U.S. Government Accountability Office

Coast Guard: Autonomous Ships and Efforts to Regulate Them

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Q&A Report to Congressional Committees

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Why This Matters

Autonomous ships are those ships and vessels that include *some* level of autonomy. Such ships range from crewed ships with automated processes and decision support to ships that can make decisions and determine actions without human involvement. These ships have technologies that can allow them to autonomously navigate, avoid collisions, control the speed and direction of the ship, or communicate with other ships. Autonomous ship technologies are developing quickly—domestically and abroad—and have the potential to transform the maritime environment. While autonomous ships offer a range of potential benefits, these new technologies also pose new safety risks that could present challenges to a U.S. legal framework that requires crews to be onboard.

As autonomous ship technologies develop, some countries are pursuing various approaches to regulating them. In the U.S., the Coast Guard is the federal agency responsible for regulating U.S. waterways to ensure that they are safe and secure. This includes promulgating regulations and guidance pertaining to the design, construction, and operation of commercial ships; certifying their compliance with applicable laws and Coast Guard regulations; and issuing and administering the credentials of seafarers. The Coast Guard is currently conducting a statutorily directed pilot program for autonomous at-sea rocket recovery that began in 2023. The Coast Guard acts as the lead agency within the U.S. delegation to the International Maritime Organization (IMO)—a specialized agency of the United Nations with the responsibility for the safety, security, and environmental performance of international shipping.

The fiscal year 2023 National Defense Authorization Act includes a provision for GAO to submit a report on, among other things, how commercial autonomous ships are used, how they may affect safety and the maritime workforce, and how these ships are regulated internationally and domestically. (Pub. L. No. 117-263, § 11504(j), 136 Stat. 2395, 4133-34 (2022)). This report describes commercial autonomous maritime ship usage globally and the associated benefits and challenges, how the IMO and selected countries are regulating these technologies, and how the Coast Guard is regulating autonomous ships and the challenges it may face in the future.

Key Takeaways

- Although the potential for autonomous ships is broad, current commercial uses are fairly narrow. According to the IMO, all current uses should have a human who is in control or can take control if needed. U.S and international stakeholders we interviewed described improved safety and efficiency, among other benefits. However, some expressed concerns and noted challenges involved in developing and proving these technologies for safe commercial use. Additionally, uncrewed or fully autonomous ship technologies may pose new safety risks in the maritime environment and

could present challenges to a U.S. legal framework that requires (or is written with a presumption that) crew be aboard and in control of every ship.

- The IMO is developing a regulatory framework for autonomous ships in commercial operation in international waters that addresses cross-cutting issues such as safety, training, and legal liabilities. It is generally expected to be adopted by member countries on a non-mandatory basis in 2025 and in force on a mandatory basis for member countries in 2032 by amending an existing IMO convention. Selected countries have approached regulation of autonomous ships in various ways, including regulating them within the framework of existing laws and regulations, modifying regulations, and creating new regulations and policies.
- According to Coast Guard officials, the Coast Guard regulates the design, construction, and operation of autonomous ships through existing laws and regulations which are sufficient for it to execute its safety mission.
- Various statutes establish the minimum number of crew required per vessel. Coast Guard officials told us that they do not have the authority to waive these crew requirements outside of the limited scope of the at-sea rocket recovery pilot program. However, officials have heard concerns from industry stakeholders that the inability to reduce crew below the minimum statutory requirements could make the capital cost of developing technologies that would take the place of crew—and thus save labor costs—impractical. Coast Guard officials said they monitor developments that could prompt a need for new or revised laws and regulations, and brief Congress periodically.

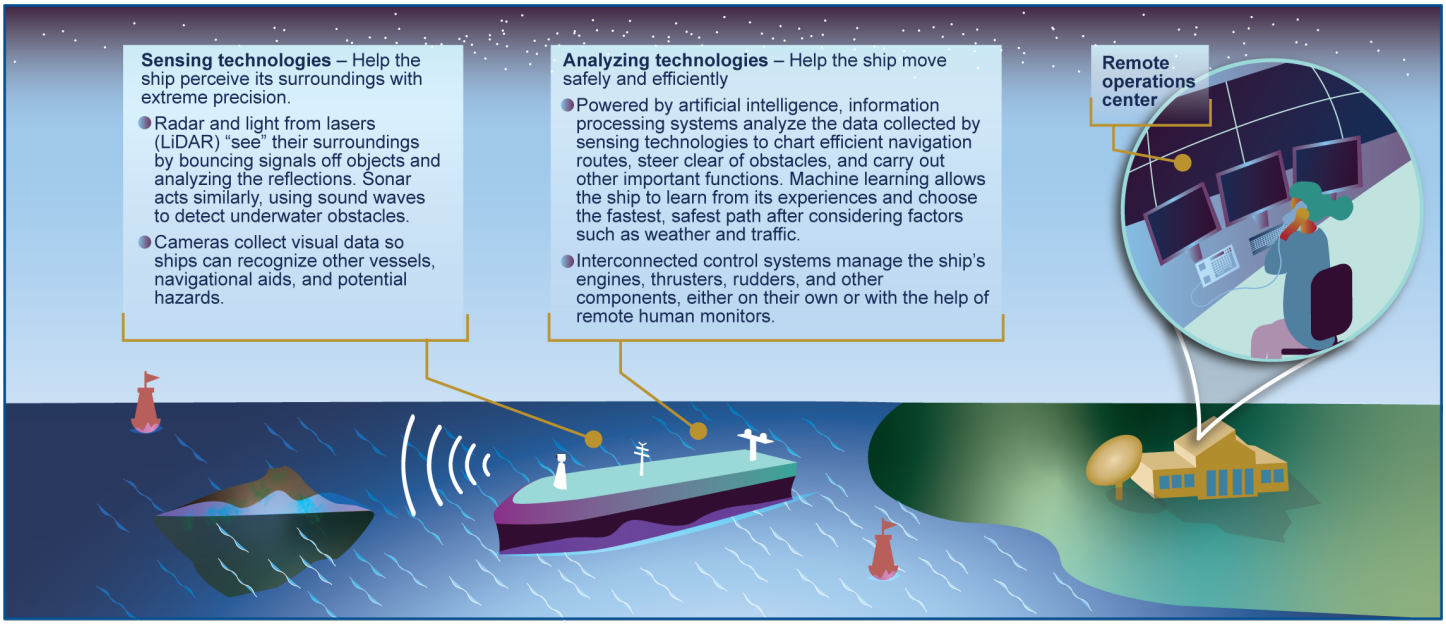
What are autonomous ships?

According to leading maritime standard-setting bodies and industry organizations, ship autonomy exists along a spectrum based on the level of control enabled by increasingly sophisticated technologies. A fully autonomous ship uses technological processes to control its navigation and propulsion functions without the need for human input. At the lower end of the spectrum, automated ship systems may simply collect data about the ship's surroundings and help human crew make decisions.

For the purposes of this report, "autonomous ships" refer to all types of maritime vessels with some level of autonomy.[1] Notably, in terms of onboard crew, autonomy does not equal "uncrewed." These ships can either be crewed, remotely operated with or without crew, or fully autonomous with or without crew.

