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Abstract

International shipping is on the eve of a new era where remotely controlled and partially or fully automated and unmanned Maritime Autonomous Surface Ships (MASS) will be carrying international trade. The regulation of navigation and shipping in the contemporary international law of the sea and international maritime law are premised on human presence and control on-board ships. Provisions of the United Nations Convention on the Law of the Sea, 1982 and several maritime conventions will need to be revisited to determine how MASS may be accommodated, and where not possible, what further legal development may be needed. Recently, the IMO decided to address the expected regulatory impacts of these ships and to prepare an agenda for their proactive regulation. This article explores regulatory impacts that would need to be considered and argues that MASS have the potential to provide new directions for international law and the IMO.

Keywords

International Law of the Sea, International Maritime Law, International Maritime Organization, Maritime Autonomous Surface Ships, Unmanned Ships

I. Introduction

In recent years, research in artificial intelligence and ship technology has advanced to such an extent as to pave the way for partial or full autonomous commercial shipping. Technology has always been at the centre of shipping regulation and is frequently a major driver for new

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standards. Recent technological and commercial triggers are leading major industry actors to explore different degrees of remotely-controlled ship voyages[1] and autonomous ship operations for the near future.[2] Some port operations appear to be also planning to embrace automation.[3] The absence of a crew on a vessel, *per se,* is not a new development, as unmanned towed barges and remotely operated submersibles for research and offshore petroleum development have long been in use. What is new is a combination of passive presence or even absence of on-board crew, remotely-controlled ships, and partial or full autonomous decision-making through instrumentation. These technologies are anticipated not only for new builds, but also for vessels retrofitted for remote control operations.[4] The range of ships affected is diverse.[5]

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[1] Rolls-Royce and towage company Svitzer claim to have performed the first remotely-controlled vessel operation. See *Anon.,*World's First Remotely-Controlled Commercial Vessel Put to the Test in Copenhagen, gCaptain, 20 June 2017, available at: http://gcaptain.com/worlds-first-remotely-controlled-commercial-vessel-put-to-the-test-in-copenhagen/?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+Gcaptain+%28gCaptain.com%29 (accessed on 18 September 2017). *Wei Zhe Tan,* NYK aims to pilot remote-controlled boxship in 2019, Lloyd's List, 24 August 2017, available at: https://lloydslist.maritimeintelligence.informa.com/LL111056/NYK-aims-to-pilot-remotecontrolled-boxship-in-2019 (accessed on 14 December 2017). See also *Michelle Howard,* Wärtsilä Tests Remote Control Ship Operating Capability, Marine Link, 18 September 2017, available at: https://www.marinelink.com/news/capability-operating428998?utm_source=MT-ENews-2017-09-01&utm_medium=email&utm_campaign=MT-ENews (accessed on 18 September 2017).

[2] The Unmanned Cargo Ship Development Alliance plans to deliver the first unmanned cargo ship in 2021. The Alliance is led by Chinese HNA Technology Group Co and includes CCS, China Ship Research & Development Institute, Shanghai Marine Diesel Engine Research Institute, Hudong-Zhonghua Shipbuilding (Group) Co., Marine Design Research Institute of China (MARIC), Rolls-Royce, Wärtsilä, and the American Bureau of Shipping (ABS), *Anon.,* ABS Joins Alliance Developing Unmanned Cargo Ship, gCaptain, 26 July 2017, available at: http://gcaptain.com/abs-joins-alliance-to-develop-unmanned-cargo-ship/ (accessed on 14 December 2017). A 120 Twenty-foot Equivalent Units autonomous open top fully-electric and zero emission container ship is under construction, see Kongsberg Maritime, Autonomous ship project, key facts about YARA Birkeland, available at: https://www.km.kongsberg.com/ks/web/nokbg0240.nsf/AllWeb/4B8113B707A50A4FC125811D00407045?OpenDocument (accessed on 18 September 2017). Bourbon, Automated Ships Ltd, and Kongsberg Gruppen ASA plan to build autonomous offshore service vessels, see *Anon.,* Bourbon Joins Project to Build World's First Autonomous Offshore Vessel, gCaptain, 11 July 2017, available at: http://gcaptain.com/bourbon-joins-project-to-build-first-autonomous-offshore-vessel/ (accessed on 18 September 2017).

[3] *Anon.,* VCIT world's first fully automated container terminal: Cargotec, Canadian Shipper, 11 September 2017, available at: https://www.canadianshipper.com/transportation-and-logistics/vcit-worlds-first-fully-automated-container-terminal-cargotec/1003374728/ (accessed on 18 September 2017).

[4] *Alan M. Weigel/Sean T. Pribyl,* The Future Is Now: Unmanned and Autonomous Surface Vessels and Their Impact on the Maritime Industry, Mainbrace, June 2017, 22, 23, available at: http://www.blankrome.com/siteFiles/Publications/Mainbrace_June_2017.pdf (accessed on 18 September 2017).

[5] In particular, the carriage of bulk cargoes is expected to be a prime candidate for autonomous ships, see *David Stringer,* Autonomous Cargo Ships Extend Miner's Technology Drive to Seas, gCaptain, 7 June 2017, available at: http://gcaptain.com/autonomous-cargo-ships-extend-miners-technology-drive-seas/?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+Gcaptain+%28gCaptain.com%29 (accessed on 18 September 2017). However, automation on containerships is also anticipated. NYK is reported to be planning to test remote controlled steering of a boxship with a stand-by crew, *Anon.,* NYK to Test Autonomous Box Ship in the Pacific Oceans in 2019, World Maritime News, 25 August 2017, available at:

The history of international maritime law is punctuated by game-changing technological milestones. This is not surprising as the ship is a platform for varied instrumentation, with the consequence that technological development serves to enhance ship function and operations and, in turn, rules and standards for safety, security, and environment protection. The advent of the modern cruise liner and early ship losses, most especially the *Titanic*, led to the adoption of the first convention on safety of life at sea.[6] In the mid-19th century, the first rules of the road were introduced as a result of the introduction of the steam engine in shipping and the need to reduce collisions at sea. Following the Second World War, the widespread introduction of radar on commercial vessels led to numerous radar-assisted collisions which resulted in important changes in the application of the rules of the road.[7] During the same period, on-board freezer technology enabled the transportation of refrigerated cargoes and in the process produced new trades.[8] Within a short period thereafter, the advent of the supertanker and containerisation revolutionised the carriage of goods in bulk and packaged form. The increased use of tankers led to far-reaching vessel-source pollution regulation in both the public and private law spheres. This extended to construction and operational requirements[9] as well as liability regimes.[10] Container vessels transformed maritime trade and multi-modal carriage of cargo.[11] More recently, with the receding of summer sea ice as a result of climate change and growth of shipping in polar regions, new rules for the construction, equipping, crewing, and operations for vessels navigating those waters have been adopted.[12] The technology of shipping has driven much of the *opus* of the

http://worldmaritimenews.com/archives/228202/nyk-to-test-autonomous-boxship-in-2019/ (accessed on 18 September 2017).

[6] Eventually leading to the current iteration, the International Convention for the Safety of Life at Sea, 1 November 1974, UNTS 1184, 2 (SOLAS Convention).

[7] In particular the rules on look out and safe speed. Arts. 5-6 Convention on the International Regulations for Preventing Collisions at Sea, 20 October 1972, UNTS 1050, 16 (COLREGS).

[8] See *Stanley H. Beaver*, Ships and Shipping: The Geographical Consequences of Technological Progress, Geography 52 (1967), 133.

[9] Primarily under the International Convention for the Prevention of Pollution from Ships, 2 November 1973, UNTS 1340, 184, as amended by the Protocol Relating to the International Convention for the Prevention of Pollution from Ships of 1973, 17 February 1978, UNTS 1340, 61 (MARPOL). Annex 1 includes standards and rules for construction and discharge of oily wastes from tank washing at sea.

[10] In particular the following: International Convention on Civil Liability for Oil Pollution Damage, 29 November 1969, UNTS 973, 3 (CLC Convention); International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage, 18 December 1971, UNTS 1110, 57 (IOPCF Convention).

[11] See *Marc Levinson*, The Box: How the Shipping Container Made the World Smaller and the World Economy Bigger (2006).

[12] International Association of Classification Societies (IACS), Requirements Concerning Polar Class (2011), available at: http://www.iacs.org.uk/document/public/Publications/Unified_requirements/PDF/UR_I_pdf410.pdf

International Maritime Organization (IMO), a specialised agency of the United Nations and the competent organisation with respect to international shipping.[13] Maritime autonomous surface ships (MASS) have the potential of triggering new regulatory responses and the IMO is yet again expected to lead that exercise.

