sample contains all cases heard by the Dutch Shipping Council between 1982 and 1985 or it was a smaller selection.

However, a report concerning accidents in a coastal region was published in 2018 attributes the human factor for 84% of the accidents. The report covered accidents that took place between the years 2008-2016.[76]

A source of information that seems less used when discussing the human factors in accidents within the shipping industry is the yearly report from EMSA. Their reports puts the number of accidents attributed to the human factor substantially lower than other sources. In the reports covering the years between 2015 and up to 2018, the percentage the number of accidents

[70] Komianos (2018) p. 336.
[71] Burmeister et al. (2014)
[72] Rothblum (2000)
[73] Ibid.
[74] Wagenaar et al. (1987) p. 594.
[75] Ibid. p. 596.
[76] Japan P&I (2018) p. 2

that in some respect could be attributed to a faulty action by humans varies between 67% in 2015[77] and 58% for the year 2018.[78] According to these reports, that includes accidents all over the world, the share of accidents that in some way can be attributed the human factor have been in steady decline. The number for the year 2016 was 62%[79] and in 2017 60%.[80]

It is not possible to delve much further into this discrepancy between the numbers, within the scope of this work. However, a couple of explanations for the deviation in the figures might rest in the methodology of the reports, who reported the cases, how was it reported, and what kind of accidents was covered. The previously mentioned report from 2018 is based on accidents in a coastal environment while the EMSA report cover accidents of all kinds no matter where they occurred or what kind of ship that was involved. One circumstance that could be of importance is that the accidents in the older studies are all pre-ISM Code.[81] Arguably, a great deal of development has taken place since these accidents occurred.

It could therefore be argued that the widespread notion within the shipping industry that the human factor accounts for such a large portion of the accidents are a lingering echo of studies that to some extent might be obsolete. The truly worrisome factor would be if the accidents routinely attributed to human errors in reality should be attributed to equipment or machinery failure.

Some factor that could also be considered is insurance conditions or clauses and the interest of the manufacturers of equipment and machinery.
How are the insurance conditions constructed, do they more favourably cover the crew and their actions? If that is the case, then it could be better if a claim were made on the basis of crew failure rather than attribute it to the equipment. There could be strong economic interests from the manufacturers that the accidents is not blamed on equipment and machinery, as that could hurt the sales.

One could of course argue for that everything that happens in shipping could be attributed to the human factor since it is an industry created by humans.

With this in mind the potential for reducing the number of accidents attributed to the human factors with the help of autonomous shipping might not be as large as expected.

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[77] EMSA (2015) p. 8
[78] EMSA (2018) p. 8
[79] EMSA (2016) p. 8
[80] EMSA (2017) p. 8
[81] See 3.4.3 and 4.8 of this thesis for further information on the ISM Code

There is also a notion that the autonomous ships could reduce the risk for piracy. [82] In a sense it might seem correct that the risk of kidnapping and holding the crew for ransom drops dramatically if there is no crew on-board. However, the piracy activity around the Horn of Africa that has focused on holding the crew and cargo for ransom are deemed unique compared with the rest of the world. In other parts of the world, outright cargo theft are more common.[83] With no crew, the ship might be vulnerable for other kinds of attacks.

The nature of piracy might change and take other forms and focus more on cargo theft. The *modus operandi* could develop and include both attacking with brute force, using RGP[84] and other weapons, and electronic attacks, e.g. jamming equipment. Attacking with weapons could be directed against the propulsion system or communication devices, like antennas. The jamming equipment could be used either to gain control over the ship or block the communication between the ship and the SCC or satellites or disturb the navigation systems in some other way.

2.3.3 Environment

Another advantage that has been presented for autonomous shipping is the possibility of reduced CO2 emissions.

We could perhaps see an accelerated development of autonomous vessels because of the change regarding sulphur limit in ship's fuel oil in MARPOL that will come into effect 1 January 2020.[85]

This means that a lot of vessels have to switch to lower sulphur fuel oil or install "scrubbers" in order to lower the sulphuric emissions.[86] However, installing new equipment does not come cheap and there will be additional costs for training of the crew in order to handle the new equipment.

The demand for this new equipment might also exceed the supply and force some shipping companies to use lower sulphur fuel oil, at a higher cost. The increased cost for this amendment to MARPOL has been estimated to $60 billon. Some carriers has already announced that they will raise the rates and therefore transfer the cost to the costumer.[87]

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[82] Piracy and robbery are treated as the same crime here, even if they have different definitions.
[83] One Earth Future (2018) p. 2
[84] Rocket-Propelled Grenade.
[85] 'Bunker delivery note amendments enter into force as sulphur 2020 requirement looms' (IMO, 7 January 2019) <http://www.imo.org/en/MediaCentre/PressBriefings/Pages/01-MARPOLamendments01012019.aspx> Accessed 6 February 2019.
[86] Simin Ngai, 'Debate over scrubbers continues to split shipping' (Safety at Sea, 21 September 2018) <https://fairplay.ihs.com/environment/article/4306721/debate-over-scrubbers-continues-to-split-shipping> Accessed 15 February 2019.
[87] 'Hapag-Lloyd Announces Sulfur Fuel Charge' (The Maritime Executive, 8 October 2018) <https://www.maritime-executive.com/article/hapag-lloyd-announces-sulfur-fuel-charge> Accessed 15 February 2019.

There is an ongoing debate in the shipping industry as regards the financial issues related to the installation of "scrubbers". There will be a need for capital in order to finance the installations and there is an uncertainty as how long time the payback time for the equipment will be.[88]

Investing in "scrubbers" will only be profitable if the ships can use the lower-cost high-sulphuric fuel oil. If the demand for high-sulphuric fuel oil drops and because of that the supply decreases the shipping companies that invested in "scrubbers" might find themselves in the situation that they have to use high-cost low-sulphuric fuel oil. In turn, this means that the shipping companies might find it hard to recuperate their investment cost for "scrubbers".

One action, though not exclusively reserved for autonomous ships, is slow steam. This means lowering the speed of the ship, which in turn means that the voyage takes longer. If there is still a crew on-board then some of the savings will be offset by the increased salary and charter. This action is not anything that is unique for autonomous ships, any ship could lower its speed and save on fuel.[89]

For anyone who is chartering a ship and employing a crew the potential economic upside of the technic of slow steam could be slim. As the lowered speed results in a higher number of days in transit the charter cost will rise along with the crew salary.[90] The gain would lie in the lowered CO2 emissions and that could be used as a competitive advantage in relation to other less environmental friendly competitors when competing for business. The raised costs for fuel will make slow steam an interesting concept for most ship-owners as it is an, easy, way to lower the operating costs.

There have been discussions that IMO might call for a general reduction in speed as a mean for reducing the CO2 emissions from the shipping industry. This might result in a demand for increased tonnage in order to compensate for the prolonged transport time.[91]

Several zero emission ship projects, like YARA Birkeland, are being developed.[92] These ships could in the future move transport of goods by roads onto the waterways. This could reduce the CO2 emissions and relive

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[88] Simin Ngai, 'Debate over scrubbers continues to split shipping' (Safety at Sea, 21 September 2018) <https://fairplay.ihs.com/environment/article/4306721/debate-over-scrubbers-continues-to-split-shipping> Accessed 15 February 2019.

[89] (Rødseth et al. 2012) p. 8.

[90] Ibid. p. 8.

[91] John Gallagher, 'Green slow-steaming proposal would reduce ship capacity', (JOC.com, 8 March 2018) <https://www.joc.com/maritime-news/ships-shipbuilding/green-slow-steaming-plan-would-reduce-ship-capacity-short-term_20180308.html> Accessed 19 April 2019.

[92] Anish Wankhede 'Top 5 Zero Emission Ship Concepts of the Shipping World', (Marine Insight, 8 April 2019) <https://www.marineinsight.com/green-shipping/top-5-zero-emission-ship-concepts/> Accessed 13 May 2019.

the congested roads of, primarily, Europe. This might be a factor that helps usher in the new era of autonomous shipping.

2.4 Concluding remarks

As long the autonomous ship still needs fuel in the form of oil, it is difficult to see any large savings on the operating costs. If battery powered ship were to be introduced on a grander scale then a significant drop in operating cost might be expected. The drawbacks would be a large capital investment when building the ship and the need for a different infrastructure in the ports, allowing for the possibility for charging batteries on the ships. On a societal level, the need for energy would increase if the shipping industry would decide to phase out the usage of fossil fuel.

The Productivity Paradox as noted by economists means that despite the large scale introduction of computer technology into society the “growth rate of total factor productivity” fell “to historic lows”[93]. One cannot expect that continuing to invest in IT will “cause a surge of productivity“[94], at least not in the short term. It took nearly 40 years for the introduction of electricity in America to have a significant impact in terms of productivity.[95]

The introduction of the superior technology of electric power did not make the previous means of power, coal and steam, unprofitable overnight instead it was sound to let them operate as long as they were serviceable. The tipping point in favour for electric power was reached when it had captured a 50% market share.[96] We might see a similar development concerning autonomous shipping, the benefits might not be realised for quite some time.

The near future will most likely see an increased focus on environmental issues and this will also affect the shipping industry. This will affect the whole industry and not only the autonomous ships. A recently published report showed that the CO2 emissions on the Baltic Sea were almost twice as much than previously estimated.[97]

It is highly dubious that autonomous vessels will eliminate or at least largely remove the human factor. The now prevailing errors might diminish but we could see the introduction of new and unforeseen errors relating to the new technology. Overconfidence in technology can be problematic and even disastrous. With the broad introduction of radar in the merchant fleet, a category of accidents dubbed “radar assisted collisions” occurred during the

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[93] David et al. p. 27.
[94] Ibid. p. 28.
[95] Ibid. p. 22.
[96] Ibid. p. 6.
[97] ‘SMHIs metod Shipair visar utsläppsstatistik från sjöfart’ (SMHI, 7 May 2019) <https://www.smhi.se/nyhetsarkiv/smhis-metod-shipair-visar-utslappsstatistik-fran-sjofart-1.147353> Accessed 15 May 2019.

1960s and 1970s. Recent examples includes accidents caused by overconfidence in technology or poorly designed technology.[98]

However, there might be one potential advantage of only performing maintenance during port stops. Performing these tasks during safer conditions and with a, probably, more experienced personnel could improve the quality of the work and the overall safety.[99]

While one might expect a drop in some categories of piracy, e.g. robbing the crew or holding them for ransom would of course drop dramatically if there is no crew on-board the ships. On a global basis piracy activity has seen a steady decline the last decade, but the activity can vary between different parts of the world and a war or other conflict can increase the piracy activity in a region.[100] One could also conceive different forms of piracy or related activities, an attacker could threat to sink a vessel in order to receive a ransom.

[98] Schröder-Hinrichs et al. (2012) p. 159.
[99] AAWA p. 44.
[100] One Earth Future (2018) p. 7.

3 The Concept of Autonomous ships: terminology and legal concept

3.1 Introduction

When autonomous ship and shipping are mentioned the picture that usually springs to mind is that of a huge container ship that travels the high seas without any crew and utilises software to circumnavigate the globe.

However, even ships with a high level of autonomy can have a crew, or in some cases operators or supervisors. In existing definitions, there is consensus that there are several levels of autonomy, which may or may not include on-board crew.

The most widely circulated categorisation of autonomous ships has been developed by Lloyd's[101], MUNIN[102], NFAS[103], IMO[104] and Waterborne[105]. Most definitions, if not all, draw upon previously developed nomenclature and models from the field of human-machine interaction, like the levels of autonomy.[106]

The conventions and legislation that will be scrutinised later on in this chapter have been selected due to their importance within the maritime sector today. There are a few exceptions. The Hamburg Rules have a limited importance, since so few countries have ratified the convention. The Rotterdam Rules, not yet in force, have been selected in an effort to shed light on a possible development in the field of carriage of goods by sea. The field of carriage of goods by sea is covered by five conventions whereof of four have entered into force.