Like other forms of advanced transportation systems, autonomous ships use technologies ranging from advanced sensor and control systems to artificial intelligence and machine learning. They use these and other technologies to collect and assess information, make decisions, and then act, 24 hours a day, without the need for a break (see fig. 1).

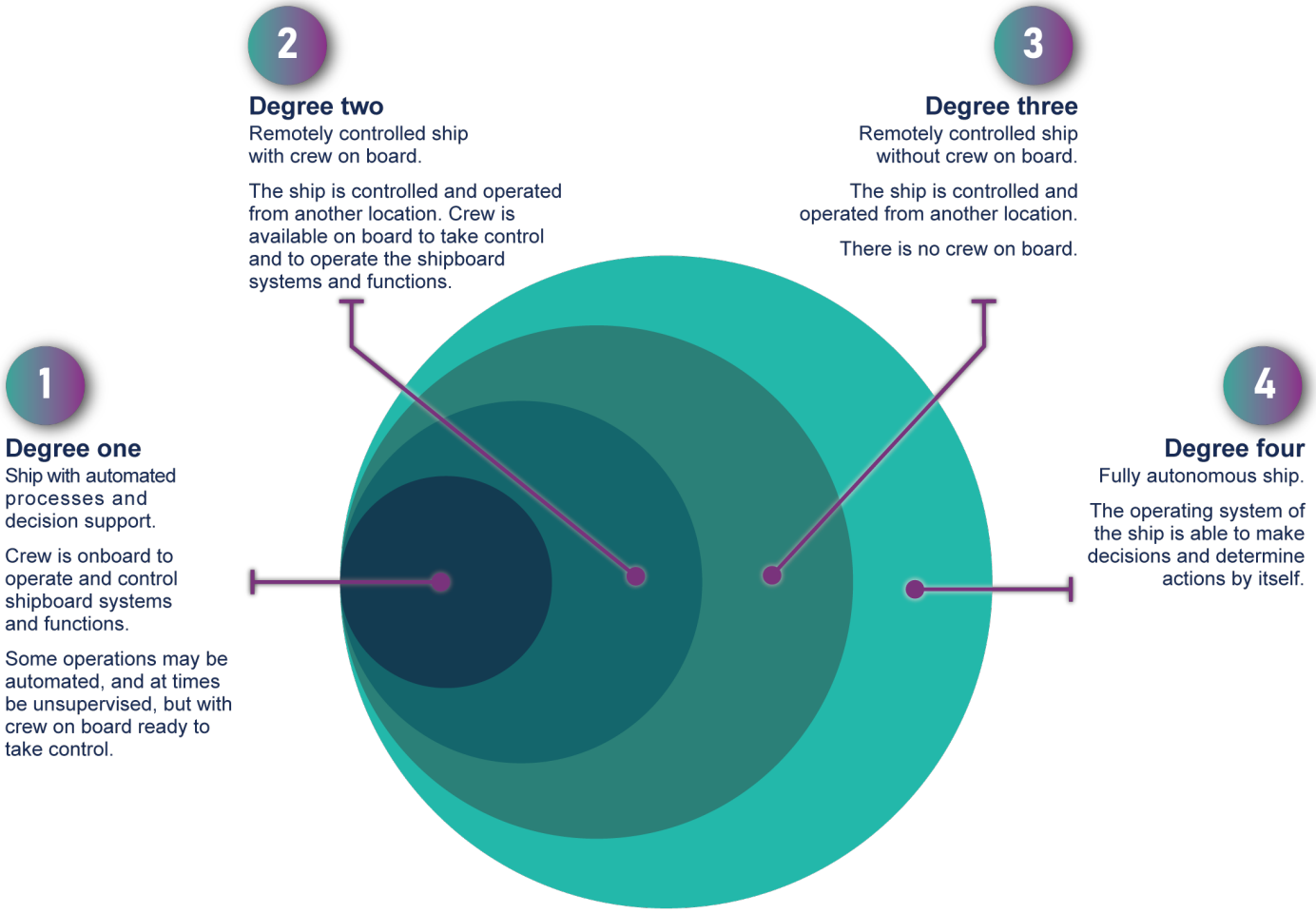
Figure 1: Examples of Commercial Autonomous Ship Technologies in Use as of June 2024



Source: GAO illustration and analysis of autonomous ship information. | GAO-24-107059

Similar to other types of autonomous transportation technologies, maritime standards-setting organizations define degrees of automation based on the degree to which a task is automated. One such framework was proposed by the IMO in 2018 (see fig. 2). In addition, ships may not always fall within one degree of autonomy. For example, a ship could run autonomously in open water, but crew could help operate it when leaving or returning to port.

Figure 2: Degrees of Ship Autonomy as Proposed by the International Maritime Organization



Source: GAO illustration and analysis of of International Maritime Organization information. | GAO-24-107059

How are autonomous ships used commercially today?

Autonomous commercial ships in use today around the world are commonly designed or adapted to perform a variety of specialized tasks. Many stakeholders we interviewed said they are currently well-suited to perform limited, controlled, and fixed-route applications that are closer to shore, at lower speeds, and in less frequently trafficked areas. Many stakeholders also told us that autonomous ships are only being used when there is a business case, such as potential cost-savings, or operational benefits. According to the IMO, all autonomous ships should have a human in control either onboard or in a remote location, or who can take control when necessary. Autonomous applications described included:

Scientific and other observations. Slow-moving research vessels can collect weather and other data, monitor the environment, or map the seafloor. These vessels can be much smaller and remain at sea much longer than crewed vessels.

Clean up and disaster response. Ships that can remove humans from harmful environments, such as when monitoring highly polluted waters after an oil spill or extinguishing ships that are on fire.

Short distance cargo hauling. Small to medium-sized cargo ships can traverse smaller bodies of water, such as rivers or inland waterways, to deliver goods to ports.

Short distance passenger transport. Ferries can navigate themselves as they carry people along inland, river, or coastal routes.

Maneuvering larger vessels in confined spaces. Tugboats, either retrofitted or designed with autonomous ship technologies, can help bigger vessels leave and enter ports.

For specific examples of current autonomous ships, see figure 3.

Figure 3: Examples of Commercial Autonomous Ships in Use as of June 2024

Source: GAO analysis of information provided by SpaceX, Fugro, and Kongsberg Maritime. Images provided courtesy of those companies. | GAO-24-107059

How might autonomous ships affect safety, labor, security, and the environment?

U.S. and international stakeholders we interviewed shared a range of perspectives on the potential effects commercial autonomous ships could have on mariner safety and labor, ship security, and the environment around the world.

Safety. According to most stakeholders and the literature, autonomous ships have the potential to be safer by reducing human error and removing humans from dangerous situations. Specifically, most stakeholders supported the idea that these technologies could reduce errors caused in part by fatigue and lessen the risks of collisions with hazards or other vessels. One of the risks some stakeholders told us that autonomous ship technologies could lessen is the risk when crew have to perform hazardous duties, such as working on deck in rough seas or foul weather.

