4. Autonomous ships, drones and other innovations in shipping

Autonomous ships: Potential benefits and challenges

Among the advances in cybersystems and digitalization in the maritime industry, maritime autonomous surface ships, also known as unmanned surface vessels, are attracting increased attention. As with autonomous technologies in other industries, autonomous ships have the potential to provide enhanced safety and cost savings by removing the human element from certain operations. The term "autonomous ship" is not the same as "unmanned ship", as the former may operate at various levels of autonomy, including partially autonomous (with human input) and fully autonomous (not requiring human intervention). However, such terms have not yet been completely defined either nationally or internationally, and many different formulations exist of the levels of autonomy (Danish Maritime Authority, 2017). In any event, human intervention will still be needed in most ship operations in the near future, and the transportation of cargo and passengers in fully autonomous ships remains a long-term ambition. Autonomous ships could potentially be used in a wide range of operations, including salvage, oil spill response, passenger ferrying, offshore supply, towing and the carriage of cargo. However, at present, they are mostly used for marine scientific research and various maritime operations in the defence sector (Comité Maritime International, 2017). The first remotely controlled or fully autonomous commercial cargo vessel may be in operation by 2020; for example, the first fully electric and autonomous container ship, with zero emissions, may be in operation on a short coastal route in either a remotely controlled or autonomous mode by 2020 (Marine Electronics and Communications, 2018b). The technology may first be deployed on vessels that undertake coastal and short sea routes, and remotely controlled and autonomous ships sailing open oceans could be in operation by 2030 or earlier. An autonomous, fully battery-powered short sea vessel with zero emissions is also currently in development (DNV GL, 2018).

Other recent developments with regard to autonomous ships include the following: a prototype of the world's first fully autonomous and cost-efficient vessel for offshore operations (Kongsberg, 2017); the first electrically powered inland container vessel in Europe, with five small ships in the series expected to be completed in 2018 and six larger ships in preparation with features that prepare them for autonomous operations (*The Maritime Executive*, 2018); an agreement between two companies, possibly a first in the marine sector, to develop an artificial intelligence-based classification system for detecting, identifying and tracking the objects a vessel can encounter at sea, aimed at making existing vessels safer and progressing towards making autonomous ships a reality (Rolls-Royce, 2017); the One Sea autonomous maritime ecosystem project, aimed at enabling fully remote-controlled vessels in the Baltic Sea by 2020 and achieving autonomous commercial operations by 2025 (IMO, 2018b); and the testing of remotely controlled vessels in the Pacific Ocean, due to begin in 2019, aimed at achieving autonomous vessels by 2025 (Bloomberg, 2017).

An area that might benefit from the use of autonomous ships is the safety and security of ship operations. Advances have been made in electronic navigational systems and tools, yet the human factor continues to have an important role in most marine incidents and casualties. Some studies estimate that 75–96 per cent of marine accidents can be attributed to human error and human error reportedly accounted for approximately 75 per cent of the value of almost 15,000 marine liability insurance claims in 2011–2016, equivalent to over $1.6 billion (Allianz Global Corporate and Specialty, 2017).

Crew costs can constitute up to 42 per cent of a ship's operating costs (Stopford, 2009). This cost decreases for vessels with fewer or no crew, as does the risk of piracy and hostage-taking and the respective insurance coverage rates and costs. Vessel construction costs may also be reduced, with less space required for seafarer accommodation and other amenities, which could instead be used for cargo storage. Vessel operations could also become more environmentally friendly, as new autonomous ships are designed to operate with alternate fuel sources, zero-emissions technologies and no ballast. In addition, given fewer or no crew on board, there would be less garbage and sewage to manage and treat.

There are a number of potential benefits, yet challenges in implementation, which include concerns about the following: cybersecurity, although this is not unique to autonomous ships; safety, related to the lack of crew on board; undue impacts on seafarer jobs and shipping rates; and whether insurance cover would be offered by underwriters, insurers and protection and indemnity insurance clubs for commercial autonomous ships (Fairplay, 2017). The potential loss of seafarer jobs is a particular concern in developing countries, as a significant majority of seafarers are from these countries.

