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Regulating the Autonomous Ocean

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INTRODUCTION

Ocean-going robots are changing the landscape of what is possible on the world's oceans, capturing imaginations and reinventing human interactions with the marine environment. People around the world are donating millions to robotic systems designed to clean plastic from the world's oceans.[1] Technology billionaires are developing plans for the seasteading cities of the future: autonomous ships circling the world's oceans, free from the national laws and environmental pressures of land.[2] Global militaries have moved from training dolphins to developing highly sophisticated unmanned submersibles that can quickly travel on information collecting missions.[3] These new classes of robotic technologies are rapidly expanding human possibilities on the ocean, shattering many of the practical and economic limitations that have constrained ocean operations for centuries.

Maritime drones, unlike their cousins, aerial drones, or self-driving cars, have not prompted significant social and legal discussion despite their increased usage. This is reflected in the legal academy, where, for instance, the literature surrounding aerial drone use is rich, covering issues from privacy to military

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† Assistant Professor, University of Florida Levin College of Law. Thanks to participants in workshops at WeRobot 2021, the University of Florida College of Law, and the Southeastern Association of Law Schools for comments on earlier drafts, and to Ryan Scott for research assistance.

1 Gloria Dickie, *Ocean Cleanup Struggles to Fulfill Promise to Scoop Up Plastic at Sea*, REUTERS (Sept. 16, 2021, 6:31 AM), https://www.reuters.com/business/environment/ocean-cleanup-struggles-fulfill-promise-scoop-up-plastic-sea-2021-09-16/ [https://perma.cc/KR8W-BT6L].

2 Oliver Wainwright, *Seasteading—A Vanity Project for the Rich or the Future of Humanity?*, GUARDIAN (June 24, 2020, 7:32 AM), https://www.theguardian.com/environment/2020/jun/24/seasteading-a-vanity-project-for-the-rich-or-the-future-of-humanity [https://perma.cc/J5L7-DHT5].

3 *See, e.g.*, Harriet Agerholm, *China Seizes US Navy Underwater Drone in International Waters of South China Sea*, INDEP. (Dec. 16, 2016, 5:05 PM), http://www.independent.co.uk/news/world/asia/china-seize-us-navy-underwater-vehicle-south-china-sea-one-china-taiwan-a7480016.html [https://perma.cc/3QUY-C2XP].

uses to self-defense,[4] while the legal literature on maritime drone use remains limited. In addition, although the discussions around the widespread use of aerial drones or other types of robotic interventions address important constitutional and ethical questions, including how to protect individual privacy from drone surveillance and what safety measures regulatory agencies must embrace to limit negative impacts,[5] scholars have largely ignored these same issues as they relate to marine robotics in the race to work out the logistics of complying with maritime safety regulations. Instead, academic and policy debate on marine robotics is primarily focused on narrow regulatory questions centered around compliance with existing safety laws or whether drones should be considered vessels.[6]

Today, as the use of maritime drones grows, it is necessary to consider the legal implications of this development. The shift to autonomy in the world's oceans challenges centuries-old cultural norms and regulatory regimes. Commercial operators are increasingly looking to autonomous technologies as the future of their vessels, raising the very real possibility that much of global cargo shipping will eventually be

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4 *See generally* Timothy T. Takahashi, *Drones and Privacy*, 14 COLUM. SCI. & TECH. L. REV. 72 (2012) (discussing the privacy implications of the use of military drones by local police); A. Michael Froomkin & P. Zak Colangelo, *Self-Defense Against Robots and Drones*, 48 CONN. L. REV. 1 (2015) (examining the right to privacy and self-defense with respect to autonomous robots); Michael L. Smith, *Regulating Law Enforcement's Use of Drones: The Need for State Legislation*, 52 HARV. J. ON LEGIS. 423 (2015) (outlining state legislative attempts to regulate police use of drones as enforcement tools); GREGORY MCNEAL, CTR. FOR TECH. INNOVATION AT BROOKINGS, DRONES AND AERIAL AERIAL SURVEILLANCE: CONSIDERATIONS FOR LEGISLATURES 1 (2014) (outlining measures state legislators should take to address issues in privacy and surveillance that have arisen from the use of drones); Margot E. Kaminski, *Drone Federalism: Civilian Drones and the Things They Carry*, 4 CALIF. L. REV. CIR. 57 (2013) (arguing for state control—not federal—over the regulation of drone use, privacy protection, and surveillance).

5 *See generally* Lane Page, *Drone Trespass and the Line Separating the National Airspace and Private Property*, 86 GEO. WASH. L. REV. 1152 (2018) (discussing trespass and airspace property rights as a result of the development of drone technology); Emily A. Donaher, *Using Drones to Reduce the Risk of Litigation in the Construction, Energy, and Agriculture Industries*, 96 N.D. L. REV. 1 (2021) (analyzing federal and state unmanned aerial vehicle laws); Joseph J. Vacek, *The Next Frontier in Drone Law: Liability for Cybersecurity Negligence and Data Breaches for UAS Operators*, 39 CAMPBELL L. REV. 135 (2017) (addressing the legal implications of cybersecurity negligence and data breaches relating to unmanned aircraft system); Adam Zwickle et al., *Comparing Public Concern and Support for Drone Regulation to the Current Legal Framework*, 37 BEHAV. SCI. L. 109 (2018) (assessing the extent of U.S. drone laws in protecting personal privacy).

6 *See, e.g.*, Henrik Ringbom, *Regulating Autonomous Ships—Concepts, Challenges and Precedents*, 50 OCEAN DEV. & INT'L. L. 141, 141–42 (2019); Craig H. Allen, *The Seabots Are Coming Here: Should They Be Treated as 'Vessels'?*, 65 J. NAVIGATION 749, 749–52 (2012); Rob McLaughlin, *Unmanned Naval Vehicles at Sea: USVs, UUVs, and the Adequacy of the Law*, 21 J.L. INFO. & SCI. 100, 100–01 (2011).

on unmanned vessels.[7] In 2018, Finland successfully ran the first trial of a fully autonomous passenger ferry on one of the country's many sea routes.[8] Surveillance drones are navigating oceans throughout the world to carry out military, law enforcement, and scientific missions.[9] Chinese fishermen have now several times picked up small unmanned, autonomous vessels off of their coast.[10] Equipped with sophisticated sensor equipment and enough solar panels to power these vessels across the Pacific Ocean, these were underwater drones presumed to originate from the US Navy to conduct surveillance on Chinese coastlines.[11] Navies around the world are developing new classes of military drones that can launch missiles from unmanned platforms and engage in other types of offensive and defensive missions.[12] In 2020, IBM and ProMare launched the Mayflower, an autonomous vessel designed to cross the Atlantic, retracing the route of the original 1620 Mayflower and collecting scientific data.[13] The legal questions raised by these advances are significant, from whether Chinese fishermen who pick up a US Naval drone in Chinese waters have a right to possess that vessel,[14] to which safety and navigation rules an autonomous

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7 AAWA, AUTONOMOUS SHIPS: THE NEXT STEPS 2–3, 7–8 (2016), https://www.rolls-royce.com/~/media/Files/R/Rolls-Royce/documents/%20customers/marine/ship-intel/rr-ship-intel-aawa-8pg.pdf [https://perma.cc/GD3L-J5BK] ("'Autonomous shipping is the future of the maritime industry. As disruptive as the smart phone'").

8 Mike Ball, *Remotely Operated Passenger Ferry Trialled in Finland*, UNMANNED SYS. TECH. (Dec. 8, 2018), https://www.unmannedsystemstechnology.com/2018/12/unmanned-passenger-ferry-trialled-in-finland/ [https://perma.cc/CAB7-XWBJ].

9 *See* NAT'L ACADS. SCI., ENG'G, & MED., LEVERAGING UNMANNED SYSTEMS FOR COAST GUARD MISSIONS 1, 8–9, 14 (2020).

10 The high rewards to Chinese fishermen for finding autonomous vessels are perhaps incentivizing their capture more rapidly than in other countries. *See* Owen Amos, *Why Are Chinese Fishermen Finding So Many 'Submarine Spies'?*, BBC (Jan. 16, 2020), https://www.bbc.com/news/world-asia-china-51130644 [https://perma.cc/7YRL-9SNM] (noting that "the rewards were huge—up to 500,000 yuan ($72,000; £55,000)—around 17 times the average disposable income in China").

11 *See Chinese Fishermen Catch Foreign-Made Surveillance Drone in Yellow Sea*, MAR. EXEC. (Apr. 16, 2021, 4:43 PM), https://www.maritime-executive.com/article/chinese-fishermen-catch-foreign-made-surveillance-drone-in-yellow-sea [https://perma.cc/2GN9-RTMM]; *see also* Agerholm, *supra* note 3.

