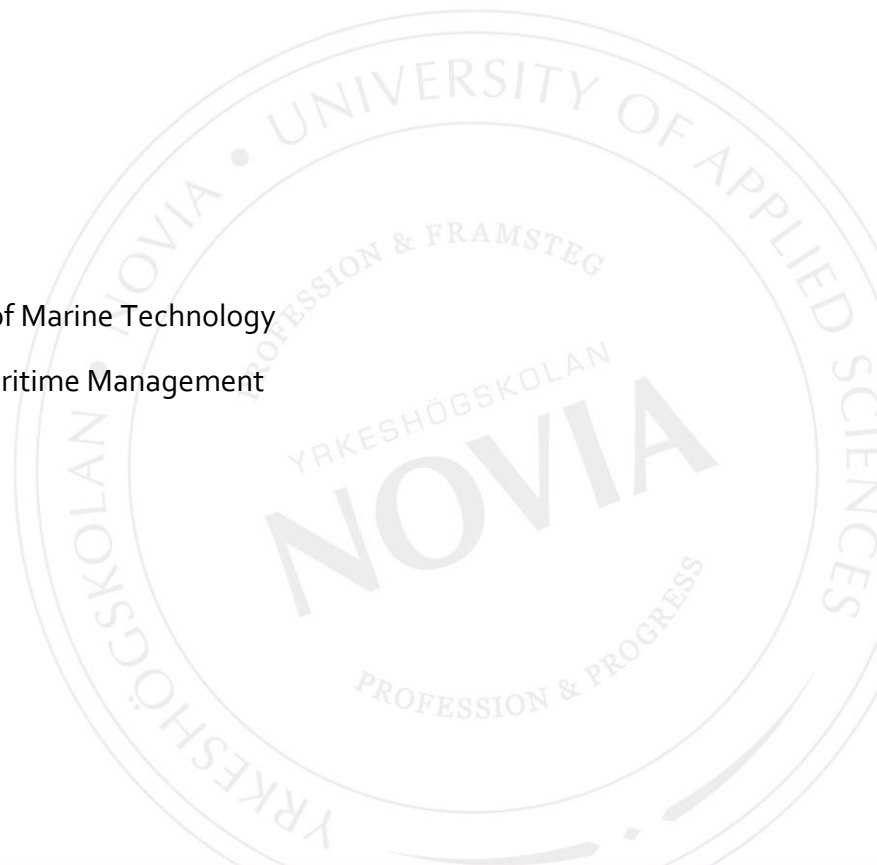# Challenges of unmanned vessels

**Technical risks and legal problems**

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Degree Thesis, Bachelor of Marine Technology

Degree programme in Maritime Management

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# EXAMENSARBETE

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## Abstrakt

Denna avhandling fördjupar sig i tekniska risker och juridiska problem i samband med utplacering av obemannade fartyg. Syftet var att ta reda på vilken typ av teknik som skall användas och vilka risker som ingår och vilken typ av juridiska problem som måste lösas innan obemannade operationer är möjliga.

För detta ändamål intervjuade vi experter som arbetar med obemannade skeppsutvecklingsprojekt. Vårt forskningsmaterial innehåller nyhetsartiklar, vetenskapliga artiklar, presentationer och begränsat material tillgängligt för intervjuade.

Vi kom fram till att tekniska enheter kommer att behöva mycket testning för att göra sina begränsningar och risker tillräckligt kända och bra samt att kunna fixa eller minimera dem. Den teknik som används måste vara pålitlig och av bästa möjliga kvalitet.

På lånssidan konstaterade vi att det finns flera problem, men det är möjligt för dem att påbörja och senare skapa helt nya regler och föreskrifter om obemannade fartyg. På grund av lånproblem måste man starta driften inom hushållstrafiken, men det är möjligt att börja med den inhemska erfarenheten av att utarbeta internationella bestämmelser som senare möjliggör lanseringen av globala verksamheter.

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Språk: Engelska          Nyckelord: obemannade fartyg, autonoma fartyg

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# OPINNÄYTETYÖ

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Nimike: Challenges of unmanned vessels

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Päivämäärä 07.12.2017   Sivumäärä 38            Liitteet 0

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## Tiivistelmä

Tämä opinnäytetyö perehtyy teknisiin riskeihin ja lainopillisiin ongelmiin, jotka liittyvät miehittämättömien alusten käyttöönottoon. Tarkoituksena oli selvittää millaista teknologiaa tullaan käyttämään ja mitä riskejä niihin sisältyy, sekä minkälaisia lainopillisia ongelmia on ratkaistava ennen kuin miehittämätön operointi on mahdollista.

Työtä varten haastattelimme asiantuntijoita, jotka toimivat miehittämättömien alusten kehitysprojekteissa. Tutkimusmateriaaleihimme kuuluivat uutisartikkelit, tieteelliset artikkelit, esitykset sekä rajoitetusti saatavilla olevaa materiaalia haastatelluilta.

Tulimme johtopäätökseen, että tekniset laitteet tulevat tarvitsemaan paljon testausta, jotta niiden rajoitukset ja riskit tunnetaan riittävän hyvin, ja jotta ne voidaan korjata tai minimoida. Käytettävän teknologian tulee olla luotettavaa ja parasta laatua.

Lainopillisella puolella saimme selville, että useita ongelmia kohdataan, mutta niiden kanssa on aluksi mahdollista tulla toimeen, ja myöhemmin luoda täysin uusia kokonaisuuksia asetuksista ja määräyksistä koskien miehittämättömiä aluksia. Lainopillisten ongelmien takia operointi on aloitettava kotimaanliikenteessä, mutta kotimaisilla kokemuksilla on mahdollista aloittaa laatimaan kansainvälisiä määräyksiä, jotka myöhemmin mahdollistavat maailmanlaajuisen operoinnin aloittamisen.

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Kieli: Englanti            Avainsanat: miehittämättömät alukset, autonomiset laivat

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**BACHELOR'S THESIS**

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**Abstract**

This thesis looks into the technical risks and legal problems involved in the introduction of unmanned vessels. The aim was to find out what kind of technology is used and what risks it will have, and what kind of legal problems have to be dealt before unmanned operations are possible.

We conducted interviews of experts working on development projects of unmanned vessels. Research materials included news articles, scientific articles, presentations and restricted source materials provided by the people interviewed.

We came into conclusion that the technical devices need a lot of testing, so that the limitations and risks are well known, and can be fixed or minimized. The technologies used have to be reliable high-end products.

On the legal side we found out that many problems are faced, but they are possible to first workaround, and later to create a new set of rules specifically meant for unmanned vessels. Due to legal problems operations have to start as domestic, but with domestic experiences it's possible to start drafting international regulations, which will later allow starting worldwide operations.

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Language: English         Key words: unmanned vessels, autonomous ships

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# Contents

# 1 Introduction

Mankind has sailed the seas for thousands of years step-by-step developing the ships, equipment and navigation skills. Beginning from small manpowered rowing boats and navigation by basic optic and celestial observations we have come to giant oceangoing ships, which are powered by huge marine diesel engines, and are equipped with many navigational aid equipment. Already the role of human on the ship navigation has decreased, since the positioning equipment and autopilots do most of the work when at sea, though the responsibilities and decision-making are of course still in hands of the masters and officers of watch.

Depending of the voyage there might be hours, or even days when the ship sails with the same exact course, so one can ask is it really necessary to man the bridge, or even the whole ship at all. Especially when we already have UAVs (unmanned aerial vehicles) and robot cars. The environment and its challenges are different to aerial and land going vehicles, but still: the technology for unmanned ships already exists. The main problem is how to make it work with the rules and regulations. By replacing the crew with top of the line technology shipping companies can achieve better profits from reduced manning costs and increased cargo carrying capacities, while the whole industry could become safer by removing most of the human factor leading to incidents. This will create new kind of threats and errors but if they're at least leveled or even decreased comparing to current ones, we will have more efficient ships without the risks for human life.

In this thesis we are going to find out how unmanned vessels are going to be made reality, with what kind of technical solutions, and interpretation and changing of maritime laws. The main goal is to find out what kind of risks will emerge from this kind of trend in the development. We won't take deeper sight to the things which are pushing the industry to this, it's basically money and lack of seafarers, because it's not so relevant in the eyes of a seafarer.

We're actually quite lucky for Finland being in the front row in researching and developing unmanned vessels, so it will, in addition to offering us useful source material, create special kind of interest into it. This leads to our main resource of research being the AAWA project (The Advanced Autonomous Waterborne Applications) which is a joint-project of universities, ship designers, equipment manufacturers, and classification societies. With working experience from seafaring and informational technology sectors we are also

interested how the human navigators can be replaced with computers and algorithms, and how the systems and connections will be made failproof and with what kind of protections. After all, there's a great possibility of us both working with unmanned vessels in the next decade or two.

## 2  Our research

When we we're looking for a topic for our thesis back in autumn of 2016, we asked suggestions from Markku Mylly, executive director of European Maritime Safety Agency. Along with the idea for this thesis, we also received tips and contacts where to start from our research process. We had of course earlier read news articles about unmanned vessels, so we had some knowledge what we we're digging into. Since we're lucky to have ongoing development for these vessels also in Finland, we first agreed a meeting in December with Rolls-Royce's Esa Jokioinen who acts as the Head of Blue Ocean Team. This interview opened up the big picture of the industry for us, along with details of schedules and solutions for at least one project. In addition to this recorded interview, we also got some materials, contacts and tips for further research. Before continuing we did kind of a background research from the internet, to gather information about different projects ongoing at the moment. For the technical side of research Lauri was in contact with Dr. Robert Oates who acts as Cyber Security Lead on Rolls-Royce's Ship Intelligence division.