Autonomous ships: Regulatory issues

The operation of autonomous ships is closely related to the roles of master and crew on board, a feature that affects the full spectrum of applicable maritime laws and regulations. Regulatory frameworks governing the maritime industry have had to adapt over the years to accommodate new technologies, yet they do not take into consideration the operation of ships without a crew. Therefore, the traditional on-board roles of master and crew, as well as artificial intelligence and shore-based staff supervising remotely controlled or autonomous ships will need to be assessed and redefined. At the international level, aspects of the regulatory framework that need to be considered in the context of autonomous ships include the following:

- Jurisdictional rules specifying the rights and obligations of States with regard to ships in various marine areas and, more specifically, the principles and rules related to flag, port and coastal State jurisdictions, which are mostly covered by the United Nations Convention on the Law of the Sea, 1982. This is a widely ratified framework convention, with 168 States Parties as at 31 July 2018, which defines the rights and responsibilities of nations with regard to their use of the world's oceans, the protection of the marine environment and the management of marine natural resources.
- Technical rules related to, among others, safety, security and the environment, seafarer issues, training and watchkeeping standards, which impose obligations on flag States to enact national legislation reflecting the internationally agreed standards developed by and adopted at IMO.
- Private law rules covering liability for, among others, personal injury, pollution, cargo-related losses and collisions, which are in some instances subject to relevant international legal instruments but may also be subject to national laws.

Recent international regulatory developments of note include a scoping exercise for the review of relevant instruments, to ensure the safe design, construction and operation of autonomous ships, initiated at IMO in 2017 following a decision by the Maritime Safety Committee. A similar review was proposed by the Legal Committee in April 2018, aimed at ensuring that the legal framework set out in legal instruments under its purview provides for the same level of protection for autonomous ships as that provided for operations with non-autonomous ships (IMO, 2018b). Other committees, including the Facilitation Committee and the Marine Environment Protection Committee, may need to undertake similar reviews, as some of the IMO instruments that may need to be considered as part of a comprehensive regulatory review fall under their purview. The Technical Cooperation Committee may also have inputs, in particular when implementation issues are considered.

A cross-divisional task force has been established to facilitate the coordination of work between different committees (IMO, 2018c; IMO, 2018d). In May 2018, the Maritime Safety Committee requested the IMO secretariat to review the work undertaken to date by several organizations that had considered regulatory arrangements and submitted the results of their work to the Committee, and to submit a consolidated report for its consideration at its 100th session in December 2018 (IMO, 2018d; for further information, see the following documents: MSC 99/5, MSC 99/5/1-12, MSC 99/INF.3, MSC 99/INF.5, MSC 99/INF.8, MSC 99/INF.13, MSC 99/INF.14 and MSC 99/INF.16).

Some of the most pertinent IMO instruments with requirements that may need to be evaluated in the context of the navigation of autonomous ships are addressed in this section.

International Convention for the Safety of Life at Sea, 1974

This Convention is the most important of all of the international conventions concerning the safety of commercial ships, and is widely ratified, with 164 States Parties as at 31 July 2018. It applies to over 99 per cent of the world's tonnage and specifies the minimum standards for the construction, equipment and operation of ships, compatible with their safety. This Convention is one of the key IMO conventions, along with the International Convention for the Prevention of Pollution from Ships, 1973/1978, and the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978, as amended. In addition, the Maritime Labour Convention, 2006, with 88 ratifications as at 31 July 2018, and representing 91 per cent of the world's tonnage, is the main international instrument setting out seafarers' rights to decent conditions of work. These Conventions constitute the four pillars of the international regulatory regime for quality shipping.

A review of 12 chapters of the International Convention for the Safety of Life at Sea, as follows, may be needed to determine how autonomous ships may be covered by the provisions: chapter I, general provisions, including definitions; chapter II-1, construction, including structure, subdivision and stability, machinery and electrical installations; chapter II-2, fire protection, fire detection and fire extinction; chapter III, life-saving appliances and arrangements; chapter IV, radiocommunications; chapter V, safety of navigation; chapter VI, carriage of cargoes; chapter VII, carriage of dangerous goods; chapter VIII, nuclear ships; chapter IX, management for the safe operation of ships; chapter X, safety measures for high-speed craft; chapter XI-1, special measures to enhance maritime safety; and chapter XII, additional safety measures for bulk carriers.

