Safely Navigating the Oceans with Unmanned Ships

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ABSTRACT: Unmanned ships represent the biggest advancement in shipping in decades, but they pose some of the biggest regulatory challenges. This paper focuses on the legal requirements which have to be fulfilled as part of safe navigation. In relation to safe navigation the biggest legal challenges are posed by the International Regulations for Preventing Collisions at Sea, 1972 (COLREGS), the International Convention for the Safety of Life at Sea, 1974 (SOLAS), and the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978 (STCW). The challenges posed by STCW can be avoided by not applying it, though it could be useful in developing regulations for remote control centres. By considering technological developments and remote controllers as fulfilling existing obligations in COLREGS and SOLAS, it becomes clear that unmanned ships can be considered, in law, as capable of navigating as safely as existing ships.

1 INTRODUCTION

Unmanned ships represent the biggest advancement in shipping in decades. They represent a culmination of technological advancements, including navigation and collision avoidance systems. They will transport goods more efficiently and with reduced human error. Therefore, this advancement is being welcomed to revolutionise the industry while improving safety. However, a little more consideration has to be given as to whether unmanned ships fulfil the legal obligations, which were designed for manned ships.

A lot of previous and current research in the industry has focused on the technical challenges primarily, although they have considered the law as well (e.g. Maritime Unmanned Navigation through Intelligence in Networks, and Advanced Autonomous Waterborne Applications Initiative). This paper's primary focus is the law, and what an analysis of the law can indicate as the fundamental areas that engineers can focus on when developing remote and autonomous systems for unmanned ships.

This paper discusses safe navigation in law, and thus will focus on Conventions and not the practice of navigation. The biggest challenges are posed by the International Regulations for Preventing Collisions at Sea (COLREGS), 1972, the International Convention for the Safety of Life at Sea (SOLAS), 1974, and the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), 1978. Each of these Conventions have improved maritime safety, thus unmanned ships must be able to fulfil their provisions, or potentially equivalents, in order to be considered safe enough to operate. This paper will show how selective application, purposive interpretations, remote control, and the use of systems, COLREGS, SOLAS, and STCW will not prevent unmanned ships becoming a reality while ensuring that they are safe. One of the key ways of holding legal obligations fulfilled is by considering the monitoring of the ship on shore through transmitted data from the ship to being equivalent to being on board.

By considering these technological developments as fulfilling existing obligations, it becomes clear that unmanned ships can be as safe existing ships (Rolls-Royce. 2016). Without holding unmanned ships to the same or equivalent obligations they represent a risk that the shipping industry (including the wider stakeholders of society, governance, and legal bodies) is unwilling to accept.

2 STANDARDS FOR SEAFARERS

STCW would appear to create an obvious problem for unmanned ships, as without a master and crew the requirements cannot be met. However, the preferred interpretation is that, since there is not a master and crew on board (Article 1(2)), STCW does not apply to unmanned ships (Veal et al. 2016). For instance, requirements for the master and chief mate in Regulation II/2 are for *"every master and chief mate on a seagoing ship…"* Since there will not be a master or chief mate 'on' the ship this Regulation does not apply.

2.1 *Challenges posed by STCW*

One of the challenges of interpretation avoided by this is Regulation VIII/2 2.1 which requires the physical presence of officers on the navigating bridge. The requirement for physical presence is problematic for an unmanned ship, as there is no officer physically present on the ship's bridge. Although this could be interpreted so that the remote control centre's virtual bridge fulfills this requirement, it is simpler to consider it as not applicable (especially for autonomous ships).

2.2 *Shore control centres*

Additionally, although STCW does not apply to unmanned ships, it may be worth using STCW for examples of some requirements that should apply to shore control centres (with some revisions). For instance, Regulation II/1 requires all officers on navigational watch to have a certificate of competency, as well as other requirements. It would be useful to also require this of remote controllers. At first it may also be useful to require seagoing experience (Regulation II/1 2.2), but as remote control becomes more common thus may not be necessary.

3 SAFETY OF LIFE AT SEA

However, SOLAS is more problematic than STCW. STCW regulates those on board, but SOLAS regulates the safety of life at sea (which extends beyond the master and crew) to create a safe environment for ships to operate.