As the research and writing of thesis progressed, we found out with aid from the lecturers at school, that our original vision of dealing with the whole safety matter of unmanned vessels would be too extensive. As a result, we limited the work for a more speculative approach, by changing the focus from safety to challenges, more specifically to technical risks and legal problems. This meant that we had to adjust the body of the thesis a bit, because of a different view, and also to seek for a legal specialist to gain further knowledge of how the legal process could take shape over time. For the legal questions we contacted Nils Haktor Bua, who works as a surveyor at Norwegian Maritime Authority (Sjøfartsdirektoratet), and is also involved in various projects concerning introduction of unmanned vessels in Norway. We thought that since at the moment Norway seems to be a little step further in the testing phase of unmanned vessels, they probably are also further in the legislation concerns. We

had quite comprehensive questions about legal issues, which we had found earlier doing research from internet, and although some processes are already ongoing it's still quite hard and speculative to answer questions about what's going to happen in the future. But we gained some knowledge how the first steps can be taken and when we can expect more to happen also on the legal sector.

Overall all the information gained from these interviews are purely individual opinions and views of the persons interviewed, and not opinions of their employers.

# 3   Visions and projects

## 3.1   Visions

Throughout the history the development in every aspect of work done by humans, the aim has been to replace humans with mechanical solutions, and later on also with computers. Some jobs may have been considered as a must for a human to deal with, but still at least it has been aided with technology. The same goes for ships: where the ancient ships had hundreds of men as a crew, in the last 200 years the size of the crew for large ocean-going cargo ships has reduced to a tenth of what it had been, although the size of the ships has grown. The largest container ships nowadays, which are nearly 400 meters in length and 60 meters in width and can carry almost 20 000 containers at a time, have usually only a crew of 16 people. The idea of replacing these last crew members with computers and other solutions has matured for some decades.

In the 1970's when the level of automation was rising rapidly, the first thoughts about fully automated ships were laid. In 1973 in his book "Ships and Shipping of Tomorrow" Rolf Schonknecht described the ships of the future where a captain could perform his duties in an office building somewhere onshore, when the ship would navigate itself with onboard computers. (Andrews 2016, Robot ships and unmanned boats)

During the 1980's, in Japan, the idea of intelligent ships operating without crews was discussed, but when cheaper foreign crews became available the idea was discarded. (Andrews 2016, Robot ships and unmanned boats)

In 1994 Kai Levander, a Finnish ship designer, stated: *"A ship with no crew onboard could travel aided by the GPS chain and guided from the traffic stations. Pilots could board near the harbor and take the ship into port. An automated mooring system secures the ship to the quay without help from the crew."* A bit later, in 1996, German naval architect Volker Bertram said that a combination AI (artificial intelligent) and tele-operation would be feasible for ships, but this concept was found economically unattractive due to the high maintenance costs. (Bertram 2013, Towards Unmanned Ships)

In 2000's the concept of intelligent ships re-emerged in a 2007 paper on the future development of the maritime industry by Waterborne TP, which was a cluster of European maritime stakeholders. This paper suggested more advanced automation and improved sensors might be desirable for ships, but did not advocate full automation. (Andrews 2016, Robot ships and unmanned boats)

In the 2000's several different projects for researching and developing unmanned ships have been risen, taking a bit altering approaches to the subject and leading to different conclusions. In the next chapter we focus on our main project of interest, led by Rolls-Royce, while the others are seen through in later chapters.
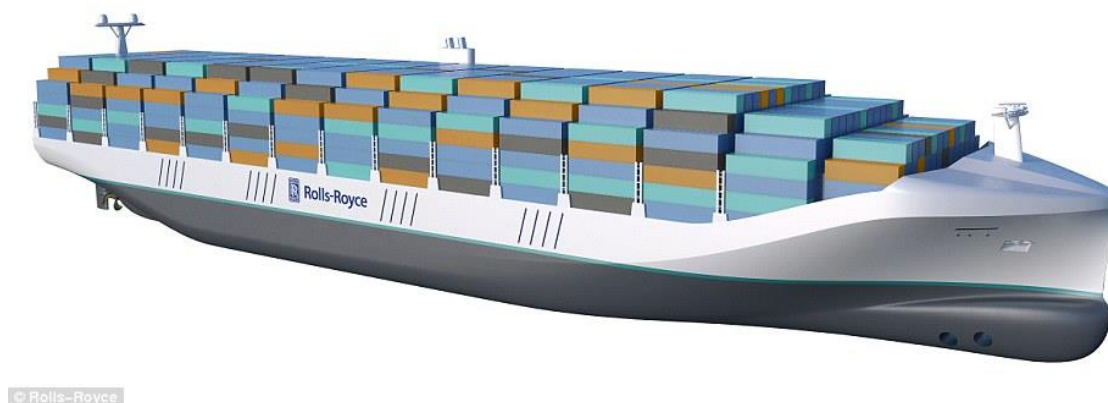


*Figure 3.1.1 Concept of Rolls-Royce unmanned container vessel (Rolls-Royce 2016)*

## 3.2   Rolls-Royce

Rolls-Royces project of autonomous vessels has been one of the leading ones in the industry. As we know company has long history from aviation as airplane engine manufacture. In

autonomous vessel industry company has a vision to be purely system manufacture. But along with other autonomous vessels projects Rolls-Royce is just one player it the game.



*Figure 3.2.1 (Rolls-Royce Ship Intelligence 2016)*

Rolls Royce is not planning to make own vessels, or even product all the needed technology themselves. Company is simply providing system that will make remote-control of the vessels possible. Basic idea with Rolls-Royce is go on with idea step by step. They will test and develop the different parts of their system in real timeline. First vessels are planned to sail in coastal areas and will have system and connection between ship and land, where vessel can be only monitored in part of navigation, engines and propulsion. This of course meant these vessels are not unmanned.

After stage that monitoring is working from ship to land, company want to take next step. This is that navigation, engines and propulsion is planned to be also controlled from land. Even in this stage ships are planned to sail in coastal areas but unmanned. At the section 4.1.2 there is more about testing opportunities and more information about testing area at open sea, because Rolls-Royces next step is to test unmanned vessels in open sea conditions. The final vision of Rolls-Royce is that all the vessels would be autonomous, equipped with their technology. (Rolls-Royce 2016)

## 3.3  MUNIN

MUNIN stands as abbreviation for *Maritime Unmanned Navigation through Intelligence in Networks*, which highlighted the project's aim to develop technology for an autonomous unmanned vessel. It was a three years project co-funded by EU, which consortium consists of eight partners from scientific and industrial backgrounds located in Germany, Norway,

Sweden, Iceland and Ireland. While the research partners dealt with the technical, legal and business aspects of the project, the industry partners represented different business areas of the ship supplier market and linked MUNIN to current demands of the market. (MUNIN 2013, MUNIN Brochure 2013)

MUNIN's concept of autonomous ships was similar with European Waterborne Technology Platform's one, which stated: *"Next generation modular control systems and communications technology (that) 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".* (MUNIN 2013, MUNIN Brochure 2013)

The project's rationale behind the need of unmanned ships was that due to the slow steaming done nowadays, the longer voyage times would drain on the already limited number of seamen needed for more demanding tasks. Also, if the crew costs can be reduced in addition to the other savings from slow steaming, the total savings would become bigger and the whole concept of slow steaming more sustainable economically. Other benefits would be its social sustainability, when the seamen could do their jobs monitoring and controlling the vessels from ashore and enjoy their normal social life on land; and its environmental sustainability making slow steaming more profitable and so on the lower fuel consumption resulting in reduced exhaust emissions. (MUNIN 2013, MUNIN Brochure 2013)

The MUNIN's results envisage autonomous operation of an unmanned vessel only during deep-sea-voyage, and not in congested waters or during the approach. This means that those tasks would still be executed by a crew onboard. It also leads to that the deep-sea/voyage-length ratio would be very important economic factor for the total operational efficiency. Due to restricted satellite bandwidth in some regions and high communication costs would make a simple remote-control solution unattractive, MUNIN proposed a concept, where the ship is autonomically operated by new systems on board, while the monitoring and controlling functions would be executed by an operator ashore. (MUNIN 2016)

The following picture (figure 3.3.1) shows how the concept of MUNIN's autonomous vessel would work. Starting from the left with manned operation, for example after leaving a harbor and disembarking the pilot, also the crew of the vessel would disembark, and the vessel would be set to "autonomous execution mode". This mode would control the ship autonomously, and when an unintended event would be detected if it couldn't deal with it itself, the ship would get human support by remote controlled operation. When human

support is no longer required the ship would go back to autonomous control. If the remote-control interaction was lost, the ship would go to "fail to safe" procedure, which could be emergency anchoring or some other action to minimize the risks of collision, grounding etc. Then either if the interaction possibility was restored the ship would go back to remote control operation, if not, an emergency crew would be embarked.