The difference concerning the four existing conventions, in the scope of application. HVR covers tackle-to-tackle[107], the Hamburg Rules covers port to port and finally the Rotterdam Rules that cover door to door.

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[101] ShipRight pp. 1-2.
[102] 'The Autonomous Ship' <http://www.unmanned-ship.org/munin/about/the-autonomus-ship/> Accessed 22 February 2019.
[103] Rødseth et al. (2017) pp. 11-12.
[104] 'Maritime Safety Committee (MSC), 100th session, 3-7 December 2018' <http://www.imo.org/en/MediaCentre/MeetingSummaries/MSC/Pages/MSC-100th-session.aspx> Accessed 24 April 2019.
[105] 'Implementation of the Waterborne Strategic Research Agenda - Route Map 2011', <http://www.waterborne.eu/media/20002/wirmplus2011plusprint-2-.pdf> Accessed 26 April 2019.
[106] Parasuraman (2000) et al. p. 287.
[107] "Defined as "the time the cargo is loaded to the vessel to the time it is discharged".

3.2 Definition of an autonomous ship

The most basic conditions an autonomous ship must fulfil are that for an ordinary ship, as will be discussed below. This part concerns factors that distinguish automated or autonomous ships from an ordinary ship.

3.2.1 Waterborne project

The Waterborne TP project defined autonomous ships as:

> "Next generation modular control systems and communications technology will enable wireless monitoring and control functions both on and off board.
>
> These will include advanced decision support systems to provide a capability to operate ships remotely under semi or fully autonomous control."[108]

3.2.2 MUNIN

The MUNIN project embraces a definition concerning autonomous ships that includes remotely controlled ships “where the tasks of operating the ship are performed via a remote control mechanism e.g. by a shore based human operator” and a fully automated (independent) ship “where advanced decision support systems on board undertake all the operational decisions independently without intervention of a human operator”.[109]

3.2.3 NFAS

While NFAS outlines a definition of a fully autonomous ship they still remain sceptical about the introduction of fully independent ships. The starting point is that although the ship might be autonomous a human will still supervise it and that connection might never be severed.[110]

The NFAS definition does not only try to define what an autonomous ship is, it also, briefly, touches upon what a ship is. NFAS choose the following definition of as ship:

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[108] ‘Implementation of the Waterborne Strategic Research Agenda - Route Map 2011’, <http://www.waterborne.eu/media/20002/wirmplus2011plusprint-2-.pdf> Accessed 26 April 2019.

[109] ‘The Autonomous Ship’ <http://www.unmanned-ship.org/munin/about/the-autonomus-ship/> Accessed 22 February 2019.

[110] Rødseth et al. (2017) p. 3.

> “ a vessel with its own propulsion and steering system, which execute commercially useful transport of passengers or cargo and which is subject to a civilian regulatory framework ”.[111]

NFAS defines an autonomous ship as:

> “that has some level of automation and self-governance. Automation is used as a general term for the processes, often computerized, that make the ship able to do certain operations without a human controlling it.”[112]

3.2.4 Lloyd’s Registers definitions of autonomy levels of vessels

Lloyd’s definition divides the vessels into seven different levels of autonomy ranging from Autonomy Level (AL) 0 to AL 6. AL 0 defined as a manual vessel with no autonomous function, the human control all actions.[113] AL 6 represents the highest level of autonomy. The vessel is fully autonomous, it is unsupervised and the decisions made and executed entirely by the systems.[114]

The Lloyd’s model covers more than just autonomous ships it also covers non-autonomous ships and furthermore it divides even fully autonomous ships into two separate categories.

		Decisions made	Comments
AL 0	No autonomous function	All action and decision-making performed manually, human controls all the action	
AL 1	On-board Decision Support	All actions taken by human Operator, but decision support tool can present options or otherwise influence the actions chosen.	Data is provided by systems on board.
AL 2	On &Off-board Decision Support	All actions taken by human Operator, but decision support tool can present options or otherwise influence the actions chosen.	Data may be provided by systems on or off-board.
AL 3	Active’ Human in the loop	Decisions and actions are performed with human supervision	Data may be provided by systems on or off-board.

[111] Rødseth et al. (2017) p. 5
[112] Ibid. (2017) p. 5
[113] ShipRight pp. 1-2
[114] Ibid. p. 2

AL 4	Human on the loop, Operator/ Supervisory	Decisions and actions are performed autonomously with human supervision. Human operators can intercede and over-ride high impact decisions.
AL 5	Fully autonomous	Rarely supervised operation where decisions are entirely made and actioned by the system.
AL 6	Fully autonomous	Unsupervised operation where decisions are entirely made and actioned by the system during the mission

[115]

3.2.5 IMO definitions of autonomy levels of ships

In late 2018 IMO launched a regulatory scoping exercise concerning maritime autonomous surface ships that will be concluded in 2020. As a part of that process IMO identified four levels of autonomy.

1. Ship with automated processes and decision support

2. Remotely controlled ship with seafarers on board

3. Remotely controlled ship without seafarers on board

4. Fully autonomous ship

The scoping exercise aims to identify which IMO conventions apply to MASS or not or if the present any obstacles, in order to determine if the conventions need to be amended or clarified. Among the conventions that will be covered are SOLAS, STCW and COLREG.[116]

The IMO model is restricted to only ships with some level of autonomy and focus more on the ship and technology than the actions of a present or non-present crew.

3.3 Shore control centre

Shore control centre seems to be a generally accepted denomination for the facility that will control or supervise autonomous ships. Several industry stakeholders uses this term.[117] This facility will gather all necessary

[115] ShipRight pp. 1-2 (text transferred to an matrix).
[116] ‘Maritime Safety Committee (MSC), 100th session, 3-7 December 2018’ <http://www.imo.org/en/MediaCentre/MeetingSummaries/MSC/Pages/MSC-100th-session.aspx> Accessed 24 April 2019.
[117] Kongsberg, AAWA, MUNIN

recourses needed to either remote control the ships or monitoring the voyages and standby ready to take control in case of an emergency. The concept of the SSC could be dubbed an innovation for the shipping industry.[118]

The giants of the industry would likely have several SSC guaranteeing local presence and assuring that the personnel have good knowledge about the local conditions. Several SSC would allow for the possibility to maintain an overcapacity, it would also allow the possibility to transfer the controlling or supervision of the ships between the SSC.[119] Like handing over a baton in a rely or like an air-traffic controller keeping track of commercial airplanes.

There need to be protocols or routines in place for when a situation needs to be escalated or moved up in the chain of command or when the operators at the SCC needs to intervene. The reason could be bad weather closing in on the position of the ship or increased traffic in the area. There is a difference between routine and protocol. A routine practice calls for the supervision by a human operator when the ship reaches specific and expected points during its voyage and protocol describes which action is called for, in case something unexpected happens.

In theory, an SSC could be set up to handle only one ship but that would probably not be a sound investment, the more likely scenario would be a SSC controlling or supervising several ships.[120]

The introduction of SCC raises the question of suitable qualifications, it is not necessary a master or helmsman that are the most qualified persons to monitor or remote control the ships. It could perhaps call for a completely new skill set, which requires other qualifications and training than that of a master or helmsman.

3.4 Is an unmanned ship a ship?

One important question that has been raised is whether an unmanned ship could be considered as a ship altogether. Since there is no single definition of such a ship, one has to investigate each relevant convention or law in order to determine if an autonomous ship could be considered as a ship in a legal sense.

Automated ships with a human crew on-board should fulfil the definitions.

[118] MUNIN (2015) p. 8
[119] Ibid. (2015) p. 8
[120] Ibid. (2015) p. 8

3.4.1 UNCLOS

3.4.1.1 Background

Sometimes UNCLOS is described as the constitution of the sea[121] and it could be characterised as an effort to create one legal framework regulating the usage of the ocean, e.g. right to innocent passage[122], duties of the flags state[123] and rights of costal states.[124]

Even if this Convention from 1982 only came into force in 1994 after the condition of 60 ratifications was fulfilled,[125] the roots of the Convention go much further back. It replaced four previous Conventions whereof the oldest dated back to 1958.[126]

The Convention has 168 parties[127] and is binding for State Parties.[128]

3.4.1.2 Definition of a ship

The UNCLOS does not provide a general definition of a ship or vessel. In Article 29 the Convention gives a definition, for the purpose of the convention, of warships. However, it does not describe physical attributes of the ship itself, instead it focuses on ownership and who commands the ship. The definition of a pirate ship in Article 103 follows the same formula. It seems that the Convention deliberately avoids providing a definition.
It can also be noted that the Convention[129] uses the terms “ship” and “vessel” interchangeably.[130]

Instead, UNCLOS leaves it to the flag state to regulate which ships and what kind of ships it register and give “the right to fly its flag”.[131]

UNCLOS could present a barrier for autonomous ships as it gives coastal states some jurisdiction over ships of other nationalities.[132] Articles 25(2), 211(3) and 22 could be used as a barrier for giving autonomous ships access to ports and internal waters.[133]

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[121] Barret et al (2016) p. 3.
[122] UNCLOS art. 17.
[123] UNCLOS art. 94.
[124] UNCLOS art. 142.
[125] UNCLOS art. 308.
[126] Barret et al (2016) p. lxxx.
[127] ‘United Nations Convention on the Law of the Sea Montego Bay 1982’ <https://treaties.un.org/pages/ViewDetailsIII.aspx?src=TREATY&mtdsg_no=XXI-6&chapter=21&Temp=mtdsg3&clang=_en> Accessed 5 April 2019.
[128] UNCLOS art. 1 (2)(1).
[129] This applies to the English version of the convention, but the French text seems to use only one word, “*Navire”*. This could be seen as a support for the opinion that there is no difference between vessel and ship in the English version.
[130] Hooydonk (2014) p. 406.
[131] UNCLOS art. 91.
[132] DMA (2017) p. 40.
[133] Ibid. p. 16.

Article 22 regulates access to sea lanes and traffic separation schemes in the territorial sea. Article 25(2) concerns access to internal waters and port calls. Both these articles can be found in Section 3 Innocent Passage in the Territorial Sea.

Article 211 deals with pollution from ships and stipulates that a state can "establish particular requirements…as a condition for the entry of foreign vessels into their ports or internal waters". The article can be found in Section 5 "International Rules and National Legislation to Prevent, Reduce and Control Pollution of the Marine Environment."

However, under Article 300 the coastal state regulations cannot "constitute an abuse of right". The regulations must also abide by general international law principles on proportionality.[134]

It would seem improbable that coastal states could prevent autonomous ships of different kinds the right to innocent passage, only based on the fact that they lacking crew or have a higher level of autonomy than conventional ships.

In theory, UNCLOS seems to present some regulatory issues concerning if autonomous vessels could be considered as ships in their own right. In reality these regulations will probably not cause any problems. It is questionable if a state want to, or could, shut out other states ships from their coastal waters in fear of retaliation.

In order for a smooth transition into the autonomous era, an amendment could be made to UNCLOS to clarify that autonomous ships should be considered as a ship. UNCLOS might be difficult to amend and it could take a long time for it to materialise but it would perhaps be the best way to move forward.

3.4.2 MARPOL 73/78

3.4.2.1 Background

MARPOL is the main convention that aims to protect the maritime environment from pollution by ships. One important factor that led to its adoption was a string of tanker accidents. The Convention covers both accidents and routine operations.[135]

[134] DMA (2017) p. 41.
[135] 'International Convention for the Prevention of Pollution from Ships' (MARPOL) <http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx> Accessed 5 April 2019.

The Convention that came into force 1983 has 157 Contracting States and it covers over 99% of the world tonnage.[136]

3.4.2.2 Definition of a ship

MARPOL contains a broad definition of a ship;

> "Ship means a vessel of any type whatsoever operating in marine environment and includes hydrofoil boats, air-cushion vehicles, submersibles, floating craft and fixed or floating platforms."[137]

The concept of vessel is not defined separately in MARPOL but seems to have a very broad scope according to the above mentioned definition of a ship.