12 ERICH C. FRANDRUP, ATL. COUNCIL, EMBRACING UNDERSEAS ROBOTS: A US STRATEGY TO MAINTAIN UNDERSEA SUPERIORITY IN AN AGE OF UNMANNED SYSTEMS 2–5 (2020), https://www.atlanticcouncil.org/wp-content/uploads/2020/10/Embracing-Undersea-Robots.pdf [https://perma.cc/U9V4-BVFQ].

13 The Mayflower journey successfully concluded in 2022. *Mayflower Autonomous Ship Launches*, IBM (Sept. 15, 2020), https://newsroom.ibm.com/2020-09-15-Mayflower-Autonomous-Ship-Launches [https://perma.cc/6HSB-87FX].

14 *See* Christopher P. Cavas, *China Grabs Underwater Drone Operated by US Navy in South China Sea*, DEFENSENEWS (Dec. 16, 2016), https://www.defensenews.com/naval/2016/12/16/china-grabs-underwater-drone-operated-by-us-navy-in-south-china-sea/ [https://perma.cc/7K89-F34J].

vessel must comply with,[15] to whether marine drones should even be considered vessels at all.[16]

This article looks broadly at how the rise in widespread Unmanned Marine Vehicle (UMV) use is altering interactions within the ocean and which questions this raises for national and international legal regimes, not just regarding safety, but in all areas of maritime law. Part I begins by describing the landscape of autonomous vessels across the oceans. It notes that while most policy attention is focused on the advent of large commercial shipping UMVs that may begin operation in several decades, there are already many other types of UMVs currently in regular use. Part II lays out the regulatory frameworks that form the foundation of UMV governance and discusses proposals at the US and international levels to regulate UMV use going forward. It then goes on to identify gaps in current and proposed governance models that need to be addressed for UMV regulation to be successful. While certain areas of UMV operation will be well covered by modifying existing rules, for instance, in the areas of safety; in other situations, current regulations will fail to cover the impacts of UMV use. New regulatory schemes must address these core gaps. Part III concludes by expanding upon this analysis to identify core principles for UMV regulation. It draws on regulatory action taken by the Federal Aviation Administration (FAA) to govern aerial drones as well as best practices for regulating emerging and rapidly evolving technologies to propose mechanisms to regulate autonomy on the oceans moving forward.

I. THE LANDSCAPE OF OCEAN ROBOTICS

Humans have been using remotely controlled robots in the ocean for nearly a century out of operational necessity. Nikola Tesla's first tests on remotely control objects were done on small boats in 1898.[17] Since then, commercial, scientific, and military operations have relied on small robots to carry out tasks that humans were unable to do. These devices historically were remotely operated, attached by a communication tether to larger vessels. The advent of more sophisticated technologies in the last decade has allowed these vehicles to ditch their tethers and

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[15] Ringbom, *supra* note 6, at 143.

[16] Craig H. Allen, *Determining the Legal Status of Unmanned Maritime Vehicles: Formalism vs Functionalism*, 49 J. MAR. L. & COM. 477, 480 (2018).

[17] Ian G. R. Shaw, *The Rise of the Predator Empire: Tracing the History of U.S. Drones*, UNDERSTANDING EMPIRE: TECH., POWER, POLITICS (2014), https://understanding empire.word-press.com/2-0-a-brief-history-of-u-s-drones/ [https://perma.cc/VSG9-XXKS].

travel freely around the oceans. This has dramatically expanded what ocean-going robots can do, ushering in a new era of autonomy. This Part lays out the landscape of current UMV operation in the oceans. While most commercial and policy attention has been focused on planning for the advent of large, autonomous cargo ships; in practice, hybrid systems that include some degree of human oversight are currently much more common and will likely continue to be so for the near term.[18]

There are many different definitions and naming conventions for marine robots (a foreshadowing of the fragmented regulatory approach applied to marine robotics). Different organizations often use their own definitions of marine robotic systems, with one report on the area finding twenty-six commonly used acronyms to describe these types of systems.[19] In this article, I use UMV broadly to include a variety of different types of marine robots that share the defining characteristic of being able to move around the ocean while unmanned by human crew.[20] UMVs includes vehicles operating in all areas of the ocean, both Unmanned Marine Systems (UMS) or Unmanned Surface Systems (USS) and Unmanned Underwater Systems (UUS).[21] This broad UMV definition includes both UMVs that fit that current legal definitions of a vessel and those that do not.[22]

Determining whether a vessel is "manned" or "unmanned" under this definition can be complicated. For vessels without any humans onboard, the distinction is relatively clear: they are unmanned. In many cases, though, human crews may remain onboard larger ships in some capacity to make repairs or provide other types of support, even if they are not involved in steering the vessel. In these cases, the legal distinctions turn not on whether a vessel is manned or unmanned, but instead on where crew are physically located on a vessel and what their operational role is.[23] I interpret unmanned broadly to include situations where vessels are either periodically unmanned or operating autonomously without

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[18] Ringbom, *supra* note 6, at 145.

[19] NAT'L ACADS. SCI., ENG'G, & MED., *supra* note 9, at 154.

[20] Notably, this article also focuses solely on unmanned vehicles, not the many robotic technologies that may be use onboard existing vessels to improve operations in various ways.

[21] NAT'L ACADS. SCI., ENG'G, & MED., *supra* note 9, at 30.

[22] For more on this distinction, see *infra* Section II.E.

[23] *See* Ringbom, *supra* note 6, at 143 (noting that "[t]he level of manning, for example, is to be separated from the location of the crew . . . . Some legal hurdles manifest themselves as soon as the watchkeeping officer leaves the bridge unmanned, even for a very brief period of time, while other requirements, such as the duty to have a master or a ship security officer on board, can—in theory at least—be met as long as a single crew member remains on board the ship").

humans in the loop. This is distinct from vessels that are manned by some automated systems, which are much easier to incorporate into existing legal regimes and are currently used as a routine matter on most ships around the world.[24]

Some scholars prefer to look not at whether a vessel is manned, but instead at how much autonomy the vessel is operating with when categorizing vessel types. Unmanned vessels can be operated completely autonomously or remotely controlled by human operators. However, most UMVs are somewhere in the middle of the spectrum, making them difficult to categorize. For instance, some of the most common UMVs on the ocean are passively powered drifting platforms.[25] These are not autonomous; instead they drift on ocean currents while collecting data on their environment on programmed schedules, putting them more in the category of automated.[26] While many conflicts with existing regulation turn on whether a vessel is manned or unmanned, and not the degree of autonomy the UMV has, categorizing vessels by their levels of autonomy is likely to become an important feature of future regulation and may already be an important factor in how they are regulated, particularly under central maritime safety regulations like the International Regulations for Preventing Collisions at Sea (COLREGs).[27] In light of this challenge in categorization, I use UMV broadly to ensure that both vessels that are fully autonomous and those that are not will be subject to this article's proposed new regulatory regimes.

The heterogeneity of definitions reflects the diverse ways autonomy and robotics are currently being used in the marine realm. It will likely be decades before autonomous cargo ships are regularly roaming the ocean. In the meantime, many other types of UMVs are already in regular use and raising legal questions that few have focused on addressing. Regulatory

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[24] *Id.*

[25] *About: Argo*, ARGO, https://argo.ucsd.edu/about/ [https://perma.cc/VA7U-QL9C] (explaining there are currently passively powered 3,885 Argo floats alone currently deployed on the oceans), *with* Sarah Whiteford, *How Do Autonomous Vessels Work?*, ONESTEP POWER (Nov. 12, 2021), https://www.onesteppower.com/post/autonomous-vessels [https://perma.cc/3VAF-5U6Z] (stating there are over 1,000 MASS in operation).

[26] *See* NAT'L ACADS. SCIS., ENG'G, & MED., *supra* note 9, at 31 (distinguishing between "[r]emote, [a]utomated, or [a]utonomous [c]ontrol" in unmanned technologies).

[27] Where this is not the case, for instance surrounding COLREGs lookout requirements, I discuss this distinction in greater depth. *See infra* Part II. COLREGs, or the Convention on the International Regulations for Preventing Collisions at Sea, were promulgated by the International Maritime Organization in 1972 and form the backbone of maritime navigation rules. Together with the US Coast Guards' Inland Navigation Rules, these regulations set out the basic "rules of the road" that vessels must comply with.

regimes must recognize the many different variations in how autonomy is being implemented and how UMVs are being used.