In a nutshell, the project concluded that a "MUNIN bulker" would improve the expected present value by 7 mUSD over a 25-year period comparing to a reference bulker under certain circumstances. Besides this, a decrease of collision and foundering risk by ten times compared to manned shipping was found possible, mainly because of elimination of fatigue issues. Also, the fire risks would be reduced, and more efficient extinguishing systems could be used in fully enclosed spaces because of no humans would be presence. MUNIN states also that one could assume that unmanned ships would be less vulnerable to pirate attacks. Some stepping stones would be challenges of autonomous heavy fuel oil operation and the adaption of legal framework for unmanned operations, but these are not concerned something that couldn't be overcome. (MUNIN 2016)
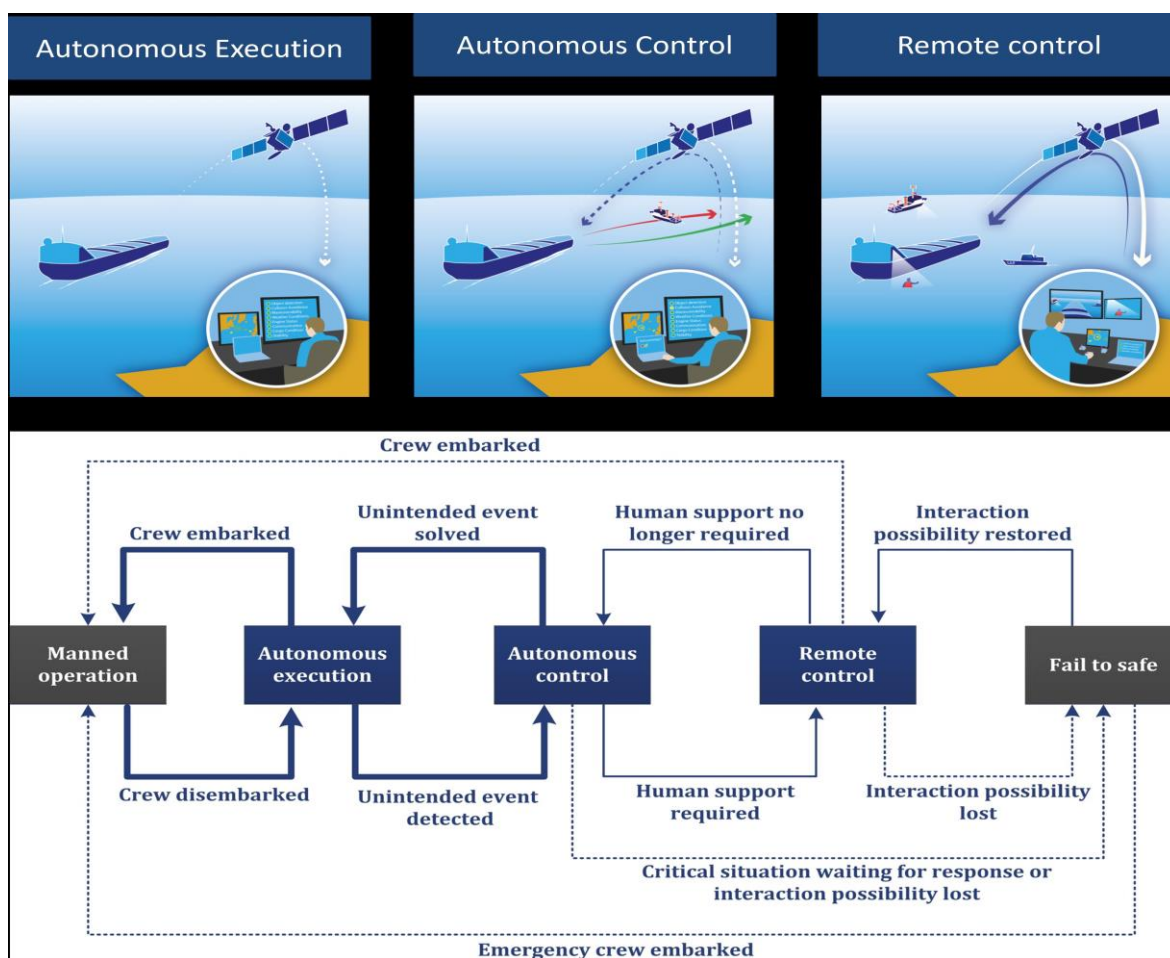


*Figure 3.3.1 MUNIN Operational modes* (Fraunhofer CML, 2016)

## 3.4  ReVolt

ReVolt is DNV GL's project developing a battery powered unmanned vessel for short-sea shipping. Instead of using marine diesel fuel the vessel is powered by a 3000-kWh battery, which reduces operating costs by minimizing the number of high maintenance parts onboard. The vessel is a 60-meter container feeder with capacity of 100 TEU and the vessel's said range would be 100 nautical miles, before the battery needs to be charged. And also, if the energy required for charging is produced from renewable sources, it would eliminate carbon dioxide emissions. The vessel's average speed is 6 knots, meaning it faces less water resistance than other ships travelling at higher speeds. This slight loss in speed allows the engineers to fit the vessel with straighter vertical bow, which further reduces water resistance along the vessel's entire profile. (Adams 2014, ReVolt – next generation short sea shipping)

The vessel is designed so, that it does not require any crew, which should tackle one of the shipping industries' weakest links: the safety record. *"With an average of 900 fatalities per year the mortality rate in shipping is 90 percent higher than in comparable land-based industries. Studies have shown that the majority of these accidents are caused by human error."* Operating a vessel without onboard crew would take the human error -factor away and make the operation more cost-efficient. This means also that without any crew, the usual crew facilities can be left out from the vessel's superstructure resulting in increase of loading capacity, and lowering operating and maintenance costs. This can be seen in the figure 3.4.1 where there isn't much space taken from the cargo section to fit the batteries. The estimated savings for ReVolt-vessels 30-year-lifetime compared to diesel-run ship could be up to 34 M USD (31.5 M €). (Adams 2014, ReVolt – next generation short sea shipping)

> *"Building and operating this vessel would be possible with today's technology. 'ReVolt' is intended to serve as inspiration for equipment makers, ship yards and ship owners to develop new solutions on the path to a safe and sustainable future"*
>
> -Hans Anton Tvete, Senior Researcher at DNV GL.
>
> (Adams 2014, ReVolt – next generation short sea shipping)

*Figure 3.4.1 A sectional picture of ReVolt (DNV GL 2016)*

DNV GL is at the moment on a three-year (started Q3/2015) testing phase of ReVolt which will bring the future concept ReVolt closer to reality. For the purpose of testing the autonomous capabilities they have built a 1:20 scaled model (DNV GL 2016). DNV GL is testing sensors, cameras and radars for monitoring the vessel's surroundings, along with the Norwegian University of Science and Technology (NTNU) and Kongsberg Maritime. The project also carries overall development of technology, since it has to work for days and weeks without any type of maintenance despite of the weather, and the today's systems simply are not designed for it. Another big element preventing immediate introduction of vessel without crew is the legislation: in most cases it requires human presence. (Hartkopf-Mikkelsen 2016, DNV GL: Unmanned container vessels could become reality in five years)

## 3.5   Yara Birkeland

On the spring of 2017 Norwegian companies Kongsberg and Yara International announced they are developing an autonomous container ship of 100-150 TEU capacity with zero emissions. The ship will transport products from Yara's Porsgrunn production plant to Brevik and Larvik in Norway, and the operation is planned to start in the latter half of 2018. The ship is named after Yara's founder scientist and innovator Kristian Birkeland, and it's going to be the world's first fully electric container feeder. It's estimated that the ship can replace up to 40 000 diesel-powered truck journeys and thus reduce NOx and CO2 emissions

while also improving road safety. The ship will be launched as a manned vessel, but it's planned to move into remote operation in 2019 and expected to be capable to perform fully autonomous operations from 2020 onwards. (Yara 2017, YARA and KONGSBERG enter into partnership to build world's first autonomous and zero emissions ship)

Kongsberg is a Norwegian international technology group supplying high-technology systems and solutions in merchant marine, defense, aerospace, offshore oil and gas industries. Kongsberg is responsible for development and delivery of all key enabling technologies such as the sensors and integration which is required for remote and autonomous ship operations of Yara Birkeland. In addition to this they also take care of the electric drive, battery and propulsion control systems of the project. (Kongsberg 2017, Autonomous ship project, key facts about YARA Birkeland)

The ship's preliminary particulars are: Length Over All >70m, beam 15m, depth 12m, draught loaded 5m, draught ballast 3m, service speed 6kn and max speed 10kn. Capacity is 100-150 TEUs and deadweight 3500-4500mt. Ship's propulsion consists of electric propulsion by two azimuth pods and two tunnel thrusters, all powered by a battery pack of 3,5-4MWh. The positioning of propulsion systems can be seen in figure 3.5.1 below. Key sensors include cameras, radars, AIS, lidar and IR cameras. The ship will operate within 12 nautical miles from coast (Norwegian territorial waters) between three ports in southern Norway. The whole area is covered by the Norwegian Coastal Administrations' VTS system at Brevik. The distances between the ports vary from 7 nautical miles to 30 nautical miles. (Kongsberg 2017, Autonomous ship project, key facts about YARA Birkeland)



*Figure 3.5.1 Concept design of the Yara Birkeland. (Kongsberg 2017)*

# 4 Technical risks

Is leaving human error away from vessel really the best solution. In this section technology and risks towards to technology are presented. Some technical systems example electrical chart systems, and positioning systems are common systems at vessels these days. Risk of fail in these systems is the same in unmanned vessels and manned vessels, because these are systems that basically will remain the same in unmanned vessels. Technical risks at the future will more have to do with technology that is trying to take over human sense, (example human vision in figure 4.1.1.2) and communications systems between unmanned vessels and land based station.

Even if devices are planned to be backed up in unmanned vessels, with the idea that if some censor, camera, computer of communication module or even just a data wiring is broken down, some very common situations are making the unmanned vessels systems not so safe. One is always fire, if vessel is on fire, all the systems are also burned. Of course, to prevent this example shipbuilding materials are planned to be fireproof, engines work with electricity and co2 systems are planned to work automatic, but also all data wiring and backup systems are in separate locations of the vessels that if in case of emergency everything is not harmed.

At the engine side, vessels have had unmanned engine rooms for a long time. Monitoring is made from different location at the ship, and in unmanned vessels idea is to make it from land based station. RR has created system called loop sound, that is basically system, that records any sounds from engine room live to land based station. Even if backing up the machinery and sensors from vessels to land, communication fail for all this data transfer is the most relevant risk. Also backing up systems in engine room, one specific thing has been on table. This is the cooling water intake system for engine/engines. This is a system that is hard to be duplicate, and engineers are still planning new ways to make this work in unmanned vessels.

Risks at the moment are mostly in communications, and securing the data. Data between vessel and land based station due satellite systems is the weak link. Of course, in this thesis we have talked about systems fails, and other risks example fire onboard, the same risks are reality in land base station. Both end systems most work properly, so the communication data is reaching another end.

Data communication, connection to provide it and moving the data safely from place to another is a challenge like earlier said. Firewall in both ends is a must, but also one main

point in all data connection is monitoring the data. Data does not have to contain any viruses to make system fail. Monitoring of the data detect a hardware/connection fail immediately, and system can be swapped to backup. This could be example fail of a camera due to a heavy weather. Updating the firewalls, and connection hardware also must be done to prevent any virus to pass true firewalls. So still manmade job at IT, with updating and monitoring must be done even there is nobody on the vessel.