MARPOL do not seem to present any obstacle for autonomous ships to be considered ships in accordance with MARPOL.

3.4.3 SOLAS and ISM Code

3.4.3.1 Background

SOLAS could be considered as the most important convention in the field of safety on merchant ships and the first incarnation was adopted in 1914 following the *Titanic* disaster.[138]

The SOLAS Convention specifies minimum standards regarding "construction, equipment and operation of ships".[139] As a main principle it is the flag state that is responsible to make sure that the ships fulfil the criteria set out in the convention.[140]

However, SOLAS gives contracting states some jurisdiction over ships from other contracting states, in form of the port state control. When there is "clear grounds for believing that the ship is not in compliance" the contracting state could have the right to effectuate a variety of actions, e.g. detention or expulsion of the ship.[141]

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[136] 'IMO - Status of Treaties' (3 March 2019) <http://www.imo.org/en/About/Conventions/StatusOfConventions/Documents/StatusOfTreaties.pdf> Accessed 5 April 2019.
[137] MARPOL (73/78) art. 2(4).
[138] 'International Convention for the Safety of Life at Sea (SOLAS)', 1974 <http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Safety-of-Life-at-Sea-(SOLAS),-1974.aspx> Accessed 9 April 2019.
[139] Ibid.
[140] Ibid.
[141] SOLAS Chap. XI-2 reg. 9

All countries, that are parties to SOLAS are bound by the ISM Code. The reason is that even if the ISM Code is a separate instrument from SOLAS it was implemented under Chapter IX in SOLAS.[142] The Code became mandatory for all passenger ships and tankers and bulk carriers from 1 July 1998 and mandatory for other cargo ships and mobile offshore drilling units from 1 July 2002.[143]

The purpose of the ISM Code is to provide an "international standard for safe management and operation of ships and for pollution management".[144] One major reason for introducing the Code was that during the 1980/early 1990 there seemed to be an increase in maritime disasters e.g. *Herald of Free Enterprise, Dona Paz, Exxon Valdez,* and *Scandinavian Star*.[145] The investigation of the disasters revealed that the reason behind them could be attributed to "major errors on the part of management".[146]

The Convention has 165 Contracting States and it covers over 99% of the world tonnage. The Convention entered into force in 1980.[147]

3.4.3.2 Definition of a ship

SOLAS does not contain a single definition of a ship; instead, they are defined depending on the usage of the ship.[148]

The Convention does not cover all kinds of ships and makes exceptions for smaller ships but all cargo ships of 300 gross tonnage and upwards are included as well as virtually every ship carrying passengers.

In conclusion it seems that the definitions in SOLAS do not exclude autonomous ships.

3.4.4 COLREGs

3.4.4.1 Background

[142] Anderson (2005) p. 97.
[143] SOLAS Chap. IX reg. 2.
[144] 'ISM Code and Guidelines on Implementation of the ISM Code' <http://www.imo.org/en/OurWork/HumanElement/SafetyManagement/Pages/ISMCode.aspx> Accessed 27 March 2019.
[145] Anderson (2005) pp.15-16.
[146] 'ISM Code and Guidelines on Implementation of the ISM Code' <http://www.imo.org/en/OurWork/HumanElement/SafetyManagement/Pages/ISMCode.aspx> Accessed 27 March 2019.
[147] 'IMO - Status of Treaties' (3 March 2019) <http://www.imo.org/en/About/Conventions/StatusOfConventions/Documents/StatusOfTreaties.pdf> Accessed 5 April 2019.
[148] SOLAS Chap. I reg. 2.

COLREGs could be described as providing traffic rules for the sea. The Convention replaced the collision regulations from 1960. One significant change from the convention from 1960 was “traffic separation schemes”.[149] These rules give a set of rules for navigating dense trafficked waterways and designate special traffic lanes.[150]

The Convention has 159 Contracting States and it covers over 99% of the world tonnage. The Convention entered into force in 1977.[151]

3.4.4.2 Definition of a ship

In COLREGS the definition of a vessel is given in Rule 3 and it,

> “ includes every description of water craft, including non-displacement craft, WIG craft and seaplanes, used or capable of being used as a means of transportation on water ”.[152]

COLREGS defines different types of vessels based on its means of propulsion or intended use, “power-driven vessel”[153], “sailing vessel”[154], “vessel engaged in fishing”.[155]

In the general definitions of COLREGs there are two definitions that need to be clarified in relation to autonomous ships. The first one is “vessel not under command”[156] and the second one is “vessel restricted in her ability to manoeuvre”[157].

Vessel not under command refers to a vessel that cannot be controlled and “is at the mercy of the winds and seas”.[158] In this case, it should be irrelevant if the ship cannot be controlled by remote control or by a crew on-board the ship. Circumstances that can lead for a ship to become NUC includes e.g. “breakdown of engines or steering gear” or “exceptional weather conditions”.[159] For an autonomous ship such a circumstance could be the loss of a communication link between an SSC or the loss of a connection to a satellite. This state of a ship is an unforeseen or at least an unwanted situation.[160]

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[149] ‘Convention on the International Regulations for Preventing Collisions at Sea, 1972 (COLREGs)’<http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/COLREG.aspx> Accessed 12 April 2019.
[150] COLREGS Rule 10.
[151] ‘IMO - Status of Treaties’ (3 March 2019) <http://www.imo.org/en/About/Conventions/StatusOfConventions/Documents/StatusOfTreaties.pdf> Accessed 5 April 2019.
[152] COLREGS Rule 3 (a).
[153] COLREGS Rule 3 (b).
[154] COLREGS Rule 3 (c).
[155] COLREGS Rule 3 (d).
[156] COLREGS Rule 3 (f).
[157] COLREGS Rule 3 (g).
[158] Salinas et.al. (2012) p. 753.
[159] Ibid. (2012) pp.754-755.
[160] Ibid. (2012) p. 755.

The second definition concerns the expected and normal situation for certain types of vessels[161] and includes e.g., laying and servicing vessels [162] and dredging vessels.[163]

Interestingly to note that COLREGs also includes seaplanes and WIG Crafts, vehicles designed to only temporary traffic the water, although, the WIG craft never strays far above the surface.

In conclusion, it appears that the general definitions in COLREGS do not exclude autonomous ships.

3.4.5 STCW

3.4.5.1 Background

This Convention was the first international agreement to establish a set of common rules regarding training, certification and watchkeeping. Previously it had been the governed by individual governments and without any regard for the regulation in other countries.[164]

The rationale behind introducing this Convention was "to promote safety of life and property at sea and the protection of the marine environment".[165]

In 1995 the STCW went through a significant revision and these amendments went into force in 1997. In 2010 the so called Manilla Amendments were adopted and came into force in 2012. Some of the important changes in the Manilla Amendments were the introduction of training in modern technology, Dynamic Positioning Systems and certificates for electro-technical engineers.[166]

The Convention has 165 Contracting States and it covers over 99% of the world tonnage. The Convention entered into force in 1984.[167]

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[161] Salinas et.al. (2012) p. 755.
[162] COLREGS Rule 3 (g) (i).
[163] COLREGS Rule 3 (g) (ii).
[164] 'International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW)' <http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-on-Standards-of-Training,-Certification-and-Watchkeeping-for-Seafarers-(STCW).aspx> Accessed 21 April 2019.
[165] 'International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978' <http://www.imo.org/en/OurWork/HumanElement/TrainingCertification/Pages/STCW-Convention.aspx> Accessed 21 April 2019.
[166] 'International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW)' <http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-on-Standards-of-Training,-Certification-and-Watchkeeping-for-Seafarers-(STCW).aspx> Accessed 21 April 2019.
[167] 'IMO - Status of Treaties' (3 March 2019) <http://www.imo.org/en/About/Conventions/StatusOfConventions/Documents/StatusOfTreaties.pdf> Accessed 5 April 2019.

3.4.5.2 Definition of a ship

STCW do not give a definition of a ship; instead they list several types of ships[168] engaged in carrying specific types of goods or the carriage of passengers.[169] Interestingly enough the Convention does not specifically mention any bulk cargo ships or container ships. Fishing ships have been regulated in a separate convention.[170]

3.4.6 Conventions for carriage of goods by sea

3.4.7 Hague-Visby Rules

3.4.7.1 Background

The Hague-Visby Rules is the most important international convention concerning carriage of goods by sea. In reality it consists of three different versions, it have different contracting states.[171]

The original Hague Rules was drafted in 1921[172] adopted in 1924 and came into force in 1931.[173] The background for developing this set of rules was that a growing perception of a great imbalance between shiponwers and cargo owners.[174] The shippers claimed that the shipowners took advantage of their strong position in order to dictate the terms and set the principle of contractual freedom aside since the shippers where more or less forced to accept the shipowners terms.[175]

The main goal of the Convention was to achieve a better balance between the shipowners and cargo owners. Since the Convention was a compromise it was met with criticism. One early remark concerned the limits of liability per unit and later critic concerned the inability to handle the technological developments within the transport industry, namely the rise of the container.[176]

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[168] Oil tanker, chemical tanker, liquefied gas tanker, passenger ship, ro-ro passenger ship.
[169] STWC Chap. 1 reg. I/1.
[170] International Convention on Standards of Training, Certification and Watchkeeping for Fishing Vessel Personnel (STCW-F).
[171] International Convention for the Unification of Certain Rules of Law relating to Bills of Lading (1924), The Hague-Visby Rules - The Hague Rules as Amended by the Brussels Protocol 1968, Protocol (SDR Protocol) amending the International Convention for the Unification of Certain Rules of Law relating to Bills of Lading of 25 August 1924 (The Hague Rules), as amended by the Protocol of 23 February 1968 (Visby Rules)
[172] Girvin (2011) p. 221.
[173] Chacón (2017) p. 76.
[174] Girvin (2011) p. 220.
[175] Chacón (2017) p. 74.
[176] Girvin (2011) p. 224.

However, the Convention went unchanged for 44 years until the amendment of the 1968 Brussels Protocol came into force in 1977.[177] The work on the amendment had been initiated two decades earlier in 1959 and seen several drafts with proposals being modified and rejected during the process.[178]

It was stated in the 1968 Protocol that “the convention and the protocol shall be read and interpreted as one single instrument”[179] and the amended convention is known as The Hague-Visby Rules.[180] The reason for this is that the draft was signed in Visby but the Protocol itself was not adopted until the conference in Brussels.

The final addition to the Convention came with the adoption of the second Protocol in 1979, the SDR Protocol, which concerns the package limitation provisions.[181]

3.4.7.2 Definition of a ship

When it comes to ships according to HVR, the Convention provides the following, rather broad, definition; "Ship' means any vessel used for the carriage of goods by sea."[182] Vessel is not defined in the HVR either. In Article VIII that concerns statutory law and the limitation of the liability of the carrier, there is a mention of sea-going vessels. However, that cannot be used for any further guidance either. It should already be clear from the definitions under Article I that the vessels covered by the Convention should be sea-going since it is vessels used for carriage by sea and not by any other means.

HVR do not seem to present any obstacle for autonomous ships to be considered as ships in accordance with HVR.

3.4.8 Hamburg Rules

3.4.8.1 Background

During the 1970 the critic against HVR grown mostly because of the inability for the convention to adapt to the economic and technological development.[183] The developing countries also raised objections that the HVR were biased in favour of the ship-owners.[184]

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[177] Ibid. p. 226.
[178] Ibid. pp. 225-226.
[179] 1968 Brussels Protocol art. 6.
[180] Girvin (2011) p. 226.
[181] Ibid. p. 227.
[182] HVR art. I(d)
[183] Chacón (2017) pp. 86-87.
[184] Girvin (2011) p. 228.