Across the field of maritime regulation, a source of constant concern is the human factor in vessel operations. Autonomous shipping has the potential to substantially reduce or even remove the human factor in the operation and navigation of the ship, relegating it to a passive or temporary on-board presence and even to fully shore-based monitoring and controlling role. The role of automation ranges from support to human decision-making to autonomous decision-making. In setting standards and rules for shipping, maritime regulation has frequently been concerned with the influence of human decision-making and conduct, by employing technologies and processes to produce safety, environmental, and security outcomes. Autonomous shipping has the potential to transfer human assessment and decision-making to artificial intelligence. This entails the use of "algorithms, tools and techniques that mimic human learning to solve specific problems" and "to recognize patterns in data, making predictions from previously unseen data."[14] These systems will be able to generate and compute more data and significantly enhance situational awareness, but will they be a replacement for human judgement?

(accessed on 18 September 2017). The IACS polar class requirements are implicitly adopted in the Polar Code, Part I-A para. 1.2.10. The Code and related amendments to international conventions were adopted in stages: Maritime Safety Committee (MSC), International Code for Ships Operating in Polar Waters (Polar Code), MSC Resolution 385(94) of 21 November 2014, Report on its 94th Session, IMO Doc. 94/21/Add.1 (27 November 2014), Annex 6; *id.*, Amendments to the International Convention for the Safety of Life at Sea of 1974, as amended, in *ibid.*, Annex 7. For a consolidated online edition of the Polar Code, see International Code for Ships Operating in Polar Waters, available at: http://www.imo.org/en/MediaCentre/HotTopics/polar/Documents/POLAR%20CODE%20TEXT%20AS%20ADOPTED.pdf (accessed on 18 September 2017).

[13] The UNCLOS designates the IMO as the competent international organization with respect to international shipping in numerous provisions. These are listed in 'Competent or Relevant International Organizations' under the United Nations Convention on the Law of the Sea, Law of the Sea Bulletin 31 (1996), 79 at 81 et seq.

[14] "Machine Learning is a set of algorithms, tools, and techniques that mimic human learning to solve specific problems. By analyzing existing data sets, machine learning can be used to recognize patterns in data, making predictions from previously unseen data. The bigger the data set, the more complex the patterns the model can recognize and the more accurate the predictions.", *Anon.*, Rolls-Royce to Use Google Machine Learning in Quest for Autonomous Ships, gCaptain, 3 October 2017, available at: http://gcaptain.com/rolls-royce-to-use-google-machine-learning-in-quest-for-autonomous-ships/ (accessed on 3 October 2017).

There are good reasons to believe that unmanned and autonomous ships will not be technologies of passing interest. There is a discernible declining interest in seafaring careers with consequent trend towards shortage of seafarers. As ships have grown bigger, crews have become smaller, working long hours and frequently performing tedious tasks, and having little if any time for port visits because of fast cargo turnaround and security reasons. Crewing costs are one of the most significant elements in a ship's cost structure.[15] Without a crew (at least permanent) and in the absence of need of full crew quarters and design to enable safe movement on board, the autonomous ship will be lighter and cheaper to build. Most passageways for crews will be removed. Crew quarters will be minimised and perhaps even removed. When needed, crew space may be containerised and installed temporarily into the ship. The bridge as conceived in contemporary ships will be smaller and simpler. In addition to saving on crew salaries, there will be savings on crew supplies and energy. The ship will have a slick design and will be equipped with a complex array of sensors and instrumentation. Its design and absence of crew will make it difficult for pirates to board. It will likely be navigated more accurately and consequently with fewer errors, if any, than crewed vessels. It will consume less energy and produce fewer greenhouse gas emissions. However, the deployment of autonomous ships could produce new concerns, in particular with respect to the interaction with crewed ships in their vicinity and cyber security.[16]

The IMO's Maritime Safety Committee (MSC) has heeded a recent call to launch a regulatory scoping exercise with respect to 'maritime autonomous surface ships' (MASS), the term used in this article to capture the emerging technologies of unmanned and autonomous ships.[17] A multi-Member State submission highlighted the undesirability of leaving the regulation of autonomous ships to the national level in the absence of an appropriate

[15] In 2015, crew costs were the third highest cost at 17% after ship finance and competition costs, each at 22%. See *Anon.*, Ship Operating Costs Set to Rise, Maritime Executive, 30 October 2015, available at: http://maritime-executive.com/article/ship-operating-costs-set-to-rise (accessed on 18 September 2017).
[16] The concern is that autonomous ships may become targets for hackers. In the recent hacking of MAERSK, the company is reported to have lost $200-300 million. Danish insurer Tryg predicts that 90% of its clients will buy cyber insurance, *Stine Jacobsen*, Rising Hacker Threat Will Trigger Boom in Cyber Crime Insurance, Tryg Says, Reuters, 4 October 2017, available at: https://www.reuters.com/article/us-tryg-cyber/rising-hacker-threat-will-trigger-boom-in-cyber-crime-insurance-tryg-says-idUSKCN1C91MV (accessed on 4 October 2017).
[17] MSC, Report of the Maritime Safety Committee on its 98th Session, IMO Doc. MSC 98/23 (28 June 2017), 79.

international framework.[18] After all, as 'the competent international organisation' with respect to international shipping matters, it is the responsibility of the IMO to develop and maintain the international standards and rules necessary for safe navigation. The IMO has been requested to identify regulations which preclude unmanned operations, regulations that do not apply to unmanned operations because of the absence of a crew, and regulations which do not preclude unmanned operations but which may need to be amended to take into consideration the operation of MASS.[19]

Against this backdrop, it is appropriate to enquire whether the advent of MASS requires mere incremental or adaptive regulation, or rather constitutes a game-changer requiring substantial new regulatory directions, and further what might be consequences for the international law of the sea with respect to provisions concerning navigation. This inquiry explores what could or should be expected regulatory impacts when the human factor is reduced or eliminated from decision-making with respect to ship operations where traditionally human presence and control are presumed, required, and regulated with attendant legal consequences. There is an emerging body of scholarship on the public and private law aspects of the subject and it raises important questions with respect to the potential impacts in both fields.[20] The focus of this article is on public law aspects. This author argues that MASS have the potential to provide new directions for international law and the IMO. As the MSC embarks on its scoping exercise during the expected four sessions, this article explores the extent to which MASS are or can be accommodated in contemporary regulation and explores areas of potential direct and indirect

[18] Maritime Autonomous Surface Ships Proposal for a Regulatory Scoping Exercise, Submitted by Denmark, Estonia, Finland, Japan, the Netherlands, Norway, the Republic of Korea, the United Kingdom and the United States, IMO Doc. MSC 98/20/2 (27 February 2017) (MASS Scoping Exercise). See also Impact of New and Advancing Technologies to Maritime Transport and the Regulatory Framework, Submitted by Denmark, Estonia, Finland, Japan, Norway, Singapore, Sweden and IMarEST, IMO Doc. MSC 98/22/7 (28 March 2017).
[19] *Ibid*.
[20] For example: *Eric Van Hooydonk*, The Law of Unmanned Merchant Shipping: An Exploration, Journal of International Maritime Law 20 (2014), 403; *Paul W. Pritchett*, Ghost Ships: Why the Law Should Embrace Unmanned Vessel Technology, Tulane Maritime Law Journal 40 (2015-2016), 197; *Hannah Stones*, Objective and Subjective Safety in Unmanned Shipping, Shipping and Trade Law (STL) 16 (9) (2016), 4; *Trudi Hogg/Samrat Ghosh*, Autonomous Merchant Vessels: Examination of Factors that Impact the Effective Implementation of Unmanned Ships, Australian Journal of Maritime and Ocean Affairs 8 (2016), 206; *Michal Chwedczuk*, Analysis of the Legal Status of Unmanned Commercial Vessels in U.S. Admiralty and Maritime Law, International Journal of Machine Learning and Cybernetics 47 (2016), 123; *Robert Veal/Michael Tsimplis*, The Integration of Unmanned Ships into the *Lex Maritima*, Lloyd's Maritime and Commercial Law Quarterly (2017), 303; *Robert Veal*, Unmanned Ships on the IMO Work Agenda, STL 17 (5) (2017), 1.

impacts. The article concludes with reflections on how well-positioned maritime regulation is, or is not, with respect to the withdrawal of the human factor from shipping in favour of automated systems and the possible implications for further legal development.