3.1 *Application of SOLAS*

SOLAS applies *"only to ships engaged on international voyages"* (Chapter 1, Regulation 1(a)) unless it is stated otherwise. It applies widely to 'ships'. Therefore, regardless of the type or purpose of unmanned ships, SOLAS will apply to unmanned ships as it is widely accepted that they are ships (Van Hooydonk. 2014).

There are exemptions mentioned in Regulation 4 of Chapter I of SOLAS. However, the first, concerning ships that do not usually engage in international voyages, is not relevant to this paper. Regulation 4(b) provides on an exemption for a ship with novel features where the regulations would impede research.

Importantly this exemption does not apply to Chapter V: Safety of Navigation. Additionally, if this exemption were to apply to more of SOLAS it only applies to research, which would only be of use when developing unmanned ships, not once they are operating as part of the shipping industry.

3.2 *Application of Chapter V*

Chapter V is the most important chapter in relation to safe navigation. Chapter V applies to *"all ships on all voyages"* and *"all ships means any ship, vessel or craft irrespective of type and purpose"* (Regulations 1.1 and 2.3). Chapter V can also be applied to internal waters if the Administration so decides. Importantly it applies to all voyages, not just international voyages, and thus has wider application than other chapters in SOLAS (under Regulation 1(a) of Chapter 1).

Although the general exemption in Chapter I does not exempt Chapter V from application, there is another exemption in Chapter V, which states: *"The Administration may grant to individual ships exemptions or equivalents of partial or conditional nature, when any such ship is engaged on a voyage where the maximum distance of the ship from the shore, the length and nature of the voyage, the absence of general navigational hazards, and other conditions affecting safety are such as to render the full application of this chapter unreasonable or unnecessary, provided that the Administration has taken into account the effect such exemptions and equivalents may have upon the safety of all other ships. (Chapter V, Regulation 3.2)"*

This exemption would not provide a practical solution to a wide introduction of unmanned ships. Firstly, these exemptions will not be made lightly by Administrations as they have to consider the safety of other ships, so at first when there is not a lot of evidence from unmanned ships operating this will be of greater concern. As the fleet of unmanned ships increases it will also become potentially impractical for Administrations to have to grant the exemptions on an individual basis.

Additionally, as account is taken of proximity to shore, it may be easier to obtain an exemption when far from shore as there are fewer obstacles, or when near shore as closer to aid in an emergency. The factors are considered as to whether they make the regulations 'unreasonable or unnecessary', so any voyage with more navigational risks could be considered as posing too greater risk for the Chapter not to apply. Finally, depending on the nature of the voyage and the type of ship could mean the safety regulations are necessary.

Equivalents for certain regulations will be more appealing to Administrations. Although this will depend on what is considered to be a satisfactory equivalent and the ability of the technology to be a satisfactory equivalent.

3.3 *Ships' routeing*

An important ability for the navigation systems of the ship to have will be the ability to determine a safe route for the ship to take, and routeing aids have developed. However, as they are now, SOLAS provides: *"Ships' routeing systems contribute to safety of life at sea, safety and efficiency of navigation and/or protection of the marine environment. (Chapter V, Regulation 10.1)"*

This regulation considers such systems as an aid, as making a contribution, and thus not the only way of determining the route. Currently, the master and crew are on board to also determine the route. Systems are not currently considered able to replace humans to the extent that it is safer without humans, merely as enhancing the safety of navigation. Therefore, this Regulation does not facilitate the introduction of unmanned ships and would have to amended so that the systems can be relied upon more for remote and autonomous control.

3.4 *Ship reporting system*

The retention of data, and its transmission, is an important factor in developing autonomous and remote control technology as it allows for effective monitoring of what the ship has done, and is doing (Chapter V, Regulation 11.7). The systems are currently seen as contributing to the safety of lives, navigation, and the marine environment. However, such a system does not have to be technological, a log book can be recorded manually, and not in a digital format. The responsibility of reporting to authorities rests with the master of the ship. Thus, it must be asked without a master on the ship, and instead having a computer transmitting automatically to the authority, whether this regulation will be fulfilled. It is possible without a master then Regulation 11.7 does not apply to an unmanned ship. Also, if a person on shore is considered to be the master in a remote controlled system then they can fulfil this duty easily, as it does not state that they must be on board.