These days connection are weak in open sea areas, and data amount moved is not small, so real issue has been hot to pack and also crypt the data, and get it to move needed speed. This is also why level of autonomy can be adjusted less control from land base station equals less needed bandwidth. If the connection is lost because of satellite connection fail, unmanned ships system is still doing backup procedure and stops making way, and uses local DP-systems to just keeps its position. (Äijälä 2015, Risks when operating unmanned ship)

## 4.1  Technical solutions

Since this thesis topic is based on all project of unmanned vessels going on, but technical solutions are since known solutions that Rolls-Royce uses at the moment., this is because we have had best opportunity to be involved with Rolls-Royce. At the Future basic principle for technical solutions are the same, but in other projects different devices and solutions might be done other way. This is of course understandable because devices are developed for better performance all the time.

Basic technical picture is that at vessel there is different modules connected to vessels propulsion and rudder systems. These modules on together "artificial intelligence" that is controlled from land by controller, true secured network connections. More specific information about these modules are introduced on Devices part.

### 4.1.1  Devices

Technical devices can be separated to different groups. Far as we know different manufacturers devices can be integrated to Rolls-Royces system e.g. Furuno's radar, and Flir-infrared cameras.
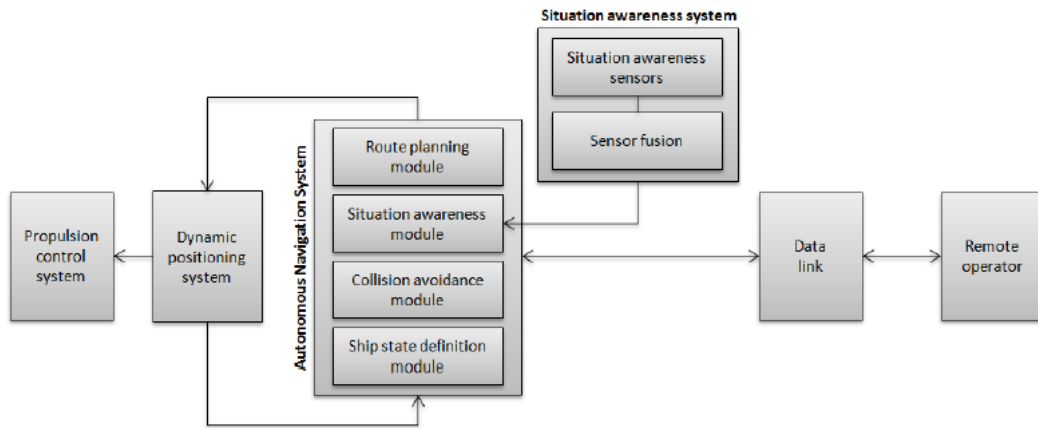
*Figure 4.1.1.1 Autonomous navigation system, (Rolls-Royce 2016)*

First Situation awareness system that basically contains sensors. It includes at least following sensors: Sound capturing and detection sensors, cameras that are user daytime, infrared cameras that can be user night time, thermal cameras and of course S and X band radars that can be user during bad weather conditions. Also, KA and W band radars (Figure 4.1.1.4) are used, because they can detect objects with very close range. Also, sensors to LIDAR that is new laser scanner system, that can measure very accurate distance measurements. Situation awareness system also includes sensor fusion, own system that collects combined data from all different sensors and knows how to use most reliable data.



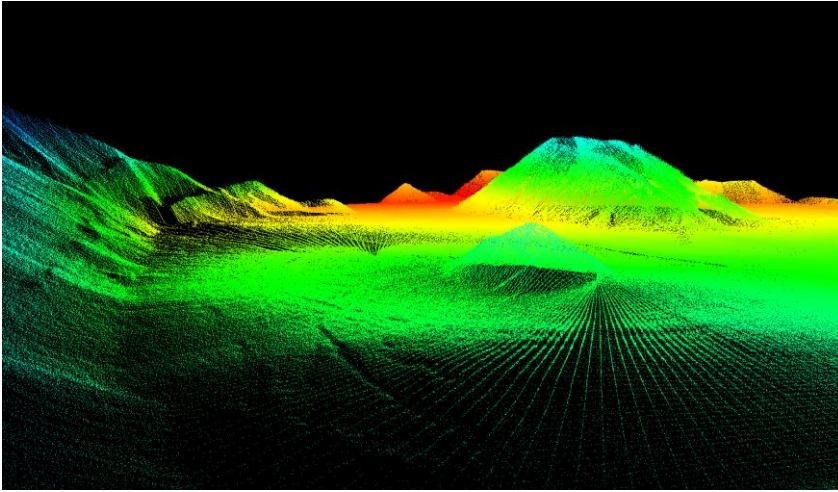*Figure 4.1.1.2 Human eye vs. thermal camera vison, (Rolls-Royce 2016)*

*Figure 4.1.1.3 LIDAR picture, (Redishaw 2016)*

| Frequency band | Frequency range (GHz) | Wavelength range (cm) |
|---|---|---|
| L band | 1–2 | 15–30 |
| S band | 2–4 | 7.5–15 |
| C band | 4–8 | 3.75–7.5 |
| X band | 8–12 | 2.5–3.75 |
| Ku band | 12–18 | 1.67–2.5 |
| K band | 18–27 | 1.11–1.67 |
| Ka band | 27–40 | 0.75–1.11 |
| V band | 40–75 | 0.4–0.75 |
| W band | 75–110 | 0.27–0.4 |

*Figure 4.1.1.4 Different radar bands*

Second autonomous navigation system, that includes route planning module, situational awareness module, collision avoidance module, and ships state definition module. All these modules are connected to each other, and to ships dynamic positioning and propulsion system.

Route planning module is basically an ECDIS but where the planned route is imported from land. At sea and in harbor areas, system uses both terrain and nautical charts like in manned vessels, but dynamic obstacles are mapped using situation awareness system. Many ways mapping dynamic obstacles is done same way that in manned vessels using AIS and radars, but in unmanned vessels user more sensors and more information for mapping.

Situation awareness module is basically and module where all the sensor data from situation awareness system is coming into.

Collision avoidance modules purpose is to make sure safe navigation. It is using data from all the other modules e.g. from route planning module where it gets the planned route, and from situation awareness module where it gets info of surrounding obstacles, DP-module where it gets maneuver limits.

Ships state module collect data from other modules, and and shares this information of ships systems condition with operator.

Ships dynamic positioning systems purpose is to maintain ships adjusted position and heading with help of GNSS devices, wind sensors, propulsion systems e.g. Azipod-system, propellers and rudder and bow/aft thrusters.

Datalink and communication is one main part of autonomous navigation system. When voyage planning is done by operator, operator also has to select level of autonomy to vessel. Meaning that operator can basically choose is ship only remote controlled or fully autonomous. Of course, 100% autonomous ship does not exist yet.
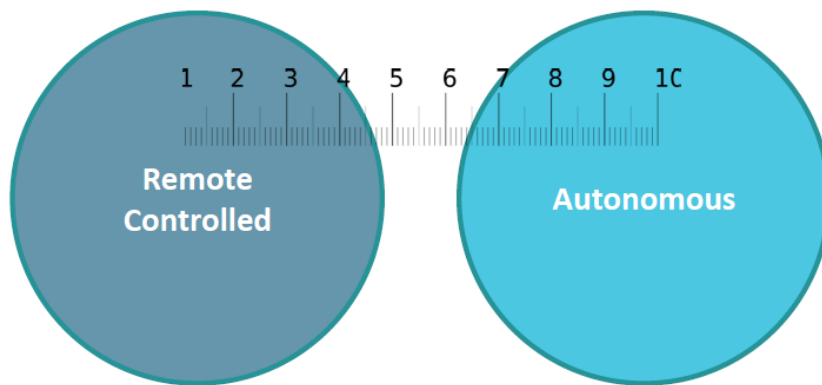


*Figure 4.1.1.3 Level of autonomy, (Rolls-Royce 2016)*

Depending what level is selected, the amount of data between ship and operator is different. More remote controlled unmanned ship is, more communication is made, and data is used between ship and operator, and more we more to autonomous, less communication and data is used. Connections at these days have not developed to high speed connections in all over the world e.g. open sea areas. In coastal areas we can use high speed connections like 5G,

but in open sea areas we can only use satellite connections. That's why in coastal areas ship can send very much data to operator e.g. HD-video, so operator can get best possible information from sensors, but in open sea amount of data changed between ship and operator is limited.

One existing satellite system for unmanned ships is Inmarsat Global Xpress system. System has a high coverage, and high bandwidths. Global Xpress uses all KA, S and X bands to operate. System can switch between these bands without operator taking action. In the future, shore connections, and satellite connections will get much faster, so problems with bandwidth are history, and ship and operator can have high speed connection with much sensor data as possible all the time anywhere. (Rolls-Royce 2016)

### 4.1.2   Technical development and testing

Early 2016 DIMECC Finnish co-operation company was started, connecting all both Finnish and global companies together working with unmanned vessels and development of them. These companies are at the moment Rolls-Royce, ABB, Wärtsilä, Cargotec, Ericsson, Meyer Turku, Tekes and Tieto. Their project has even new name "One Sea – Autonomous Maritime Ecosystem"