II. Technology and Terminology

While the term used in this article is MASS, the terminology of autonomous ships is not yet settled. The term 'MASS' appears in the initial discourse at the IMO, whereas industry circles and scholarly literature have used other diverse terms, including 'unmanned surface vessels', 'autonomous unmanned merchant vessels,' 'robot ships', 'crewless ships', 'unmanned ships', and 'automated ships', among others. In considering how MASS will impact contemporary maritime regulation, an early task for the IMO will be terminological clarity and consistency. Terminology has already triggered varying views, with some Member States preferring to define the term to clarify the scope of the Organization's future work, whereas others preferred to leave definitional matters to a later stage.[21]

Automation in shipping is not a complete novelty. Various aspects of a ship's operations have been subject to automation for some time, such as automatic course-setting and certain machinery functions in the engine room. MASS will navigate partially or fully without a master and crew on board and with its control emanating from an automated system or through remote means. The ship will be equipped with instrumentation and software programmes that will ensure its accurate location, using global positioning (GPS) and automatic identification system (AIS) transmission, and perform various functions. It will have situation awareness through sensors and cameras that will serve as its eyes and ears, sensing the presence of other vessels, as well as the usual radar so as to navigate in compliance with the rules of the road.[22] The vessel will be generating and receiving digital data *via* satellite communication. Algorithms will be at heart of computerised autonomous decision-making for safe navigation. This technology may be

[21] MSC (note 17), 79.
[22] *Thomas Porathe/Johannes Prison/Yemao Man,* Situation Awareness in Remote Control Centres for Unmanned Ships, paper presented at Human Factors in Ship Design & Operation, London, 26-27 February 2014, available at: http://publications.lib.chalmers.se/records/fulltext/194797/local_194797.pdf (accessed on 18 September 2017).

employed to assist the crew on board or even to replace them, whether temporarily or for much of, if not the whole voyage.

The term 'unmanned' does not necessarily entail the total absence of human intervention in the navigation and operation of the vessel at sea. A concept advanced by a major research project considers how the technology may be introduced with respect to bulk cargo carriage and with safety outcomes at least comparable to manned ships.[23] As bulkers have long voyages usually without multiple port cargo drops, they would need a temporary crew and pilot only during the port approach, berthing, and de-berthing. The long unmanned voyage would be monitored remotely from a shore based control centre. Thus the ship may operate autonomously for periods of time, but humans will be on standby for ready intervention if or when needed, or the vessel may be remotely controlled and operated when needed.

Differently from the autonomous vessel, the remotely controlled vessel is directed from a shore base. Thus, the traditional fully manned vessel and the concept of the fully autonomous ship are two ends of a spectrum along which there is a range of vessels with differing degrees of manning, remote control, and automation. A Danish study from an engineering perspective describes the degrees of ship automation beyond manual navigation to include, in order of increasing intensity, automatic course steering (on autopilot on the basis of a human encoded course), decision-support (the system provides information for a human decision), remotely operated navigation (off-board instructions for autopilot and machinery), remote monitoring (full off-board situational ship awareness – radar, digital, TV-monitoring – to enable remote controlled navigation), partial autonomy (on-board partial decision-making autonomy to inform on-board/off-board officer of navigation decisions), and full autonomy (full situation awareness, assessment, and decision-making without human intervention).[24]

[23] *Hans-Christoph Burmeister/Wilko Bruhn/Ørnulf Jan Rødseth/Thomas Porathe,* Autonomous Unmanned Merchant Vessel and its Contribution towards the e-Navigation Implementation: The MUNIN Perspective, International Journal of e-Navigation and Maritime Economy 1 (2014), 1.
[24] *Mogens Blanke/Michael Henriques/Jakob Bang,* A Pre-Analysis on Autonomous Ships (2016), 3, available at: https://www.dma.dk/Documents/Publikationer/Autonome%20skibe_DTU_rapport_UK.pdf (accessed on 18 September 2017).

The early legal discourse on MASS raised the question whether the autonomous vessel is in fact a 'ship' as generally understood in international maritime law in order to ascertain its legal status and application of the various public and private maritime law conventions.[25] While 'ship' and 'vessel' are used interchangeably in the United Nations Convention on the Law of the Sea (UNCLOS),[26] they are not defined in that instrument. Rather, the search for definitions leads to the international maritime conventions, several of which are considered below, but without attempting an exhaustive listing. In most cases the term 'ship' is defined and the definition includes 'vessel(s)' having specific characteristics and/or performing particular functions for the purpose of delimiting the scope and application of the instrument concerned. A perusal of several of these instruments illustrates the drafting practice. In the marine pollution conventions, 'ship' is defined as or includes: "any sea-going vessel of any type whatsoever";[27] "a vessel of any type whatsoever operating in the marine environment and includes hydrofoil boats, air-cushion vehicles, submersibles, floating craft and fixed or floating platforms";[28] "any sea-going vessel and seaborne craft of any type whatsoever constructed or adapted for the carriage of oil in bulk as cargo […]";[29] "a vessel of any type whatsoever operating in the marine environment and includes hydrofoil boats, air-cushion vehicles, submersibles, and floating craft of any type";[30] "a vessel of any type whatsoever operating in the marine environment and includes hydrofoil boats, air-cushion vehicles, submersibles, floating craft, fixed or floating platforms, floating storage units (FSUs) and floating production storage and off-loading units (FPSOs)";[31] and "a vessel of any type whatsoever operating in the aquatic environment and includes submersibles, floating

[25] For example see Comité Maritime International (CMI), CMI International Working Group Position Paper on Unmanned Ships and the International Regulatory Framework, 2017, 3, available at: http://www.comitemaritime.org/Uploads/Questionnaires/CMI%20Position%20Paper%20on%20Unmanned%20Ships.pdf (accessed on 18 September 2017).
[26] United Nations Convention on the Law of the Sea, 10 December 1982, UNTS 1833, 396 (UNCLOS).
[27] Art. II (2) International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties, 29 November 1969, UNTS 970, 211; Art. 1 (1) International Convention on Civil Liability for Bunker Oil Pollution Damage, 23 March 2001, IMO Doc. LEG/CONF.12/19 (27 March 2001); Art. 1 (1) International Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances by Sea, 2 May 1996, ILM 35, 1406.
[28] Art. 2 (4) MARPOL.
[29] Art. I (1) CLC Convention. An identical definition is included in Art. I (1) IOPCF Convention.
[30] Art. 2 (3) International Convention on Oil Pollution Preparedness, Response and Cooperation, 30 November 1990, UNTS 1891, 51.
[31] Art. 2 (9) International Convention on the Control of Harmful Anti-Fouling Systems on Ships, 5 October 2001, IMO Doc. AFS/CONF/26 Annex (18 October 2001) (AFS Convention).

craft, floating platforms, FSUs and FPSOs".[32] In a maritime security convention, 'ship' is defined as "a vessel of any type whatsoever not permanently attached to the sea-bed, including dynamically supported craft, submersibles, or any floating craft."[33] The definitions of 'ship' for maritime carriage purposes include: "vessel used for the carriage of goods by sea";[34] "only a sea-going vessel, excluding air-cushion vehicle";[35] "any self-propelled sea-going vessel used in international seaborne trade for the transport of goods, passengers, or both with the exception of less than 500 gross registered tons".[36] They share the common themes of 'sea-going' and/or performing marine transportation. It is unusual for 'ship' and 'vessel' to be inverted, as in the case of a salvage convention where "vessel means any ship or craft or any structure capable of navigation"[37] and collision avoidance rules where 'vessel' is defined to include "every description of water craft, including non-displacement craft and seaplanes, used or capable of being used as a means of transport on water."[38] However, for the purpose of the discussion of autonomous ships the difference is immaterial and none of the definitions provided above pose a problem for the consideration of autonomous vessels as 'ships'.

Accordingly, the ship will be subject to domestic and international safety, environmental and security regulations. The rules and standards will govern its entire life from construction, through operations, and eventual recycling. Its operational life will include rules with respect to its seaworthiness and crewing. The private law consequences include the generation of liens unique to ships, the ability of a creditor to arrest and proceed *in rem* against the ship, and the ability of the owner, among other related interests in the ship, to enjoy certain defences, most especially limitation of liability. The ship is a piece of property that enjoys a status unique to maritime law. The early conceptions and prototypes of MASS clearly foresee vessels that perform the full range of functions of ships that are fully manned. The distinctive characteristics

[32] Art. 1 (12) International Convention for the Control and Management of Ships' Ballast Water and Sediments, 13 February 2004, IMO Doc. BWM/CONF/36 (16 February 2004) (BWM Convention).
[33] Art. 1 Convention for the Suppression of Unlawful Acts against the Safety of Maritime Navigation, 10 March 1988, UNTS 1678, 201.
[34] Art. 2 International Convention for the Unification of Certain Rules Relating to the Limitation of Liability of Owners of Seagoing Vessels, 25 August 1924, LNTS 120, 123.
[35] Art. 1 (3) Athens Convention Relating to the Carriage of Passengers and their Luggage by Sea, 13 December 1974, UNTS 1463, 20.
[36] Art. 2 United Nations Convention on Conditions for Registration of Ships, 7 February 1986, ILM 26, 1229.
[37] Art. 1 (b) International Convention on Salvage, 28 April 1989, UNTS 1953, 165.
[38] Rule 3 (a) COLREGS.

are the absence of a crew and in the case of a fully autonomous vessel, the relegation of decision-making to an automated system. While factoring the withdrawal of the human element, there is not much reason not to consider MASS as capable to produce most of the legal consequences usually associated with ships. Rather than with definitional concerns, the focus should be on the impact of the absence of or lessened human element on particular institutions that are premised on human appraisal, judgement, and decision-making.