3.5 *Manning and language*

Requirements in relation to manning instantly appear to be problematic for unmanned ships by definition, and thus represent a greater challenge than some of the previous Regulations discussed. Regulation 14 provides: *"1 Contracting Governments undertake… all ships shall be sufficiently and efficiently manned. 2 For every ship to which chapter I applies, the Administration shall: .1 establish appropriate safe manning following a transparent procedure, taking into account the relevant guidance adopted by the Organization…"*

The first aspect to note is that it is for the State to determine manning. Therefore, arguably, this issue can be easily resolved if States want to facilitate the introduction of unmanned ships. States could decide that for the systems on board an unmanned ship that the ship is manned sufficiently and efficiently with zero (Veal et al. 2016). This could mean that States that do encourage unmanned ships will become popular flag States.

However, it could be argued that zero manning is not sufficient as there is no crew on board to intervene in a direct manner, nor efficient as personnel would have to be transported to the ship in order to perform maintenance. Although, this seems unlikely to prevent the introduction of unmanned shipping when it is a matter for the State, and a State that wants to encourage unmanned ships will use the former interpretation.

There are some Regulations relating to crewing that do not appear to be very problematic, and represent minor issues when compared to manning, but they also need to be resolved. Regulation 14.3 provides that: *"On all ships, to ensure effective crew performance in safety matters, a working language shall be established and recorded in the ship's logbook… Each seafarer shall be required to understand and, where appropriate, give orders and instructions and to report back in that language…"*

This Regulation does imply that the ship is manned through the term 'seafarer', and thus when interpreting the Regulation this implication should be ignored. A purposive interpretation allows it to be interpreted to be broader and apply to remote controllers as they are those controlling the ship.

In order to comply with SOLAS as much as possible, a working language should be established for the remote controllers within each remote control centre. However, working languages may be more complicated if remote control centres are location specific, and the ship is transferred between remote control centres throughout the voyage, as each centre may not use the same language. Therefore, it may be necessary to establish a working language for all remote control centres. Otherwise unnecessary delay could be caused during an incident resulting in loss.

3.6 *Bridge design*

In determining bridge design, placement of systems and equipment, and procedures, any decisions should aim to provide the navigators etc. with a *"full appraisal of the situation,"* and with the aim of navigating safely in all operating conditions (Chapter V, Regulation 15.1). The same should then apply to the remote control centre, especially those that use a virtual bridge. There should also be safe and effective resource management to ensure that the remote controllers use the bridge as well as a bridge at sea (Chapter V, Regulation 15.2).

The information that the pilot or bridge team use should be accessed conveniently, and continuously available (especially essential information), and be presented clearly and unambiguously in a standardised form (Chapter V, Regulation 15.3). The same standardised form can be used as on current manned ships, the greater challenge is the provision of essential information. Therefore, the transmission time from the ship to remote control centre must be adequate. Although the flow of information may be continuous it may not be effective to act on information that does not reflect the real-time situation of the ship, yet SOLAS requires the bridge to allow for *"expeditious, continuous and effective information processing and decision-making by the bridge team and pilot"* (Chapter V, Regulation 15.5). The best way to minimise this problem would be to improve communication systems and always transfer control to the remote control centre nearest the ship. It may also be necessary to set a requirement regarding how much a time delay there can be between ship and shore. Terminologically Regulation 15.3 could be avoided by arguing that the remote controllers are not the bridge team or pilot, but overall it is more logical to consider them as equivalent to a bridge team and pilot to encourage maximum compliance, so Regulation 15.3 needs to be fulfilled through the development of more 'expeditious, continuous and effective' systems.

If there is not a remote controller, but the ship processes information and makes decisions autonomously, this will need to be performed at the same or better speed and accuracy of the bridge team and pilot. Otherwise developing autonomous systems would be represent a regression in safety, instead of a development as the systems should represent.

The transferring of control from the ship's autonomous systems to shore may also have its own problems. The transfer would have to be instantaneous to avoid the chance of a potential incident developing and not acted upon quickly enough during the transfer.