For example, a review of relevant provisions in chapter V on the safety of navigation may be particularly relevant, as some of the provisions require that, from the point of view of safety, all ships must be sufficiently and efficiently staffed. Other provisions relate to the establishment of control of a ship in hazardous navigational situations and the obligation for the master of a ship to provide assistance to persons in distress at sea. A ship operating autonomously without any human oversight would not be able to comply with such provisions and, should an incident occur, issues related to safety and liability might arise. Such functions may have to be taken over by shore-based staff supervising remote-controlled or autonomous ships, and many of the liabilities may have to be assumed by shipowners, shipbuilders and manufacturers of ship components, as has been addressed in similar situations involving autonomous vehicles (The Conversation, 2018b). A way of apportioning responsibility between these parties and third parties needs to be identified, as existing liability rules applicable in the context of traditional staffed maritime activity cannot be simply transplanted to autonomous counterparts.

The provisions in chapter XI on special measures to enhance maritime safety are also particularly relevant, as they require compliance with the International Ship and Port Facility Security Code, and deal with, among others, the specific obligations of ship companies with regard to security, including security procedures, the employment of security-focused personnel and certification and verification requirements. The unique security challenges posed in the context of autonomous operability are relevant in this regard, in particular with regard to cyberinfiltration. Regulation 6 in this chapter requires ships to have a security alert system that transmits ship-to-shore security alerts to designated authorities that indicate the location of a ship and that its security is under threat, which must be able to be engaged from the bridge and at least one other location. A similar alert mechanism might therefore need to be established in an autonomous ship. Regulation 8 requires that the discretion of a master not be constrained by the company or any other person in respect of ship safety. In an autonomous ship, this role might need to be transferred to a shore-based remote controller.

International Regulations for Preventing Collisions at Sea, 1972

The Regulations set out navigational rules to be followed by vessels, aimed at avoiding collisions. A review of the five parts, as follows, may be needed to determine how autonomous ships may be covered: part A, general, including provisions related to applicability; part B, steering and sailing; part C, lights and shapes; part D, sound and light signals; and part E, exemption.

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

The Convention as amended prescribes qualification standards for masters, officers and watchkeeping personnel on board seagoing ships, along with watchkeeping procedures. Article 3, for example,

specifies that the Convention applies to seafarers serving on board seagoing ships entitled to fly the flag of a State Party. The provisions would therefore need to be amended before they could apply to autonomous ships.

International Convention for the Prevention of Pollution from Ships

This Convention is the main international convention covering the prevention of pollution of the marine environment by ships from operational or accidental causes and is widely ratified, with 157 States Parties as at 31 July 2018, and applies to over 99 per cent of the world's tonnage. It includes six technical annexes, as follows: annex I, regulations for the prevention of pollution by oil; annex II, regulations for the control of pollution by noxious liquid substances in bulk; annex III, prevention of pollution by harmful substances carried by sea in packaged form; annex IV, prevention of pollution by sewage from ships; annex V, prevention of pollution by garbage from ships; and annex VI, prevention of air pollution from ships.

Autonomous ships, when in operation, would have to comply with relevant provisions in the Convention to the same extent as traditional staffed vessels including, among others, provisions with regard to construction and equipment-related requirements for various types of ships such as oil tankers; operational and procedural requirements such as discharge limits and ship-to-ship transfers; and reporting requirements in the event of spills. These provisions will therefore need to be reviewed.

Paris Memorandum of Understanding on Port State Control, 1982

This Memorandum was concluded by 14 European shipping nations and aims to ensure an effective system for controlling the technical condition and safety of ships, in addition to inspections by the flag State. The Memorandum was also motivated by the fact that a number of flags of convenience had historically proven to not be able to effectively control ships flying their flags. The Memorandum establishes a system for port State control of ships from all countries calling at a port in States Parties. At present, the Memorandum covers all member States of the European Union, as well as Canada, Iceland, Norway and the Russian Federation, and the United States is affiliated as a cooperating country. Port State control under the Memorandum includes the inspection of seafarer certificates of competency and qualifications according to the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, as well as compliance with the International Convention for the Safety of Life at Sea, the International Convention for the Prevention of Pollution from Ships and the Maritime Labour Convention. Inspired by the Memorandum, similar regional port State control agreements have been concluded in Asia and the Pacific and in Latin America. In the European Union, Directive 2009/16 of 23 April 2009 on port State control, based on the Memorandum, sets out a number of additional obligations for information exchanges and reporting between member States of the European Union with regard to port State control, as well as on the professional qualifications of ship surveyors. Such instruments will also need to be reviewed with regard to autonomous ships.