III. Implications for the International Law of the Sea

MASS are likely to raise some questions of interpretation and application of the conventional and customary law of the sea, in particular the UNCLOS of 1982. The key question posed is the extent to which the pertinent UNCLOS regimes are sufficiently broad so as to seamlessly support the advent of MASS, or whether the characteristics of these new technologies require revisiting of the assumptions and expected applications of particular rules. Of special interest are regimes where MASS enjoy navigational rights as all other ships and jurisdictional powers with respect to international shipping based on the assumption that ships are manned, more specifically with respect to flag, coastal, and port States. At first blush, the frequent reference to the generic terms 'vessel' or 'ship' in the UNCLOS suggests that the provisions concerned apply to all ships including MASS. However, a probing analysis of some provisions raises potential issues.[39]

A. Flag State

The flag State has a right to register any class of ship and by doing so will be extending the application of its laws and protections to the ship wherever it navigates.[40] The question as to whether a national register of shipping is able to accommodate MASS is not an issue in the UNCLOS and indeed for many flag States that do not require manning as a condition for the registration of a ship. Registration requirements usually include ship name, IMO number, ownership, technical particulars, whether the vessel is on a bareboat charter, whether the vessel's previous registration is terminated, and also mortgages or hypothecs on the ship and their status.

[39] MSC (note 17), 79.
[40] Arts. 91-92 UNCLOS.

If registration of MASS ships is an issue for some States, it is likely because of domestic requirements. Once a vessel is entered into the register of ships, the flag State commences to enjoy exclusive jurisdiction over those vessels when they are on the high seas,[41] concurrent jurisdiction with coastal States during the exercise of innocent passage,[42] transit passage,[43] archipelagic sea lanes, and innocent passage in archipelagic waters,[44] and concurrent jurisdiction with port States when ships are voluntarily in a foreign port.[45] The flag State has a right to provide them with consular assistance in foreign ports.[46]

The right to establish a ship register is accompanied by the duty to effectively exercise jurisdiction and control over MASS entered into the register.[47] The actions usually associated with this power would need to be reconsidered in the case of unmanned ships. If the ship does not carry a crew the exercise of jurisdiction and control will be expected to focus on administrative and technical, rather than the maritime labour aspects (master, officers, and crew) as would be the case with crewed ships.[48] As the technology of MASS develops, it is conceivable that new rules (international and domestic) governing the desired competencies and capabilities of the shore-board personnel responsible as well as the instrumentation for the remote or automated navigation of the ship, including communications, will be needed.[49]

More of an issue in the UNCLOS is the duty of the flag State to

> take such measures for ships flying its flag as are necessary to ensure safety at sea with regard, inter alia, to: (a) the construction, equipment and seaworthiness of ships; (b) the manning of ships, labour conditions and the training of crews, taking into account the

[41] Art. 92 (1) UNCLOS.
[42] Art. 21 UNCLOS.
[43] Arts. 42 and 45 UNCLOS.
[44] Arts. 49, 52-54 UNCLOS.
[45] Art. 8 (1) UNCLOS.
[46] Arts. 27 and 231 UNCLOS.
[47] Art. 94 (1) UNCLOS.
[48] Art. 94 (1) and (2) UNCLOS.
[49] CMI (note 25), 16. This paper observes that unmanned ships will introduce a new range of personnel and qualification standards.

> applicable international instruments; (c) the use of signals, the maintenance of communications and the prevention of collisions.[50]

The contemplated measures include requirements concerning technology of the traditional ship used by an on-board crew, rather than MASS. For example, the measures are expected to include on-board "charts, nautical publications and navigational equipment and instruments as are appropriate for the safe navigation of the ship."[51] While a fully autonomous ship will have navigation equipment, it may not have charts on board, but rather will be able to download chart and navigational data as pre-programmed and as needed. Admittedly, electronic charts, digital manuals useable online, and electronic notices to shipping are now already in widespread use.

A more difficult requirement for the flag State is to ensure

> that each ship is in the charge of a master and officers who possess appropriate qualifications, in particular in seamanship, navigation, communications and marine engineering, and that the crew is appropriate in qualification and numbers for the type, size, machinery and equipment of the ship.[52]

Simply stated, the rule requires the ship to have qualified personnel on-board. One could argue that the crew requirement in this rule is relative to the type of ship and machinery, and if the ship is partially or fully automated, then it follows that a crew is not needed all of the time, if at all, without violating the rule. Thus, the practise of using towed, but unmanned barges for carriage of goods is of long standing. Further, if the fundamental purpose of the manning requirement is to ensure that there is competent operation and navigation of the vessel, it could be argued that a MASS vessel could be competently operated and navigated in a remote or autonomous manner where it can be demonstrated that safety, environmental protection, and security are assured at least to the same extent as with a manned vessel. For remotely operated vessels, "in the charge of" could be constructively interpreted to include the shore-based team of professionals in charge

[50] Art. 94 (3) UNCLOS.
[51] Art. 94 (4)(a) UNCLOS.
[52] Art. 94 (4)(b) UNCLOS.

of the vessel's navigation, but presumably the standard of human competence still applies to the shore-based team. Arguing that the element of human control is nonetheless manifested in the writer who creates the algorithm appears to stretch too far because the autonomous ship is expected to operate with ongoing human control.

A similar interpretation issue arises with respect to remotely controlled and autonomous warships. The definition of 'warships', while specifically requiring that they are under the armed forces of a State, further specifies that they are "under the command of an officer duly commissioned by the government of the State and whose name appears in the appropriate service list or its equivalent, and manned by a crew which is under regular armed forces discipline."[53] However, warships are excepted from the mandatory application of the International Convention for the Safety of Life at Sea of 1974 (SOLAS Convention)[54] and the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers of 1978 (STCW Convention).[55]

The rule

> 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[56]

is a challenge for ships in autonomous mode and will be considered further below. For remotely controlled ships, and as discussed in the previous paragraph, the shore-based team could be argued to provide the human constructive presence and expertise underlying this requirement. However, for autonomous ships it is difficult to argue that the algorithm substitutes

[53] Art. 29 UNCLOS.
[54] Ch. 1, Reg. 3 (a) SOLAS Convention.
[55] Art. 3 (a) International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 7 July 1978, UNTS 1361, 2 (STCW Convention). The exception applies to "(a) warships, naval auxiliaries or other ships owned or operated by a State and engaged only on governmental non-commercial service; however, each Party shall ensure by the adoption of appropriate measures not impairing the operations or operational capabilities of such ships owned or operated by it, that the persons serving on board such ships meet the requirements of the Convention so far as is reasonable and practicable".
[56] Art. 94 (4)(c) UNCLOS.

the requirement for fully-conversant master, officers, and crew in this provision. As for the communications aspect, which entails an ability for other vessels and public authorities to communicate with the vessel, the shore-based personnel behind a remotely controlled ship could conceivably perform this function. This constructive interpretation of the UNCLOS provisions does not easily extend to vessels in autonomous mode because decision-making is left to algorithms, rather than to direct human decision-making, and two-way communication involving a machine on the autonomous vessel and humans on vessels in its vicinity (for instance using very high frequency radio (VHF) to avoid close quarters) may not be possible, let alone desirable.

In performing these duties, the flag State "is required to conform to generally accepted international regulations, procedures and practices and to take any steps which may be necessary to secure their observance."[57] This provision invokes international regulations that may only be adopted by the IMO and at this time the pertinent maritime conventions do not directly address the particular requirements and perhaps exemptions (for example from manning requirements) that will be needed for MASS ships.

Flag States are required to ensure compliance of their ships with international rules and standards and provide for effective enforcement.[58] This duty extends to preventing their ships from operating unless they comply with requirements for design, construction, and manning,[59] and to require them to carry on board certificates which may be required under various conventions, [60] such as SOLAS[61] and the International Convention for the Prevention of Pollution from Ships of 1973/78 (MARPOL).[62] While some documentation is already available in digital format and there is a trend towards passive interactive ship-shore reporting, the operationalisation of the rule concerning documentation on board MASS will need to be reconsidered when an inspecting coastal or port State authority official requests the certificates, as will be seen below with respect to port State control.

[57] Art. 94 (5) UNCLOS.
[58] Art. 217 (1) UNCLOS.
[59] Art. 217 (2) UNCLOS.
[60] Art. 217 (3) UNCLOS.
[61] For example Ch. I, Reg. 16 SOLAS Convention on availability of certificates on board the ship.
[62] For example Annex I, Reg. 10 MARPOL with respect to the International Oil Pollution Certificate.

Another constraint with respect to MASS is the flag State's responsibility under the UNCLOS to require the master of a ship to offer assistance to persons in distress at sea,[63] also a duty under SOLAS.[64] This duty includes assistance to persons, deviating from the established course to proceed with speed to the rescue of persons in distress, and rendering assistance to the other ship involved in a collision. It is difficult to see how an unmanned ship can discharge this humanitarian duty, other than, perhaps, for the shore-based team to notify rescue services in the area of the incident and leave the MASS vessel in the area just in case search and rescue response services need to use the vessel as a platform, if appropriate.