After many years of development companies involved have already technical solutions ready for business and because goal is that unmanned vessels are coming part on everyday maritime operations in very near future, DIMECC has founded test area for unmanned vessels, this area in coast of Rauma Finland, has now name "Jaakonmeri test area"
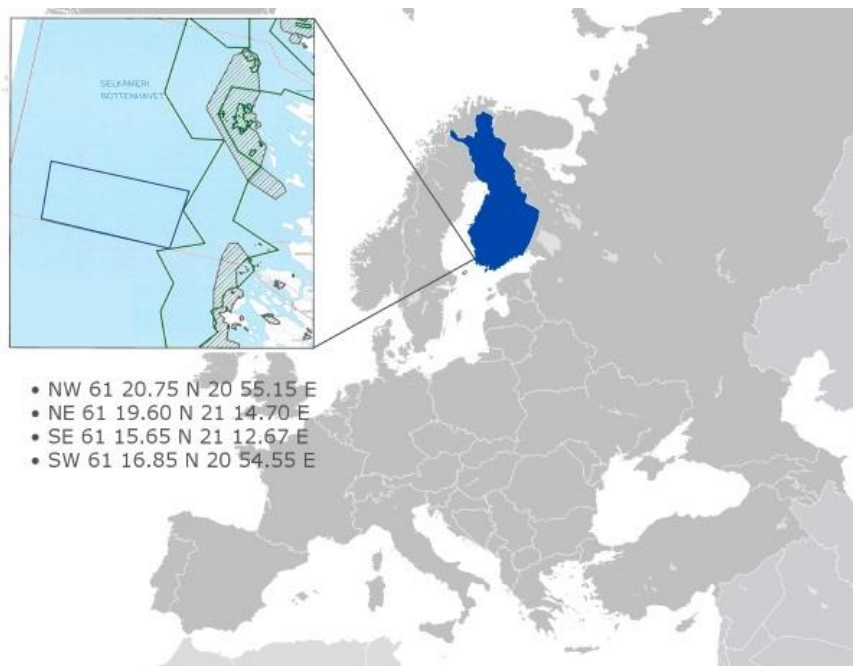
• NW 61 20.75 N 20 55.15 E
• NE 61 19.60 N 21 14.70 E
• SE 61 15.65 N 21 12.67 E
• SW 61 16.85 N 20 54.55 E

*Figure 4.1.2 Jaakonmeri test area, (DIMECC 2016)*

Dr. Talvitie from DIMECC said *"Thorough testing in authentic sea conditions is critical to ensure the functionality of systems and technology and to guarantee the required safety and reliability requirements for the autonomous vessels of the future."*

Area is of course closed from public traffic, and only unmanned vessels can use it. Area is really big about 18 kilometers x 8 kilometers wide, and is all open water. Why this area was founded to Finnish coastal are is because of good connectivity and connections testing and also chance to do testing in ice conditions during winter time.

"Jaakonmeri test area" is actually open for testing to anybody in the world, but test purposes must be to test unmanned vessels or technologies related to it. DIMECC has already said that first test is planned to be started at 2018 or even earlier. This is important step, in the roadmaps generated in one sea. Opening a test area to all the actors developing maritime autonomy will speed up the process globally and makes concept to all commercial applications in this field. (DIMECC 2017, One sea ecosystem)

## 4.2 Security

Cyber security is in key part planning how unmanned vessels systems work. With help of cyber security, we can make sure, vessels are safe and secured from internet communication technology attacks and abuse. In unmanned vessels there is lots of systems and subsystems and e.g. all the devices may be from different manufacturers. In unmanned vessels many of these systems may be intelligent and connected to internet, unlike in manned vessels where all systems all closed systems, and not connected to internet. Of course, in manned vessels we have computers onboard connected to internet, but these systems are always independent systems, and not linked to each other. So, when number of unmanned vessels is increasing, we know that amount of cyber-attacks is also increasing. When cyber security of unmanned vessels is designed, designers star by doing risk analysis. If we think who would want to make a cyber-attack to unmanned vessel and what reasons for attack would be. Possible attackers could be terrorists, hackers, activists and organized crime and the reasons for attack could be terrorist activity like causing pollution, stealing information, or demanding ransom from vessel or cargo.

Because of lots of subsystems in unmanned vessels, security is designed way that all the subsystems all implemented to system wide single security stance that covers all the devices of ship. This is because subsystems manufacturers cannot provide best possible security. Even when the security of subsystems are implemented to system wide security, also subsystem security needs to be updated all the time. When information about unmanned vessels had been published, topic has raised generic concern about safety. Questions that we have been hearing when doing this project are usually e.g. can IQ of unmanned ship be at same level than human, but like as we already know, unmanned vessels are still at these days controlled by human from land, and also the level of autonomy can be selected. Questions have been e.g. ability of unmanned ship to detect smaller objects boats etc. Can unmanned ship void collision with other ships and navigate safely on coastal fairways, but basically unmanned vessels have same and even better devices on use for detection and navigation. And also with this question we have to remember that route planning is done by operator, and level of autonomy can be selected.

Questions about unmanned vessels and manned vessels sailing in same areas, communication and rules between them. Basically, manned ships are communication everything with operator in land, and as far as know same rules of the road are applying with this situation. Questions about maintenance of unmanned vessels, and what to do if some

technical maintenance work should be at sea. With maintenance the plan is to do the maintenance in shore, and in case of technical problem at sea, always have a backup system. Most simple, but not the best solutions in economical point of view, is to have duplicated systems for everything. Also, some questions about fire, and firefighting in unmanned vessels. Once again not the best solutions in economical point of view, but non-burning materials have been idea when building new unmanned vessels. Also, automatic firefighting systems like with aerosol, or halon can be used in unmanned vessels. (MECSS 2016, Rolls-Royce 2016)
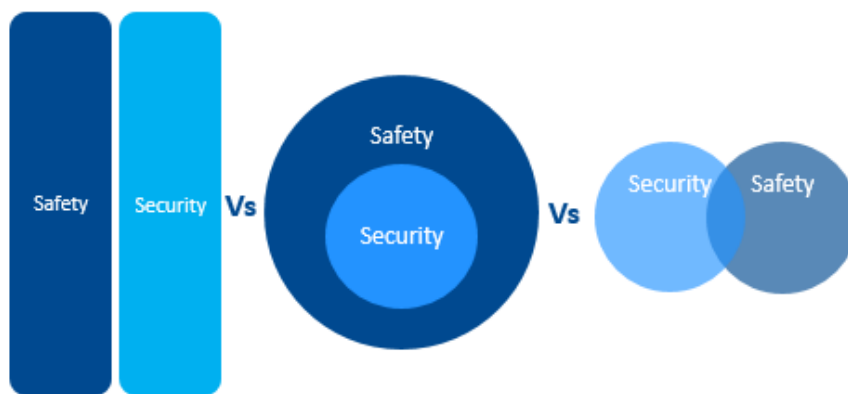


*Figure 4.2.0 Dr. Robert Oates (MECSS 2016)*

# 5   Legal problems

There is an old saying among the Finnish seafarers: "God in heaven, captain in a ship". This can be understood as the captain being a ship's almighty authority, who has the last word but also all the responsibility considering everything what's happening in and with the ship. The maritime law considers him/her a person in charge of the vessel, who has ultimate control and direction of it. But what then if there is no-one onboard, so that the one controlling the ship or maybe even just monitoring its operation, is ashore sitting in some office. There might not be any problems when everything is going as planned, but if and

when an accident occurs, everyone is looking for the human behind it for answers – the captain. In conventional vessel he has been onboard the ship in middle of the event with his crew, who can we also ask about the accident, but with unmanned vessel this so-called captain is not as easy to find. We need some kind of an amendment to define someone to a similar position, most probably the onshore vessel controller at the time. But even then, he is not in similar position – he isn't present. And that is the basic or root cause behind every legal conflict concerning unmanned vessels. The existing laws and conventions will in most cases work, but situations contemplating human presence must be modified.

One of the most important thing is international and uniform technical safety standardization, which will likely be implemented in the context of the SOLAS convention (Safety of Life at Sea) and the rules of classification societies. Most likely the Port State Control will play key role in monitoring the application of international rules on unmanned shipping. Like the term unmanned vessel says, there are no humans onboard, which makes one of the safety regulations objects "prevent human injury or loss of life" a bit of an academic, but still existing, because there will be both unmanned and manned vessels crowding the seas together. The collision regulations, which already allow exceptions for vessels of special construction, also need some refining for seamless implementation concerning unmanned vessels. Also, the International Safety Management code (ISM) needs to be revised. (Van Hooydonk 2014, The law of unmanned merchant shipping – an exploration)

## 5.1   Terminology

We can put unmanned means of transport into three basic categories: 1. Unmanned Aerial Vehicles (UAV), 2. Unmanned Ground Vehicles (UGV) and 3. Unmanned Marine Vehicles (UMV). The last category can be divided up in different ways, for example into Unmanned Water Surface Vehicles (USV) and Unmanned Underwater Vehicles. Other approach can be dividing them into Remotely Operated Vessels (ROV) and Autonomous Vessels (AV). These two are easily separated: ROVs are of course controlled remotely, most likely in the case of big ships, onshore, and the AVs are more sophisticated so called "smart vessels", which are self-guided and depend on preprogrammed instructions and artificial intelligence (AI). But even with these quite good dividers these two terms kind of a mixes up when having a ship with AI, but still the ultimate option for control lies for the human. Also, the line between unmanned vessel and i.e. waterborne robots, capsules and so on, isn't always

clearly drawn, although these underwater robots may better be considered as part of a ship or part of its equipment, because they belong by necessity to a mother ship. (Van Hooydonk 2014, The law of unmanned merchant shipping – an exploration)

## 5.2   Definition of ship and vessel

Before implementing maritime law for unmanned vessels, it has to be decided whether they are ships or something else, since there are no captain or crew on board. Anyway, the maritime law will affect them, however they are defined, but it can greatly change the approach how they are dealt with. And what makes this difficult is that the term ship is not strictly defined in the law of the sea. Even in the UN Convention on the Law of the Sea it is not defined, and it uses both English terms: ship and vessel, interchangeably. In the international customary law there is even less of an established description of the term. Most commentators undoubtedly rightly assume that unmanned vessels must be regarded as ships, for the purposes of the law of the sea. The rules of the LOSC (Convention of the law of the sea), which defines the rights and duties of states in connection with international shipping then would also apply to the operation of unmanned vessels. (Van Hooydonk 2014, The law of unmanned merchant shipping – an exploration)