Many stakeholders also described some safety concerns about controlling the ship and how autonomous systems will interact with other human crews. For example, a few were particularly concerned with technical challenges should control of the ship be passed back and forth between human operators and autonomous systems. As to safety for fully autonomous, uncrewed commercial ships, some stakeholders said it remains to be seen how developers would prove the ships are safe and reliable enough to avoid collisions. In addition, some said these ships would also have to interact in international waters with the majority of other ships that, for the foreseeable future, will still be operated by humans. One

ship builder expressed particular concern for the safety of those in the vicinity of autonomous ships, such as a kayaker in a harbor, who may not be visible to cameras.

Labor. According to a few stakeholders and the literature, autonomous ships could have substantial effects on the maritime workforce. One potential benefit was greater workforce diversity. For example, some stakeholders told us that moving crews from onboard a ship to a remote operating center could attract people with physical limitations that might not allow them to meet the physical demands of being at sea. In addition, many stakeholders said remote crews could enjoy greater work-life balance because they would be able to work a more normal schedule, which could help retain them longer. Also, some stakeholders said autonomous ships could help address what they said is a shortage of mariners. However, many stakeholders cited maritime union opposition to automation as a challenge, even though one of them suggested this may be lessening as unions realize a potential transition would be gradual. Finally, many stakeholders cited the need for additional training to train or retrain mariners to operate semi-automated systems or monitor fully autonomous ships, while a few thought that enhanced training could be more expensive.

Cybersecurity. According to many stakeholders and the literature, cybersecurity risks are substantial for autonomous ships due to network vulnerabilities to hacking. Some stakeholders said these risks are increasing because of the increased reliance on connected technologies, regardless of whether the vessel is autonomous or not. Some said cybersecurity risks could be even higher if no humans were aboard who could troubleshoot issues. In recognition of these risks, maritime organizations, such as the IMO, have developed guidelines to help stakeholders manage cyber vulnerabilities in systems such as those that control navigation and propulsion.

Physical Security. While the literature reflected mixed opinions about how autonomous ships might affect physical security, many stakeholders said that the greater the degree of autonomy on a ship, the higher the risk of theft or vandalism. Primarily, some said that is because there would be no human deterrent. However, some stakeholders thought design features and technology could provide remote operators with information that could make the ships more physically secure. For example, some stakeholders said that technology could effectively allow remote operators to perform security rounds using camera images and sensor data to detect threats and allow them to intervene by, for example, issuing audible warnings to repel intruders.

Environment. According to many stakeholders and the literature, autonomous ships could have some environmental benefits from reducing harmful engine emissions. For example, many stakeholders said that autonomous ship technologies that navigate, steer, and propel lighter ships more efficiently will consume less fuel. In addition, many stakeholders said that autonomous ships will likely use cleaner technologies such as battery electric power and alternative fuels that could reduce harmful pollutants. Moreover, some said autonomous ships can make constant steering and power adjustments based on real-time weather and sea condition data to operate more efficiently. However, some pointed out that since alternative fuels and advanced propulsion systems are not unique to autonomous ships, those environmental benefits could be realized on crewed ships as well.

How is the IMO integrating autonomous ships into its regulatory framework?

The IMO—a specialized agency of the United Nations that sets global standards for the safety and security of international shipping—has been taking steps to

integrate autonomous ships into its regulatory framework of international conventions since 2018.[2] These steps include conducting regulatory scoping exercises of IMO conventions related to maritime safety and security and establishing guidelines for testing autonomous ships. Currently, the IMO is working to develop a framework for member states to use in regulating autonomous ships, which officials hope will be adopted on a non-mandatory basis in 2025.

The IMO relies on the same processes to address autonomous ships as it does with other ships. Specifically, guidance and regulations are developed and approved by committees comprised of the member states. IMO professional staff help facilitate these committees—for example by coordinating the meeting schedules—but are not directly involved in developing or approving guidance and regulations. Three IMO committees in particular have been active in addressing autonomous ship issues:

- the Maritime Safety Committee,
- the Legal Committee, and
- the Facilitation Committee.

According to IMO documents, from 2018 to 2022, each of these three committees conducted regulatory scoping exercises to assess how the existing regulatory framework might be affected by autonomous ships. These committees reviewed IMO regulations and conventions under their respective purviews that address safety at sea, mariner competence (including training), preventing collisions at sea, and the facilitation of international maritime traffic, among other subjects.[3] As a result of these exercises, the committees identified priority issues such as clarifying the roles and responsibilities of the person in command of the ship (in maritime terminology, “master”) and crew, the roles and responsibilities of people who remotely operate ships, and designating remote operators as seafarers.[4] The Maritime Safety Committee concluded that many of the potential regulatory gaps could be addressed through a new regulatory framework for autonomous ships.[5]

During the regulatory scoping exercises, the Maritime Safety Committee approved interim guidelines for autonomous ships conducting sea trials. These guidelines assist relevant authorities and stakeholders with ensuring that at-sea tests are conducted safely, securely, and with regard to protecting the environment.[6] The guidelines also provide direction in managing safety risks, compliance with mandatory instruments, compliance with crewing and certification requirements, ensuring human involvement, and cyber risk management.

After the regulatory scoping exercises, the IMO formed a joint working group consisting of Maritime Safety, Legal, and Facilitation committee members to focus on autonomous ship issues. The working group agreed that

- autonomous ships should have a human master, either onboard or remote who can take control of the ship as needed;
- a ship can have multiple masters on a single voyage, but only one remote operating center can be responsible for an autonomous ship at any one time; and
- a master can be responsible for multiple ships under certain circumstances.

The Maritime Safety Committee, comprised of IMO member states, is currently developing a framework that addresses the regulatory gaps in the scoping exercises mentioned above. This framework intends to ensure that autonomous commercial cargo ships sailing internationally operate safely and in coexistence

with conventional ships. As of May 2024, the IMO expects to adopt the framework on a non-mandatory basis in 2025 and adopt a mandatory framework in 2030 that will be effective in 2032.[7] The Chair of the IMO Maritime Safety Committee, who is leading the overall effort to develop this framework, told us that the mandatory date is not certain because of the time needed to work through complex issues. Further, the Chair and the head of the U.S. delegation working on the regulatory framework told us that it is important that the committee gets the non-mandatory framework right the first time, since making major changes after the framework is approved could be difficult.

How is the United States involved in international efforts to regulate autonomous ships?

As the lead agency for the U.S. delegation to the IMO, the Coast Guard has led and assisted in international efforts to regulate autonomous ships. It has led and assisted in aspects of the IMO Regulatory Scoping Exercise, specifically in the review of IMO conventions related to crew competence and certification, and prevention of collisions at sea, among other conventions. According to Coast Guard officials, the U.S. is also leading IMO efforts to develop proposed text for the electrical, engine machinery, and lifesaving appliances sections for the autonomous ship regulatory framework that is currently under development.

Finally, Coast Guard officials told us that the Coast Guard leads the U.S. delegation working on the international autonomous ship regulatory framework. This delegation is comprised of a working group that includes the Navy, the U.S. Maritime Administration, the State Department, the American Pilots' Association, and a training facility affiliated with the American Maritime Officers. According to the head of the U.S. delegation, it discusses autonomous ship issues and develops joint decisions on what it thinks should be included in the autonomous ship regulatory framework.