In summary, the rules concerning duties of the flag State in the UNCLOS reflect a combination of the need for constructive interpretation of some provisions and addressing regulatory gaps with respect to ships that are unmanned. They potentially pose a problem for the flag State in the exercise of effective jurisdiction and control if the duty to ensure the manning of ships is interpreted literally as a requirement to have crew members on board of the MASS. However, if the deployment of a temporary crew for port approach navigation, berthing, and de-berthing, and a shore-based team for the long stretches of navigation of the vessel are interpreted constructively to be the equivalent of the actual manning in the case of remotely controlled ships, the gap is effectively removed. The same cannot be said for fully autonomous ships if these indeed become a reality, thus leaving a gap that would need to be addressed through other means.

B. Coastal State

The coastal State's limited jurisdiction over ships exercising the rights of innocent passage through the territorial sea, sea lanes passage through archipelagic waters, and transit passage through straits used for international navigation extends to all ships, but not to warships.[65] The coastal State may adopt laws and regulations to govern innocent passage in the territorial sea

[63] Art. 98 UNCLOS.
[64] Ch. V, Reg. 33 SOLAS Convention.
[65] Art. 32 UNCLOS.

(and archipelagic waters)[66] with respect to safety of navigation,[67] and in doing so must not apply "design, construction, manning or equipment [standards] unless they are giving effect to generally accepted international rules or standards."[68] At this time, neither the UNCLOS (*supra*) nor SOLAS (*infra*) exempts ships from actual manning requirements. In theory, a coastal State could regulate a manning requirement for MASS in transit, especially in areas of heavy traffic, because in doing so it would not be applying a standard other than a generally accepted international manning standard. An analogous argument could be made with respect to laws and regulations for pollution prevention.[69] With respect to transit passage, the coastal State has less flexibility in finding issues with MASS because its laws and regulations must "not discriminate in form or in fact among foreign ships or in their application have the practical effect of denying, hampering or impairing the rights of passage […]"[70] The UNCLOS text in this part does not provide the coastal State with a justification to impose a manning requirement.

There are potential difficulties that coastal States could face in undertaking enforcement action in accordance with UNCLOS. In undertaking enforcement action against MASS that violate pollution prevention laws applicable in the territorial sea or exclusive economic zone (EEZ) when they are voluntarily in its port, the coastal State has to contend with a scenario where it is unclear whether there is a human person behind the violation and, if there is, how to exercise jurisdiction over a human person (or corporation) who may not be within its territorial jurisdiction, despite the vessel's voluntary presence.[71] The coastal State has the power to undertake physical inspection of MASS, and where the evidence so warrants, it may detain such vessels although there are no persons on board.[72] It could be difficult for the coastal State to pin responsibility to a specific person. A commonly applied practical approach to pollution offences is strict liability, so that the *actus reus* alone will be sufficient to proceed against the ship. Another challenge is how a coastal State authority is to communicate with MASS when unmanned. When it has clear grounds to believe that there is a pollution incident, the coastal

[66] Art. 52 (1) UNCLOS.
[67] Art. 21 (1)(a) UNCLOS.
[68] Art. 21 (2) UNCLOS.
[69] Art.211 (6) UNCLOS.
[70] Art. 42 (2) UNCLOS.
[71] Art. 220 (1) UNCLOS.
[72] Art. 220 (2) and (6) UNCLOS.

State may require such a vessel to provide "information on its identity and port of registry, its last and its next port of call and other relevant information required to establish whether a violation has occurred."[73] While communication with a remotely operated vessel should not be an issue because there will be contact with a shore-based crew, two-way communication with a vessel in autonomous mode could be difficult when inspectors need to conduct a lengthy exchange unless a shore-based team intervenes. The power of a coastal State to conduct a physical inspection could be constrained.[74] The first stage of physical inspection is limited to an examination of on-board certificates, records, or other documents,[75] which as seen earlier may simply be digital. A second and more probing inspection stage may be undertaken if there are issues with such documents, and where it is established that a violation has occurred, the vessel has a right to release after reasonable procedures are completed, such as posting of a bond or other appropriate financial security, just like any other ship.[76] The coastal State may refuse release only exceptionally or release conditionally, notifying the flag State in such eventualities, who in turn may still seek prompt release.[77]

A potentially more complex issue for a coastal State is a scenario where MASS are in need of assistance and request refuge in a port or safe waters of that State. The custom of providing refuge to ships in distress has been narrowed down in State practice to humanitarian assistance.[78] An unmanned ship does not need humanitarian assistance, but its cargo could be very valuable and the vessel's distressed condition could be such as to threaten the marine environment. Although the coastal State has rights of self-protection under conventional law, it will be guided by the IMO Guidelines for Ships in Need of Assistance.[79] While the guidelines are clearly voluntary, they are increasingly considered as good practice for risk-based decision-making. However, the problem with the guidelines is that they assume that the vessel in need of assistance has a master and crew on board, and that usually the vessel will be receiving salvage

[73] Art. 220 (3) UNCLOS.
[74] Art. 220 (5) UNCLOS.
[75] Art. 226 (1)(a) UNCLOS.
[76] Art. 226 (1)(b) UNCLOS.
[77] Arts. 226 (1)(c) and 292 UNCLOS.
[78] *ACT Shipping (OTE) Ltd. v. Minister for the Marine, Ireland and the Attorney-General (The MV Toledo)* [1995] 2 ILRM 30.
[79] Guidelines on Places of Refuge for Ships in Need of Assistance, IMO Assembly Resolution A.949(23) of 5 December 2003, IMO Doc. A 23/Res.949 (5 March 2004).

assistance as well. The guidelines establish a communications process between the three parties to enable coastal State decision-makers to decide on refuge. Usually, the master and crew will be the persons who have first and most in-depth knowledge of the condition of the ship. The absence of such persons on board the vessel could constrain the decision-making process on refuge.

C. Port State

The port State's concern with MASS is with respect to the enforcement of international rules and standards and responding to the requests of other States concerning the autonomous vessel 'voluntarily' in its port.[80] The notice of arrival, which can be verbal or electronic, constitutes an indication of the intention to enter port. When a vessel is selected for inspection, there is usually communication between the port State control inspector and the ship master. Presumably, such communication may be undertaken with the shore-based team, but the inspector will need to board the ship. Usually, the inspector will board and personally communicate with the master or officer on watch (OOW). If the autonomous vessel does not have personnel on board in the foreign port, it is conceivable that the ship's agent, usually appointed to act on behalf of its interests in a foreign port, may need to step in. However, the ship agent is usually a commercial, rather than a person with technical knowledge of the ship as a crew member. Thus the inspector's questions may need to be directed to persons who are not present on the ship during the inspection, or simply wait until such persons are available.

When an autonomous vessel is port-inspected and found to have discharged wastes in violation of international standards, there is the further enforcement constraint with respect to who to proceed against when the 'person' responsible for the discharge is outside of the territorial jurisdiction of the port State. The UNCLOS does not indicate what persons would be pursued in the institution of proceedings and the vessel is personified in the sense that it is expected to comply with the inspection.[81] The port State has the power to detain the vessel to

[80] Art. 218 UNCLOS.
[81] Art. 218 (3) UNCLOS.

persuade the person(s) concerned to submit to jurisdiction. The port State would need to inform the flag State.

IV. Implications for International Maritime Law

The article now considers the potential impact of MASS on the international maritime legal system. Consisting of conventions and other legal instruments of the IMO, international maritime regulation addresses all ships and is largely premised on a human presence on board and in control of the navigation of the ship, as well as performing contingent functions such as provision of notices, log book entries, reporting, and responding to distress calls for assistance. The provision of certain services to ships is also premised on human interaction, such as in the case of pilotage where the master and OOW cooperate with the pilot in formulating the passage plan and taking and executing navigation instructions. The human element is underscored by trained crews. For the purposes of the present discussion, a selection of salient instruments and provisions are discussed to exemplify the potential impacts of MASS on contemporary maritime regulation, while acknowledging that a comprehensive analysis of all IMO regulations will be needed to ascertain the full regulatory impact of MASS.

A. Maritime Safety

The SOLAS Convention constitutes the backbone of international maritime safety regulation. Through fourteen chapters and numerous codes, it sets out standards, *inter alia*, for ship construction, machinery, cargo handling, stability, life-saving equipment and procedures, radiocommunications, safe carriage of cargoes and oil fuels, carriage of dangerous goods, additional standards for specific types of vessels (*e.g.*, nuclear ships, bulk carriers, high speed craft), safe navigation, management for safe ship operations, maritime security, and polar shipping. In principle, and whatever function they perform, MASS will be captured by a range of SOLAS rules and standards. SOLAS establishes a comprehensive system for the inspection, surveying, and certification requirements for ships to ensure compliance with international

standards.[82] The principal issues that MASS raise are with respect to safety aspects where the human factor is concerned.