Most international public law maritime conventions use the definitions tailored to the matter at hand. I.e. in the London Dumping Convention the phrase "vessels and aircrafts" means "waterborne or airborne craft of any type whatsoever", and to this is added also:*"this expression includes air cushioned craft and floating craft, whether self-propelled or not"*. In the UN Convention on Conditions for Registration of Ships, the term ship means *"any self-propelled sea-going vessel used in international seaborne trade for the transport of goods, passengers, or both, with the exception of vessels of less than 500 gross registered tons"*. The collision regulations, which can be regarded as most important affecting to the actual navigation, consider the term vessel to be *"every description of water craft, including nondisplacement craft, WIG craft and seaplanes, used or capable of being used as a means of transportation on water"*. The MARPOL convention defines a ship as a vessel of any type whatsoever operating in the marine environment including hydrofoil boats, air-cushion vehicles, submersibles, floating craft and fixed or floating platforms. (Van Hooydonk 2014, The law of unmanned merchant shipping – an exploration)

Then also many of conventions dealing with private maritime law are applicable to seagoing vessels but do not provide any definition. These kinds of conventions are i.e. the 1910 Collision Convention, the 1910 Salvage Convention and the 1952 Ship Arrest Convention. There are also instruments containing a definition, but even then they have a wide variety of choices or a very broad definition: The Hague Rules say that ships is " any vessel used for the carriage of goods by sea", CLC 1992 (International Convention on Civil Liability for Oil Pollution Damage) describe ship as "any sea-going vessel and seaborne craft of any type whatsoever constructed or adapted for the carriage of oil in bulk as cargo", the 1989 Salvage Convention states vessel as "any ship or craft, or any structure capable of navigation". There are also conventions going more into detail in the description: Strasbourg Convention of 2012 on the Limitation of Liability in Inland Navigation defines vessel as *"an inland navigation vessel used for commercial navigational purposes and shall also include hydrofoils, ferries and small craft used for commercial navigational purposes but not air-cushion vehicles"* and adds *"dredgers, floating cranes, elevators and all other floating and mobile appliances or plant of a similar nature shall also be considered vessels"*. (Van Hooydonk 2014, The law of unmanned merchant shipping – an exploration)

In national maritime laws the description of vessel gives also a wide sampling: In the United States vessel includes *"every description of watercraft or other artificial contrivance used, or capable of being used, as a means of transportation on water"*, in the UK ship includes *"every description of vessel used in navigation",* and in Netherlands ship is understood as all things *"that are not an aircraft, which pursuant to their construction are intended for flotation and which float or have floated"*. People's Republic of China differs a bit from these by defining ship as sea-going mobile units, but not including ships or craft used for military or public service purposes, nor small ships less than 20 tons gross tonnage. Belgium goes bit more specific with its draft version of the proposed new Belgian Shipping Code, which states ship as *"every craft, with or without its own propulsive power, with or without displacement, that floats or has floated and that is used, or which is suitable for use as means of traffic on the water, including air-cushion craft but to the exclusion of fixed devices, waterplanes and amphibious vehicles"*. (Van Hooydonk 2014, The law of unmanned merchant shipping – an exploration)

One of the maybe most clearly described definitions of a vessel can be found in the book "Scandinavian Maritime Law – The Norwegian Perspective". It says that this type of constructions can be identified by certain characteristics that they have in common:

*a) A vessel is a floating construction, with its own capability to float attributable partly to its hollow hull design. A log raft therefore would not be a ship.*

*b) The construction must be intended for, and capable of, moving on or through the water. Thus a submarines and hydrofoils are ships but seaplanes would not fall under this specification. Even though a seaplane can move on water, its primary purpose is to fly.*

*c) The construction must have certain minimum dimensions. It must be capable of carrying passengers or goods, and it cannot be too small. Many small vessels such as rowing boats kayaks, etc. are thus excluded.*

(Ortiz de Rozas 2014, The production of unmanned vessels and its legal implications in the maritime industry)

From the above mentioned examples we could put together that it doesn't seem to be essential part of defining a ship that it has to have master or crew onboard, so mostly unmanned ships would be covered by existing regulatory definitions, and the existing conventions and national laws would continue to be functional concerning them. (Van Hooydonk 2014, The law of unmanned merchant shipping – an exploration)

## 5.3 Unmanned vessel's link to flag state

Like any other vessel, the unmanned vessels have to fly the flag of a state. The LOSC requires a genuine link between the flag state and the ship, so that the flag state can effectively exercise "its jurisdiction and control in administrative, technical and social matters" over the ship. On a conventional ship this is done by master, officers and crew. In addition to this, every state shall take the measures necessary to ensure safety at sea with regard to *"the manning of ships, labour conditions and the training of crews, taking into account the applicable international instruments"*. These measures include those necessary to ensure:

- "that each ship, before registration and thereafter at appropriate intervals, is surveyed by a qualified surveyor of ships, and has on board such charts, nautical publications and navigational equipment and instruments as are appropriate for the safe navigation of the ship"

- "that each ship is in the charge of a master and officers who possess appropriate qualifications, in particular in seamanship, navigation, communications and marine

engineering, and that the crew is appropriate in qualification and numbers for the type, size, machinery and equipment of the ship"

- "that the master, officers and, to the extent appropriate, the crew are fully conversant with and required to observe the applicable international regulations concerning the safety of life at sea, the prevention of collisions, the prevention, reduction and control of marine pollution, and the maintenance of communications by radio"

From these provisions of the UN Convention we can understand that they are designed for conventional ships operated by master, officers and crew. This leads to that either these provisions are pointless concerning unmanned ships and will therefore remain unapplied, or must be applied by analogy to the shore-based controller of the ship. Simplified it would mean that the shore-based vessel controller who has an unmanned ship under his control would be regarded as a master. However, one can understand that the task of the shore-based controller isn't entirely similar to a ship's master, which would make such an interpretation too extensive, which tends to be frowned upon in international law. In the vernacular this means that the tasks of the shore-based controller comparing to master only partially match, so it can't be directly considered as the same. (Van Hooydonk 2014, The law of unmanned merchant shipping – an exploration)

> *"What does the link between the ship and flag state still represent when the owner of the unmanned ship is not necessarily established in that state, when the ship never calls in the ports of that state and when it is controlled and monitored by an anonymous operator sitting at a control desk somewhere in a distant low cost country, or by a computer program created in one or other country and operating 'in the cloud'? Instead of being genuine the link would then be virtual in the highest degree."*
>
> -Dr. Eric Van Hooydonk, Research Professor at the University of Ghent
>
> (Van Hooydonk 2014, The law of unmanned merchant shipping – an exploration)

When putting together the natural volatility of international maritime business and the slipperiness of informational technology, artificial intelligence and worldwide data communications, finding this so called genuine link between ship and flag state becomes a formal waste of time. In this matter trying to force the unmanned vessels into the legal straitjacket represented by the nationality of a ship could be pointless. Furthermore, the possibility of commercial breakthrough of unmanned merchant shipping would provide a good opportunity to give some of the basic concepts of the LOSC a thorough overhaul. For

example, how the flag states can fulfill their obligation of ensuring that ships flying their flag carry on-board certificates, and how the flag states obligation of requiring masters to render assistance to any person found at sea in danger of being lost or after a collision to render assistance to the other ship, can be implemented. One interesting point is also could an unmanned vessel which software was hacked, to be considered as a pirate ship. (Van Hooydonk 2014, The law of unmanned merchant shipping – an exploration)

## 5.4   Definition of master and shore-based controller

Since unmanned ships, as said in the term itself, no longer require master or crew onboard, it could seem like the laws governing the status of these people will inevitably lose all relevance. However, things are not that simple. Master's position has been downgraded slowly during the past 100 years from a dictator-like representative of a company, to a more worker-like "command executioner". This is mainly because the communications have gotten better and better during the years, so when in earlier days a master could agree business deals abroad on his own will, nowadays he must consult and approve decisions with the company. The last fort of master's unlimited powers is probably the nautical responsibility, and since the unmanned ships are filled with technology and automation to deal with navigation itself, and also with connections to take over from the shore, there is no need for an almighty commander onboard. And when a ship is operated or controlled from the shore, the question arises whether the shore-based vessel operator can in the current state of maritime law be regarded as the master or the commander of the ship. (Van Hooydonk 2014, The law of unmanned merchant shipping – an exploration)

### 5.4.1   Status of master

There is so called "Captain's Law", which is the entirety of the legal rules that determine the legal status of the master. When there is no master onboard, the legal powers exercised by one will cease to have any object. There isn't any longer anyone on board who is responsible for the nautical command of the ship, or who may in an emergency situation perform legal acts on behalf of the owners, or exercise the employer's authority over a community of workers temporarily isolated from society, and so on. In many countries there are specific laws and legal codes concerning the maintenance of order and discipline on board, and also about the detection, identification and punishment of shipboard crimes, but these also will

lose their relevance concerning ships with no humans on board. Some other rulesets, which lose their objects concerning unmanned ships and would need changes or alternates are:

- things concerning the international standardization of seafaring occupation (i.e. Maritime Labour Convention and STCW Convention)

- the IMO Guidelines on the fair treatment of seafarers in the event of a maritime accident

- the Procedures for Port State Control (contains guidelines for control of operational requirements concerning mostly everything on board)

- the International Safety Management code (formulates rules regarding the master's responsibility and authority, manning, qualifications of the crew, safety management skills of personnel aboard ships, emergency preparedness etc.)