A. Scientific UMVs

Robots are an essential tool for ocean scientists. Scientists have been using different types of marine robots to explore and learn about otherwise inaccessible ocean ecosystems for decades.[28] Robots have enabled the discovery of entire new communities of life, such as those around deep-sea vents.[29] The advent of UMVs that can operate free from remote control is allowing scientific robots to break new ground, expanding the range of what it is possible to observe and discover in the oceans. This information is essential for better understanding ocean ecosystems and informing global management decisions.

The majority of robotics currently in use in the oceans today collect baseline information on ocean conditions.[30] In the past, this *in situ* data was primarily collected by fully staffed research vessels, of which there are only a small handful globally.[31] Time and money constraints meant that data was only collected on small portions of the ocean,[32] leaving scientists with relatively little information about vast swaths of ocean ecosystems.

Ocean scientists are still inherently limited by the sheer size of the ocean, but new robotic technologies are rapidly improving the ability to gather critical baseline data on more of the world's oceans. Many scientific floats are already deployed throughout the world's oceans. These are small sensor platforms that drift with global currents, sending information to shore at regular intervals via satellite.[33] The Argo program, for example, has roughly four thousand profiling floats deployed around the globe at any given time, with an additional five hundred

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[28] *See 1977—Astounding Discoveries*, WOODS HOLE OCEANOGRAPHIC INST., https://www.whoi.edu/feature/history-hydrothermal-vents/discovery/1977.html [https://perma.cc/W295-36DW].

[29] *Id.*

[30] *About: Argo*, *supra* note 25 (describing the number of Argo floats currently deployed to collect baseline oceanographic data).

[31] *See* NAT'L OCEAN COUNCIL, EXEC. OFF. PRESIDENT, FEDERAL OCEANOGRAPHIC FLEET STATUS REPORT 9, 20–21 (May 24, 2013), https://www.nopp.org/wp-content/uploads/2010/03/federal_oceanographic_fleet_status_report.pdf [https://perma.cc/Q8WS-SCAW] (outlining the challenges researchers face in meeting the demand for research vessels, such as budget shortfalls, unexpected repairs, and rising operational costs).

[32] *Id.* at 20.

[33] *See* Katharina Bork et al., *The Legal Regulation of Floats and Gliders—In Quest of a New Regime?*, 39 OCEAN DEV. & INT'L L. 298, 299 (2008) (noting that "[a] *float* is defined as: an autonomous vehicle used for collection of . . . data . . . and floating passively").

launched each year to replace old units at the end of their life.[34] Argo floats and other similar systems have dramatically improved scientific understanding of global marine ecosystems in the more than twenty years they have been active.[35]

These observation platforms are becoming more sophisticated, moving from simple drifting floats to passively powered robots that can move independent of ocean currents (albeit slowly).[36] These UMVs rely on propulsion driven by wave, wind, or solar energy to stay at sea for up to years at a time.[37] During these lengthy periods, UMVs can travel and collect data across entire ocean basins.[38]

Two of the most advanced ocean robots, Wave Gliders and Saildrones, are already being used to collect oceanographic data globally. Wave Gliders, built by Liquid Robotics, pair solar and wave energy and can operate autonomously or be controlled through satellite links.[39] These devices are able to deploy sophisticated scientific arrays at depth by combining a surface vessel with an attached sensor payload about twenty feet below.[40] Saildrones are wind-powered robots with similar capabilities and technical specifications.[41] In the past decade of development, these drones have covered over five hundred thousand nautical miles.[42] Large scale deployment is in the works, with both scientific and law enforcement organizations beginning to use these robots.

A slew of other marine scientific robots is in the development stages, with many organizations incentivizing the creation of new, more sophisticated types of UMVs. XPrize, for instance, launched a competition to incentivize the development

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[34] *Argo's Status*, ARGO, https://argo.ucsd.edu/about/status/ [https://perma.cc/Q6JW-MSP3].

[35] *See* Dean Roemmich et al., *The Argo Program: Observing the Global Ocean with Profiling Floats*, 22 OCEANOGRAPHY 34, 35, 38–39 (2009).

[36] *See, e.g.*, *Argo's Status*, *supra* note 34 (discussing how Argo floats work); THE WAVE GLIDER: TRANSFORM HOW YOU UNDERSTAND THE OCEAN, LIQUID ROBOTICS 1, 3–4 (2019), https://www.boeing.com/resources/boeingdotcom/defense/autonomous-systems/wave-glider-sharc/wave_glider_data_sheet.pdf [https://perma.cc/5Z52-TQ3X] (discussing how Wave Glider surface vehicles operate).

[37] *See id.* at 1.

[38] *Id.*

[39] *Id.* at 1, 3–4.

[40] *Id.*

[41] *Homepage*, SAILDRONE, https://www.saildrone.com/ [https://perma.cc/28PR-K4NP].

[42] *URI Oceanographer Part of Pioneering Study to Improve Weather Prediction and Global Carbon Budget Understanding*, UNIV. R.I. (Apr. 13, 2021), https://web.uri.edu/gso/news/uri-oceanographer-part-of-pioneering-study-to-improve-weather-prediction-and-global-carbon-budget-understanding/ [https://perma.cc/WNV2-3CCT].

of UMVs capable of high-resolution seafloor mapping.[43] The winning vessels are emerging in usage globally, contributing important data to new international efforts to fully map the world's seafloor by 2030 as part of the 2021–2030 UN Decade of Ocean Science for Sustainable Development.[44]

Scientists are also increasingly leveraging robots in conjunction with existing research vessels. Tethered submersible remotely operated vehicles (ROVs) have been used for decades to complement research vessel capabilities.[45] ROVs are particularly important for exploration of deep-sea ecosystems.[46] Some organizations are transitioning to untethered ROVs or autonomous underwater vehicles (AUVs) to expand the operational scope of these robots.[47]

The explosion in scientific UMV use is a paradigm shift for oceanographic research, which in the past has been primarily conducted on research cruises that are extremely limited in geographic scope and temporal coverage. UMVs can cover more terrain than research vessels at a fraction of the cost.[48] Data collected by UMVs is already contributing to important scientific insights, from better understanding of baseline ocean conditions to more accurate global models of climate change.[49] Many of these new insights are not just useful to scientists but also to

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[43] *See* Scott K. Johnson, *XPRIZE Selects Winners of Autonomous Seafloor-Mapping Competition*, ARS TECHNICA (June 1, 2019, 2:40 PM), https://arstechnica.com/science/2019/06/xprize-selects-winners-of-autonomous-seafloor-mapping-competition/ [https://perma.cc/9987-7THN]. This prize interestingly was funded by Shell, presumably either for public relations purposes or because it is interested in ultimately adopting these developments in their own commercial efforts to better explore, and exploit, ocean resources. *See, e.g.*, Jillian Ambrose, *Last Minute Attempt to Stop Shell Oil's Exploration of Whale Breeding Grounds*, GUARDIAN (Dec. 1, 2021), https://www.theguardian.com/business/2021/dec/01/last-minute-bid-to-stop-shells-oil-exploration-in-whale-breeding-grounds-in-south-africa [https://perma.cc/8WF3-GG9M] (describing Shell's use of seismic surveying technology to explore sensitive marine areas for potential development).

[44] *See* Johnson, *supra* note 43.

[45] *See, e.g.*, *History of Alvin*, WOODS HOLE OCEANOGRAPHIC INST., https://www.whoi.edu/what-we-do/explore/underwater-vehicles/hov-alvin/history-of-alvin/ [https://perma.cc/C8F5-8LKC] (describing the history of the tethered submersible Alvin, which has been used for groundbreaking scientific research since 1964).

[46] *See* Roberto Danovaro et al., *Challenging the Paradigms of Deep-Sea Ecology*, 29 TRENDS ECOLOGY & EVOLUTION 465, 465–66 (2014).

[47] *See, e.g.*, *Autonomous Underwater Vehicle (AUV)*, SCHMIDT OCEAN INST., https://schmidtocean.org/technology/robotic-platforms/autonomous-underwater-vehicle-auv/ [https://perma.cc/4GD6-JU3A] (describing Schmidt's use of AUVs to supplement research efforts).

[48] *See generally* PAUL G. FERNANDES ET AL., AUVS AS RESEARCH VESSELS: THE PROS AND CONS 1, 4 (2002) https://www.ices.dk/sites/pub/CM%20Doccuments/2002/J/J0202.PDF [https://perma.cc/49B7-S6XN] (analyzing the pros and cons of unmanned marine vehicles for research purposes).