Work with a new convention dates back to 1960-ies with the creation of UNCTAD, however differences between developed and developing countries proved hard to overcome. The task to create a new convention was handed over to UNCITRAL, created in 1966.[185]

A draft of the new convention was prepared by UNCITRAL in 1975 and approved by UNCTAD in 1976 and then approved by a conference in 1978.[186] The most significant difference to the HVR was the increased liability for the carrier.[187]

The Convention came into force in 1992.[188]

3.4.8.2 Definition of a ship

The HR avoids giving a definition on what a ship or vessel is. It can also be noted that the Convention uses the terms ship and vessel interchangeably. There is a mention of seagoing ships in the article that concerns liability of the owners of said vessels.[189] As already noted concerning the discussion of definition of ships in HVR, "seagoing" do not add any additional information since the convention covers carriage of goods by sea.

HR do not seem to present any obstacle for autonomous ships to be considered ships in accordance with HR.

3.4.9 Rotterdam Rules

3.4.9.1 Background

The work on this Convention started in 2001 with a draft written by CMI that was later adopted by UNCITRAL. The initial ambition was to create a unifying convention that would replace the HVR and the Hamburg Rules and cover port to port. During the process the scope of the Convention changed and came to adopt a door-to-door approach.[190]

This regulatory effort can be viewed as both in volume and scope the most ambitious in the area of carriage of goods by sea. One of the biggest differences from its predecessors is that it covers the whole of the contract of carriage if it involves a sea leg.[191] The Rotterdam Rules have been described as a maritime plus convention and not a true multimodal

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[185] Ibid. p. 229.
[186] Ibid. p. 230.
[187] Ibid. p. 231.
[188] 'United Nations Convention on the Carriage of Goods by Sea 1978' <https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XI-D-3&chapter=11&lang=en> Accessed 27 February 2019.
[189] HR art. 25(1)
[190] Thomas (2009) p. 34.
[191] RR art. 1 (1).

convention.[192] The maritime plus connotation stems from the fact that the Convention has a mandatory requirement of a sea leg. An accepted definition of multimodal transport is “carriage consisting of at least two modes of transport, but only one contract”.[193]

During its 10-years existence, only four nations have ratified the RR and not any of the major seafaring nations.[194] In order for it to enter into force 20 states have to ratify the convention.[195]

3.4.9.2 Definition of a ship

RR defines ships as “any vessel used to carry goods by sea.”[196] This definition does not seem to diverge from the definition in HVR.[197] It gives the impression that the definition of a ship in the RR and HVR are in reality the same, with only a slight change of the wording. Vessel is not defined in the RR.

The article covering the limitation of liability just mentions vessel owners without the added prefix “sea”.[198]

RR do not seem to present any obstacle for autonomous ships to be considered ships in accordance with RR.

3.4.10 National legislation

3.4.11 Merchant Shipping Act 1995

3.4.11.1 Background

The Merchant Shipping Act 1995 is a consolidation of different parts of the British regulations relating to merchant shipping and the Merchant shipping acts of 1894.[199]

The MSA 1995 have been included due to the importance British maritime laws and traditions hold on the maritime industry as a whole. Cases settled in accordance with MSA 1995 could influence the international maritime

[192] Eftestøl-Wilhelmsson (2010) p. 274.
[193] Ibid. p. 274.
[194] ‘Status - United Nations Convention on Contracts for the International Carriage of Goods Wholly or Partly by Sea 2008’, <http://www.uncitral.org/uncitral/en/uncitral_texts/transport_goods/rotterdam_status.html> Accessed 27 February 2019.
[195] RR art. 94 (1).
[196] RR art.1 (25).
[197] Hooydonk (2014) p. 408.
[198] RR art. 83
[199] MSA 1995 Introduction.

industry since English courts frequently are chosen as forum even for international disputes.

3.4.11.2 Definition of a ship

According to the MSA 1995 a ship is defined as "in this act, unless the context otherwise requires … "ship" includes every description of vessel used in navigation".[200] While ship is defined for the act in its entirety, the term vessel is not. In Section 255 (1)[201], concerning salvage and wreck, the following definition can be found "in this part "vessel" includes any ship or boat, or any other description of vessel used in navigation". Although the definition of vessel only relates to salvage and wreck the wording does not seem to suggest any deviation from the general definition of a ship.[202] It would also seem strange if Section 255(1) could be narrower than the MSA general definition of a ship, it could then have the possible consequence that a ship according to Section 313 (1) (c) could not been seen as a wreck even if it otherwise qualified as a wreck. Therefore it seems safe to assume that the absence of a definition of vessel in Section 313 (1) (c) does not have any practical significance.

The definition of a ship according to MSA 1995 should be considered non-exhaustive and could be reinterpreted by the courts and given an extended definition and include even more types of vessels.

The definition of ship in general has been scrutinised in case law and there is not anything in the settled case law that seems to exclude an autonomous ship, whether unmanned or not.[203]

3.5 Concluding remarks

The problem with these competing and overlapping definitions and categorisations is that they somewhat differs and sometimes use the same terminology but assign a different meaning. The only thing all these sources of definitions seems to able to completely agree on is that ships roaming the seas on their own account without any crew or supervision is still a thing of the future. The IMO definition of levels of autonomy could be expected to gain worldwide acceptance, especially if it is used as a model for updating the relevant conventions.

The ships of today could be categorised as semi-autonomous ships. Today's merchant ships are equipped with both digital and mechanical support systems that helps the master and crew to guide the ship over the oceans. In other words, an autonomous ship does not always equal to an unmanned ship. However, a truly autonomous ship should not have an on-board crew.

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[200] MSA 1995 Part XIII Section 313 (1) (c).
[201] MSA 1995 Part IX Section 255 (1).
[202] Gauci (2016) p. 482.
[203] *Goodwin* [2006].

It could even be open for debate if it even should have a human supervisor with the ability to, if necessary, to take over the controls.

Most likely an autonomous ship will move between categories during different stages of the voyage. Leaving or entering a port will probably, for the foreseeable future, be controlled or supervised by human in some capacity, either onboard or from a shore-based control center.[204] The processes of berthing could be handled by a shore control center that is a part of the port that replaces the onboard pilot. Once the ship has left the vicinity of the port or the dense trafficked area, the ship can regain its autonomy. On the open sea were the traffic is less dense it would be imaginable that the ship could handle the voyage without much supervision or intervention.

Even if the ships would become completely autonomous there would still be a need for some kind of control center or communication station, in order to keep track of the voyages of the fleet.

The more reliant the autonomous systems become the less need for human intervention or surveillance. Such development will most likely mean that the need for crew and shore personnel will drop. If the human's only task is to oversee that the ships are following their planned routes and to act in the case of an emergency that the autonomous systems cannot handle on their own, then one operator could monitor several ships.

Apart from operators monitoring the ships there might be a need of back-up specialist in case some more serious problem arises with the ship, as well as software specialists, radar experts, communication experts, engineers with different special competences.

The introduction of autonomous ships seems to favour the giants of the industry considering the need for huge financial investments and taken into consideration that bigger companies can handle a less successful investment and sustain a loss. As the initial investment of a SSC would be quite significant and it is doubtful if it can prove to be feasible for a smaller shipping company that only operates a few ships. This could create a market for companies running independent SSC supervising ships form several smaller shipping companies.
The development of autonomous ships will most likely take off in coastal areas near land or canals. A reason for this could be that the ships will be easier to monitor. It will be much easier to intervene in case of an emergency, than to launch a rescue operation in the middle of the Atlantic Ocean. Most likely not only cargo vessels will be automated. Probably we will also see the introduction of autonomous ferries in coastal areas, such as the above mentioned Finnferries tests indicate. Ships that traffic short routes and are on a time-schedule, could be other candidates for autonomous shipping, in the near future. The next step could be long distance dry bulk

[204] AAWA p. 7.

vessels, because they are relatively easy to load and discharge the cargo and the cargo does not require a lot of "attention" during the passage.

It is necessary to consider when the operator should take control over an autonomous ship. The ship will probably have a scope within which it can operate without any interference. If these parameters are overstepped then the control should be relinquished to the human operator.

A fully autonomous ship could be given instructions to follow, but apart from that it could have freedom to sail the ocean. If the ship is on a timetable with a fixed route than, the instructions would be rather simple and standardised. The ship would need information on which ports to visit and when it is supposed to berth and a contingency plan if something goes wrong, a list of alternate or safe ports. The ship would also need to be programmed with parameters concerning on when to avoid heavy weather.[205]

If the ship carries goods of ship-owner the ship could even be given instructions to unload at the destination that would yield the best price. It would be a complex operation but would undoubtedly be solvable. Notably perishable goods would e.g. operate under a different set of rules than iron ore or oil.

For autonomous ships that still have some crew on-board, the legislation will not cause any problem. There is no need for any interpretation or reasoning. The absence of a human crew on-board the ship does not seem to cause any problem when determining what a ship is, it can be vessel with or without a crew. While the absence of a human crew might not lay down any obstacles concerning the definition of a ship, it might present problem when determining if the ship is seaworthy or not.

As stated earlier UNCLOS seems to present some issues as it gives coastal states some jurisdiction over ships of other nationalities. The regulations could, in theory, be used to prevent autonomous ships the right to enter ports or internal waters. However, the action cannot according to article 300 "constitute an abuse of right".

Still, it is fairly safe to say that the vast majority of the important conventions regulating shipping do not seem to present any insurmountable difficulties for autonomous ships. Although there is not a single definition as to what a ship is, most conventions and national legislation seems to allow for the opinion that an unmanned ship should indeed be considered a ship.

The consequences of this point of view is that the majority of the regimes that today governs the maritime area can be applicable on an unmanned vessel, even if some might need to be amended.[206] In other words, the

[205] MUNIN (2015 b) p. 20.
[206] Hooydonk (2014) pp. 409.

overall maritime regulatory framework seems to be flexible enough to allow for autonomous ships already today but it would be wise to make some amendments to clarify the status of an autonomous ship.

4 The Concept of Seaworthiness in Maritime Law

4.1 Introduction

Throughout maritime history, seaworthiness has been in the focus of both legal scholars and merchants and the concept is of vital interest for the shipping industry. The most important obligation for a ship-owner is perhaps to provide a seaworthy ship and the consequences of not doing it could prove to be dire. If a vessel is found to be unseaworthy this could result in several unfavourable outcomes for the ship-owner or carrier such as expositions to cargo claims, losing limitations of liability in HVR[207] and the voiding of a marine insurance policy.[208]

The carrier's duty to provide a seaworthy ship is of paramount importance in the shipping industry. Two main concepts of seaworthiness could be said to exist, within marine insurance and within the carriage of goods by sea.[209]

MIA's definition of seaworthiness states that "A ship is deemed to be seaworthy when she is reasonable fit in all respects to encounter the ordinary perils of the seas of the adventured insured."[210] In carriage of goods by sea the concept of seaworthiness adds the dimension of cargo worthiness.[211]

It should also be said that the concept of seaworthiness goes beyond just the physical state of the ship such as hull, machinery and equipment. It also includes the crew, the number of crewmen[212] and the training of the crew[213], documentation necessary for the voyage.[214] In reality, one could speak of three parts of seaworthiness: the ship itself and the equipment, the crew and cargo worthiness.