- Casualty Investigation Code (sets out rules for obtaining evidence from seafarers)

(Van Hooydonk 2014, The law of unmanned merchant shipping – an exploration)

Most conventions and codes define seafarers as anyone serving or working on board, i.e. the Maritime Labour Convention says, *"any person who is employed or engaged or works in any capacity on board a ship to which this Convention applies"*. Likewise, national maritime laws on work performed at sea usually only apply to work which is performed aboard a ship. However, the are other national laws that define the master as any person to whom the authority of the ship is transferred, or as the person who effectively exercises that authority, or as anybody instructed with the command of a vessel or who effectively has that command, or also any person who replaces him. These broader definitions are meant for situations where a temporarily incapacitated, absent, missing or deceased master is replaced by another officer. They are not planned for the new situation which arises when unmanned ships are introduced, but could in principle be applied to it. (Van Hooydonk 2014, The law of unmanned merchant shipping – an exploration)

### 5.4.2   Responsibilities

A good point of view is that can the specific status of a seafarer be transferred to shore-based vessel controllers. The seafarers' status is based on the unique characteristics of being employed at sea, which include i.e. highly international environment, physical

fitness requirements, safety risks, discipline, long-term presence at the work place and absence from home which limits social and family life. A shore-based vessel controller does not face any of these factors, so it's hard to think any valid reason why his employment should be directly governed by these existing specific rules of the maritime law. On the other hand, many of the current responsibilities, of the master and his officers, are needed to be shifted to the shore-based vessel controller. Although sitting ashore in some remote-control center, he is still responsible for carrying out the satisfactory handling of a very expensive mean of transport, which may be carrying a valuable cargo, and also the avoidance of accidents which could cause considerable harm for the environment, the waterway, other traffic and also humans which still are at sea, or i.e. living on the coasts. Therefore, the shore-based controller must have similar qualities than a master: good judgement, good communication skills, good nerves in emergencies, and also the required technical knowledge of both nautical and IT matters. (Van Hooydonk 2014, The law of unmanned merchant shipping – an exploration)

In addition to that the classical legal responsibilities of a master are likely to be passed to the shore-based vessel controller, also i.e. the duty to maintain a proper look-out and to proceed at a safe speed would be his/hers concern. Rules like these which are set in Collison Regulations are addressed to "every vessel", and do not point out are there any deck officers on board or not, so they could be applied without further amendments. More difficult job is to define how far can we expect the shore-based vessel controller to be able to respond flexibly to changing circumstances by making a necessary departure from the Rules of the Road, which the Collision Regulations approve for avoiding an immediate danger. It could be a little harsh to expect same kind of abilities than an officer who is on board his vessel. On the other hand, the status of shore-based controller doesn't differ much from a on board officer who's navigating in poor visibility: they're both reliant on the radar. When thinking even further, the shore-based controller might have even more and better applications for observing dangers and surroundings, i.e. with laser scanners and thermal cameras. But still we come to a major obstacle: the SOLAS Convention requires that there must be possibility to switch over to manual steering with the assistance of a helmsman. (Van Hooydonk 2014, The law of unmanned merchant shipping – an exploration)

As said, many controversies may also be found in International Safety Management Code, which would then require revising to give a proper framework for shore-based controllers. It should set, in relation and between to shore-based personnel of shipping companies,

clear standards regarding organizational structure, internal hierarchies, lines of communication and the clearing of information, and also qualifications, certification and emergency procedures. It must also be assumed that the shore-based vessel controllers are able to demand an inspection of Port State Control. The powers of the PSC authorities to inspect the ships controlled by shore-based organizations in another country must also be clearly defined. (Van Hooydonk 2014, The law of unmanned merchant shipping – an exploration)

### 5.4.3 Documentation

When we have no souls on board, it's of course becomes quite obvious that there are no physical documents kept on board either, since it would become pointless when there isn't anyone keeping them up to date. These documents include i.e. the certificate of registry, all safety certificates, the tonnage certificates, the minimum safe manning document, manuals and instructions, bills of lading, the manifest, the crew list, the oil log, the log books, the charts, etc. All of these should most probably to be kept as in digital format, and to be able to be submitted to port officials for inspection when so requested. There would be need for a new official report of who acts as shore-based controller of the vessel, and to be made compulsory that these persons have the most recent digital charts. New regulations will be necessary to achieve that all the documentation and acts of shore-based controllers is kept in digital form. The modern maritime law already includes rules about Voyage Data Recording (VDR), but these rules would also need revising for making the actions of shore-based controller, and also the data available for him, accessible when needed, i.e. when investigating an accident. But when we consider all this information being very important, so do we also have to care about the accessibility and conditions subject to which it may be used, i.e. in connection with the protection of personal data. (Van Hooydonk 2014, The law of unmanned merchant shipping – an exploration)

### 5.4.4 Pilots role

The status of pilot is defined in local regulations, not in any general international convention. Classically the pilot is regarded as an advisor with local knowledge, who assists the master on board with advice about navigation in the pilotage waters in the approaches to ports and in waterways. Efficient pilotage is a sum of effectiveness of communication and information exchanges between master, pilot and other bridge personnel, and the mutual understanding of each's functions and duties amongst each other. There are also already places where the

pilot gives his advice from the shore by means of radio communications. In those cases, the pilot still acts as an advisor. It is still too early to debate how the pilotage concerning unmanned ships is going to be work, because as said it's mainly in the hands of the nations of the ports of calls of the vessels. This is also one key stepping stone among other local laws and regulations which prevents immediate and worldwide introduction of unmanned vessels. Most likely the possible growth of unmanned merchant shipping will change the nature of pilotage services and the profession of pilots, but the direction of these developments depends largely on how the technology develops. Anyway, the is no doubt that a shore-based controller will benefit from the assistance of a local guide. Another problem arising in pilotage is command of towing, if it's used. As maritime law now stands it's usually the master of the seagoing ship, which is being towed. If the current arrangement is going to be used with unmanned vessels, contractual clauses, national laws and local regulations are going to be needed adjusted also in that matter. (Van Hooydonk 2014, The law of unmanned merchant shipping – an exploration)

## 5.5  Liabilities

### 5.5.1  Individual and criminal liability

Currently any breaches of navigational and port regulations are subject to criminal sanctions, meaning that breaching these regulations or prohibitions imposed by the harbor master or other authorized port personnel may result in fines, imprisonment and/or the detention of the ship. The effective authority of the regulations and the competent officials is formed with this sanctioning mechanism, so the situation could become very confusing with unmanned vessel involved in some breach of these rules: the owner of the ship and the shore-based controller are not on board, but located in some far-away country possibly, or even maybe the ship might not have a controller at the time and be acting entirely autonomously. Finding the party or person to be punished in these kind of situations is going to be really hard, since punishing i.e. the programmer of the autonomous ship would be pointless. One possibility to resolve these kind of problems is reorganization so that the port authority, or one or more service providers with clearly designated natural persons, can take control of the ship and guide it in and out of the ports. This could mean a new kind of pilot who would remain in a shore station guiding the ship in, or at least supervising it, and being able to take direct action if and when necessary. This would mean that new international and national regulations on

the qualifications, training, certification, refresher training, task and liability of such shore-based operators would become necessary. (Van Hooydonk 2014, The law of unmanned merchant shipping – an exploration)

Generally, the normal rules of liability can continue to function as long as there is: 1. a traceable path of control over and responsibility for their employment, 2. recognition of the scope for error or mistake. In the following quotation is arguing about liabilities of unmanned combat surface vessels, but this can be applied also for unmanned merchant vessels.

> *Only when the line of control and/or responsibility becomes uncertain or unidentifiable at law does the governance offered by general principles potentially become fundamentally inadequate. Even in this situation, however, it is not at all clear that because an applicable general principle cannot clearly identify the criminally liable human(s), it then necessarily follows that there is no responsible human. Just because – in a future of completely autonomous unmanned combat surface vehicles (UCSV) – there is no individual who physically pushes the required button which launches missiles at a truck ashore carrying refugees, does not mean that there is no line of responsibility.*
>
> -R. McLaughlin, Associate Professor, College of Law, Australian National University
>
> (Van Hooydonk 2014, The law of unmanned merchant shipping – an exploration)

The logic is quite clear, so the application of existing rules on contractual and extra-contractual liability to unmanned shipping needs further consideration.

It's still quite a bit of an open question how unmanned navigation will be integrated into the ship and crew management industry, but it seems possible that a new service would be developed for offering shore-based vessel controllers. This would mean that new and specific international standard contracts for that sector would be drafted. I.e. because it would seem obvious that the ship manager would reject liability for the mistakes of shore-based controller. New international conventions in this sector won't be needed as the whole subject of chartering and ship management is, to the general satisfaction of all concerned, left to freedom of contract. Nonetheless the national lawmakers shall amend the non-mandatory framework for chartering. (Van Hooydonk 2014, The law of unmanned merchant shipping – an exploration)

### 5.5.2 Incidents at sea

The Collision law seems to be able to stand up well against the arrival of unmanned ships. The 1910 Collision Convention governs the liability for collisions on the basis of the errors

of the ships, rather than the errors of the master and the other crew members, even though these human actions are of course the cause of the collision. These rules also apply when the collision is caused by the error of a pilot, even when the use of pilot's services is compulsory. If a collision is caused by an error of a shore-based vessel controller, nothing will change regarding liability. (Van Hooydonk 2014, The law of unmanned merchant shipping – an exploration)

*"The master of a ship at sea which is in a position to be able to provide assistance on receiving information from any source that persons are in distress at sea, is bound to proceed with all speed to their assistance, if possible informing them or the search and rescue service that the ship is doing so. This obligation to provide assistance applies regardless of the nationality or status of such persons or the circumstances in which they are found. If the ship receiving the distress alert is unable or, in the special circumstances of the case, considers it unreasonable or unnecessary to proceed to their assistance, the master must enter in the log-book the reason for failing to proceed to the assistance of the persons in distress, taking into account the recommendation of the Organization, to inform the appropriate search and rescue service accordingly."*

(SOLAS Convention, Chapter V - Regulation 33 - Distress Situations: Obligations and Procedures)

Above quotation is from the SOLAS (Safe of life at sea) convention, and the regulation establishes a general principle to every ship that the masters have the duty of responding to information of any source about persons in distress at sea. Furthermore, the International Convention on Salvage 1989 states that *"masters of ships who have embarked persons in distress at sea shall treat them with humanity, within the capabilities and limitations of the ship"*. But when we have an unmanned vessel with no souls onboard receiving distress information we might encounter some problems concerning the potential salvage operation: at least at the time of writing this there isn't knowledge are these vessels going to be fitted with any devices or infrastructure that would enable the shore-based vessel controllers to deal with distress situations. It is quite easily understood that that there isn't need for lifesaving equipment, at least not for conventional ones, because there are no humans onboard the vessel who could end up in the sea. So, to be able to rescue anyone from the sea most likely new devices would be needed to be designed, but still then we would face the other factor against the rescuing capacity of an unmanned vessel: there are no sufficient spaces for the rescued persons to stay, neither than anyone to "treat them with humanity".