[49] *See, e.g.*, Lijing Cheng et al., *How Fast are the Oceans Warming?*, 363 SCI. 128, 128–29 (2019).

industries whose operations benefit from nuanced understanding of ocean conditions.[50]

B. Commercial UMVs

The commercial maritime industry has long relied on robots for its operations. From inspecting oil platforms to repairing deep-sea cables, robots enable operations in environments that are very difficult or impossible for humans to reach. Historically, these robots primarily were ROVs tethered to ships and operated remotely. Today, with the advent of automated and fully autonomous software, these vehicles are much less likely to be tethered and instead operate freely. These increased technological capabilities are not just improving current operations, but they are also enabling entirely new spheres of maritime commerce.

1. Shipping

Of all ocean industries, the shipping industry has the potential to see the greatest changes with the advent of unmanned, autonomous shipping vessels, and the majority of UMV discussion by policymakers and industry members has been focused on this sector. Major maritime industry players see autonomy as the future of the shipping industry, making up an estimated market value of $165 billion by 2030.[51] The majority of global trade in goods is supported by marine shipping, with over eleven billion tons of cargo a year transported at sea on over one hundred thousand vessels.[52] Shipping is a relatively inexpensive way of transporting goods around the world, but the cost of paying human crews (and the resulting injury claims that accompany them) is significant enough that the world's large shipping companies are almost universally investigating the potential for autonomous ships to replace traditionally crewed vessels. Converting existing ships to fully autonomous ones may save companies between 4 and 11 percent in operational costs,

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[50] *See, e.g.*, Anne-Cathrin Wölfl et al., *Seafloor Mapping–The Challenge of a Truly Global Ocean Bathymetry*, FRONTIERS MARINE SCI., June 5, 2019, at 1–2, 4–6, https://www.frontiersin.org/articles/10.3389/fmars.2019.00283/pdf [https://perma.cc/TUT2-73XT] (discussing the use of bathymetry data by industry and other stakeholders).

[51] *See* AAWA, *supra* note 7, at 4; Akshay Jadhav & Sonia Mutreja, *Autonomous Ships Market*, ALLIED MKT. RSCH. (2020), https://www.alliedmarketresearch.com/autonomous-ships-market [https://perma.cc/7S4E-KJX4].

[52] U.N. CONF. ON TRADE & DEV., REVIEW OF MARITIME TRANSPORT 2020 1–2 (2020).

while reducing carbon emissions by as much as 20 percent due to improved fuel and routing efficiency.[53]

In many ways, the shipping industry is ripe for a transition to autonomous vessels in a way that many land-based sectors, such as cars, are not. The ocean is a relatively uncrowded operational environment, making artificial intelligence (AI) use easier than navigating through complex cities and around people.[54] The difficulties in integrating autonomous cars into existing terrestrial infrastructure has already resulted in a number of high-profile companies like Uber retreating from large-scale self-driving car deployment plans.[55] Meanwhile, on the ocean, ship crews already use autopilot systems nearly all of the time to steer their ships.[56] These systems can pilot the vessel between fixed GPS waypoints and, in some cases, are sophisticated enough to avoid major weather systems or other obstacles along the way.[57] Creating fully autonomous vessels will require building out these systems considerably, but in many cases, the technical and mechanical foundations for self-steering is already in place.

Some also point out that switching to autonomous ships may decrease existing safety problems in the shipping industry.[58] Proponents of autonomous technologies note that by some estimates, up to 85 percent of collisions at sea are caused by human error.[59] Automation may reduce the likelihood of these types of errors, although it may increase other types of errors introduced by technical failure or inability to fix mechanical or other systems problems when humans are not physically onboard.

The hurdles for autonomous shipping vessels come when the vessels approach land. Ports are operationally complex

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53 Pivi Haikkola, One Sea/DIMECC, Comment on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies into the Maritime Transportation System (Oct. 13, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0022; One Sea, *One Sea: Autonomous Shipping Has Clear Environmental Benefits*, MAR. EXEC. (Oct. 28, 2021, 4:49 PM), https://www.maritime-executive.com/editorials/one-sea-autonomous-shipping-has-clear-environmental-benefits [https://perma.cc/B3HW-64BT].

54 *See* Rodney Brooks, *The Big Problem With Self-Driving Cars is People*, IEEE SPECTRUM (July 27, 2017), https://spectrum.ieee.org/the-big-problem-with-selfdriving-cars-is-people [https://perma.cc/QT5H-9GXE].

55 *See* Faiz Siddiqui, *Uber Offloads Troubled Self-Driving Unit to Startup Aurora*, WASH. POST (Dec. 7, 2020, 6:32 PM), https://www.washingtonpost.com/technology/2020/12/07/uber-aurora-self-driving/ [https://perma.cc/K84Z-XT6A].

56 Lokukaluge P. Perera & C. Guedes Soares, *Weather Routing and Safe Ship Handling in the Future of Shipping*, 130 OCEAN ENG'G 684, 689 (2017).

57 *Id.*

58 *See* Jiri de Vos et al., *The Impact of Autonomous Ships on Safety at Sea—A Statistical Analysis*, 210 RELIABILITY ENG'G & SYS. SAFETY 1, 2 (2021).

59 Andrzej Felski & Karolina Zwolak, *The Ocean-Going Autonomous Ship—Challenges and Threats*, 8 J. MARINE SCI. & ENG'G 1, 8 (2020).

bottlenecks with unique and changing local characteristics that are difficult to program.[60] Ports are so difficult to navigate even for human mariners that most large vessels are required to bring local pilots on board to steer ships into harbor.[61] Current discussions of autonomous shipping vessels often rely on a similar system, planning for vessels to cross ocean basins autonomously and then be guided into port by human pilots (either remotely or on the vessel itself).[62]

The other major hurdle for autonomous shipping vessels is the sheer difficulty of maintaining systems in the marine environment.[63] Shipping vessels today employ as many engineers as they do mariners whose job is to steer the boat. These engineers are needed to maintain and fix engine and mechanical systems when they inevitably break. A conversion to fully automated shipping will require not just AI that can steer a boat, but improvements in the mechanical infrastructure that allow the ship to either fix itself or be fully redundant if and when systems fail. If communication infrastructure breaks down, the AI command system itself fails, or an adversary commits a cyberattack,[64] there will be few options to effectively ensure that these vessels are able to return to shore. The consequences of either mechanical failure or failure of the control systems are high: the ocean is very large, and reaching any stranded vessel to make repairs could take weeks. These failures happen not only out at sea but also when approaching ports, raising the risk to other people and property. The port of Los Angeles alone sees one or two breakdowns a month in its waters, which must be handled quickly and effectively to prevent major accidents.[65] For this important logistical reason, most companies imagine that autonomous cargo ships will be

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[60] Stephanie Guerra, *Ready About, Here Comes AI: Potential Maritime Law Challenges for Autonomous Shipping Comments*, 30 U.S.F. MAR. L.J. 69, 81 (2017).

[61] David J. Bederman, *Compulsory Pilotage, Public Policy, and the Early Private International Law of Torts*, 64 TUL. L. REV. 1033, 1038 (1990).

[62] *See, e.g.*, Salah Eldin Farag & Omar Mohamed Fouad Farid, *The Impact of Maritime Accidents on the Autonomous Ships Proving Their Missions in the Future*, 11 J. SHIPPING & OCEAN ENG'G 64, 64-65 (2021) (proposing such a system).

[63] *See* Glenn Wright, GMATEK Inc., Comment Letter on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies into the Maritime Transportation System (Oct. 13, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0019.

[64] *See* Joan Mileski et al., *Cyberattacks on Ships: A Wicked Problem Approach*, 3 MAR. BUS. REV. 414, 414–17 (2018).

[65] Marine Exch. of S. Cal. & Vessel Traffic Serv. of L.A. & Long Beach, Comment Letter on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies into the Maritime Transportation System (Oct. 13, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0032.

attended by a skeleton engineering crew for the foreseeable future.

The International Maritime Organization has proposed four major categories, or degrees, for classifying Marine Autonomous Surface Ships (MASS) that take into account the heterogeneity of implementation. Degree One of autonomy uses AI decision support tools on crewed vessels. This is already common around the world, with AI systems helping to steer and route ships with human oversight. Degree Two vessels are remotely operated but still crewed, while Degree Three vessels are remotely operated and uncrewed.[66] Neither of these types of ship are used commercially, although they are being tested. Degree Four vessels are fully autonomous. Fully autonomous vessels are now being widely tested and have, in limited cases, been used in commercial applications.[67] However, despite being capable of being "fully autonomous," these vessels are still operated with crews during these testing phases.[68] Legal questions around unmanned, autonomous vessels are likely to hamper widespread use of Degree Four vessels for the near future.[69]

While the United States has been a leader in UMV deployment in the defense sector, Europe and Asia lead the way with commercial UMV efforts. The European Union recently committed nearly thirty million Euros to the Autoship project, which aims to build and launch two autonomous cargo vessels operating in nearshore European waters in the next several years.[70] Globally, the major shipping companies are all putting significant resources into developing autonomous technology. Early focus areas for autonomous shipping are with tugboats and general near-shore routes.[71] The promise of autonomous vessels is even more attractive after the impacts of COVID-19 on the shipping industry, which included thousands of crew members stranded around the world.[72]

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[66] Felski & Zwolak, *supra* note 59, at 4–5.