How are select countries addressing autonomous ships?

While IMO is developing its regulatory framework for autonomous ships, the countries we selected to review have taken various approaches to addressing autonomous ships. According to regulators from Canada, Norway, and the United Kingdom, these approaches include providing guidance to stakeholders on how to comply with existing laws and regulations, modifying regulations, and creating new regulations and policies. Some of the challenges they identified in regulating autonomous ships are a lack of clarity on the definition and role of a ship's master and on the requirements for remote operators and remote operating centers.

Canada: According to Transport Canada officials, the Canadian government regulates autonomous ships as it does any other vessels. However, in cases of highly autonomous ship operations, it can provide exemptions to legal requirements such as the requirement for an onboard lookout. Canadian officials also told us that this process has been effective and that there have not been any challenges in approving autonomous ships through the exemption process. In 2022, the Canadian government created a policy that establishes an alternative process specific to small autonomous ships for complying with existing laws and regulations by establishing minimum design, construction, and operational standards.[8] For example, the guidance specifies that

- small autonomous ships must carry a device that can broadcast a distinct signal that identifies it as an autonomous ship;
- all small autonomous ship operations must be communicated to the local Canadian Coast Guard prior to operation so that the time, place, and distinct signal for autonomous ship operations can be communicated to others; and

- for uncrewed autonomous ships, there must be a qualified person at a remote-control center at all times to either operate the ship or stand by to take control in case of an emergency.

Norway: According to Norwegian Maritime Authority guidance issued in 2020, the Norwegian government utilizes the existing laws applicable for each ship type (i.e., cargo ships, passenger ships, fishing vessels) as the basis for regulating the construction and operation of autonomous ships since there are no regulations that specifically address autonomous ships. The guidance also states that the Norwegian government uses IMO guidelines for the approval of alternative and equivalent autonomous ship technologies to ensure autonomous ships have at least the same level of safety as conventional ships. The guidance includes design and safety (including cybersecurity) requirements; and when the ship is remotely operated or crewing is eliminated, it describes the process for ensuring that all required functions are performed.

An official at the Norwegian Maritime Authority told us that some of the challenges the agency encountered in addressing autonomous ships are related to ensuring the safe function of ships with minimal or no crew onboard and whether current laws and regulations require a ship's master to be onboard or if a remotely located master is sufficient. To address these challenges, the Norwegian Maritime Authority is working with ship owners to test the safety of the technology and adjust requirements accordingly. For example, an official from the company that owns the world's first autonomous electric container ship, the *Yara Birkeland,* told us that even though its ship is autonomous and controlled from a remote operating center onshore, it maintains a crew of three that can take control of the ship to comply with Norwegian crew requirements. The company official told us that the Norwegian Maritime Authority allowed them to reduce their crew from the prior requirement of five because of successful tests and no safety incidents. The official said the company hopes crew will get down to two after additional tests.

United Kingdom (UK): According to the Maritime and Coastguard Agency, autonomous ships currently operating in the UK, or flagged in the UK and operating elsewhere, are addressed through exemptions and equivalences to existing regulations.[9] Additionally, every time an autonomous ship test is organized, the operator must prove its safety and obtain exemptions from national and international maritime safety requirements for each voyage. The larger the autonomous ship and the higher the level of autonomy proposed, the more complex the burden becomes because more regulations must be accommodated through equivalence or exemption. With such a process, a tailored approach is required for each ship and voyage.

In September 2023, the UK government completed a regulatory review aimed at addressing areas where existing regulations may be outdated, a barrier to innovation, or not designed with new technologies and business models in mind. The review highlighted a number of issues and areas for clarification in existing law. These include the need to clarify terms like "master," update requirements for onboard carriage of documentation, and address gaps such as the requirements for remote operations centers. The regulatory review proposed that primary legislation be amended to regulate all autonomous ships regardless of size; however, it also acknowledged that there is a risk in developing a domestic legal framework that could diverge from the IMO regulatory framework when it is developed.

In December 2023, the Maritime and Coastguard Agency modified its regulations for small commercial ships.[10] These regulations were modified to allow for remote operation of vessels under 24 meters and include definitions for "remote operations centre" and "remotely operated unmanned vessel," and provide

certain exemptions for remotely operated unmanned vessels, such as the requirement to keep logbooks on remotely operated uncrewed small vessels.

An official from the Maritime and Coastguard Agency told us that it is facing the same challenges as that of many other countries in updating its maritime laws that were put in place assuming a ship would have a crew onboard. For example, they told us that there needs to be clarity on how to regulate remote operating centers.

How is the U.S. Coast Guard currently regulating autonomous ships?

The Coast Guard is applying current regulations to autonomous ships to allow for certain operations and testing. These operations and tests are typically handled by local Captains of the Port—the Coast Guard officer directly responsible for law enforcement activities within a designated area.[11] Captains of the Port apply regulations and guidance to allow for operations on a case-by-case basis and, when appropriate, forward industry requests to the Coast Guard Commandant. The Coast Guard has not developed new regulations specific to autonomous systems or ships since 1988.[12] Current regulations are based upon relevant statutes, such as those that require certain numbers of persons, or that require persons with certain qualifications to be aboard operating ships, as discussed further below. According to Coast Guard officials, autonomous ship operations must comply with statutory minimum crew requirements. Coast Guard officials told us that they execute their safety mission within their current authorities and regulations.

The Coast Guard's current regulations allow automated systems to be used on vessels under certain conditions.[13] These automated systems may replace specific engineering department crew based on (1) the capabilities of the automated system, (2) its demonstrated and continuing reliability, and (3) a planned maintenance program that ensures continued safe operation of all vital systems.[14] The Coast Guard's *Marine Safety Manual Volume III* sets forth the approval process for vessels with automated vital systems—systems that may ultimately reduce specific engineering department crewing requirements once reviewed and approved by the Officer in Charge, Marine Inspection.

The Coast Guard's current regulations also allow for "equivalents" to the current regulatory standards for the design and construction of commercial vessels.[15] Under current regulations, the Coast Guard can grant equivalents when officials are satisfied that the use of any particular equipment, apparatus, or arrangement not specifically required by law is unreasonable or impracticable and the alternative may be implemented safely.[16] According to officials, the Coast Guard can grant equivalents for autonomous ship technologies that comply with existing legal frameworks. For example, Coast Guard officials advised that the agency could consider, as an equivalent, approving a system that would autonomously navigate a vessel if it also complied with statutory minimum crewing requirements. Coast Guard officials told us that they have received one design standard equivalency request involving autonomous ship technology.

The Coast Guard's current policy guidance also supports the testing of autonomous ship technologies under certain conditions. For example, Policy Letter 22-01 (Change 1), *Guidelines for Human-Supervised Testing of Remote Controlled and Autonomous Systems on Vessels*, provides guidance to Captains of the Port for the testing of autonomous ship technologies.[17] Testing under this guidance is intended to help the maritime industry better understand the benefits and limitations of autonomous systems and to highlight any unintended consequences. Coast Guard officials advised us that these tests cannot be conducted in a way that reduces the number of crew on a vessel to fall below what is prescribed by statute.