There would also have to be a comprehensive summary of the situation to inform the new remote control centre quickly when transferring between centres. Firstly, this would have to include any specifics of the ships. Secondly, there would need to be voyage details. Thirdly, information about any incidents or damage that occurred, or the same for any that may be developing or in progress. Also, it is important that transfers do not happen automatically, as a remote control centre could be performing an important manoeuvre that should not be interrupted by the transfer process. There needs to be preparation and communication before, during, and after the transfer, which itself should be instantaneous.

Another aspect of bridge design that is regulated in SOLAS is the avoidance of unnecessary work or distractions that could have a negative impact on the bridge team or pilot (Chapter V, Regulation 15.6). The use of autonomous systems could aid in the minimisation of work to allow the bridge team on shore to be more effective when they do have to make decisions.

Semi-autonomous ships would be ideal for fulfilling the aim in Regulation 15.7, which reads: *"minimizing the risk of human error and detecting such error, if it occurs, through monitoring and alarm systems, in time for the bridge team and the pilot to take appropriate action."* The aim of autonomous systems is to remove a lot of the decisions from humans, so that they do not make an error, and when complemented through a checking and monitoring system on shore, any human error that may have occurred during the programming of the control system should be detected. When humans do need to make decisions on shore, having more than one person and a command structure will allow for the detection of errors in the remote control centre itself.

3.7 *Shipborne navigational equipment, maintenance, and voyage data*

The bridge as whole is not the only problem in relation to Regulations on the design of the ship, but also the equipment on the ship. Regulation 19.2 requires that *"all ships, irrespective of size, shall have"* certain equipment. It could be argued that if the equipment is in a remote control centre on shore then the ship does have equipment (as it has complete access, and is part of the operation of the ship). However, Regulation 19.2 is headed *"shipborne navigational equipment and systems."* The term 'shipborne' implies that it is physically on board the ship. Therefore, it must be considered that this equipment may still need to be on board. Some of the equipment would necessarily have to be on board, for instance a compass, but it is required to be independent of a power supply and this would not be of any use on an unmanned ship as the information could not be transmitted to shore or processed by the ship's autonomous control system (Chapter V, Regulation 19.2.1.2). Therefore, it may be more appropriate to have a different redundancy system for the compass that does involve a power supply.

Regulation 19.2.1.8 requires that when a bridge is enclosed that there is a sound reception system to allow sound signals to be perceived on the bridge, a similar requirement can be made so that sound reception system is required to transmit to a simulated bridge in the remote control centre. This will aid in providing multi-sensory perception, and fulfilling the need for a lookout (COLREGS, Rule 5).

The requirement for ships to have an Automatic Identification System (AIS) includes the requirement that it transmits to equipped shore stations, and ships, and receives information from other ships' AIS. This could function even better if more ships are operated from shore, and all ships are required to have AIS, and there will be more shore centres that receive the information, and then the control centre can directly act on that information.

Some bridge systems on ships are already integrated, as they would be on shore, so Regulation 19.6 requires that they are *"so arranged that the failure of one sub-system is brought to the attention of the officer in charge of the navigational watch by audible and visual alarms and does not cause failure to any other sub-system. In case of failure in one part of an integrated navigational system, it shall be possible to operate each other individual item of equipment or part of the system separately."*

All of the equipment required by Regulation 19 should be *"installed, tested and maintained as to minimize malfunction"* (Chapter V, Regulation 19.6). Maintenance presents one of the greatest challenges to unmanned ships, and the fulfilment of this provision will rely on the sensors and regular maintenance on shore instead of being able to react while at sea.

The provisions for ensuring that the ship is well maintained in Regulation of 16 of Chapter V may be more problematic as it requires that all reasonable steps are taken to ensure that equipment is in efficient working order. Again, there will need to be greater reliance on sensors and checks in port to ensure that the equipment is in working order otherwise it will risk more malfunctioning of the equipment. As on an unmanned ship malfunctioning at sea is more likely to be considered to not be in efficient working order.

The development of Voyage Data Recorders (VDRs) are an important aspect to making unmanned ships feasible, and will keep record of any pertinent information in relation to incidents especially (e.g. equipment malfunctioning, and maintenance required but not performed). In the absence of a crew on board to relay the circumstances and the events of an incident, the independent recording of data is necessary for investigations. VDRs will hopefully provide a more accurate and complete record of events, without the inconsistency of human testimony.