[67] For an overview of some of the autonomous vessel trials to date, see PAUL DEAN ET AL., HFW, AUTONOMOUS SHIPS: MASS FOR THE MASSES (2020), https://www.hfw.com/Autonomous-ships-MASS-for-the-MASSes [https://perma.cc/ZUR8-TKY4].

[68] *See, e.g.*, Felski & Zwolak, *supra* note 59, at 4, 12–13 (noting that while the vessel did operate in autonomous mode, there was a crew onboard to oversee the system and to ensure the trial proceeded successfully).

[69] For a more detailed discussion of these issues, see *infra* Part II.

[70] Felski & Zwolak, *supra* note 59, at 1.

[71] James A. Watson, Am. Bureau of Shipping, Comment Letter on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies into the Maritime Transportation System, (Oct. 13, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0023.

[72] *Id.*

The importance of autonomous vessels for the commercial maritime sector has led major maritime training academies to begin UMV-specific training programs. Maine Maritime Academy, for example, has started one of the first of these programs, complete with a test UMV for students to use.[73] These programs provide students with the opportunity to train on autonomous vessels, including participating in shoreside operations centers and helping to install and oversee autonomous control systems.[74] Globally, other maritime training sectors are considering how they need to update already rigorous training requirements for seafarers in light of autonomous vessel deployment.[75]

The move to UMVs to replace cargo shipping is a significant one, but one with many logistical and regulatory hurdles to overcome before it is implemented widely. This is a process that will likely take decades.

2. Industrial

Other commercial maritime industries are also increasingly turning towards robotics for future operations. For example, commercial diving on drilling rigs is extremely dangerous, often requiring saturation dives that keep divers underwater for weeks at a time in submersible habitats.[76] Because of this, the oil and gas drilling industries have long used robots to carry out drilling and extraction and to inspect underwater equipment.[77] However, improved UMVs may be able to take the place of human divers in many cases, lowering costs and increasing efficiency and inspection coverage.[78]

The oil and gas industry, as well as emerging renewable energy users, are increasingly relying on robots to carry out surveys.[79] High resolution mapping of seafloor geology is

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[73] *Sea Machines Partners with Maine Maritime Academy & MARAD to Include Intelligent Vessel Systems in Curriculum*, SEA MACH. (July 30, 2020), https://sea-machines.com/sea-machines-partners-with-maine-maritime-academy-marad-to-include-intelligent-vessel-systems-in-curriculum [https://perma.cc/V8FQ-788F].

[74] *See id.*

[75] *See* Blagovest Belev et al., *Autonomous ships in maritime education model course 7.01*, 35 SCI. J. MAR. RSCH. 388, 389–91 (2021).

[76] Jen Banbury, *The Weird, Dangerous, Isolated Life of the Saturation Diver*, ATLAS OBSCURA (May 9, 2018), https://www.atlasobscura.com/articles/what-is-a-saturation-diver [https://perma.cc/PR2W-CJXA].

[77] *See ROVs in the Oil and Gas Industry*, BULGIN, https://blog.bulgin.com/blog/rovs-in-the-oil-gas-industry [https://perma.cc/LZ9S-KLYH].

[78] *See id.*

[79] *See, e.g.*, Adrijana Buljan, *Could a 30-Kilogram Portable AUV Replace Geophysical Survey Vessels in Offshore Wind?*, OFFSHORE WIND (2022),

necessary to determine where key resources are located.[80] In the past, this has been done with ships.[81] Now, robots can cover far larger areas with less resource investment.

Robots are also enabling new types of extractive marine industries. Deep-sea mining, for example, has only become commercially viable with the advent of highly sophisticated marine robotics.[82] Deep-sea mining targets rare earth minerals that are located in nodules on the seafloor, often thousands of meters deep.[83] These include many rare earths that are critical components in batteries, such as cadmium. In the past, steady terrestrial supplies of these elements combined with the technical difficulty of reaching these deep-sea areas has prevented deep-sea mining from taking place. The current explosion in demand for batteries is projected to lead to shortages in key rare earths that could be filled with deep-sea minerals.[84] New companies are developing robotic technologies that will be able to descend to the seafloor in extremely deep areas and harvest nodules.[85] These robots will pioneer commercial operations in areas that have so far been simply impossible to operate in.

3. Fishing

The last large maritime industry is fishing. Like extractive industries and transportation, the fishing industry is increasingly relying upon robots to carry out existing operations.[86] Unlike in shipping, there has been little effort put into creating fully autonomous fishing vessels.[87] There are

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https://www.offshorewind.biz/2022/06/09/could-a-30-kilogram-portable-auv-replace-geophysical-survey-vessels-in-offshore-wind/ [https://perma.cc/A8ZY-E8PM].

[80] Wölfl et al., *supra* note 50, at 5.

[81] *See id.* at 3.

[82] *See generally* Dingxin Leng et al., *A Brief Review of Recent Progress on Deep Sea Mining Vehicle*, 228 OCEAN ENG'G 1 (2021) (discussing the important role deep-sea mining vehicle plays in deep-sea operation and the development of deep-sea mining system and technology).

[83] *Id.* at 1.

[84] Alexandra Gillespie, *Your Next Car May Be Built with Ocean Rocks. Scientists Can't Agree if That's Good*, NPR (Sept. 3, 2021, 6:00 AM), https://www.npr.org/2021/09/03/1031434711/your-next-car-may-be-built-with-ocean-rocks-scientists-cant-agree-if-thats-good [https://perma.cc/PBD2-YGXX].

[85] *See, e.g.*, *Nodules*, THE METALS CO., https://metals.co/nodules/ [https://perma.cc/SQB7-JAPA].

[86] Particularly in aquaculture, see, e.g., Estonian Rsch. Council, *Biorobotics is the Future of Fish Farming*PHYS.ORG (Apr. 16, 2020), https://phys.org/news/2020-04-biorobotics-future-fish-farming.html [https://perma.cc/SKS7-MGWG].

[87] *See* Loïs Vanhée et al., *Autonomous Fishing Vessels Roving the Seas: What Multiagent Systems Have Got to Do with It*, *in* 17TH INTERNATIONAL CONFERENCE ON AUTONOMOUS AGENTS AND MULTIAGENT SYSTEMS (AAMAS 2018) 1193, 1196 (2018).

myriad reasons for this. Fishing is a much more complex process than cargo transportation, which is largely a matter of going from point A to point B. Fishing requires identifying potentially successful locations, stopping frequently, deploying gear, and bringing fish on board. Additionally, fishermen are needed on boats to ensure compliance with regulations by only bringing on board target species and releasing any bycatch or protected species back into the ocean.[88] Doing these tasks well is currently beyond the technical capabilities of any UMVs, and it will likely continue to be for the foreseeable future.

However, the fishing industry is increasingly turning to robotic and autonomous technologies to augment human crewmembers. Bringing autonomous technologies to the fishing industry has the potential to dramatically reduce injury and accidents onboard fishing vessels, which are some of the most dangerous jobs in the world. In particular, Electronic Monitoring (EM) technologies are increasingly being used onboard fishing vessels.[89] Primarily a regulatory tool, EM places video cameras onboard vessels to ensure that fishing vessels are complying with existing fisheries laws.[90] Video surveillance data from EM is sent to shore, where it is analyzed with AI to determine violations.[91] Future versions of EM, although a long way from being operationally viable, may rely more on active robotic elements. For instance, underwater video cameras are currently used to identify when nontarget or protected species enter fishing nets and allow crew to trigger safety mechanism in the net to allow these species to swim free.[92]

Outside of wild-caught fisheries, robotics use is also emerging in aquaculture. Aquaculture, or fish farming, is a rapidly growing industry and one that many look to as an essential source of protein for a growing global population. In particular, efforts to successfully farm large pelagic species are

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[88] *See, e.g.*, *Bycatch*, N. PAC. FISHERY MGMT. COUNCIL, https://www.npfmc.org/fisheries-issues/bycatch/ [https://perma.cc/V6D3-B3YH] (describing regulatory discards as opposed to economic discards).