Coast Guard Captains of the Port we spoke to said approving these systems is a case-by-case process at the local level. They work directly with the applicant to understand the project, assess the technology, reach an agreement on the conditions of the operation, and inform other waterways users about the project. One Captain of the Port told us they are generally able to approve industry requests, but noted the process is resource intensive and time consuming. This official added that they are learning and improving with each new project. Most industry representatives we interviewed who commented on their experiences working with Coast Guard indicated they had been able to test and develop their technologies within the current regulatory framework.

Captains of the Port also told us they keep Coast Guard headquarters informed of autonomous testing and operations when appropriate and document these tests and operations in the Coast Guard's data systems. Headquarters officials noted that the Coast Guard's regulatory framework gives Captains of the Port discretion on decision-making. These officials noted that industry stakeholders have raised concerns about consistency across individual ports. Consequently, officials said that the Coast Guard is working to ensure Captains of the Port have the guidance they need and use the same risk assessment framework so that they can consistently assess project risks within the unique characteristics of each individual port and geographic location.

How does the U.S. Coast Guard monitor the development of autonomous ship technology?

The Coast Guard conducts a number of internal and external activities to monitor autonomous ship technology as it develops domestically and internationally. These include knowledge-building activities such as forming an advisory committee and engaging with industry stakeholders. As we have previously reported, these types of activities can help agencies develop an effective regulatory response for emerging technologies.[18]

On June 22, 2021, the Coast Guard chartered the Automated and Autonomous Vessel Policy Council (AutoPoCo), an internal advisory committee composed of several Coast Guard headquarters offices. The AutoPoCo meets regularly to work on autonomous ship technologies planning and assessment activities, including developing guidance for Captains of the Port; identifying legal, regulatory, and policy gaps and providing recommendations; and engaging key industry stakeholders.

Coast Guard officials told us that the AutoPoCo is currently focused on collecting data, monitoring, and providing guidance related to the at-sea rocket recovery pilot program established in the 2023 National Defense Authorization Act. The Act gave the Coast Guard interim statutory authority to allow specified uncrewed, remote autonomous at-sea operations and activities.[19] Officials told us that the Coast Guard office responsible for managing the pilot program is receiving data from pilot program participants and sharing that information with the AutoPoCo. Additionally, the AutoPoCo receives regular updates from the local Captain of the Port who is observing the program operations first-hand. Coast Guard officials told us that this pilot program is giving the AutoPoCo practical experience in assessing autonomous ship technologies. However, one stakeholder participating in the pilot program told us that they were concerned about the slow pace in which they have received policy guidance about operations within the pilot program from the Coast Guard.

The Coast Guard also collaborates externally with industry stakeholders and other federal agencies to share and gather information on autonomous ship technologies. The Coast Guard participates in stakeholder panels and events and has invited stakeholders to present their work to the AutoPoCo. It also

collects industry perspectives through forums like the National Merchant Marine Personnel Advisory Committee, which provided the Coast Guard with recommendations on the role of seafarers on these vessels and the competence requirements for operators. Additionally, in 2020, the Coast Guard issued a request for information from the public on autonomous ships and, according to officials, is incorporating the comments it received into its ongoing policy discussions.[20] The Coast Guard also communicates and shares information with other federal agencies that use autonomous ships such as the National Oceanographic and Atmospheric Administration and the Navy.

Finally, the Coast Guard observes and monitors international developments in autonomous ships in its capacity as the lead agency for the U.S. delegation to the IMO. This includes its efforts to help develop the IMO autonomous ship regulatory framework. This role positions the Coast Guard to be in tune with industry priorities and perspectives domestically, and monitor and participate in developing an international framework that could affect how autonomous ship technologies continue to develop.

What challenges has the U.S. Coast Guard identified in regulating autonomous ships as they develop?

The Coast Guard identified several factors that could constrain or complicate its ability as a regulator to enable the development and adoption of autonomous ships. These include limited statutory authority to allow for reduced crewing on ships, few domestic examples demonstrating autonomous ship technologies, and challenges in harmonizing international and domestic regulations.

Statutory requirements. The Coast Guard has limited authority to reduce crew requirements due to various statutes that establish the minimum number of crew required per vessel. A primary statute establishing minimum crew requirements prescribes the minimum number of required officers on certain vessels generally depending on the gross tonnage of the vessel and requires that each vessel have a credentialed master.[21] Other relevant statutory provisions include, for example, the requirement that the certificate of inspection issued to a vessel state the complement of officers and ratings considered by the Coast Guard to be necessary for safe operation.[22] In addition to statutes that establish minimum crew requirements, the Coast Guard advised us that any statute based upon the assumption that humans are aboard the vessel may present challenges as human operators are removed from ships as autonomous ship use and technology progresses.[23]

Coast Guard officials said they do not have authority to waive these requirements for autonomous vessels outside of the limited scope of the at-sea rocket recovery pilot program. While officials noted their inability to waive these requirements, these officials told us that they are currently able to meet their mission to ensure a safe, secure, and environmentally sound waterways system with the authorities they have. However, officials have heard concerns from industry stakeholders that the inability to reduce crew below the minimum statutory requirements could make the capital cost of developing technologies that would take the place of crew—and thus save labor costs—impractical. Coast Guard officials told us they briefed congressional staff in February 2024 on autonomous maritime issues including the potential statutory barriers to regulation and on the progress of the pilot program, which is still in its early stages. They told us they plan to provide quarterly briefings to congressional staff on future developments related to the at-sea rocket recovery pilot.

Limited information on technology. Coast Guard officials said that incorporating new technology into an existing regulatory regime requires sufficient data and examples of the technology for the Coast Guard to evaluate.

Coast Guard officials explained that, in general, to incorporate new technology into the existing regulatory regime, they first evaluate the technology on a case-by-case basis. Once the technology develops and patterns begin to emerge in how the industry is seeking to use the technology, then the agency can issue policy guidance and develop regulatory design standards based on similar characteristics.

Furthermore, these early uses of autonomous technologies could allow the Coast Guard to better understand specifically how, if at all, autonomous ship technologies can comply with laws, regulations, and policies that were originally written with the assumption of humans onboard a ship. For example, Coast Guard officials stated that how autonomous ship technologies can comply with domestic and international collision regulations has not been established. These regulations require that "[e]very vessel shall at all times maintain a proper look-out by sight and hearing as well as by all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and the risk of collision."[24]

Coast Guard officials told us that, internationally, the IMO recently determined that autonomous ships will need to comply with the look-out requirement. Furthermore, the IMO determined that the international regulation would not need to be amended at this time to accommodate autonomous ships. Accordingly, Coast Guard officials told us every country will need to determine how autonomous ships comply with this requirement. Domestically, Coast Guard officials said that before determining which autonomous ship technologies can comply with domestic and international lookout requirements and before they can determine how to verify compliance, the agency needs to see actual examples of autonomous ship technologies performing lookout functions.[25] Coast Guard officials told us that thus far, stakeholders have not been willing or able to share examples of such technology with the agency. Officials said the lack of examples may be due to the nascent nature of the technology, companies being unwilling to share proprietary design standards, and the additional costs of complying with statutory minimum crew requirements.