3.8 *Visibility*

In relation to the bridge, there are not just equipment Regulations, there are also provisions in relation visibility. For ships of 55 metres or more in length, there must be an unobscured view of the sea meeting some conditions (Chapter V, Regulation 22.1). Therefore, it is suggested that is replicated in a bridge simulator, to enable remote-controllers to have the same view as though they were on board the ship. This may require the amalgamation of many different camera angles, including those situated where the bridge would have been. The requirements for the view from the bridge windows based on a person's height, may also need to be replicated. Replicating these conditions may also aid seafarers in navigating from shore, as they will be accustomed to that view.

However, it must be noted, that the requirements for the dimensions and framing of the windows on the bridge are not necessary for an unmanned ship, whether controlled remotely or autonomously (Chapter V, Regulation 22.1.9). This can be resolved through the utilisation of the exception that allows the Administration to permit an alternative deign that allows for *"a level of visibility that is as near as practical to that prescribed in this regulation"* (Chapter V, Regulation 22.3). The cameras can provide for the same level of visibility for the form of control utilised without windows, which would not be practical to include when they do not in fact aid visibility in a remote control centre.

3.9 *Pilotage*

If a ship would currently utilise pilotage, then it is subject to Regulation 23 of Chapter V. However, it is thought that pilotage would operate differently as remote control develops, so that the ship is transferred to a local remote control centre, so that a pilot with local knowledge can navigate the ship for that part of the voyage (Maritime Unmanned Navigation through Intelligence in Networks. 2015).

3.10 *Track control systems*

There are many different systems that will contribute to the safe navigation of unmanned ship, which will be utilised by the equivalents of the master, crew, and pilots – one of which is the track control system. Regulation 24.1 provides that: *"In areas of high traffic density, in conditions of restricted visibility and in all other hazardous navigational situations where heading and/or track control systems are in* *use, it shall be possible to establish manual control of the ship's steering."* This Regulation may be problematic, given that 'manual control' implies a person on board the ship to physically take control. It is possible to interpret the Regulation, so that as long as remote control, with full control for each decision being made by the remote controller, is possible then manual (remote) control is possible. In order to fulfil this Regulation, it is also important that control is taken 'immediately': this does not mean instantaneously, for instance even if an officer on the bridge were to take control it would not be instant, as they would have to move, make decisions etc. Therefore, as long as the communication systems allow the remote controller to take control quickly, make decisions, and implement them through communications systems then this provision could arguably be met.

Regulation 24 goes on to provide that the officer on watch will have to be *"available without delay the services of a qualified helmsperson who shall be ready at all times to take over steering control."* Therefore, in addition to the measures to ensure compliance with subsection 1, the remote control centre will have to have a qualified helmsperson available.

If a ship is generally controlled by an autonomous system, and remote control is available as a redundancy measure and available to take control in such hazardous navigational circumstances, then this transfer of control shall be supervised by a responsible officer in the remote control centre (Chapter V, Regulation 24.3). In addition, the Regulation requires the testing of the manual steering after using heading and/or track control systems for a prolonged period, or prior to navigating in an area that is known to require caution (Chapter V, Regulation 24.4). This aids in ensuring the readiness of manual control at those times, and when a hazardous navigational situation arises unpredictably. Therefore, control would have to be taken on a regular basis to test the system that changes the method of control.

3.11 *Instructions*

In order to ensure that manual control is taken of steering gears and their power units, Regulation 26.3.1 requires that instructions are displayed on the bridge, and in the steering compartment. This Regulation may not be possible to entirely fulfil. The instructions could be posted in the remote control centre, as equivalent to the bridge. Although instructions technically could be in the steering compartment, the steering compartment would not have the ability to take manual control, so it would serve no practical benefit.

Although ships could still be constructed, so that they can be controlled manually on board, which would then favour the posting of such instructions on the bridge, in the steering compartment, and additionally in the remote control centre; this writer does not favour this suggestion, as it would invite pirates to take physical control of the ship without a people on board to resist them. This would be an additional safety risk that should not be taken, especially when all ships, not just new unmanned ships, will need to have heightened cyber-security to prevent piracy through hacking.