Seaworthiness can also vary depending on the conditions of the voyage and during which season it takes place.[215] The nature of the deficiencies that can lead to unseaworthiness covers a broad spectrum. In *The Hong Kong Fir* Diplock LJ described the obligation as "It can be broken by the presence of

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[207] HVR art IV.
[208] MIA 1906 Section 39, also see *The Star Sea* (1995) 1 Lloyd's rep 651.
[209] Chacón (2017) p. 118.
[210] MIA 1906 Section 39 (4).
[211] Chacón (2017) p. 118.
[212] *The Hong Kong Fir* [1962] 2 Q.B. 26.
[213] *The Eurasian Dream.*
[214] Chacón (2017) p. 144.
[215] *Daniels v Harris.*

trivial defects easily and rapidly remediable as well as by defects that must inevitably result in a total loss of the vessel."[216]

4.1.1 Seaworthiness of the ship and equipment

According to the judgement in *Kopitoff* v *Wilson* a seaworthy vessel was defined as a vessel that is "fit to meet and undergo the perils of the sea and other incidental risks to which of necessity she must be exposed in the course of a voyage".[217]

Channell J in the *McFadden* v *Blue Star Line* case constructed a test[218] for determining seaworthiness "would a prudent owner have required that it should have be made good before sending his ship to sea had he known of it?"[219]

The concept of seaworthiness is not a static condition but can be relative, it depends on the particular voyage, stage of the voyage, cargo that is carried, and the kind of ship it is.[220]

Blackburn J held in *Burges* v *Wickham* that "the standard of seaworthiness must rise with the improved knowledge of shipbuilding and navigation".[221] However, there is no obligation to provide a perfect ship "which might withstand all conceivable hazards"[222] but "a ship that is reasonably suitable for the intended use".[223] Already in 1887 in American case, *The Rover*, Judge Brown stated that "Perfection is unattainable. Only a reasonable fitness for the service designed is required."[224]

In other words, there is no obligation for the ship-owner to constantly update the ship and its equipment as long as the existing configuration fills the demand for the intended voyage.

In *The Portland Trader*, the judge determined that radar is indeed a valuable aid for navigation and had the vessel been equipped with it the disaster could have been avoided. Kilkenny DJ notes that the determination of seaworthiness is determined at the commencement of the voyage and no other time. The judge also found that it was established that it did not exist a worldwide or even an American practice to use radar.[225]

Kilkenny elaborated that when technological improvements in navigation emerge they are not immediately necessary. It only becomes necessary

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[216] *The Hong Kong Fir* [1962] 2 Q.B. 26, p. 71.
[217] *Kopitoff* v *Wilson* (1876) 1 QBD 377, 380.
[218] Eder (2015) p. 132.
[219] *McFadden* v *Blue Star Line* [1905] 1 K.B. p. 706.
[220] Girvin (2011) p. 384.
[221] *Burges* v *Wickham* (1836) B&S 669, p.693.
[222] *The Portland Trader* (D.Or. 1962) p. 356.
[223] *The Portland Trader* (D.Or. 1962) p. 356.
[224] *The Rover* (D.C.) 33 Fed. 515, p. 521.
[225] *The Portland Trader* (D.Or. 1962) p. 356.

when the use has been established and in 1960 there was not such a widespread use.[226]

However, when a new technology or practice has been widely adopted by the shipping industry it could then be seen as a mandatory requirement for a seaworthy vessel. Most of the time this technology or practice is not regulated by law or conventions instead it is left to the market to handle it.[227]

Most likely the courts will allow for some time for the shipping industry to adapt technological advancements, if it not some mandatory requirement that has been introduced. A vast majority of ships constructed after 1 July 2002 have a mandatory requirement to be fitted with a radar, among several other navigations aids.[228] Another step was taken in 2009 when IMO adopted a resolution concerning BNWAS and ECDIS. BNWAS become mandatory for most existing ships with the first survey[229] after 1 July 2012. ECDIS was gradually introduced starting with the first survey after 1 July 2012 and will be finished by first survey after 1 July 2018.[230]

Since upgrading or retrofitting an existing fleet of ships could prove to be very expensive this could play a part for allowing a gradual introduction of new technology into the shipping industry.

Tetley, based on the settled case law, drew the conclusion that even if a certain piece of equipment is not a requirement for seaworthiness it must once installed, be properly installed and maintained.[231]

4.1.2 Crew and Master

The crew and master still play an important role in determining the seaworthiness for a vessel. As stated above the concept of seaworthiness includes not just the physical and technical state of the vessel and its equipment but also the ability of the crew to handle and take care of the vessel and cargo and face the perils of the sea.

For a vessel to be properly manned it does not just mean a certain numbers of crewmembers but also that they have adequate training, competence and experience to handle their tasks.

Different aspects of crew competence have been the subject of numerous court cases over the years.[232] Apart from case law there is also international

[226] *The Portland Trader* (D.Or. 1962) p. 356.
[227] Chacón (2017) p. 137.
[228] SOLAS Chapter V Regulation 19.
[229] IMO Regulation MSC.1/Circ.1290.
[230] IMO Resolution MSC.282(86).
[231] Tetley Vol 1, p. 915.
[232] Chacón (2017) p. 133.

conventions[233] that have established minimum levels concerning numbers and capacity of crew members. A “violation of statutory regulations regarding the number and the capacity of the crewmembers rends the vessel unseaworthy”.[234]

In *The Hong Kong Fir* Salmon J formulated a test as regards the incompetence, or insufficiency, of the crew “would a reasonably prudent owner, knowing the relevant facts, have allowed this vessel to put to sea with this engine room staff?”[235]

He then proceeded to find that due to the old age of the engines of the ship it was necessary to hire a crew for the engine room “of exceptional ability, experience and dependability”[236]. Since the owners had failed to do that, the ship was found to be unseaworthy since the engine room staff was both “incompetent and insufficient in numbers”.[237]

The case of *The Eurasian Dream* stated that if a vessel has been found “unseaworthy due to the incompetence or inefficiency of the master or crew”[238] then the carrier has “to show that it has exercised proper care”[239] in relation to “the appointment of a generally competent Master/crew”[240] and “the specific competence of the Master in relation to the vessel and voyage in question”[241]. The owner and managers could not just rely on the documents presented by the seamen, but should also conduct interviews and inquire with former employer. In order to make sure that the crewmember is reasonably fit for the specific post. “The owners/managers must also provide the Master and crew with reasonably necessary specific instruction and supervision, on an ongoing basis, in relation to the vessel and voyage.”[242]

The company had also, among a plethora of things, failed to equip the vessel with “ship specific manual dealing with fire prevention and control”.[243] Instead the company had issued generic manuals at the ship in their fleet, regardless of what kind of ship it was or if it belonged or Phase I or Phase II.[244]

Even if the ISM Code did not apply for *The Eurasian Dream*[245] it seems that Cresswell J adopted the general principles as a benchmark.[246]

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[233] SOLAS, STCW, MLC
[234] Chacón (2017) p. 132.
[235] *The Hong Kong Fir* [1962] 2 Q.B. 26, p. 34.
[236] *The Hong Kong Fir* [1962] 2 Q.B. 26, p. 34.
[237] *The Hong Kong Fir* [1962] 2 Q.B. 26, p. 34.
[238] *The Eurasian Dream* para. 132.
[239] *The Eurasian Dream* para. 132.
[240] *The Eurasian Dream* para. 132.
[241] *The Eurasian Dream* para. 132.
[242] *The Eurasian Dream* para. 132.
[243] *The Eurasian Dream* para. 151 p. 12.
[244] Anderson (2005) p. 231.
[245] *The Eurasian Dream* para. 110.
[246] Anderson (2005) pp. 232-233.

In the case, Cresswell J identified 18 separate deficiencies that in turn were divided into several subcategories. His conclusion was that the owner had failed the test set up by Salmon J in *The Hong Kong Fir* and that a prudent owner would not have allowed *The Eurasian Dream* to be put to sea with the master and crew.[247]

Incompetence of the crew and master can come in several shapes; personal reasons; lack of ability or mental disability or incapacity or factors relating to inadequate training, general lack of knowledge or lack of knowledge relating to particular vessel or system.[248]

4.1.3 Cargo Worthiness

The concept of cargo worthiness consists of two components, the general condition of the ship and the stowage of the cargo.[249] The first part includes cleaning and fumigation and the presence of the necessary equipment to avoid damage to the cargo carried.[250] However, a ship could still be considered seaworthy even though the ship-owner knows that the cargo inevitably will suffer some minor damage.[251]

A ship was found to be perfectly seaworthy, with one exception, and that was to transport the cargo wet sugar that she was contracted to carry.[252] The pumps, although sufficient in general, of the ship could not handle the combination of moisture from the sugar and the ordinary leakage of the ship. It was found that the ship was not reasonable fit to carry a cargo of wet sugar. The case was appealed and affirmed.[253]

The second part regarding the stowage of the cargo concerns whether the cargo is properly handled or if ship is overloaded or the cargo is stowed in such way that it threatens the safety of the ship itself or damage other cargo.[254] In *The Aconcagua* Clarke J. held it that “A vessel may be unseaworthy if there is no system in operation to deal with the ordinary incidents of a voyage, including the need for the cargo to be stowed in a way that does not endanger the ship.”[255]

The vessel carried containers with calcium hypochlorite that self-ignited, the containers had been stowed next to a bunker tank that was heated during the voyage. The ensuing fire caused extensive damage to the vessel and cargo. The vessel was nonetheless found to be seaworthy since it could not be

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[247] *The Eurasian Dream* para. 151 p. 18.
[248] Tetley Vol 1. p. 891.
[249] Chacón (2017) p. 137.
[250] Ibid. p. 138.
[251] Eder (2015) p. 133, citing *MCD Ltd* v *NV Zeevaart Maatshappij* Beursstrat [1962] 1 Lloyd’s Rep 180.
[252] *Stanton* v *Richardson* (1872) L.R. 7 C.P. 421.
[253] *Stanton* v *Richardson* (1874) L.R. 9 C.P. 390.
[254] Chacón (2017) pp. 138-139.
[255] *The Aconcagua* p. 367.

proven that the heating was the cause of the explosion. Clarke also decided that the heating of the bunker tank did not constitute or result from unseaworthiness.[256] The case was later confirmed by the Court of Appeal.[257]

4.2 Common law

Under common law the shipowner has an absolute duty to provide a seaworthy vessel while under the HVR the carrier has an obligation to exercise due diligence.[258]

4.3 Hague Rules/Hague-Visby Rules

HR/HVR are by far the most important convention on the carriage of goods by sea. More than 80 countries adhere to some of its incarnations and covers 90% of the global shipping tonnage.[259]

Under Article III in the HVR the carrier is bound to exercise due diligence before and at the beginning of the voyage to make the ship seaworthy, properly man, equip and supply the ship.

In order to ensure that the ship is in seaworthy condition the carrier must perform a thorough inspection.[260]

4.4 Hamburg Rules

HR are of limited importance, so far, only 34 countries have ratified the convention and not any of the major seafaring nations have adopted it.[261] The ratifying countries share of the world trade is estimated at about 5%.[262]

HR do not mention seaworthiness explicitly. Instead, Article 5 extended the responsibility of the carrier to the whole period the goods are in the carriers charge as defined in Article 4.

This regulation is based on “the principle of presumed fault or neglect”[263]. The carrier has to prove that he or his agents took all reasonable measure to avoid loss or damage.[264]

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[256] *The Aconcagua* p. 375.
[257] *The Aconcagua* [2010] EWCA Civ 1403.
[258] Eder (2015) pp.130-131.
[259] Djadjev (2017) p. 36.
[260] Chacón (2017) p. 148.
[261] ‘United Nations Convention on the Carriage of Goods by Sea 1978’ <https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XI-D-3&chapter=11&lang=en> Accessed 27 February 2019.
[262] Djadjev (2017) p. 37.
[263] HR Annex II
[264] HR art. 5.1

HR also restricts the carrier's possibilities to limit liability. Under the HR the carrier will be liable for "error or negligence in navigation and management of the ship".[265]

4.5 Rotterdam Rules

Under Article 14 in the RR the carrier is bound, before, at the beginning of and during the voyage to exercise due diligence to make and keep the ship seaworthy.[266]

HVR and RR contain the same three conditions, with very similar wording, on seaworthiness. The difference between the two conventions lies in the fact that under the RR the carrier is bound to make and keep the ship seaworthy during the voyage. The consequence would be that if a defect were to arise while under voyage the carrier is under a due diligence obligation to correct the issue.[267]

4.6 UNCLOS

UNCLOS does not contain any regulations defining the concept of seaworthiness. However, the Convention addresses the issue in three articles.