Examples of international legal instruments and legal issues that the Legal Committee of IMO may need to examine with regard to autonomous ships are outlined below.

Nairobi International Convention on the Removal of Wrecks, 2007

This Convention, with 41 States Parties as at 31 July 2018, representing 72.41 per cent of the world's tonnage, provides the legal basis for States to remove or have removed shipwrecks that may have the potential to adversely affect the safety of lives, goods and property at sea, as well as the marine environment. With regard to autonomous ships, the terms "master" and "operator" and the requirement for the master and operator of a ship to report a wreck may need to be reviewed. In addition, the requirement that the master and operator report without delay on the nature of the damage may need to be reviewed. The requirement under various liability conventions that certificates attesting that insurance or other financial security is in place must be carried on board may not be relevant if there is no crew on board (IMO, 2018b).

Other relevant instruments

Other relevant instruments that may be covered under the scoping exercise include the following: Convention on Facilitation of International Maritime Traffic, 1965; International Convention on Load Lines, 1966; International Convention on Tonnage Measurement of Ships, 1969; International Convention on Maritime Search and Rescue, 1979; Convention for the Suppression of Unlawful Acts Against the Safety of Maritime Navigation, 1988; and International Convention on Salvage, 1989.

Autonomous ships: Jurisdictional issues

According to the United Nations Convention on the Law of the Sea, which in large part codifies established customary international law, the nationality of a ship is determined by its flag, that is, by its country of registration, and the law of the flag State applies to the ship or any conduct that takes place on it (articles 91 and 94). Each State has the right to determine the conditions for granting its nationality to ships, for registering ships in its territory and for the right to fly its flag (article 91 (1)), as well as the obligation to maintain a register of ships flying its flag (article 94 (2) (a)). Flag States have an important role in the implementation and enforcement of international conventions, including

those dealing with the technical and safety aspects of shipping, seafarer working conditions and crew training, and in monitoring compliance with relevant mandatory standards (article 94). In parallel with flag State jurisdiction, which applies to a ship irrespective of its location, port and coastal State jurisdiction also applies, depending on the maritime zone in which the ship is located, that is, a port, internal waters, a territorial sea, an exclusive economic zone or the high seas (Comité Maritime International, 2017).

Autonomous ships: Definitions

Certain concepts such as master and crew and related qualifications that may already exist in various international conventions that presume there is a crew on board, such as article 94 (4) (b) of the United Nations Convention on the Law of the Sea, may need to be clarified with regard to their applicability to autonomous ships. The definition of the terms "vessel" and "ship" may also need to be reviewed, as they may exist in various international conventions based on their area of focus, such as the Nairobi International Convention on the Removal of Wrecks, the International Convention on Salvage and the International Convention on Civil Liability for Oil Pollution Damage, 1969, and its 1992 Protocol.

Autonomous ships: Liability rules

Liability rules applicable in the context of traditional staffed maritime activity cannot be applied to the various levels of autonomy in the context of autonomous ships. New regulations and practices may need to be developed that will likely "involve further standards of due diligence on the part of the shipowner, additional certification requirements for component/software developers and new training and qualification standards for pre-programming and shore-based navigation" (Comité Maritime International, 2017).

Drones

Drones, that is, unmanned aircraft, may offer benefits to the maritime industry with regard to, for instance, cost reduction, the saving of time and the enhancement of safety for operations traditionally conducted by staff. A number of companies are developing autonomous drones to enable the following: inspect and survey ships and offshore installations (DNV GL, 2017; UASweekly.com, 2018); map oil spills and assist in rescue operations (see, for example, www.planckaero.com/maritimedrone); monitor emissions from ships (SUAS News, 2017); and carry and deliver goods and supplies (Baird Maritime, 2018; Fast Company, 2017; *The Maritime Executive*, 2017). However, the relevant jurisdictional issues and implications for the legal framework governing combined aviation and maritime operations need to be further explored and better understood.