Harmonization. Finally, Coast Guard officials told us they will need to determine how to adopt the forthcoming IMO autonomous ship regulatory framework within the U.S. legal framework, including any instances where the IMO framework may conflict with minimum crewing and other statutory requirements. Additionally, officials told us the Coast Guard does not currently intend to amend domestic regulations or issue policy guidance for autonomous ships in advance of the IMO regulatory framework because harmonizing U.S. regulations will be more effective once the IMO framework is established. Officials noted that the IMO framework is goal-based and that member states will need to determine how to incorporate it and verify compliance with it. Therefore, while officials hope that the IMO framework provides the Coast Guard with a method to assess autonomous ship technology functions, the implementation of the IMO framework will be subject to U.S. statutory requirements, including minimum crew requirements.

What is the Coast Guard's approach to identifying a need for regulatory action?

The Coast Guard is currently assessing market demand and collecting information related to autonomous ships to identify when, if at all, regulatory or statutory changes are needed in accordance with its established process. Coast Guard officials said that they will develop policy guidance and regulatory design standards for autonomous ship technologies when the technology reaches a critical mass. Officials indicated that the conditions for initiating rulemaking have not yet been reached.

According to Coast Guard officials, the Coast Guard's current approach—relying on existing regulations for autonomous ships—reflects its determination, based on its process, that new regulations are not yet needed. The Coast Guard Commandant Instruction Manual *Preparation of Headquarters Regulations* describes several sources that might establish a need for new or modified regulations, and states that new regulation should be considered only when it appears that a statute or existing regulation cannot adequately address a need.[26]

Coast Guard officials said they have processes in place to monitor each of these sources and identify whether the needs identified by these sources can be met through statute or existing regulation (see table 1). One such source is public petitions. Officials told us that the Coast Guard participates in several public forums, and any requests for autonomous ship operations they have received so far could be met through existing regulations. As autonomous ship technology continues to develop and be deployed, Coast Guard officials told us they will continue to use their existing processes to help the agency identify whether conditions change and the need for regulatory action emerges.

Table 1: Examples of Coast Guard Activities to Monitor Potential Sources of Regulatory Need for Autonomous Ships

Potential Source of Regulatory Need	Example of Coast Guard Activities
New statutory requirements	The Coast Guard's Autonomous Vessel Policy Council (AutoPoCo) engages with the Coast Guard's Office of Legislative Counsel to stay informed on legislative proposals and/or enacted statutes related to autonomous ships.
Internal review of existing policies or rules	The AutoPoCo reviews applicable laws, regulations, and policies, identifies potential gaps and, where appropriate, provides recommendations.
Recommendations from an advisory group or its members	The Coast Guard solicits recommendations from federal advisory committees, such as the National Merchant Marine Personnel Advisory Committee.
New technology	The Coast Guard participates in several meetings—such as the AutoPoCo and International Maritime Organization (IMO) autonomous ship regulatory framework deliberations—to help it stay informed on new technology developments related to autonomous ships.
Changes in industry operations or practices	The Coast Guard (1) connects with industry through the AutoPoCo to learn about new or ongoing initiatives; (2) issued a Request for Information in 2020 asking stakeholders to advise on the ways commercial vessels are using autonomous ship technologies; and (3) works with stakeholders to implement systems in accordance with existing policy guidance.
Court decisions	The Coast Guard's Office of Maritime and International Law is part of the AutoPoCo and reviews relevant court decisions in response to issues identified by AutoPoCo.
Amendments to international agreements to which the U.S. is a party	The Coast Guard serves as the lead agency for the U.S. delegation to the IMO and is actively involved in deliberations for the IMO autonomous ship regulatory framework.
Executive branch orders or policy changes	The Coast Guard has liaisons in other executive branch offices to facilitate communication and coordination on policy priorities and changes.
Public suggestions or petitions for rulemaking	The Coast Guard has previously participated in and continues to participate in several public forums and regularly engages with industry stakeholders.

Source: GAO analysis of U.S. Coast Guard Documents and Interviews | GAO-24-107059

Agency Comments

We provided a draft of this report to the Maritime Administration through the Department of Transportation and the Coast Guard though the Department of Homeland Security for review and comment. We also provided relevant excerpts to the foreign maritime regulators and other third-parties we gathered evidence from to ensure the accuracy of our descriptions. We received technical comments from the Department of Homeland Security which we incorporated into the draft.

How GAO Did This Study

To inform all our work, we conducted a literature search and reviewed relevant studies, papers, and journal articles. We searched for literature published between January 2014 and March 2024 in database platforms—including ProQuest, Lexis+, Janes, IEEE Xplore, and Scopus—using search terms including "autonomous," "unmanned," or "uncrewed ship." We reviewed abstracts of publications in the search results to select and obtain those most relevant to autonomous domestic and international ship technologies, and the benefits and challenges autonomous ships present related to safety, labor and workforce, cyber and physical security, and the environment.

To describe various types of autonomous ship technologies and their potential uses, we reviewed the selected literature. We reviewed the same sources to describe some of the benefits and challenges related to safety, labor and workforce, cyber and physical security, and the environment. We also used interviews (see below) to describe these technologies, uses, benefits, and challenges.

To select stakeholders who would inform all our work, we reviewed news, trade and industry publications, and industry organization websites to develop a list of stakeholders with subject-matter expertise on autonomous ships and categorized them based on their roles. We selected stakeholders based on their leadership within their respective category, their current level of involvement with autonomous ship technologies, the country they are based in, and other relevant factors. We used professional judgment to make selections that spanned these categories such that, taken as a whole, the selected stakeholders could provide a fair and broad discussion of different issues and perspectives. In some cases, the selected stakeholders chose to submit answers to our questions in writing, which we accepted. See table 2 for a list of the 17 stakeholders we selected and interviewed. Due to the varying experiences of officials in the places we selected, not all officials had opinions on all questions or issues during our interviews. To summarize industry stakeholders' statements, we use "most" to refer to 13-16 stakeholders, "many" to refer to 8-12 stakeholders, "some" to refer to 5-7 stakeholders, and "a few" to refer to 3-4 stakeholders.

Table 2: List of Interviewed Stakeholders by Type

Category	Organization (one of two)	Organization (two of two)
Autonomous Ship Technology Developers	Fugro (Netherlands)	Sea Machines Robotics (U.S.)
Autonomous Ship Technology Developers	Kongsberg Maritime (Norway)	Space Exploration Technologies Corporation (SpaceX, U.S.)
Labor Associations	American Maritime Officers (U.S.)	International Transport Workers' Federation (U.K.)
Maritime Training Providers, Research Institutions, and Academia	Fisheries and Marine Institute of Memorial University of Newfoundland/The Launch (Canada)	National Academies of Sciences, Marine Board and ad hoc New Coast Guard Authorities Committee member Sean Pribyl (U.S.)
Maritime Training Providers, Research Institutions, and Academia	Norwegian Forum for Autonomous Ships (Norway)	Maritime Institute of Technology and Graduate Studies (U.S.)
Non-governmental Maritime Organizations	American Bureau of Shipping (U.S.)	
Non-governmental Maritime Organizations	Association for Uncrewed Vehicle Systems International (U.S.)	Smart Ships Coalition (U.S.)