UNCLOS states that it is the responsibility of the flag state to take the necessary measures for ensuring safety at sea. The article concerning duties of the flag state gives a, non-exhaustive, list of issues to be addressed. These issues concerns, construction, equipment, seaworthiness of ships,[268] manning, labour conditions and training,[269] signals, communication, and prevention of collisions.[270]

Usually construction and equipment tends to be included in the concept of seaworthiness and not separated as in this article. However, it does not appear to strive for a different understanding of the concept of seaworthiness, perhaps merely a desire to be very clear on the matter of what factors that should be included. The section concerning manning and training states that the flag state should take "into account the applicable international instruments", which in this context should refer to, e.g. regulations like the ISM Code and STWC.

The second regulation in UNCLOS relating to seaworthiness do not give any definition or guidance. It simply states that if a vessel a port or off-shore

[265] Chacón (2017) p. 90.
[266] The convention has not entered into force and its regulations have not been tried in a court.
[267] Baaz et al. (2009) s. 40.
[268] UNCLOS art. 94(3)(a).
[269] UNCLOS art. 94(3)(b).
[270] UNCLOS art. 94(3)(c).

terminal violates “applicable international rules and standards relating to seaworthiness of vessels”.[271] There is no further information regarding what these rules and standards the wording refers to. The regulation itself concerns the avoidance of pollution in marine environment.

The third and last regulation in UNCLOS referring to seaworthiness also mentions “applicable international rules and standards”[272] without any further description or information. The regulation concerns investigation of foreign vessels relating to pollution threats to the marine environment.

4.7 COLREGs

Almost every regulation in COLREGs refers to the responsibility of the vessel and not that of the master or crew or owner. However, there is one mentioning of master, crew and owner alongside with the vessel. The particular rule refers to human making decision based on experience, “ordinary practice of seamen”[273].

This rule seems to affect other rules in COLREGs, e.g. “every vessel shall at all times maintain a proper look-out”[274], “proceed at a safe speed”[275] and “proper use shall be made of radar equipment”[276].

A remote controlled ship would most likely fulfil the conditions. If there were a human involved in or could be involved in the decision making, it seems that the conditions would be met since there do not seem to be any proximity qualifications in this particular rule. In other words, it seems indifferent if the decision is executed on the bridge or at a SCC.

It is not entirely certain how a fully autonomous and unmanned ship would fulfil the rule. Perhaps it could be technically feasible to develop an algorithm that would incorporate the whole width of the “ordinary experience of seamen”, but the second part of the rule would call for creativity, “which may make a departure from these Rules necessary to avoid immediate danger”.[277] Under “special circumstances”, there could be a reason to deviate from years of experience in order to rectify a dangerous situation.

[271] UNCLOS art. 219.
[272] UNCLOS art. 226(1)(c).
[273] COLREGs rule 2 (a).
[274] COLREGs rule 5.
[275] COLREGs rule 6
[276] COLREGs rule 7 (b)
[277] COLREGs rule 2 (b)

4.8 SOLAS and ISM Code

An indication on seaworthiness could be if the ship complies with the ISM Code or not.[278] However, it seems that the ambition of the code goes, a bit, beyond the general understanding of seaworthiness. Paragraph 1.2.2 of the Code states that the "safety management objectives of the company should, inter alia:" "assess all identified risks to its ships, personnel and the environment and establish appropriate safeguards"[279] The original wording had perhaps an even broader scope.[280]

It would go against settled case law concerning seaworthiness since it is obvious that the courts have not imposed a demand for perfection on the ship-owners and have clearly stated so in the rulings.[281]

A regulation that might create some problem for an unmanned autonomous ship could be regulation calling for ships to be, "sufficiently and efficiently manned".[282] However, the regulation do no stipulate a minimum number for the crew and instead leave it to the flag state.

If the ship is remotely controlled, the shore-based supervisor could arguably be seen as master or crew. If so, the ship could be considered to fulfil the condition of being sufficiently and efficiently manned.

It can be more questionable if the ship is not remotely controlled, but truly autonomous and do not have any humans involved in the decision process. The case could still be made for the ship being sufficiently and efficiently manned. It would have to rest on the argument that the technology guiding the ship can adequately handle the situation at least as good as any human crew. The result would when be that the sufficient number of humans needed to be involved in the decision process would be zero.

There is another regulation that indirectly could set a minimum number for the crew. That regulation stipulates that it must be possible to switch over from automatic to manual steering with the assistance of a qualified helmsperson.[283] It could be argued, that for an autonomous ship the number of crew present on the ship still could be zero but with a supervising operator in a SCC ready to take control of the ship if the need arises.

The regulation concerning qualified radio personnel states that, "every ship shall carry" someone that is qualified for distress and safety radio communication.[284] This regulation seems to unconditionally demand that at least one crewmember has to be present on-board the ship. If the purpose of

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[278] Eder (2015) p. 133.
[279] Resolution MSC.273(85).
[280] "Establish safeguards against all identified risks".
[281] One example can be found in *The Portland Trader* (D.Or. 1962) p. 356.
[282] SOLAS Chapter V Regulation 14.
[283] SOLAS Chapter V Regulation 24.
[284] SOLAS Chapter IV Regulation 16.

the regulation is to guarantee that, the radio-communication always is monitored then a ship-owner might try to invoke an exemption. The argument would be that the intention of the regulation would be fulfilled if a SSC supervisor monitor the radio-communication.[285] In order to avoid confusion and discussion the regulation concerning radio personnel should be amended.

In general, it seems that most regulations in SOLAS and ISM Code could be applied on autonomous ships, both remote controlled ships and ships under supervision.

4.9 STCW

A position that might see an increased importance are the position as ETO, it was introduced as a certified position with the Manilla Amendment in 2010. It is not a mandatory position but should be on the crew on larger ships.[286] As long as there, is any crew on-board ships the ETO should be an important part of the crew and form one link in the cyber defence. [287]

When the crew finally disembark the ship, the ETO or its replacement should still form an important part of the team operating the ships.

4.10 Merchant Shipping Act 1995

MSA defines master as “every person (except a pilot) having command or charge of a ship and, in relation to a fishing vessel, means the skipper”.[288] Someone remotely controlling the ship could be considered as the “master” since they effectively are in charge of the ship.

Operators who are only monitoring the voyage of fully autonomous ships might not meet the criteria of a “master” in MSA. They could perhaps be seen as the “master” if they are able to take control of the ship without too much delay. MSA should be amended in order to clarify the status of SSC operators.

The term “crew” is used in MSA but is not defined in the Act, instead the term “seaman” is defined. "Seaman” includes every person (except masters and pilots) employed or engaged in any capacity on board any ship".[289] The mentioning of “on board” seems to exclude persons not physically present on the ship, which would exclude land based personnel. However, the word “engaged” could possibly extend to persons not present at the ship, an operator responsible for monitoring the engine room on an autonomous ship could perhaps be seen as “engaged”. However, the most reasonable way to

[285] DMA (2017) p. 78.
[286] SITWF p. 16
[287] Mileski et. al. (2018) p. 426.
[288] MAS 1995 Section 313 (1).
[289] MAS 1995 Section 313 (1) (c).

interpret the regulation should be to consider the whole phrase “employed or engaged in any capacity on board any ship” and not limit it to the single word “engage”. Taking in consideration the context it should be clear that land based personnel could not be considered crew or seamen according to MSA.

4.11 Concluding remarks

The general development in shipbuilding will affect the understanding of seaworthiness. As established in settled case law the technological advancement will affect what devices are to be included in order for the ship to be considered seaworthy. Cutting edge technology will not be a condition but technical solutions and practices will be included in the general understanding of seaworthiness when it have become either a widespread practice in the industry or when it has become mandatory through conventions or other regulations. Since the concept of seaworthiness as regards to autonomous vessels has not been addressed by the courts, the question warrants further discussion.

There are no settled case law concerning cyber security or cyber risk in particular. What one has to rely on is the case law concerning equipment and technological advancement in general. This indicates that the importance of cyber related issues will grow. It will become increasingly important that the software and hardware of the ship is fully up-dated as it otherwise could be vulnerable for cyber attacks.

A software patch not available to the shipping company or ship-owner before the start of a voyage should not make the ship unseaworthy even if it is evident later on that it was the absence of that particular patch that made the vessel vulnerable to the cyber-attack. Perhaps a court could reach the conclusion that a failure of the shipping company or owner to immediately remotely update the ships software when the patch became available and the seriousness become known could render the ship unseaworthy.

This conclusion would break the old and settled condition that the ship only has to be deemed seaworthy before and at the beginning of the voyage and that this condition does not extend to the whole voyage. Such a conclusion as the above suggested would however be in line the seaworthiness provision in the Rotterdam Rules so it would not be a gigantic leap.

The industry practice will be of paramount importance when determining whether the ship is seaworthy or not. Should software be updated immediately, no matter where the ship is or should they only be carried out during port stops.

Training of the crew will be ever so vital with the new demands and qualifications that autonomous shipping will put on the crew. The lack of adequate IT-management systems and cyber security systems at a corporate level might affect the assessment of a ships seaworthiness.

If or when the fully autonomous ships navigates the high seas, it is a necessity that the manufacturer can show why the control systems took a certain action. If they cannot show that, the ship may be considered un-seaworthy and they could be liable, software manufacturer or ship-owner. If it were not possible to designate blame, the insurance companies would most likely end up with the bill for the loss, which they would try to avoid at almost, all costs. If they were to insure all cyber related issues, the policies would most likely be very costly.

The effects of a breach of a cyber security system not need to be of epic and catastrophic proportions and result in total loss, an insufficient cyber security procedure could e.g. make is possible to affect a system that controls the refrigerating units. If the cargo then were damaged, because of this breach, the cargo owner probably could be successful in claiming that the ship was not cargo worthy as understood by the HVR and the carrier could be found liable for the claim. If a chartered ship becomes unavailable for usage due to a cyber related issue, then the ship would probably be off-hire and the ship owner would lose money even if the ship or cargo are not damaged in any way.

As noted in the previous chapter the overall maritime regulatory framework seems flexible enough to allow for autonomous ships. However, there are some provisions in the conventions addressed above that could need some clarification or amendments.

MSA refers to crew in such a way that it would benefit from an amendment to clarify the status of operators remotely controlling or supervising a ship.

HVR and RR contain provisions that the carrier should exercise due diligence to properly man, equip and supply the ship. SOLAS also contains regulations requiring a ship to be sufficiently and efficiently manned. One could make an argument that in order to fulfil the condition “properly manned” or “sufficiently manned” does not necessarily mean that there has to be any on-board crew or any land-based crew either. The proper number of crew could amount to zero if the ship and its systems could prove to be able to handle the ordinary perils of the sea that the ship is expected to meet during a specific voyage.

5 Legal concepts of Cyber security

5.1 The Present state

The shipping industry is perceived as slow when it comes to taking measures against cyber threats.[290] Some estimate that the shipping industry lags a staggering 20 years behind equivalent sectors, as regards cyber security.[291] Other industries have taken steps and measures to be protected against cyber threats meaning that the shipping industry could become even more exposed since cyber criminals of course go after the easiest target.

Despite this bleak assessment of cyber security, it seems that the industry is in a better shape than a decade ago. The assessment made by the EU back in 2011 was that the awareness on cyber security was "very low level or even non-existent".[292] The report noted that maritime regulations and policies only considered "physical aspects of security and safety".[293] Since then the pace, concerning the work on cyber security in the maritime industry has gathered steam.

As shown in this chapter several initiative, from the industry at large, international organisations and from single companies, for improving or addressing cyber security have been taken.