[89] *See* KATIE WESTFALL ET AL., ENV'T DEF. FUND, ELECTRONIC TECHNOLOGIES AND DATA POLICY FOR U.S. FISHERIES: KEY TOPICS, BARRIERS, AND OPPORTUNITIES 2, 4, 6, 8 (2020), https://www.edf.org/sites/default/files/documents/EDFWhitePaper,ElectronicTechnologiesAndDataPolicyForU.S.Fisheries,6-22-20.pdf [https://perma.cc/2PCW-4KPJ].

[90] *Id.*at 3, 5.

[91] *Id.* at 14 (noting that "EM service providers are also experimenting with applying AI" to video surveillance data that is mailed via hard drive or transmitted wirelessly).

[92] Gunvor Hatling Midtbø, *A Fish-Eye View of Trawling*, FULL PICTURE MAG. (Dec. 2020), https://www.kongsberg.com/kmagazine/2020/12/a-fish-eye-view-of-trawling/ [https://perma.cc/ZY4Z-566J].

increasing.[93] These open ocean aquaculture facilities are notoriously difficult to operate because of their distance from shore, making maintenance and feeding operations lengthy. To date, open ocean aquaculture facilities have only been trialed in a few locations where access to ports is easy and weather patterns are calm enough to allow boats to go out to the facility nearly every day.[94] Robotics has the potential to expand what is possible with these aquaculture facilities and where they can be sited.

C. Government UMVs

Militaries globally have already been early and rapid adopters of UMV technologies, with some arguing that the next chapter of marine warfare is "an age of unmanned systems."[95] The United States and China are leading this charge, with China also investing heavily in developing both offensive and defensive UMVs.[96] The military has long had creative approaches to gathering information about ocean environments. Various militaries use dolphins and other marine mammals to complete a range of missions underwater, from detecting mines to gathering information.[97] UMVs add to this operational capacity.

The US Navy has been a pioneer in autonomous vessel technology and other types of marine robotics, adopting a UMV strategy as early as 2007.[98] These vessels are being used for all types of operational roles, from mine clearing to information gathering to surface warfare.[99] The size and type of Naval UMVs ranges significantly from full ship sized unmanned underwater vehicles (UUVs), such as SeaHunter, which completed its first voyage from California to Hawaii in 2018,[100] to smaller information-gathering platforms.[101]

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[93] Daniel D. Benetti, *Aquaculture of Pelagic Fish, Part 1*, GLOB. SEAFOOD ALL. (Apr. 1, 2000), https://www.globalseafood.org/advocate/aquaculture-of-pelagic-fish-part-1/ [https://perma.cc/34YR-MWZ4].

[94] *See, e.g.*, Chad Pettrone, *Open Blue Cobia*, NE. SEAFOOD PRODS. (Mar. 8, 2018), https://northeastseafood.com/open-blue-cobia/ [https://perma.cc/424E-NC4C], for an example of an open ocean aquaculture facility.

[95] FRANDRUP, *supra* note 12, at 3.

[96] *See id.*

[97] *See, e.g.*, *U.S. Navy Marine Mammal Program*, NAVAL INFO. WARFARE CTR. PAC., https://www.niwcpacific.navy.mil/marine-mammal-program/ [https://perma.cc/LNC3-LH5X].

[98] NAT'L ACADS. SCI., ENG'G, & MED., *supra* note 9, at 71, 73–75.

[99] *Id.* at 44, 71, 73–74.

[100] Joseph Trevithick, *Navy's Sea Hunter Drone Ship Has Sailed Autonomously to Hawaii and Back Amid Talk of New Roles*, DRIVE (Feb. 4, 2019, 2:45 PM), https://www.thedrive.com/the-war-zone/26319/usns-sea-hunter-drone-ship-has-sailed-autonomously-to-hawaii-and-back-amid-talk-of-new-roles [https://perma.cc/Y22C-V245].

[101] NAT'L ACADS. SCI., ENG'G, & MED., *supra* note 9, at 74.

While the US Navy has been a heavy investor in autonomous technologies, the US Coast Guard has not.[102] The Coast Guard currently has some aerial drones in active use and is testing other types of UMV technologies.[103] To date, the Coast Guard's approach to autonomous technologies has been relatively underfunded and ad hoc.[104] In contrast with the US Navy, which directly funds and leads autonomous system development, the Coast Guard's relatively small budget means that they strive to be a "fast follower" regarding technology adoption.[105]

However, the benefits to the Coast Guard of expanding marine robotic use are notable. Many of the Coast Guard's missions require huge expenditures of resources to reach distant areas of the ocean. Robotics could supplement existing capabilities particularly in reaching these distant areas and helping to conserve resources.[106] For instance, search and rescue at sea is limited by geography: many of the calls for help that occur are from boats thousands of miles from shore. Reaching these vessels can take days or weeks for the nearest ship.[107] The US Coast Guard and other military assets use planes to reach vessels in distress but are limited in the types of assistance they can provide. Search and rescue UMVs could dramatically improve rescue capability, with the ability to station UMVs throughout the ocean that are able to quickly respond in the case of emergency.[108] In addition to contracts with purpose built UMVs, several companies have developed software systems that can turn any vessel into an autonomous platform.[109] The Coast Guard is beginning to use these systems on some of their existing smaller vessels.[110]

The Coast Guard is also using new robotics specifically for operations under the ice in the Arctic.[111] A strategically important area with competing claims from Canada, Russia, and the United States that is seeing a rapid expansion in commercial and recreational traffic, vessel operations in the Arctic have long been difficult. Initial UMV deployment to the area is focused on

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[102] *Id.* at 7–8.

[103] *See generally id.* (discussing aerial systems utilized by Coast Guard and their current invested research and development in the area).

[104] *Id.* at 62.

[105] NAT'L ACADS. SCI., ENG'G, & MED., *supra* note 9, at 29.

[106] *Id.* at 85–86.

[107] *Id.* at 86–87.

[108] SCOTT SAVITZ ET AL., HSOAC, THE MARINE TRANSPORTATION SYSTEM, AUTONOMOUS TECHNOLOGY, AND IMPLICATIONS FOR THE U.S. COAST GUARD 5–6 (2020).

[109] *See* NAT'L ACADS. SCI., ENG'G, & MED., *supra* note 9, at 54 (describing the "Spatial Integrated Systems' Multi Agent Robotic Teams Autonomy System").

[110] *Id.*

[111] *Id.* at 56–57.

preparing for oil spill detection and response, though other capabilities are likely to come online in the future.[112]

The Coast Guard and maritime law enforcement agencies globally will benefit from increasingly sophisticated and cost-effective UMVs. In addition to their operational roles, UMVs can be used as a deterrent: having more visible law enforcement presence may prevent certain types of illegal activity.[113] UMVs are also being used to support environmental protection missions by enforcing existing protected areas and no-take fisheries zones.[114] In the future, they may be used to respond to oil spills or other emergencies in dangerous operational conditions.[115]

On the other hand, illegal actors are also increasingly using marine robotics to evade law enforcement. Illegal submarines have long been used for drug trafficking, as they are relatively difficult to detect. Improving these to make them unmanned vastly increases potential success for traffickers. Marine robotics are also being used to disrupt law enforcement operations, through physically interfering with and distracting Coast Guard vessels or by jamming communication frequencies.[116]

D. Recreational UMVs

Scientists and industry have used various types of robots for decades, but their availability to members of the general public is a new development. In the past, marine robotics have been prohibitively expensive, limiting their use to sophisticated and well-capitalized commercial and defense organizations. The advent of low-cost, open-source technologies and developments in autonomy from the military and commercial sectors are beginning to trickle down to recreational applications.[117]

In recent years, small, low-cost tethered ROVs have become available to the public, setting the stage for a transition to autonomous recreational platforms. Current ROVs are

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[112] Interestingly, the Coast Guard anticipates some of the cost of development of oil spill detection UMVs to be recouped from the legally responsible party in the event of an oil spill. *Id.* at 55–56.

[113] *Id.*

[114] *Id.* at 88–90.

[115] SAVITZ ET AL., *supra* note 108, at 7.

[116] *See generally* Anna Petrig, *Autonomous Offender Ships and International Maritime Security Law*, *in* AUTONOMOUS SHIPS AND THE LAW (Henrik Ringbom et al. eds., 2020).