Category	Organization (one of two)	Organization (two of two)
Vessel Owners and Ship Builders	Crowley (U.S.)	Yara International ASA (Norway)
Vessel Owners and Ship Builders	Nichols Brothers Boat Builders (U.S.)	HD Hyundai/Avikus (South Korea)

Source: GAO Documents | GAO-24-107059

Note: The country of origin is listed in parenthesis for each of the listed stakeholders. Three stakeholders provided written responses.

To describe how the IMO is integrating autonomous ships into its regulatory framework and how the U.S. was involved in the process, we reviewed relevant IMO reports and interviewed U.S. Coast Guard officials who function as the Chair of the IMO Committee leading the efforts to develop an autonomous ship regulatory framework, and to the head of the U.S. delegation to the IMO.

To describe how other countries are regulating autonomous ships and understand any challenges they may be experiencing, we originally selected the following five countries: Canada, Japan, South Korea, Norway, and the United Kingdom. We selected Canada because of the shared waterways and the cooperative relationship with the U.S. We learned about this relationship at the 2023 International Conference of Maritime Autonomous Surface Ships. As for the remaining countries, we identified two leading European countries (Norway and UK) and two leading Asian countries (Japan and Korea), based on a review of the literature described above, stakeholder interviews, conference presentations, and review of submissions to IMO. We reviewed relevant documents and met with representatives from Canada and Norway and discussed these issues with them and received written responses to our questions from the UK. We did not receive responses from Japan or Korea in time for publication.

To describe how the Coast Guard is currently regulating autonomous ships, we reviewed the Coast Guard's current legal authorities, including relevant statutes and regulations, strategic plans, as well as policy letters and other guidance, such as *Marine Safety Manual Volume III*. We also interviewed Coast Guard headquarters officials in the Office of Commercial Vessel Compliance, Office of Design and Engineering Standards, and Office of Budget and Programs to understand how the aforementioned documents are used to regulate autonomous ships. Furthermore, we spoke to officials from four Coast Guard districts—New England (District 1), Southeast (District 7), Great Lakes (District 9) and Pacific Southwest (District 11)—to learn how they managed autonomous ship operations in their districts. We selected these four districts because stakeholders recommended them as areas with autonomous ship activities underway or because they have participated in the at-sea rocket recovery pilot program.

To describe the Coast Guard's monitoring and regulatory planning efforts and the challenges they might face, we reviewed relevant laws and Coast Guard policies, guidance, and analyses, such as the Automated and AutoPoCo charter. We also interviewed Coast Guard officials in the Office of Commercial Vessel Compliance, Office of Design and Engineering Standards, and Office of Budget and Programs to understand the progress on their ongoing activities and hear their perspectives regarding the potential challenges they face in regulating autonomous ships.

To describe the process that the Coast Guard uses to identify a need for regulatory action, we reviewed the Coast Guard's own guidance on identifying a need for regulatory action from COMDTINST M16703.1A: *Preparation of Headquarters Regulations*. We then reviewed the evidence we gathered through

our review of documents and interviews with officials, to understand how the Coast Guard's current activities enable it to identify potential sources of regulatory need as described in its guidance. We also spoke to a Coast Guard official in the Office of Design and Engineering Standards to understand how the Coast Guard considers and accounts for these factors related to its ongoing work on autonomous ships.

We conducted this performance audit from September 2023 to August 2024 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

List of Addressees

The Honorable Maria Cantwell
Chair
The Honorable Ted Cruz
Ranking Member
Committee on Commerce, Science, and Transportation
United States Senate

The Honorable Sam Graves
Chairman
The Honorable Rick Larsen
Ranking Member
Committee on Transportation and Infrastructure
House of Representatives

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Endnotes

[1]The term "vessel" includes every description of watercraft or other artificial contrivance used, or capable of being used, as a means of transportation on water. 1 U.S.C. § 3.

[2]The IMO adopts standards and recommended practices in accordance with the Convention on the International Maritime Organization to facilitate cooperation among participating states (including the U.S.) in the field of international shipping and to encourage the adoption of the highest practicable standards in matters related to maritime safety and efficiency of navigation.

[3]*See, e.g., International Convention on Standards of Training, Certification and Watchkeeping for Seafarers*, 1978, and *Seafarers' Training, Certification and Watchkeeping Code*; *International Convention for the Safety of Life at Sea*, Nov. 1, 1974, 32 U.S.T. 47; *International Regulations for Preventing Collisions at Sea*, Oct. 20, 1972, 28 U.S.T. 3459.

[4]46 U.S.C. § 10101 defines "master" as the individual having command of a vessel.

[5]In the Outcome of the Regulatory Scoping Exercise, the Maritime Safety Committee concluded that a new instrument, which could be made mandatory by means of amending an existing IMO convention, was the most appropriate way to address autonomous ship operations. The committee explained that amending individual conventions separately could lead to inconsistencies, confusion and raise potential barriers for the application of existing regulations to conventional ships.

[6]International Maritime Organization, *Interim Guidelines For MASS Trials*, London, UK. (June 14, 2019)

[7]The Chair of the IMO Maritime Safety Committee told us that minor changes may be made to the mandatory regulatory framework based on feedback from member states during the non-mandatory period.

[8]This policy applies to autonomous ships 12 meters in length or less, or 15 gross tons or less in weight. See: Transport Canada, *Tier I – Policy – Oversight of Small Maritime Autonomous Surface Ships*. Ottawa, Canada. (February 1, 2022)

[9]According to the United Nations *International Convention for the Safety of Life at Sea (1974)*, an "equivalent" is an alternative fitting, material, appliance or apparatus, or type thereof, or provision that is at least as effective as that required by the present regulations. *International Convention for the Safety of Life at Sea*, Nov. 1, 1974, 32 U.S.T. 47.

[10]*The Merchant Shipping (Small Workboats and Pilot Boats) Regulations 2023* (UK).

[11]Pursuant to 14 U.S.C. § 311, any officer may be designated by the Commandant as captain of the port or ports or adjacent high seas or waters over which the United States has jurisdiction, as the Commandant deems necessary to facilitate execution of Coast Guard duties. Captains of the Port enforce port safety and security and marine environmental protection regulations within their respective areas, including regulations for the protection and security of vessels, harbors, and waterfront facilities; anchorages; security zones; safety zones; regulated navigation areas; deepwater ports; water pollution; and ports and waterways safety. 33 C.F.R. § 1.01-30.

[12]Regulations pertaining to autonomous systems or ships have not been developed since the Coast Guard promulgated 46 C.F.R. § 15.715 (automated vessels) in 1987 and 46 C.F.R. § 62.50-30 (additional requirements for periodically unattended machinery plants) in 1988.