5.2 Regulations concerning cyber security

5.2.1 IMO

On 16 June 2017 IMO adopted a resolution that:

> "encourages administrations that cyber risks are appropriately addressed in safety management systems no later than the first annual verification of the company's document of compliance after 1 January 2021."

It is not meant to create a new framework for cyber risk management. Instead, the ISM safety management system will address the issues.[294] The

[290] Mileski et. al. (2018) p. 417.
[291] Tam et al. (2018) p. 147.
[292] ENISA p. 8
[293] Ibid. p. 2
[294] IMO MSC.428(98).

consequence of not meeting the conditions in the resolution can result in detaining.[295]

IMO uses the term maritime cyber risk, which seems to be the equivalent of cyber security. IMO defines it as:

> "a measure of the extent to which a technology asset could be threatened by a potential circumstance or event, which may result in shipping-related operational, safety or security failures as a consequence of information or systems being corrupted, lost or compromised".[296]

On 5 July 2017 IMO issued Guidelines on Maritime Cyber Risk Management. The Guidelines note that traditionally risk management has equalled physical risks but the growing digitalisation and automation has created a need for cyber risk management.[297]

While neither of the Guidelines or the resolution exclude autonomous ships, the viewpoint for the regulations undoubtedly seems to be a ship with a crew.

The routines and guidelines that shipping companies must implement stretch from responsibilities on a management and corporate level down to how to use and not use hardware on-board ships, e.g. unauthorised memory stick.[298]

The Guidelines acknowledge that usage of cyber related systems varies within the shipping industry. Ships with less technology dependence will not have to adhere to the same conditions as ships that depends heavily on technology.[299]

The Guidelines do not provide any technical specification or advice on how to handle the cyber risk related issues practically. These Guideline aims to provide a framework for handling and managing cyber risks, setting up routines and addressing the administrative problems. Concerning more practical procedures the IMO Guidelines explicitly refers to requirements on State level as well as industry standards and best practice.[300]

The Guideline also list the BIMCO Guidelines, see discussion below, as an example for a more detailed approach concerning best practice for cyber risk issues.[301]

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[295] See SOLAS 3.4.3.1 in this thesis.
[296] IMO SC-FAL.1/Circ.3 p. 1.
[297] Ibid. p. 1.
[298] Ibid. pp. 1-2.
[299] Ibid. p. 3.
[300] Ibid. p. 1.
[301] Ibid. p. 4.

5.2.2 Industry initiative

5.2.2.1 BIMCO

BIMCO[302] has issued a guideline regarding Cyber Security.[303] The guideline is meant to be harmonised with the above mentioned IMO Resolution and Guidelines. It focuses on improving cyber security in general and not specifically autonomous vessels. It identifies the increased digitalisation and automation as a need for greater attention to cyber security.[304] The guideline can be used as a guide for improving cyber security regardless of whether the vessel has a crew on-board or not. However, the guidelines seems to assume the presence of a crew on-board the ship.[305]

These guidelines differentiate between cyber security and cyber safety. Cyber security concerns the protection of critical systems and data while cyber safety concern the risk from “loss of availability or integrity of safety critical data”.[306]

BIMCO acknowledge that the cyber risk will vary depending on what kind of systems are used, what level of automation, what kind of trade the ship is involved in. The guideline also states that when developing management systems best practice should be used.[307] BIMCO emphasises physical as well as digital security as a part of cyber security. One such digital safety measure is to encrypt the communication flow.[308]

5.2.2.2 American Bureau of Shipping

American Bureau of Shipping is a classification society[309] that has issued a guide for cyber security concerning both marine and offshore operations. ABS considers that the area of cyber security encompasses not only the shipping company and all of it systems and equipment but also includes third parties like subcontractors and external components. The ABS initiative is an effort to provide on what could be considered best practice in the industry. The Guide emphasis that it is a developing work and that the threats will evolve.[310]

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302 Even if the guidelines are frequently referred to as BIMCO it is in reality a joint product between several industry stakeholders, CLIA, ICS, Intercargo,, InterManager, INTERTANKO, IUMI, OCIMF, WSC.
303 BIMCO.
304 BIMCO p. 1.
305 Ibid. p. 29.
306 Ibid. p. 3.
307 Ibid. p. 17.
308 Ibid. pp. 26-27.
309 A non-governmental organisation in the shipping industry, a classification society establishes and maintains technical standards for construction and operation of marine vessels and offshore structures. ‘Classification society & IACS’ <http://maritime-connector.com/ wiki/classification-society/>Accessed 8 May 2019.
310 ABS b p. iii.

The Guide define cyber security as "the application of security methods and controls to provide for, and to verify, deterministic behavior of cyber-enabled systems".[311]

The focus is on increasing cyber security and awareness regarding potential cyber threats. The Guide are not restricted to autonomous ships, it includes all kinds of ships.[312] The Guide seems to assume that a vessel has a crew or controller that can intervene, if necessary.[313]

In conjunction with the Guide, ABS also issued a document, meant to be "a readable summary" of the more detailed guideline. In summary, autonomous ships are specifically mentioned, although they are referred to as "smart assets".[314]

The Guide are meant to assist the ship-owners to implement management practices and more hands-on criteria concerning cyber security regarding software and hardware. The Guide is connected to the requirements of the ISM Code. In order to maintain the certification the company must go through an annual process.[315]

The Guide identify the need for protecting the communication for critical systems, both physical[316] as well as digital through e.g. encryption.[317]

5.2.2.3 Bureau Veritas

Bureau Veritas, a company in the testing, inspection and certification sector, has issued guidelines for autonomous shipping. The guideline concerns "surface units which may be considered as a ship by the authorities". It exemplifies that the ship has to have a gross tonnage of 500 gross tonnage or above, the guideline also excludes ships under 20 meters[318]

Autonomous ships are defined as having autonomous systems that can make decisions and perform "actions with or without humans" involved. An autonomous ship includes both unmanned vessels and vessels with a crew.[319]

The Guidelines defines cyber security as "preservation of confidentiality, integrity and availability of information in the Cyberspace".[320]

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[311] ABS b p.13.
[312] Ibid. p. 1.
[313] Ibid. p. 2.
[314] ABS a pp. 1-2.
[315] ABS b. pp.1-3.
[316] Ibid. p. 45.
[317] Ibid. p. 61.
[318] Veritas section 1 1.2.2 p. 5.
[319] Ibid. section 1 1.4.1 p. 5.
[320] Veritas section 1 1.4.1 p. 5.

The Guidelines, states, that with the use of IT-systems it is possible to gain unauthorised access or control over autonomous ships and that best practice should be used to avoid these risks. Encryption should therefore be used to protect the communication.[321] Other important means of protection is to have redundancy system that do not use the same set of information input, e.g. a non-GPS system to determine position.[322]

The Guidelines, states, the ship should be able to withstand both physical and virtual trespassing. This should also be valid for the SCC since the guideline consider it an extension of the ship.[323]

5.3 Cyber risks

The consequence of introduction or expansion of IT in an industry has always had effect of, "existing risks being increased and new risks being introduced".[324]

If an IT system is compromised and personal information is leaked and violating GDPR[325] it most likely will not affect the seaworthiness of the ship. However, if that information could be used in order to gain control of a safety critical system the consequence of the breach could render the ship un-seaworthy.

Since the time for a cyber intrusion is not clear to begin with, a breach could have happened months prior to the "incident". It could be of major importance if the IT systems were compromised long before the "incident", thus making the vessel and quite possible the whole fleet un-seaworthy. This could depend on what system that was affected. If the navigation or the ballast systems were affected the ship could in reality be unseaworthy. If it happened during the voyage it could be a more open question whether the vessel was un-seaworthy or not. If the Rotterdam Rules would be used as a starting point, then the vessel would be un-seaworthy since the owner or carrier had failed to provide a seaworthy vessel.

Perhaps the biggest safety issues regarding autonomous vessels do not concern malicious cyber attacks but rather how the technology handles unexpected situations or situations that might require some hands-on action.

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[321] Veritas section 1 2.6.1-2.6.2 p. 8.
[322] Ibid. Table 14 p. 13.
[323] Ibid. Section 1 2.3.1. p. 7.
[324] Kavallieratos et al. (2018) p. 21.
[325] Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation) <https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32016R0679>

According to a survey from 2018 as few as 15% of seafarers had received any cyber security training.[326]

One of the most important weaknesses of the autonomous shipping will be the communication channels.[327] No matter if it is remote controlled or truly autonomous it will be depending on a reliable connection for communication with satellites, SCC or other ships, whether autonomous or not.

One difference between autonomous ships and highly automated ships with an ordinary crew could be the need for safe and secure means of communication. Most likely the need for encrypted communication would be greater for the autonomous ship since it does not have a crew to intervene if something goes awry. It will be important to run the equipment on different networks or at least to have several networks. Some might be open for sharing information with other ships and with local authorities along the voyage, like the AIS.

The communication could be severed, by infecting the ship systems with malware or hijacking the communication link.[328]

Cyber security does not only mean to protect ships and control stations from being hijacked through remote actions but also physical protection and security measures so that unauthorised persons do not gain access to the systems. On an autonomous ship, this might mean that navigation and communication equipment are physically well protected. If unauthorised persons gain access to a ship, the physical security must be high, otherwise the ship could be considered unseaworthy due to lacking necessary security protection for the digital systems.

To hijack, an autonomous ship, by technical means, could perhaps be easier than catch a ship on the high sea and then proceed to board it to take control over crew and ship. Electronically hijacking a ship can be done from a distance and would not include the confrontation by a human crew and the risk of getting the piracy plans foiled if the crew switched over to manual steering and shutting down the autonomous or remote control system.

If a ship is remote controlled, pirates can disrupt the “control feed” and most likely the ship will have some default mode that then will be activated. The alternatives could e.g. be circling a small area until the connection is re-established or seek the closest designated safe harbour. However, if the pirates are able to spoof the “control feed” or feed the ship fake GPS coordinates, they could take control of the ship. They could then proceed to guide the hijacked vessel to prospective buyers without the pirates ever have to entering the seas. There have been claims of such successful hijackings of UAV:s. In one case, the communication was jammed that resulted in that

[326] Futurenautics p. 11.
[327] MUNIN (2012) p. 12.
[328] Rødseth et al. (2015) p. 48.

the drone went into autopilot mode and could be fooled to land in enemy territory with the help of GPS-spoofing.[329]

When creating redundancy systems, one solution might be to use different suppliers of equipment, if it is possible, for primary and back-up systems. The idea is that if anything goes wrong with one system the other system should be able to detect that something is wrong and take appropriate action.[330] A challenge would be to get additional systems to communicate flawlessly with each other. If the back-up system is identical or uses the same set of data input, they could also share the same risks and vulnerability and the safety in having a back-up would be an illusion.

A possibility would be to fully separate the backup-system from the primary system and not allowing the backup-system to have any connection with the internet and let it only be accessible through a physical connection. This would minimise the consequences of remote tampering of the ship. The idea would be that the backup-system is set in action if it perceived that the main system had become corrupted in any way and active an emergency protocol. The obvious downside with this concept is that if the backup-system had been compromised then the shipowner would have no possibility to regain remote control of the ship. Instead, the ship would have to be boarded.

5.4 Concluding remarks

The precise content of what cyber security concerning seaworthiness will mean is difficult to prophesise. However, it will to a great extent depend on the standard set by the industry.

The industry standard will determine what will be included in an assessment of seaworthiness. The industry standard will also be guiding concerning the assessment of the company and its policies and organisation. No organisation can design contingency plans for every eventuality but the organisation's plan will have to take into account every reasonable event. The plans and organisation will have to show some lever of resilience against the most common forms of cyber threats.

The measures a prudent ship-owner should take in order to make the ship seaworthy, from a cyber security perspective, should be on par with the rest of the industry, or at least within an acceptable margin.