[117] Bill Pike, *Special Report: The Dawn of Driverless Boats*, POWER & MOTORYACHT (June 17, 2021), https://www.powerandmotoryacht.com/special-report/the-dawn-of-driverless-boats [https://perma.cc/5NMC-WE49] ("[T]he pressure to create, refine and expand autonomous marine technology in military, mercantile and other sectors is already beginning to push enhancements and expansions toward the realm of recreational boating.").

equipped with sophisticated camera equipment and allow users both to look in real time at what is happening underwater as well as to record video footage for later use.[118] These ROVs are being used by schools for educational purposes and by environmental nonprofits and others to identify and remedy ecosystem degradation.[119] The Rosalia Project, for instance, uses these ROVs to find and clean up marine trash.[120] While currently tethered, these platforms set the stage for future upgrades to autonomous technologies. Similar small autonomous platforms are already being developed and marketed to recreational users, for instance the iBubble, a small UMV designed to follow divers underwater and film their activities.[121]

More sophisticated autonomous systems may soon be available for recreational vessels. These systems range from assisted docking technologies to collision avoidance features that integrate with existing autopilots to fully autonomous technologies.[122] Many are excited about the potential for these systems to reduce recreational boating accidents by providing additional safety features to recreational mariners, a group who is generally less experienced than professionals and could benefit more from these measures.[123] However, converting recreational vessels to autonomous technologies is implicating many of the same safety and regulatory hurdles posed by other UMVs, ultimately slowing the development and adoption of recreational autonomy.[124]

Autonomous technology is also enabling the development of entirely new types of marine robots, a trend that is being spearheaded by a group of hyperwealthy individuals. Some of these new UMVs have environmental conservation goals, such as the Ocean Cleanup.[125] Others are mainly for exploration, sometimes with a scientific gloss, like the UMVs associated with Ray Dalio's OceanX.[126] Bill Stone's Sunfish AI is intended to

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[118] *See, e.g.*, CHASING DORY, https://www.chasing.com/chasing-dory.html?key=NjBhZTY3NDQ5OWU5Mg== [https://perma.cc/C8J2-WFLX].

[119] *See, e.g.*, *What We Do*, OCEANSWIDE, https://www.oceanswide.org/about [https://perma.cc/3CXY-45E7]; Duncan DeCraemer, *Using ROVs to Engage Youth Education with the Environment*, DEEP TREKKER (Feb. 21, 2020), https://www.deeptrekker.com/news/using-rovs-to-engage-youth-education-with-the-environment [https://perma.cc/6KWB-Z4VZ].

[120] *Innovation and Technology*, ROZALIA PROJECT, https://www.rozaliaproject.org/programs/innovation-technology [https://perma.cc/7T6B-GVZ4].

[121] *See* IBUBBLE, https://ibubble.camera/ [https://perma.cc/F9YK-Z452].

[122] Pike, *supra* note 117.

[123] *Id.*

[124] *See id.*

[125] *Homepage*, OCEAN CLEANUP, https://theoceancleanup.com/ [https://perma.cc/425Q-BX5N].

[126] *Deep Sea Vehicles*, OCEANX, https://oceanx.org/oceanxplorer/deep-sea-vehicles.

push cave exploration boundaries by autonomously exploring and mapping underwater cave systems.[127] Several other exploration projects developed by the private sector are centered around UMVs. These wealthy private sector actors are adding to the work of scientific and military communities to push the boundaries of UMV development. The resulting landscape of UMV use is diverse: many different actors are using an array of UMV types to achieve their operational missions.

The technical challenges associated with UMVs are still significant, both in the development of UMV platforms that can withstand the harsh operational conditions of the ocean as well as in the creation of interfaces that allow humans to interact with and understand the many new UMVs on the ocean. These technical challenges are rapidly being overcome and, in many cases, the major barrier to increased development and implementation is the regulatory uncertainty surrounding UMVs.

II. CURRENT UMV GOVERNANCE

UMVs are governed by a variety of different regimes, depending on their location, origin country, and the type of the vehicle. This is a rapidly evolving area, with many countries and international organizations currently drafting and adopting regulatory schemes to govern emerging types of marine robots.[128] These regulatory advancements must work in concert with existing maritime regulation, much of which is ancient, anachronistic, and unlikely to be updated. The constraints imposed by existing legal regimes and current proposals for regulating marine robots must bridge an ideal regulatory landscape with one that is feasible given existing laws. Many scholars and industry members agree that the best approach is to create new laws governing marine robotics that can act in concert

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[127] *See* SUNFISH, https://sunfishinc.com/ [https://perma.cc/PFH2-2JAF].

[128] *See, e.g.*, *Autonomous Ships: Regulatory Scoping Exercise Completed*, INT'L MAR. ORG. (May 25, 2021), https://www.imo.org/en/MediaCentre/PressBriefings/pages/MASSRSE2021.aspx [https://perma.cc/4L7C-EH7K]; DEP'T FOR TRANSP., FUTURE OF TRANSPORT REGULATORY REVIEW CONSULTATION: MARITIME AUTONOMY AND REMOTE OPERATIONS 10–11 (2021), https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1020986/future-of-transport-regulatory-review-maritime-autonomy-and-remote-operations-print-version.pdf [https://perma.cc/NPV5-KUC8]; *Guidance in Connection with the Construction or Installation of Automated Functionality Aimed at Performing Unmanned or Partially Unmanned Operations*, NORWEGIAN MAR. AUTH. (Aug. 27, 2020), https://www.sdir.no/en/shipping/legislation/directives/guidance-in-connection-with-the-construction-or-installation-of-automated-functionality-aimed-at-performing-unmanned-or-partially-unmanned-operations/ [https://perma.cc/3LFA-T8GN].

with existing regulation, as opposed to trying unsuccessfully to amend current international and national legislation.[129]

This Part sets out the existing regulatory schemes governing robots in the marine environment, focusing on major US and international laws. Despite the myriad types of UMVs, nearly all the discussion about UMV regulation is devoted to the regulation of large, commercial UMVs. This Part discusses these proposals, noting where additional regulation is needed to effectively govern the full landscape of UMV use.

A. Public Law

Public laws at the national and international level are the primary mechanism for regulating vessels on the oceans, including UMVs. These laws in many cases codify centuries of custom in maritime operations. However, UMVs and their increasing commonness raise a variety of new issues that existing regulation often does not cover.

1. Are UMVs Vessels?

In both US and international law, determining whether, and how, applicable safety regulations and other public maritime laws will apply to UMVs requires answering the threshold question of whether UMVs are considered vessels. If UMVs are not vessels, in many cases, existing regulations will not apply to them, as very few other types of ocean-going vehicles existed historically and were therefore contemplated by maritime regulations. For instance, it is unclear whether small, passively powered scientific floats would be considered vessels under current international definitions.[130] If they are not considered vessels, they will be effectively unregulated and not required to comply with even the most basic maritime safety laws, like the installation of navigational lights for nighttime operation. New categories will likely need to be created to regulate the full landscape of UMVs without needing to apply the full international and national regulatory requirements of ships in cases where this is inefficient.

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[129] Ringbom, *supra* note 6, at 151–52; DNV GL USA, Inc., Comment Letter on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies into the Maritime Transportation System (Oct. 13, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0026 ("To allow for autonomous unmanned ships it is better to formulate standards that apply to these ships separately, without amending current laws/standard.").

[130] Bork et al., *supra* note 33, at 308–09 (arguing that despite the uncertainty, floats and gliders likely should not be considered ships under international law).

Determining whether a UMV is a vessel is not simple and has become the subject of considerable academic discourse.[131] The question of what makes something a vessel has come up throughout US history, most recently in *Lozman*, where the Supreme Court determined that a houseboat incapable of its own propulsion was not considered a vessel.[132] The United States has codified a broad definition of what constitutes a vessel, including "every description of water craft, including non-displacement craft, WIG craft and seaplanes, used or capable of being used as a means of transportation on water."[133] The Coast Guard has interpreted this expansively and developed a set of characteristics that constitute a vessel.[134]

Currently, many UMVs are functionally treated as vessels by default.[135] There are no alternative categories that could hold them under US or international law, with the possible exception of "[h]azard[s] to navigation."[136] The National Oceanic and Atmospheric Administration's (NOAA) itself acknowledges that some of its scientific UMVs are likely considered vessels

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131 *See, e.g.*, Allen, *supra* note 6, at 749; Ringbom, *supra* note 6, at 161; Andrew H. Henderson, *Murky Waters: The Legal Status of Unmanned Undersea Vehicles*, 53 NAV. L. REV. 55, 56–57 (2006); McLaughlin, *supra* note 6, at 108; Daniel Vallejo, *Electric Currents: Programming Legal Status into Autonomous Unmanned Maritime Vehicles*, 47 CASE W. RES. J. INT'L L. 405, 407 (2015).