As observed in the earlier discussion with respect to the flag State's duties under the UNCLOS, a key SOLAS rule provides that "Contracting Governments undertake, each for its national ships, to maintain, or, if it is necessary, to adopt measures for the purposes of ensuring that, from the point of view of safety of life at sea, all ships shall be sufficiently and efficiently manned".[83] The intention of this rule is to ensure that all ships are sufficiently manned to ensure they can operate safely. Crewing is equated with the safety outcome. An interpretation of this provision analogous to the earlier discussion on a similar requirement in Article 94 (3) UNCLOS is that as long as safety outcomes at least comparable to, if not exceeding, manned vessels, can be achieved by MASS vessels, the intended outcome of the rule is achieved. The presence of a shore-based team in remote control or standby (or an on-board crew on standby) and temporary crews on unmanned autonomous ships provides the overseeing human element implicit in this rule. Naturally, to remove any doubt, it would be preferable for this manning rule to be amended to reflect the needs of MASS.

The application of SOLAS principles and standards relating to bridge design and location of equipment are premised on personnel manning the bridge.[84] The ergonomics should be such as to facilitate the "tasks to be performed by the bridge team and the pilot in making full appraisal of the situation and in navigating the ship safely under all operational conditions" and "safe and effective bridge resource management."[85] As observed earlier, MASS will be guided by a different bridge concept, possibly much smaller for fully autonomous vessels in the event a crew is needed on board, and with a shore-based equivalent. This is important from another perspective. In gathering information on navigational conditions, the ship is also in a position, and indeed has a duty, to relay information on any dangerous conditions encountered. Thus the master has a duty to communicate to ships in the vicinity and competent authorities any danger messages concerning the presence of dangerous ice, dangerous derelict, other direct danger to

[82] Ch. I SOLAS Convention.
[83] Ch. V, Reg. 14 SOLAS Convention.
[84] Ch. V, Reg. 15 SOLAS Convention.
[85] *Ibid*.

navigation, tropical storm, encounters with sub-freezing air temperatures associated with gales, and winds of force 10 or above on the Beaufort scale not forecasted.[86] At this time it is unclear how MASS would comply with the danger message rule.

It is likely that the new international standards would need to be developed and regulated for the new instrumentation and processes that will replace these human tasks. At this time SOLAS does not have rules addressing the shore-based control room. In remotely controlled and autonomous vessels, the bridge and watch tasks performed by humans will be replaced by a suite of sensors and daytime and infrared cameras in addition to the usual instrumentation, such as radar and AIS, to enable processing of complex data streams and enable full appraisal of the ship's location and situation. Rules concerning the maintenance of a watch during the operation of the vessel are currently premised on crew presence. While at sea a ship is required to maintain a continuous watch, including a radio watch for broadcasts of maritime safety information.[87] For watch purposes, SOLAS requires that every ship shall carry personnel qualified for distress and safety radiocommunication.[88] The pertinent rules would need to be adapted to enable performance of watch functions by the off-board team responsible for the ship or to permit automated task performance.

With no crew, the vessel might not need the usual number of survival craft. The rules concerning the manning of survival craft would have contingent (in the event the vessel is boarded), if any application. The general rule for all ships is that they have a sufficient number of trained persons on board for mustering and assisting untrained persons, and a sufficient number of crew members must be available for launching an on-board survival craft.[89] MASS could justify an exemption from or modification of these rules.

The International Convention on Load Lines of 1966 (LLC),[90] another vital maritime safety instrument, in addition to setting out rules for the safe loading of ships, further provides

[86] Ch. V, Reg. 31 SOLAS Convention.
[87] Ch. IV, Reg. 12 SOLAS Convention.
[88] Ch. IV, Reg. 16 SOLAS Convention.
[89] Ch. III, Reg. 10 SOLAS Convention.
[90] International Convention on Load Lines, 5 April 1966, UNTS 640, 133 (LLC); Protocol of 1988 relating to the International Convention on Load Lines, 11 November 1988, IMO Doc. HSSC/CONF/12.

for construction standards to ensure safe work and passage spaces on board. The LLC has provisions for the protection of the crew, such as standards for deckhouses for accommodation, guard rails, safe passageways, and stowage of cargo in a manner to permit safe crew passage,[91] which might not be required in the design and construction of MASS to the same extent. It is likely that an exemption for MASS will be also be required in this instrument.

B. Crew Training, Certification, and Work Conditions

The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers of 1978 (STCW Convention) is the principal international maritime instrument dedicated to the training and certification of seafarers. The Convention establishes that "each Administration shall require every company to ensure that its ships are manned in compliance with the applicable safe manning requirements of the Administration".[92] Shipping companies[93] are responsible for the manning of their ships in compliance with the Convention and that properly certificated seafarers are assigned for service on their ships.[94] The ship's complement must be able to "effectively co-ordinate their activities in an emergency situation and in performing functions vital to safety or to the prevention or mitigation of pollution."[95] Levels of safe manning are further addressed by the Principles of Minimum Safe Manning.[96]

In theory, where MASS are fully autonomous, they will render redundant the application of much of the STCW Convention, as well as the important Maritime Labour Convention of 2006 (MLC) which promotes the rights of seafarers and establishes a framework for conditions

[91] Annex I, Ch. II, Regs. 25 and 25-1 LLC.
[92] Ch. I, Reg. I/14 (1) STCW Convention.
[93] 'Company' is defined as "the owner of the ship or any other organization or person such as the manager, or the bareboat charterer, who has assumed the responsibility for operation of the ship from the shipowner and who, on assuming such responsibility, has agreed to take over all the duties and responsibilities imposed on the company by these regulations.", Ch. I, Reg. I/1 (23) STCW Convention.
[94] *Ibid*.
[95] *Ibid*.
[96] IMO Assembly, Principles of Minimum Safe Manning, Resolution A.1047(27) of 30 November 2011, IMO Doc. A 27/Res.1047 (20 December 2011). The Principles consist of: Annex 1 – Guidelines for the Application of Principles of Safe Manning; Annex 2 – Guidelines for Determination of Minimum Safe Manning; Annex 3 – Responsibilities in the Application of Principles of Minimum Safe Manning; Annex 4 – Guidance on Contents and Model Form of Minimum Safe Manning Document; and Annex 5 – Framework for Determining Minimum Safe Manning.

of employment and occupational health and safety on ships.[97] Where MASS have crews deployed temporarily, the STCW Convention and MLC will apply. The MLC protections are likely not extendable to the team operating MASS from shore as the definition of seafarer presumes work at sea.[98] In practice, there are a number of vital functions performed on board the ship, both in normal and emergency situations pursuant to SOLAS and articulated in terms of personnel requirements, that would need to be addressed by MASS and the teams responsible for their operation or for overseeing the systems that run the vessels. The potential impact of automation is already recognised in the framework for determining minimum safe manning, in particular that functions on board a ship "may increase or decrease manning levels depending on availability and appropriate procedures and of specific capability enabling technology/automation."[99]

The usual personnel training requirements reflect the various functions on board the ship. For deck operations, the rules include mandatory minimum requirements for officers in charge of the navigational watch on ships of 500 gross tonnage (GRT) or more[100] as well as for certification of masters and chief mates for ships of both more and less than 500 GRT,[101] and certification of ratings.[102] There are similar requirements for the engine room department. The rules include certification on the engineering watch both in manned and, when on duty, in unmanned engine rooms,[103] and mandatory minimum requirements for certification of ratings on the watch in manned engine-rooms and, when periodically on duty, in unmanned engine-rooms.[104] The recent updating of standards to reflect the reality that ships may have unmanned engine rooms for prolonged periods is evidence that certain ship functions are already capable of full automation. Requirements for radiocommunications and radio personnel include mandatory minimum requirements for certification for Global Maritime Distress and Safety System (GMDSS).[105] There are also mandatory minimum special personnel training requirements for

[97] Maritime Labour Convention, 23 February 2006, ILM 45, 792 (MLC).
[98] According to Art. 2 (1)(f) MLC 'seafarer' means "any person who is employed or engaged or works in any capacity on board a ship to which this Convention applies".
[99] Principles of Minimum Safe Manning (note 97), Annex 5 at 1.5.
[100] Ch. II, Reg. II/1 STCW Convention.
[101] Ch. II, Reg. II/2-3 STCW Convention.
[102] Ch. II, Reg. II/4 STCW Convention.
[103] Ch. III, Reg. III/1 STCW Convention.
[104] Ch. III, Reg. III/4 STCW Convention.
[105] Ch. IV, Reg. IV/2 STCW Convention.

certain classes of ships, such as tankers, ro-ro ships, and passenger vessels.[106] A vital rule in the Convention is that "a safe continuous watch or watches appropriate to the prevailing circumstances and conditions are maintained in all seagoing ships at all times"[107] under the direction of the master. The interpretation of 'watch' functions with respect to SOLAS are relevant here as well.