The pre-emptive measures will play an important part in assessing if the ships and ship-owners meet their responsibilities. If an industry standard are developed, like the industry initiative suggest, then that standard will be of paramount importance in order to determine if the ship and ship-owners live up to required level of cyber security. Old equipment or outdated material will most likely not be accepted if the ship are to be considered seaworthy

[329] Cyber Road (2015) p. 21.
[330] Lighthouse (2016) p. 36.

from a cyber security point of view. The older IT systems for the transport and logistics industry was designed in another time and lack proper safety features.[331]

The insurance industry and P&I Clubs[332] might act as catalysts for an improvement in cyber security in the shipping industry. These two entities could refuse to insure ships if the ship-owners and ship are found to lack proper cyber security or cyber management protocols. This does not imply that they would cover the costs the could arise from a cyber attack, just that the insurance companies and P&I Clubs could refuse to insure a ship altogether if it lacked proper cyber security.

One possible short term development could be that some carriers chose to either downgrade the usage of technology during the voyages or choses to let other companies lead the technological development. As long as it does not violates mandatory regulations or go against a widespread practice in the industry this might be a feasible short-term solution. If avoiding using cutting edge technology and practices the company might be less vulnerable for cyber-attacks. According to the credo, if the ship is not connected it will not be subjected to a risk.

Can there perhaps arise a praxis that smaller companies can do less, concerning cyber security, than the giants in the industry depending on the means of resources. If not then there might be a push for consolidation in the industry, pushing out the smaller companies or forcing them to consolidate.

To speculate as to what might be included in seaworthiness in the future, concerning technical aspects, this should include redundancy systems. If a system breaks down or somehow comes offline, its tasks should be taken over by another system. The back-up system should not, if possible depend on the same input as the malfunctioning system. If the navigation system goes off line, a default setting could be for the ship to circle until the issue is solved or seek the closest port, if some back-up navigation system would allow the ship to safely manoeuvre to port.

Even if the shipping industry uses highly complex systems that adds to the difficulty organising cyber security it will not be an un-surmountable obstacle for the industry to overcome. They can draw upon the experience from existing practice in other industries, e.g. air transport and other areas that have a need for high level of security. Bureau Veritas drew from their

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[331] Cyber Road (2015) p. 14.

[332] "A P&I club is a non-profit marine insurers' association. It is a group of shipowners who mutually indulge in the coverage of their own civil liability risks.",Shipowners' responsibility: the P&I Clubs (Atlas Magazine Insurance News around the World, 13 May 2013) <https://www.atlas-mag.net/en/article/shipowners-responsibility-the-pi-clubs> Accessed 23 May 2019.

experience in the aviation industry and automotive industry when developing their guidelines for autonomous shipping.[333]

When it comes to cyber security in general, there is an abundance of material relating to those issues and there will be no need for the shipping industry to construct their own methods or concepts from scratch. A couple of interesting methods have been suggested as analysing tools for testing cyber security in the shipping industry.

One such concept is STRIDE[334], which stands for Spoofing of identity, Tampering, Repudiation, Information disclosure, Denial of service (D.o.S), Elevation of privilege.[335] Since the concept is used by scholars and industry[336] it would provide a benchmark for the comparing the shipping industry with other suitable industries.

The assessment of the autonomous ship that was performed revealed several potentially serious security flaws. Several of the most vulnerable systems were systems involving navigating.[337]

Another model suggested as a tool for evaluating cyber-risk in the maritime industry is MaCRA. The model uses three main criteria to evaluate the cyber-security; system vulnerability and effect, ease of-exploit, and reward. This suggested model chiefly concerns the on-board technology but also take into consideration actions of the crew.[338]

Ease-of-exploit concerns what resources an intruder must launch in order to perform a successful attack. The reward part focus on what value the attacker hope to achieve with the attack.[339] The concept behind the model is to create a more holistic approach concerning cyber-risk assessment and not focus on a single or few factors. Furthermore, its claimed that the existing models for assessing cyber-risk are not suitable for the unique marine environment.[340]

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[333] 'Autonomous ships' (17 August 2018) <https://marine-offshore.bureauveritas.com /autonomous-ships> Accessed 15 May 2019.
[334] Kavallieratos et al. (2018) p. 21.
[335] Shostack pp. 9-10.
[336] Kavallieratos et al. (2018) p. 23.
[337] Ibid. p. 34.
[338] Tam et al. (2019) pp.131-132.
[339] Ibid. p. 134.
[340] Ibid. pp.159-160.

6 Summary and conclusions

6.1 Summary

At the beginning of the thesis, four question were presented:

Does there exist a universal definition of what an autonomous surface vessel is?

Can an autonomous vessel be considered as a ship or is it a new type of entity?

Will there be any need for an amended legislation framework or is the present legislation broad enough to include autonomous vessels?

Will the introduction of autonomous vessels affect the understanding and definitions of seaworthiness, especially regarding cyber security?

As presented in Chapter 3 several and somewhat conflicting definitions concerning autonomous ships exists, which means that, there is no universal definition. However, the definitions serve different purposes and one could expect that the IMO definition will be the prevalent concerning legal definition of an autonomous ship. One interesting issue that can be noted here is that the status of a ship can vary during a voyage. During one leg it can be fully autonomous, most likely during the ocean passage, and during other parts of the voyage more or less a conventional ship, e.g. in heavily trafficked waters.

Also presented in Chapter 3, the analysis showed that, under the existing legal framework, autonomous ship most likely should be considered a ship and not a new type of entity. The absence of a human crew do not seem to create any problems when determining what a ship is. This is somewhat interesting considering all existing legal framework was conceived during a time when a human crew was indispensable.

In Chapter 3 and 4, the question whether the existing legal framework needed to be amended was discussed. The conclusion was that for most parts the framework was flexible enough to allow for autonomous ships. Ships that have some crew on-board would most likely fulfil all demands. However, there are some issues especially concerning manning of ships that could affect the seaworthiness. The ambiguities should be addressed properly, so that the legal status of e.g. operator in SCC are determined, should they be considered crew or have a different status.

Theoretically, UNCLOS could be used in order to deny autonomous ships access to ports and internal waters, but in reality the right should be difficult to exercise without violating the spirit of good faith of the Convention.

Chapter 5 concerned if autonomous vessels would affect the definitions of seaworthiness, especially concerning cyber security. The conclusion was that it will affect the concept of seaworthiness but in what way will be harder to foresee. It will depend on how the best practice in the maritime industry develops. An important indication on the content will be given by the various guidelines issued by industry organisations, e.g. BIMCO.

Concerning cyber security and seaworthiness, the future might already be here. A redefined seaworthiness could already have been developed. However, as long as the acceptable industry standard has not been scrutinised in a court the doubts will remain. Even though there is no case law concerning cyber related issues, the settled case law concerning technological development in general could serve as a guideline. When a case concerning cyber security comes before a court it will try to establish what the best practice in the industry is and then proceed from there. Most certainly, the scope of seaworthiness will extend beyond the ship and include distant physical installations such as SSC and the organisation that owns or operates the ship.

6.2 Conclusions

There are already a few autonomous ships traveling the seas; when they will be in majority or even a common sight on the seas remains unclear. There are a few obstacles for the autonomous ships today with respect to maritime legal framework, and there seem to exist a consensus that autonomous ships are indeed ships and not a new kind of entity. However, the commercial breakthrough for the autonomous ships might still be a couple of decades away. The capital investment needed for the development of viable autonomous technology will be huge, and the existing fleet of merchant ships will not be obsolete. Some of the ships might be serviceable for decades to come. It will not be economically feasible to scrap them and invest in autonomous ships.

As previously mentioned a likely scenario would be for the gradual introduction of autonomous ships, starting in coastal areas or canals. It could serve two purposes; it will be easier to intervene if anything goes wrong, and it will allow time to amend conventions and legislation before the autonomous ships set sail on the high seas.

The introduction of autonomous ships will probably be an evolution and not a revolution, which means that the redefinition of seaworthiness will undergo a gradual development. The understanding and definition of cyber security for autonomous ships have already seen a significant development. The IMO Resolution that take effect in 2021 will be an important step towards developing a redefined seaworthiness with respect to cyber security.

One could use *The Eurasian Dream* and *Burges* v *Wickham* as an argument for that there will be no real need for a separate legislative regulation of what cyber security means in reality. It will be up to the market to decide what it means, and the industry standard will define cyber security in relation to seaworthiness. The legislation will follow suit when the standard is firmly settled or undisputed. As was the situation with radar in *The Portland Trader*. An effort to define cyber security through means of legislation would most likely be an unattainable task.

Over time the occurrence of cyber attacks aimed at the shipping industry will provide ample information about what types of intrusions could be expected and how to counter them.

There will undoubtedly be changes in how autonomous ships regulates in the future and there will be a change in how seaworthiness is understood. Not just from a technical point of view, but perhaps even more from an organisational point of view. The risks connected to cyber security can no longer be ignored and must be addressed at the top level of the maritime industry.

There will be a development of the concept of seaworthiness. However, it is important to keep in mind that much of the technology that might be used for autonomous ships are already in use. The difference will be in how the technology is utilised. The difference will rest in the amount of autonomy the ships will get and the amount humans will be involved in the decision making process.

Most likely the need for a crew will not disappear instantaneously, and if there is a human crew on-board the ship they can intervene in case of an emergency or if the ship encounter an unexpected circumstance. This could mean that the connection between the ship and SCC could be severed without a catastrophic failure. The industry might accept a weaker protection for the connection between the ship and SCC if there is an on-board crew standing by acting as a failsafe. This means of course that the crew will have to be fully qualified to handle the situation; both handle the ship and if possible restore communication with the SCC.

In the short to medium time perspective, the industry must let the crews of their ships undergo training relevant for the new challenges. As previously seen there have been reports of inadequate training levels concerning IT related issues, and this refers to the industry as a whole. In order to live up to seaworthiness in the cyber era the industry must emphasise IT related training for the years to come. If the crew do not have acceptable IT knowledge, a ship might easily be considered unseaworthy with the ever-increasing amount of technology on the ships.

When the autonomous ship becomes unmanned, the need for additional security measures will be necessary. This will translate into strengthened physical security and redundancy of crucial IT systems both on-board the ships and in the SCC's. The communication links between the ship and a SCC must be heavily protected, both the physical installations and the communication flow itself. One could envision severely encrypted communication channels for crucial systems, like the feed between navigation systems and satellites and less secure communication for the less crucial systems.

The redefinition of seaworthiness in the cyber era is not just an exercise in technology. This will concern both what kind of IT security measures will have to be taken, and what physical security measures will have to be implemented in order to protect both the ship and land based installations. The concept of seaworthiness will need to extend well beyond the ship itself. Steps must be taken to protect the communication between the ship and external navigation aids like satellites.

Policies concerning how to handle the cyber security issues that arise when the automation of the world's merchant fleet continue to increase needs to be implemented.

The more complex the AI or other guiding systems gets, the more problematic it could get for the humans that oversees the operations. It could well be that an automated decision executed by the machine cannot be comprehended in real time and can only be understood after a meticulous investigation after the events. If the human operator has the possibility to override a decision taken by an automated system and chooses to do so, the human could cause an accident otherwise avoided by the automated system. This could be seen as an argument to completely remove the human element from the decision making process.

The next important legal step concerning autonomous ships should therefore be to address the legal implications of letting ships be operated by artificial intelligence and the consequences of the ships becoming self-learning.

Ever since mankind first set sail, humans have been present on the ships. However, the ships of tomorrow might dispense of a human crew altogether and traverse the ocean itself. The role of the human crew is changing; it has gone from being a worker taking care of the ship and cargo. This role is slowly transferring into a more and more supervising performance. The greatest difference between today's concept of seaworthiness and that of tomorrow will not be marked by the presence of machines and technology; instead, its most defining aspect will be the absence of humans.

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