[13]As defined in the Coast Guard's regulations, "automated" means the use of automatic or remote control, instrumentation, or alarms. 46 C.F.R. § 62.10-1. These regulations correspond to the IMO's first degree of autonomy for purposes of defining autonomous ships. Pursuant to degree one, a ship with automated processes and decision support has seafarers that are onboard to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised but with seafarers onboard ready to take control. The Coast Guard's regulations contain the general requirements applicable to the automation of vital systems, including the requirements when automated systems are provided to replace specific personnel in the control and observation of the engineering plant and spaces or to reduce overall crew requirements. 46 C.F.R. §§ 62.01-3, 62.50-1. "Vital systems" are those systems that are essential to the safety of the vessel, its passengers and crew, including fire detection, alarm, and extinguishing systems, flooding safety systems, steering systems, electrical power generation and distribution, and propulsion systems. 46 C.F.R. § 62.10-1.

[14]46 C.F.R. § 15.715(a).

[15]*See* 46 U.S.C. § 3306 (authorizing the Coast Guard to prescribe regulations for the design, construction, alteration, repair, and operation of vessels to ensure safety); 46 C.F.R. chapter I (setting forth regulatory design standards for various types of vessels and allowing for equivalents under certain circumstances). An "equivalent" is an arrangement, fitting, appliance, apparatus, equipment, calculation, information, or test that provides the same level of safety as that established by applicable regulatory standards.

[16]46 C.F.R. §§ 30.15-1 (tank vessels), 70.15-1 (passenger vessels), 90.15-1 (cargo and miscellaneous vessels), 114.540 small passenger vessels carrying more than 150 passengers), 125.170 (offshore supply vessels), 136.115 (towing vessels), and 175.540 (small passenger vessels). The Coast Guard's Policy Letter 01-23, *Design Basis Agreement Submission Guidance*, provides guidance to vessel owners and operators when submitting design standard equivalency requests to the Coast Guard for consideration. As provided in Policy Letter 01-23, the Coast Guard will evaluate alternate arrangement or novel design proposals to ensure that alternatives provide a level of safety equivalent to that established by applicable regulatory standards.

[17]Additionally, the Coast Guard's Policy Letter 01-20, *Evaluation of Risk Posed by Novel Uses of the Marine Environment*, provides procedures for assessing and mitigating the risk posed by novel uses of the marine environment, including requests for areas within the navigable waters of the

United States to test remotely or autonomously operated vessels or marine systems and the use of floating platforms to launch and receive space vehicles within the marine environment.

[18]See GAO, *Federal Regulation: Selected Emerging Technologies Highlight the Need for Legislative Analysis and Enhanced Coordination*, GAO-24-106122, (Washington, D.C.: January 25, 2024)

[19]James M. Inhofe National Defense Authorization Act for Fiscal Year 2023, Pub. L. No. 117-263, § 11504, 136 Stat. 2395, 4131-32 (2022). Authorized activities under the pilot program include: "(1) remote over-the-horizon monitoring operations related to the active at-sea recovery of spaceflight components on an unmanned vessel or platform; (2) procedures for the unaccompanied operation and monitoring of an unmanned spaceflight recovery vessel or platform; and (3) unmanned vessel transits and testing operations without a physical tow line related to space launch and recovery operations, except within 12 nautical miles of a port."

[20]*Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies Into the Maritime Transportation System*, 85 Fed. Reg. 48548 (Aug. 11, 2020). In the request for information, the Coast Guard requested information on existing statutes and regulations that may present a barrier to the development and deployment of autonomous ship technology, the benefits and cost-savings of autonomous ship technology, and the ways in which commercial vessels are currently making use of autonomous ship technologies, among other topics.

[21]For example, any vessel propelled by machinery or carrying passengers must have a licensed master, and a vessel of at least 1,000 gross tons must generally have three licensed mates. 46 U.S.C. § 8301(a).

[22]46 U.S.C. § 8101(a). *See also* 46 U.S.C. § 8102(a), which requires the owner, charterer, or managing operator of a vessel carrying passengers during the nighttime to keep a suitable number of watchmen in the vicinity of the cabins or staterooms and on each deck to guard against and give alarm in case of a fire or other danger; 46 U.S.C. § 8103(a), which mandates that, with limited exceptions, only a citizen of the United States may serve as master, chief engineer, radio officer, or officer in charge of a deck watch or engineering watch; and 46 U.S.C. § 8502, which requires that a U.S. pilot generally be present for navigation in U.S. waters.

[23]For example, a statutory provision requiring that each recreational vessel be equipped with an engine cut-off switch assumes that there will be a human onboard the vessel to operate the switch. 46 U.S.C. § 4312.

[24]*International Regulations for Preventing Collisions at Sea* art. IX, Oct. 20, 1972, 28 U.S.T. 3459; 33 C.F.R. § 83.05. The *International Regulations for Preventing Collisions at Sea* (COLREGs) is a treaty that established international rules for the navigational safety of surface vessels, which the United States has ratified. *See* 33 U.S.C. §§ 1601–1608. The COLREGs apply to vessels upon the high seas and in all connecting navigable waters, and the corresponding *Inland Navigation Rules* apply to vessels upon the inland waters of the United States. 33 U.S.C. § 1603; *International Regulations for Preventing Collisions at Sea* art. IX, Oct. 20, 1972, 28 U.S.T. 3459; 33 C.F.R. § 83.01. The "inland waters" means the navigable waters of the United States shoreward of the navigational demarcation lines dividing the high seas from harbors, rivers, and other inland waters of the United States and the waters of the Great Lakes on the United States side of the International Boundary. 33 C.F.R. § 83.03(q).

[25]This determination of which autonomous technologies comply with the lookout requirements of the COLREGs may have implications for other aspects of United States law, such as civil liability for collisions involving autonomous ships. In federal maritime cases involving negligence claims, United States courts apply the "Pennsylvania Rule," which creates a presumption that if a party is involved in a collision and has violated a law intended to prevent that type of collision from occurring, then such party is liable, unless it can show that the violation could not have caused the collision. *Steamship Pa. v. Troop*, 86 U.S. 125 (1874); *see also Havinga v. Crowley Towing & Transp. Co.,* 24 F.3d 1480 (1st Cir. 1994) (finding that a violation of the COLREGs implicates the causation presumption under the Pennsylvania Rule). The Pennsylvania Rule may present unique challenges for cases involving autonomous ships because causation for collisions and other accidents may be attributable to several unique factors. A recent article published by the American Bar Association highlights several of these potential factors, including "whether the AI navigation system was defective and that defect caused the vessel to perform in a manner other than intended; whether the operator of the autonomous vessel (wherever located) improperly engaged or disengaged the AI or decision-making autonomous system; or, whether the system decided and chose between outcomes, such as between grounding the ship or colliding with another vessel (the so-called 'trolley car dilemma')." Sean T. Pribyl, *Autonomous Transport Claims: Emerging Issues in the Maritime Sector*, 52 A.B.A. The Brief 46 (2022).

[26]U.S. Department of Homeland Security, United States Coast Guard, *Preparation of Headquarters Regulations*, COMDTINST M16703.1A (April 2020).