As smarter ships develop, pirates will use smart technology, they may even venture into new areas of the oceans and target more ships. It is conceded that it may be possible to counter this through remote control overrides, but if the pirates sever the communication link they could take manual control as it would be favourable to allow autonomous control in general to override manual control (as it has been argued that it would be there for emergencies, and when autonomous control is not sufficient). Additionally, pirates may target the remote control centres to take remote control easily, or target multiple ships.

3.12 *Communicating with other ships, and distress*

When there is a danger or if it is voyage that is in an icy area the chance of danger is higher, there may be times when there is a danger to navigation, so the ship must be able to communicate this danger to all other ships in the area and the relevant authorities (Chapter V, Regulation 31.1). Therefore, they will need to be able to communicate with all types of unmanned ships, as well as manned ships.

It will be easiest to communicate with ships that utilise remote control centres, as soon as the information reaches the centre it can be disseminated between centres (and the information applied on the ships). However, communicating with manned ships will be more difficult, unless a remote control centre controls a means of communicating through sound and visual signals on the ship. Another solution would be to require a common method of communication on all ships that the ship can automatically relay information through to all types of ships.

It is well documented that the requirement to provide assistance to other ships in distress is another challenge for unmanned ships (Veal et al. 2016). Regulation 33.1 states: *"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…"*

Most unmanned ships will not be in the 'position to be able to provide assistance', due to the lack of facilities and persons on board to aid those in distress, and will not be bound to provide assistance. Therefore, most unmanned ships will simply be required to record the information (having processed it by whatever means), and potentially forward it to other ships, and search and rescue.

3.13 *SOLAS Chapter V and beyond*

This section has focused on some of the regulatory challenges posed by Chapter V of SOLAS. However, there are many additional challenges in SOLAS and other sources of maritime law. For example, Regulation 5 of Chapter IX of SOLAS requires that *"the safety-management system shall be maintained in accordance with the provisions of the International Safety Management Code."* The challenges posed the International Safety Management Code (last amended in 2014), as worthy of considerations especially in relation to safety, but it is not within the scope of this paper.

4 COLLISION REGULATIONS

COLREGS are also well-known to be problematic for all unmanned ships, as Chapter V of SOLAS is, because it is so important for the shipping industry and safety for it to apply (Veal et al.). COLREGS applies to *"all vessels upon the high seas and in all waters connected therewith navigable by seagoing vessels"* (Rule 1(a)). And vessel is defined as *"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"* (Rule 3(a)). This definition is sufficiently wide to encompass unmanned ships.

4.1 *Exemptions*

Since COLREGS applies, it is important to consider whether there is an exemption. The definitions of vessels that would be exempted in Rule 3(g)-(h) would not exclude unmanned ships by definition of being unmanned, but if their work or draught was such to constrain them.

Rule 3(f) refers to a *"vessel not under command,"* but an unmanned ship would not be classified as such (although the terminology would appear superficially to be appropriate for an autonomous ship), as it is not due to an *"exceptional circumstance"* but the design of the ship.

There is an exception for vessels of a special construction or purpose in relation to lights, shapes, or sound signals, but the ship must comply as closely as possible with the Rules (Rule 1(e)). Close compliance with ordinary practice of seamen could be achieved by having seamen as the remote controllers.

Departure from the Rules is also allowed if *"necessary to avoid immediate danger"* (Rule 2(b)). However, this exception is allowed for danger, and special circumstances, including the limitations of the vessel. Therefore, although this exception is not applicable generally as the danger would be due to the design of the vessel it is allowed to be a contributing factor if there is danger by other means (Rule 2(b)).

4.2 *Perception of vessels, and keeping a lookout*

Some of the issues posed by COLREGS will now be discussed, since it has been established that there is no broad exemption for unmanned ships. Rule 3(k) deems vessels *"to be in sight of one another only when once can be observed visually from the other."* It must be considered whether the lack of a crew on any unmanned ship, means since there is no direct visual perception that such ships cannot be in sight. However, a better interpretation is to focus on the 'can' in the Rule, it does not require observation in fact, and 'observed visually' can be interpreted broadly to include the use of cameras relaying the information to shore or through the autonomous control system (and thus it becomes an issue of when the cameras and sensors observe other ships, and they must be able to observe as well as a human on the other ship to avoid confusion and collisions).