The STCW Convention effectively defines the standards of competence expected of all human-performed functions on-board at all times. The Convention ensures human competence in decision-making. While MASS will largely shed off the human component and integrate the various functions into a single system, they are still expected to produce comparable safety, environmental, and security outcomes as manned ships. During the voyage, the system, whether overseen remotely from off-board and/or in an automated manner, provides centralised overview and management of all ship operations. While in port, MASS would be serviced and maintained as other ships. With respect to shore-based personnel monitoring and/or in control of MASS, 'competence' will continue to be a requirement, although the precise content will need to be redefined and adapted. The shore-based personnel will be highly qualified personnel in navigational, engineering, and informatics aspects of the vessel. Standards for their training and certification will likely need to be enhanced. In the case of fully automated vessels, autonomous decision-making introduces a novel approach to 'competence' and it is likely that new technical standards will need to be developed.

Also, and as observed earlier, the STCW rules on manning requirements do not apply to warships. The exception applies to "warships, naval auxiliaries and other ships owned or operated by a State and engaged only on governmental non-commercial service."[108] This exception is accompanied by an important proviso to the effect that "each Party shall ensure by the adoption of appropriate measures not impairing the operations or operational capabilities of such ships owned or operated by it, that the persons serving on board such ships meet the requirements of the Convention so far as is reasonable and practicable."[109]

[106] Ch. V STCW Convention.
[107] Ch. VIII, Reg. VIII/1 STCW Convention.
[108] Art. III (a) STCW Convention.
[109] *Ibid*.

C. The 'Rules of the Road'

The 'rules of the road' for the safe navigation of ships are set out in the Convention on the International Regulations for Preventing Collisions at Sea of 1972 (COLREGS) and apply to the high seas and all navigable waters.[110] The COLREGS include core rules for safe navigation (Part A – general; Part B – steering and sailing rules) in conditions of normal and reduced visibility and signalling to other ships in the vicinity (Part C – lights and shapes; Part D – sound and light signals). The rules nourish the standard of good seamanship expected of the ordinary mariner and against which the standard of care in the navigation of a vessel is assessed. Thus the rules provide no basis for exemptions from compliance with the rules or from exercising the precaution necessary and expected in the ordinary practice of seamen.[111]

Although unmanned, MASS are required to observe the COLREGS and the underlying standard of good seamanship. The rules are explicit in their reference to vessels and therefore do not provide any immediate problem of textual interpretation. The definition of vessel as "every description of water craft" used or capable of being used as means of transportation over water easily covers MASS.[112] MASS will not be expected to enjoy special privileges. They do not qualify as vessels 'not under command', which enjoy the privilege of a stand-on vessel, because this technical term refers only to "a vessel which through some exceptional circumstance is unable to manoeuvre as required by these Rules and is therefore unable to keep out of the way of another vessel."[113] Rather, the issues that could arise likely stem from how they would be applied when an autonomous vessel is in the vicinity of other vessels and the potential legal consequences.

In general, the Part B rules apply to MASS without significant issues of interpretation. The steering rules require that every vessel must maintain a proper look-out in any condition of visibility. This is described as "by sight and hearing as well as by all available means appropriate

[110] Rule 1 (a) COLREGS.
[111] Rule 2 (a) COLREGS.
[112] Rule 3 (a) COLREGS.
[113] Rule 3 (f) COLREGS.

in the prevailing circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision."[114] As described earlier, MASS will be equipped with a sophisticated system of technologies for full situational awareness, including geopositioning, radar, sensors, and continuous streaming cameras, all generating data for an algorithm to translate into information and advice for human or automated decision-making. In theory, automation will be able to more accurately navigate the vessel and avoid the human element contribution to maritime collisions and allisions. There is a lesson to be learned from over-reliance on technology for safe navigation. Following the introduction of radar on board ships, there were numerous radar-assisted collisions that were ultimately attributed to poor look-out. Seafarers at the time misused radar or over-relied on its use, thus refraining from using all means available to determine the position of other vessels and communicate with them if necessary to avoid close quarters.[115] There could also be complex legal consequences in determining contributory negligence and consequential liabilities, in particular where the vessel is fully automated. In collision cases, unlike allisions, it is often the case that the collision is the result of negligence on the part of both ships involved.

Another rule whose operationalisation will need careful consideration concerns the risk of collision and the action to be taken to avoid close quarters. The vessel has the duty to "use all available means appropriate to the prevailing circumstances and conditions to determine if risk of collision exists" and in case of doubt to deem that a risk of collision exists.[116] The rule is supported by further rules concerning the proper use of radar (learning from radar-assisted collisions) and avoiding of assumptions on scanty information. This rule relies heavily on data inputs on traffic within the vicinity of the vessel, general conditions of navigation (*e.g.* weather, visibility, ice presence, *etc.*), proper use of equipment, and intelligent judgement. It is argued that MASS will be better able to collect data and make intelligent decisions.[117] In less than optimal

[114] Rule 5 COLREGS.
[115] *Nicholas J. Healy,* Radar and the New Collision Regulations, Tulane Law Review 37 (1962-1963), 37.
[116] Rule 7 (a) COLREGS.
[117] *Porathe/Prison/Man* (note 22); *Are E. Ottesen,* Situation Awareness in Remote Operation of Autonomous Ships: Shore Control Center Guidelines, available at: https://www.ntnu.no/documents/10401/1264435841/Artikkel+Are+E+Ottesen.pdf/abb533ae-e73a-489e-80ec-f0e198e72c0a (accessed on 18 September 2017).

conditions when information is scanty, the extent to which human experience and judgement call, accompanied by good seamanship, can be replaced by an algorithm remains to be seen.

The Part C rules on lights and shapes, respectively for night time and day time sailing, will apply. These rules are important to enable vessels in each other's vicinity to recognise their respective status and privilege and apply the respective rule for stand-on and give-way vessels while ensuring safe distances. While not granting them any special privilege, the introduction of dedicated new lights and shapes for MASS ships to indicate their presence to other vessels in their vicinity could be sensible and precautionary additions to the rules. The Part D rules on sounds and signals also apply, although the actual operation of manoeuvring and warning whistle blasts and light signals would be done remotely or automatically.

D. Environment Protection

The absence of crews on MASS can be expected to produce impacts on environmental regulation with respect to on-board procedures, waste management, and reporting requirements. Again, examples are provided to highlight the point. MARPOL Annex I on-board requirements for the master or crew's familiarity with essential shipboard procedures relating to the prevention of pollution by oil in the case of unmanned ships would need to be reviewed to enable a port State inspector to ascertain compliance with requirements in some other manner.[118] The absence of a crew might significantly reduce the relevance of Annexes IV and V respectively concerning sewage and garbage. There would be a strong argument to consider the granting of exemptions from certain certification requirements with respect to these wastes. An analogous issue was recently considered by the IMO's Marine Environment Protection Committee (MPEC) with respect to proposed amendments to introduce certain exemptions from MARPOL Annexes I, IV, and VI survey and certification requirements for unmanned non-self-propelled barges.[119] The reasoning was that these unmanned barges do not have structures or equipment that generate pollutants addressed by MARPOL, such as sewage, and that the added administrative

[118] Annex I, Reg. 11 MARPOL.
[119] Marine Environment Protection Committee (MEPC), Report of the Marine Environment Protection Committee on its 69th Session, IMO Doc. MEPC 69/21 (13 May 2016), 52.

requirements, such as issuing and carrying the required International Sewage Pollution Prevention Certificate, were unnecessary. Among other, this was relevant for the implementation of the III Code in the conduct of the audits of Annexes for compliance with instruments covered by that code and port State inspection.[120] The MEPC decided against an open-ended exemption, and favoured a capped exemption of no more than five years, despite views to the contrary.[121]

In addition to MARPOL, other environmental conventions could be impacted with respect to functions to be performed by the crew. In particular, the International Convention for the Control and Management of Ships' Ballast Water and Sediments of 2004 prescribes that some officers and crew be familiar with the Ballast Water Management Plan and their duties in ballast water management operations on their ship.[122] In the case of MASS this knowledge expectation will need to be transferred to the shore-based personnel or even performed autonomously.

V. Discussion

This article has identified several issues concerning potential impacts of MASS on the international law of the sea and international maritime law. The pertinent UNCLOS jurisdictional frameworks relevant for MASS were set out, while the IMO conventions that nourish that framework and the nitty-gritty international rules and standards were considered. Functioning together, the two systems ensure that international navigation rights enjoyed by all ships are protected and that the exercise of jurisdiction over international shipping is within that framework and in accordance with generally accepted international maritime rules and standards. The advent of MASS, although potentially accommodated, has been demonstrated to challenge the application of particular rules of the two systems. While there is room for interpreting affected rules in the conventions in a manner consistent with the general rules for the interpretation of treaties,[123] there are also gaps that are not easily addressed through

[120] IMO Assembly, IMO Instruments Implementation Code (III Code), Resolution A.1070(28) of 4 December 2013, IMO Doc. A 28/Res.1070 (10 December 2013).
[121] MEPC (note 120), 52. Contrary views were expressed by China, Japan, Norway, and South Korea. Proposed amendments to MARPOL Annexes I, IV and VI to facilitate the exemption of survey and certification requirements for Unmanned Non-Self-Propelled (UNSP) barges, Submitted by Japan and the Republic of Korea, IMO Doc. MEPC 69/13/2 (12 February 2016).
[122] Annex, Reg. B-6 BWM Convention.
[123] Art. 31 Vienna Convention on the Law of Treaties, 23 May 1969, UNTS 1155, 331.

interpretation alone. Moreover, in the interest of clarity, amendment of a rule might be preferable to waiting for an interpretation from an authoritative body.