Most likely, if no special equipment for them to be able to rescue persons in distress are introduced, unmanned vessels will follow the exception of being unable to assist and "the master must enter in the log-book the reason for failing to proceed to the assistance of the persons in distress". (Ortiz de Rozas 2014, The production of unmanned vessels and its legal implications in the maritime industry)

One other possibility however is that the unmanned vessels could be required and act as search-only vessels, because of their better arsenal of technical equipment for finding objects from the sea with i.e. thermal cameras and laser-scanners. This could be timesaving and helpful for the other vessels then to approach and rescue the persons found by an unmanned vessel.

### 5.5.3   Stowaways

It seems like that apart from possible passengers on board an unmanned ship, stowaways would be the only persons who would retain their status in maritime law as it is. Although there might not be any good spaces for hiding and travelling an unmanned vessel with, we can't think that there wasn't any chance of a stowaway boarding this kind of vessel. Stowaway is a person who goes on board without the consent of the shipowner or the master, as stated in 1957 Convention on Stowaways, and IMO's 2011 Stowaway Guidelines. Although no master is present, the absence of permission to go on board is sufficient to class the intruder as a stowaway. Still the current law on stowaways would need some amendments because there would be no master on board either who could take measures on handling them. This leads to questions how the stowaways on board unmanned vessels are to be treated, can there be i.e. physical measures to be taken from a distance. (Van Hooydonk 2014, The law of unmanned merchant shipping – an exploration)

### 5.5.4   Pirates

Also, likewise the stowaways, it would be naïve to assume that there wouldn't be any pirates and terrorists involved in the unmanned vessels' operation. They might even think that these new ships would be softer targets, and bring new players to the scene. In the meaning of the UN Convention on the Law of the Sea it's not so clear that would the hacker of IT systems be a pirate. Possibly the 2005 SUA Convention could be applicable, since it doesn't assume that all acts are committed on board, but it also contains some provisions about the powers of master, which of course again appear impracticable. (Van Hooydonk 2014, The law of unmanned merchant shipping – an exploration)

# 6 Conclusions

## 6.1 Technical

After other parts in this thesis have been written, conclusions are written last. This topic was also new to us, so after research and lots of studying, reading, interviewing people and specialists I think we can determinate what is the situation now for unmanned vessels and their technical risks. Of course, where situation is developing nobody can precise, only sure thing is that when technology is coming now finally huge part of vessels development is really fast.

Result of this of course vessels do not have crews anymore onboard, and lots of jobs are lost to technology, but after all whole point of unmanned vessels are based to economic reasons. Original idea of making trade and shipping has been making money and profits, only change is that these days shipping companies are in many cases part of investment funds so this point of making best possible profit cutting costs is understandable. This is the direction industry is doing to and of course its driven by money.

As situations is today, discussion among seafarers usually is "are autonomy in vessels taking our jobs" but with ordinary people thoughts have mostly been about security. How to avoid risks then? I think that systems included are tested and replicated to get them working 100%. Testing contains risk analysis so possible risks can be pre-known. Also, quality of the ships is very important. Radars, cameras, sensors etc. must be high end quality and still replicated. Also, probably most relevant quality must be in connections, and cyber security, and for now we can say that this is the so far weak part of unmanned vessels.

As both seafarers and ordinary people are thinking these questions, we once again have to remember that unmanned vessels are not fully controlled by themselves and IQ. Still human is adjusting level of autonomy and controlling actions (Figure 4.1.1.3). The shore based master or OOW has the same responsibilities that with manned vessels.

## 6.2  Legal

Laws and regulations are basically the key steppingstones that prevent us introducing unmanned vessels already. Other major part is of course economical approach: although humans can build high-tech space equipment and explore the space, we simply cannot put that kind of investment in designing unmanned vessels for transporting goods at sea. There is no need for that. Even if we could start designing and building an unmanned autonomous ship without any limitations on budget, we would end up fighting against the current legislations governing seafaring, both internationally and nationally. But the latter, national legislation, is much more easily adapted and updated for allowing this to happen. And this means that the first steps of introducing unmanned vessels at sea is going to happen domestically.

According to Nils Haktor Bua from Norwegian Maritime Authority, they have quite free hands for governing how to regulate vessels and operations happening on their territorial waters. And this is what the Yara-Birkeland project is about: transporting goods domestically with unmanned vessel. He also states that since they are only in a way changing some parts from a conventional ship to make it autonomous, there isn't any need at the beginning to make a set of new regulations concerning them. It's easier to just add some new parts to the current regulations and laws. It's also possible to stretch the existing regulations so that e.g. the land based operator could be seen as a replacement of onboard master, as would someone else taking over his position if he is inhibited to do so because of the circumstances. The most important thing doubtless is to determine who is responsible of the vessel and its actions. This has to be regulated before any legal autonomous operation is possible. The testing phases are launched with humans still onboard, so it accommodates the existing regulations. Another quite crucial determination is the basic definition of an unmanned vessel. According to Nils Haktor Bua, this may vary depending on the level of automation the ship is operating. Although he thinks that the current laws and regulations can be amended to allow starting domestic operations, he also thinks that later on, after seeing how the operations are concluded, a new set of regulations specifically for unmanned vessels are needed.

The vessel's link to flag-state issue, shouldn't be too hard to overcome according to Nils Haktor Bua. When on a conventional vessel the master with his crew exercises the flag states law and jurisdiction, on an unmanned vessel this simply should fall to the company owning the vessel, and also to the person operating it from ashore. Still according to Dr. Eric Van

Hooydonk (Van Hooydonk 2014, The law of unmanned merchant shipping – an exploration), it could be a good idea to update the LOSC convention, since otherwise the land based operator would be directly considered as master, although their tasks do not fully match each other's.

One key element steering the formation of new regulations is the area where a vessel is operating. Since this also determines the level of automation a vessel is under, and also the amount of possible risks, it greatly affects the need and strictness of rules governing the operation. From the interview of Nils Haktor Bua we can conclude that whereas an unmanned vessel can easily take care of itself on the open sea, the risks and dangers are higher on high-traffic areas and coastal waters, where for that reason probably more detailed regulations are needed.

One hot topic, at least among seafarers, is how current Collision Regulations (COLREG) enable introduction of unmanned vessels. But from our interviews and references we can easily conclude that it really isn't too big of a stepping stone – technology can replace humans, and on many parts, be even better at things. At the beginning on domestic shipping, these regulations can be stretched so that e.g. lookout can be replaced with sensors like cameras, radars and microphones. Probably later on, when some unmanned shipping is experimented, also the COLREGs are going to be updated, along with some other stuff, cause the rules are quite much behind development overall.

According to Nils Haktor Bua at the beginning these land based operator will be people with master's license, but still of course they need special training to know how the vessels they control work. Preferably also, when starting on domestic trade, they will have pilot exemption licenses, so that they can perform pilotage without need for external pilot. Later when international shipping would be started, it becomes bigger issue. But still, most likely these unmanned vessels would sail between the same ports on permanent shipping line, so the operator could have competency and certificates to perform the pilotage themselves. Esa Jokioinen from Rolls-Royce also mentioned an interesting possibility, that an unmanned vessel could possibly follow a pilot boat, and this could remove the need of a pilot to climb onboard a vessel to steer it safely to it's destination. This same kind of development is also backed up in Finland with introduction of legislative amendments to allow remote pilotage (Ministry of Transport and Communications 2017). This means that whereas a conventional vessel might in the future be able to replace the current form of pilotage with different kind

of navigational aids provided, it would of course also be possible for unmanned vessels if decided so.

Since there is no need for accommodation it's possible to build an unmanned vessel so that there isn't really any possibilities to climb onboard, or enter the vessel unauthorized. Esa Jokioinen thought that there could be some sort of room enabling local controlling, but it wouldn't be like a usual bridge. It can just be some room deep inside the vessel. This kind of model of a hull limit quite much, in addition to have no humans onboard, the salvage possibilities for these vessels. Basically no-one cannot been retrieved from water to safety, so we can assume that the operator in control of unmanned vessel wouldn't have similar responsibilities for salvage than onboard master does. One possibility is of course to launch some sort of lifebuoys or rafts. Later there might be some new regulations which could state i.e. that these vessels had to act as standby vessels providing video, radar pictures, sounds etc. from the scene. The hull shape along with other things also seems to reduce the risks of stowaways: it's hard or impossible to get onboard, and there isn't any place to stay.

## 6.3   Final words

Our findings show that it's possible to start unmanned shipping operations domestic in quite short schedule, maybe in just a few years. The testing phase for a number of projects is already ongoing, and through this testing the technical risks of operation are better found out, and then possible to minimize. Before it's possible to start operations on international waters and between multiple countries a lot of work for setting up a legal framework must be done. On the next MSC session (IMO's Maritime Safety Committee) on May 2018, it's scheduled to review the current international conventions for the purpose of allowing introduction of unmanned vessels (Simonsen Vogtwiig 2017, Maritime law in the wake of the unmanned vessel). Also, later when some operation has been started and experience gained, there is need for making i.e. own part of ISM-code for unmanned vessels. Overall, it's hard to make wide regulations before first seeing how these vessels will develop, since there are so many possibilities. We could expect international operations in about ten year's time, probably around 2030. The purpose of laws and regulations is not to obstruct development, it's to steer it to commonly accepted safe way. And like always: the first accident involving this kind of a vessel, will lead to reviewing and possibly adding and tightening the regulations.

As mentioned, because the era of unmanned vessels is just about to start, our thesis is quite speculative. This subject then will provide more grounds for research and thesis writing later when the operation is started. Then it's possible to look at how these risks and problems have been dealt with, and if new ones have arised. One subject gaining interest among maritime students is going to be of course how the training for land based operators is going to be made. After all as a seafarer the introduction of unmanned vessels can still be seen as a possibility for new kinds of job openings and safer industry, instead of just reducing number of jobs and creating new worst-case scenarios.

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