Rule 5 requiring a lookout by sight and hearing is considered to be a problematic requirement if it is interpreted narrowly, as 'sight and hearing' indicate a person as opposed to visual and audio. However, it is usually interpreted so that as long as there is an equivalent to sight and hearing then it is fulfilled (Veal et al.). Importantly, this is not just sight, and although a lot of discussion focuses on cameras and sensors, there must also be that audio element in the perceptive tools of an unmanned ship.

4.3 *Making decisions and determining risk*

COLREGS considers decision making, as well as perception in relation to preventing collisions. Rule 6 requires a judgement decision to be made in determining a safe speed, taking various factors into account. This process will be the same for the remote controller as it is for the master and crew. For autonomous unmanned ships it leads to the question of how an autonomous system will be programmed to make that decision. This does highlight the need for the ship not just to follow a pre-programmed list of responses, but collect data and make a decision based on that data, responses available, and wider information of the potential implications of those responses. This solution is also relevant for the section for ships in sight of one another (Part B, Section II).

In determining if there is a risk of collision *"all available means shall be used,"* and thus is wide enough not to require a crew (Rule 7). Rule 7 specifically refers to radar to ensure that it is used properly, and that assumptions should not be made from *"scanty information, especially scanty radar information."* This indicates a certain amount of scepticism regarding the reliability of radar, which will be more relied upon on unmanned ships as will other forms of technology.

One of the most important provisions in COLREGS for decision making concerns the duty of good seamanship. Rule 8(a) includes the duty to act with *"due regard to the observance of good seamanship."* This is especially problematic in relation to unmanned ships that are controlled autonomously as this duty cannot be programmed directly, and avoiding violations of the Rules in COLREGS may not be sufficient (Veal et al. 2016). The system can be programmed to act in accordance with the law, details on manoeuvres, and only to act differently when permitted by the law, and this may need to considered sufficient.

4.4 *Restricted visibility*

The lack of people on board, especially for autonomous ships can be considered as disabling the ship (at least as it is currently perceived). This is especially true when considering the duty of good seamanship above. This approach means Rule 19 for the conduct of vessels in restricted visibility could be relevant, as it could be argued that without people on board visibility is restricted, as the most established means of perception is not available. However, the changes in conduct that it would involve for conditions that are not present, and thus would lead to confusion and increase the risk of a collision.

4.5 *Lights, Shapes, Sounds, and Signals*

There are some issues with unmanned ships are purely practical, and although not in COLREGS would create a problem with compliance. For instance, if a bulb is blown this cannot be detected or remedied at sea, and thus the light signals will not comply with COLREGS' Rules on light and sound signals (in Parts C and D).

There have been recommendations to create new light signals for smaller unmanned craft to exhibit when not practical to exhibit ordinary lighting, which could be extended to exhibit not the inability comply with all provisions due to being unmanned and small, but simply as an unmanned ship (Norris 2013). Although unmanned ships should comply with COLREGS generally, this will make other users of the seas aware that the ship will be doing so differently and can encourage caution. Other writers have raised concerns that it will encourage other ships to violate the law as the unmanned ship will have to react, this writer suggests that this can be avoided through strong penalties for such behavior. Greater awareness will be especially useful when they are first introduced and there is more concern about how they will operate and interact.

5 CONCLUSIONS

This paper has considered three of the most important Conventions in shipping generally: STCW, SOLAS, and COLREGS.

STCW is the easiest of the three to apply to unmanned ships in the fact that it is not applicable as there is no one 'on board'. However, it has been noted that its provisions on qualifications and experience in particular may be useful when developing Regulations for remote controllers.

SOLAS, however, is more complicated to apply to unmanned ships. The requirement for manning can be resolved by the State determining that zero manning is sufficient and efficient. Other Regulations in SOLAS will depend more directly on the technology: e.g. transmitting data adequately, allowing for instant control changes etc. Thus, the analysis in this paper will hopefully encourage technical development

Finally, COLREGS poses its greatest challenge in the duty of good seamanship to autonomous ships. Other challenges can be resolved by considering the technology as equivalent to a person or a person onshore as equivalent to one at sea, which relies to the technological development (as SOLAS does). The suggestion for lights to indicate that the ship is unmanned will aid in ensuring safe navigation in relation to COLREGS, but also SOLAS.

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