The respective abilities of the UNCLOS and IMO conventions to respond to the change in the operational environment of shipping and navigation promised by MASS are different. In the event the manning requirements in Article 94 UNCLOS cannot be waived through a functional interpretation, it could be difficult to amend the Convention. While the UNCLOS has amendment procedures, they have not been utilised to date and change to the Convention has been effected through separate implementation agreements adopted after laborious diplomatic processes.[124] However, the UNCLOS has a simplified procedure, as yet untested, that could potentially be used to address technical changes to Article 94. A State party would need to propose an amendment for adoption through the simplified procedure, communicated to the UN Secretary-General who in turn communicates the proposal to all States parties, and in the event of no objection being lodged by a State party within a period of one year, the amendment would be adopted.[125] Should interpretation or amendment of Article 94 UNCLOS not be possible, future State practice in registering MASS vessels and exercising effective jurisdiction and control over them to the same extent as manned ships could well provide a customary law basis for accommodating automated ships.[126]

In comparison, IMO regulation is substantially more adaptable because several of the key instruments affected by MASS have tacit amendment procedures. The MEPC and MSC, as the two key committees tasked with the maintenance of the safety and environmental conventions for which the IMO is responsible, have the necessary authority and machinery to amend the technical aspects of safety and environmental conventions using the simplified tacit acceptance procedure following consideration by the pertinent committee, instead of a diplomatic conference convened by the Organization.[127] However, a potential issue for the IMO is how to eliminate the manning requirement for fully autonomous ships in a manner that retains

[124] Specifically with respect to Part VII's provisions on straddling stocks and highly migratory species and Part XI provisions on deep seabed mining.
[125] Art. 313 UNCLOS.
[126] It is arguable that MASS, as a matter unregulated by the UNCLOS, may be governed by rules of general international law, see the UNCLOS preamble.
[127] For example: Art. 16 MARPOL; Art. VIII SOLAS Convention.

consistency with a provision to the contrary in Article 94 UNCLOS,[128] unless the text can be interpreted to accommodate MASS as discussed earlier.

The IMO is well poised and advised to proactively address the regulatory needs of MASS. As other studies, this article has observed that while much of the IMO regulatory system will be able to accommodate this new class(es) of vessels, it is very likely that there are many rules and standards in several maritime conventions that will need to be adapted through interpretation or amendment. The IMO's strategic directions provide for keeping "under review the technical and operational safety aspects of all types of ships",[129] which will include MASS. It oversees the maintenance of a regulatory system to promote harmonisation and facilitate compliance with its instruments. Hence, the multi-Member State proposal for a regulatory scoping exercise of the Organization's instruments is timely[130] and the initial approach defined by the MSC appropriate.[131] The IMO will take a proactive approach that will explore a range of impacts of surface vessels employing different levels of automation, including on safety, security, ports, pilotage, and incident response, including legal responsibility and liability issues.[132]

One can speculate on what precise regulatory changes will be necessary. Degrees of automation with respect to aspects of ship operation have been gradually introduced over time, but automation on a large scale as in the case of MASS has not yet been considered by the IMO. Given the multiple points of impact of MASS on maritime regulations discussed in this article, at a minimum the approach to adaptation should be systemic, rather than a piecemeal convention by convention, code by code approach. Hence, a comprehensive impact review of all of the IMO

[128] The IMO Committees "when exercising the functions conferred upon it by or under any international convention or other instrument, shall conform to the relevant provisions of the convention or instrument in question.", Art. 31 (on the MSC) and Art. 41 (on the MEPC) Convention on the International Maritime Organization, 6 March 1948, UNTS 289, 3. The IMO policy has been that the adoption of an instrument is without prejudice to "the codification and development of the law of the sea in UNCLOS or any present or future claims and legal views of any State concerning the law of the sea and the nature and extent of coastal and flag State jurisdiction", IMO Secretariat, Implications of the United Nations Convention on the Law of the Sea for the International Maritime Organization: Study by the Secretariat of the IMO, IMO Doc. LEG/MISC.7 (19 January 2012), 7.
[129] IMO Assembly, Strategic Plan for the Organization (2016-2021), Resolution A.1097(29) of 1 December 2015, High-level Action 5.2.1.
[130] MASS Scoping Exercise (note 18).
[131] MSC (note 17), 79.
[132] *Ibid.*

instruments is highly desirable and some studies have already made the first efforts in this direction.[133]

Changes to rules and standards concerning ship construction and equipping will be expected, in particular to take account of modifications to the usual designs for the bridge, equipment on board, crew accommodations and passageways, and life-saving craft. What is uncertain at this early stage is the extent of the change as we can reasonably expect different levels of automation on MASS, and across several classes of ships (*e.g.* bulkers, container ships). In this respect, the goal-based approach to maritime regulation will substantially facilitate the accommodation of various technologies to produce desired safety, security, and environmental outcomes.[134]

Particular MASS vessels can be expected to justify exemptions from certain rules. Some conventions have provisions permitting exemptions issued by national maritime administrations, and other States parties are expected to be notified of exemptions[135] or equivalents.[136] This flexibility will be useful in transitioning MASS into a system designed for very different ships. For example, compliance with particular certification requirements will be superfluous on ships with the highest levels of automation (*e.g.* sewage certificates), and exemptions would be appropriate. In other instances, rule compliance for MASS might need adaptation of the regulatory requirement. A fully automated vessel will likely have an electronic log. Consistently with the current trend, documentation requirements will be satisfied electronically and reporting for various regulatory purposes will become increasingly passive.

[133] For example the CMI Working Paper (note 25).
[134] IMO Assembly, Principles to be Considered when Drafting IMO Instruments, Resolution A.1103(29) of 26 November 2015, Annex.
[135] For example Ch. I, Reg. 4(b) SOLAS Convention: "The Administration may exempt any ship which embodies features of a novel kind from any of the provisions of Chapters II-1, II-2, III and IV of these Regulations the application of which might seriously impede research into the development of such features and their incorporation in ships engaged on international voyages. Any such ship shall, however, comply with safety requirements which, in the opinion of that Administration, are adequate for the service for which it is intended and are such as to ensure the overall safety of the ship and which are acceptable to the Governments of the States to be visited by the ship. The Administration which allows any such exemption shall communicate to the Organization particulars of same and the reasons therefor which the Organization shall circulate to the Contracting Governments for their information".
[136] Ch. I, Reg. 5 SOLAS Convention.

Classification Societies will play a key role in helping to develop appropriate standards and unified requirements. IMO regulation frequently relies on the unified requirements adopted by the International Association of Classification Societies. However, regulatory accommodations will likely impact the mandatory audits under the III Code whose purpose is to promote compliance with international instruments with no more favourable treatment. The implications will extend to port State control inspections, which enforce international instruments also with no more favourable treatment to ship or flag.

There will be implications for private law purposes which, while beyond the remit of this article, should be mentioned, such as the evolving meaning of seaworthiness in the carriage of goods by sea and insurance contracts, among others, since the ability of MASS vessels to depart on and complete the maritime adventure in a timely and safe manner will also depend on shore-based systems.

VI. Conclusion

The advent of MASS is a potential game-changer for international shipping and its regulation. As the human factor is withdrawn from shipping in favour of artificial intelligence and accompanying automated systems, international maritime law is not likely to function on a business-as-usual scenario and will need to be adapted and further developed. However, it is unlikely that the human factor will be fully removed from shipping as there will continue to be trades and regions that will rely on manned ships. What can be envisioned is a future that will have a versatile mix of manned and unmanned ships, often interacting when in close proximity while navigating, varying by trading region, and with some trading regions having a higher concentration of automated ship operations because of early regional buy-in.

MASS will potentially produce a range of direct and indirect impacts on the law of the sea and maritime law, in particular during their early introduction when the two legal regimes will need to adapt to the new technological environment. MASS will challenge a regulatory system that has often lagged behind technology. The IMO has an opportunity to put an anticipatory regulatory framework in place to influence the directions of the MASS technologies.

Finally, in scoping the regulatory impacts and future agenda, the IMO should also consider larger social questions. For example, as automated systems produce greater efficiencies and cost-savings, are the technological risks fully internalised? Is substitution of artificial intelligence for human judgement socially acceptable in all areas and aspects of shipping and navigation, for example also with respect to passenger vessels? Are safety valves against technological failure and hacking needed? How will MASS affect the distribution of risk in shipping and with what consequences for responsibility and liability?