132 Lozman v. Riviera Beach, 568 U.S. 115, 122 (2013).

133 33 C.F.R. § 83.03(a); 33 U.S.C. § 1602 (proclaiming that the International Regulations for Preventing Collisions at Sea, 1972 are in effect in the United States); Convention on the International Regulations for Preventing Collisions at Sea, Oct. 20, 1972, 28 U.S.T. 3459, T.I.A.S. No. 8587, 1050 U.N.T.S. 16, at r. 3(a), (consolidated ed., 2018) [hereinafter COLREGs], https://www.libramar.net/news/colreg_consolidated_edition_2018/2022-03-31-4370.

134 In finding that a paddleboard was a vessel, the Coast Guard articulated five factors to address:

1. Whether the [vessel] is "practically capable" of carrying persons or property,
2. Whether the operating range of the device is limited by the physical endurance of its operator,
3. Whether the device poses a substantial hazard to navigation not already present,
4. Whether the normal objectives sought to be accomplished by the regulation of [the] device as a "vessel" are present, and
5. Whether the operator and/or cargo would no longer be safe in the water if the device became disabled.

NAT'L ACADS. SCI., ENG'G, & MED., *supra* note 9, at 163.

135 For an argument that this functionalism threatens to undermine international law approaches to UMV regulation, see Allen, *supra* note 16, at 480 ("[A] functional approach is only appropriate when the treaty itself incorporated provisions for such flexibility (as do some IMO treaties listed in). Where, however, the treaty does not include such provisions we must look to more formal methods for treaty interpretation or amendment codified in the Vienna Convention on the Law of Treaties. Respect for the increasingly fragile global rules-based order requires nothing less.").

136 *See* 33 C.F.R. § 64.06 (2021) (hazards to navigation are a broad category of objects that block channels, disrupt vessel routes, or otherwise impede navigation).

under US definitions.[137] In some unclear cases, specific institutions have gone so far as to certify that UMVs in their fleets are vessels. The Navy, for instance, has certified that several of its UMVs are vessels, even though they are unable to comply with certain COLREGs requirements.[138]

The question of what a vessel is has important implications for what UMVs can do. Avoiding international and domestic regulations may be appealing, and some robotics companies such as Saildrone have gone so far as to profess that their small UMVs should not be considered vessels because they are not designed for transportation.[139] This reduces the regulatory compliance burden when designing robots. However, evading regulation prevents UMVs from participating in important safety protocols like Automatic Identification System (AIS), a GPS transponder that automatically transmits a vessel's information and location. AIS is used by other vessels to avoid collisions, as well as by port authorities and law enforcement. Some UMV operators have determined that they are not legally permitted to carry AIS units.[140]

Proposals to redefine what a vessel is may not fix this problem. Some definitions are so broad as to include anything "capable of traversing the sea."[141] On the other hand, the US definition that centers around the function of vessels to provide transportation for people or goods may exclude new types of UMVs such as scientific ones, which are transporting neither, regardless of their size.[142] These debates are centered around historical understandings of what constitutes a vessel. Instead, the questions that needs to be answered are whether and what types of UMVs should be regulated as vessels. Agencies should determine when categorizing a UMV as a vessel helps to promote the regulatory goals of our current international and national maritime regimes, to promote safety at sea and to

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[137] NOAA, Comment Letter on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies into the Maritime Transportation System (Oct. 13, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0027.

[138] *See* NAT'L ACADS. SCI., ENG'G, & MED., *supra* note 9, at 164 (explaining that the 1972 Convention on the International Regulations for Preventing Collisions at Sea (COLREGs) established global safety standards that apply to all vessels). For instance, vessels operating autonomously do not carry lookouts as COLREGs dictates. *Id.*; 33 C.F.R. § 83.05.

[139] SAILDRONE, Inc., Comment Letter on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies into the Maritime Transportation System (Oct. 13, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0035.

[140] *Id.*

[141] Allen, *supra* note 16, at 495.

[142] *Id.* at 494.

ensure environmental protection. The ultimate answer to this question will likely depend on the specific characteristics of the UMV in question. In the next Section, I will consider both laws applying to UMVs that are clearly vessels and those that apply to UMVs that may not be considered vessels. As noted above, this article focuses on vehicles that are unmanned or otherwise operating autonomously, without humans in the loop.

2. UMVs Under International Law

The United Nations Convention on the Law of the Sea (UNCLOS) is the primary international law governing activities on the ocean.[143] Additional International Maritime Organization (IMO) treaties and topic-specific regulations fill in the framework created by UNCLOS to create the international maritime law system that we have today.[144] Ensuring that UMVs are consistent with these laws—most of which were developed long before anyone considered autonomous ships a possibility—will require significant regulatory changes.

Like COLREGs, the Law of the Sea was drafted with specific language detailing the requirements for a human crew. For instance, Article 94 of UNCLOS requires that flag states ensure "that each ship is in the charge of a master and officers who possess appropriate qualifications."[145] This is a major impediment to the adoption of autonomous, unmanned vessels. Academics and others are considering several workarounds so that UMVs can still meet these requirements, for instance by having land-based command centers with qualified masters "overseeing" the operations of UMVs.[146]

In 2017, the IMO began a scoping process specifically to look at regulation of MASS.[147] This scoping is focused on the advent of large, autonomous ships used for carrying cargo. IMO scoping is still in early stages, with no intention of generating new international rules likely until the late 2030s.[148] The IMO's current process is to some extent informed by earlier, largely unsuccessful, moves toward automation. A push for One Man

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143 United Nations Convention on the Law of the Sea art. 94(4)(b), Dec. 10, 1982, 21 I.L.M. 1261, 1833 U.N.T.S. 434 (entered into force Nov. 16, 1994) [hereinafter UNCLOS].

144 *See generally List of IMO Conventions*, INT'L. MAR. ORG., https://www.imo.org/en/About/Conventions/Pages/ListOfConventions.aspx [https://perma.cc/6DEB-XWV4] (listing IMO conventions that are organized by topic covered at each convention).

145 UNCLOS, *supra* note 143, art. 94(4)(b).

146 *See* Ringbom, *supra* note 6, at 157, 159.

147 INT'L MAR. ORG., *supra* note 128.

148 *See id.*

Bridge Operations, or a reduction in the number of crew required to steer a vessel, in the 1980s led to proposed amendments to COLREGs but was ultimately unsuccessful due to concerns about safety and fragmented support from coastal states.[149]

There is already debate about the effectiveness of the IMO process. For instance, the lack of clarity in the four different categories of autonomy created by IMO may cause regulatory confusion.[150] Others worry that the IMO's proposed autonomous vessel regulation may be ineffective on a broader level.[151] IMO scoping is also limited to considering how autonomous ships may conflict with existing IMO conventions.[152] While an understandable focus, and one that is reflected by the US Coast Guard's approach to regulating UMVs, this scope inherently limits what IMO can accomplish. Current regulations do conflict with autonomous vessel operation in some ways, but the more pressing issue is whether current regulations will adequately regulate autonomous vessels at all. The IMO is not asking this question. IMO conventions, all of which were drafted decades ago, simply do not address the issues posed by autonomous vessels.

For instance, current maritime law has little to say about underwater operations.[153] While surface operations are regulated under both national and international regimes, subsurface operations have few regulatory limits. Historically, submarines were limited in number and primarily operated by militaries. This landscape is changing, with the advent of many new actors using UUVs. While some view the lack of regulation in this area positively, with no impediments to UUV operation or experimentation, increasingly widespread UUV operation is not without risks.[154] It will be important to create regulatory regimes for marine robots that address not just surface, but also subsurface vessel operations.

Current international law also dictates where UMVs can operate depending on what they are being used for. Certain activities, peaceful transit for instance, are allowed virtually everywhere throughout the ocean, while others, such as resource exploitation, are heavily governed by national law (when within two hundred nautical miles of a coastal nation's shore) or international organizations (when fishing in the high seas, for

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149 *See* Allen, *supra* note 6, at 751; Ringbom, *supra* note 6, at 151.
150 Ringbom, *supra* note 6, at 149–50
151 Allen, *supra* note 16, at 500–05.
152 Ringbom, *supra* note 6, at 161.
153 NAT'L ACADS. SCI., ENG'G, & MED., *supra* note 9, at 141.
154 *See id.*

instance).[155] An already popular approach is to claim that UMVs are being used for scientific research.[156] Under UNCLOS, the freedom of scientific research is protected and is essentially unrestricted on the high seas.[157] Within coastal waters researchers must gain the consent of the coastal state, but coastal states may not withhold this consent if it is for peaceful purposes.[158] While some have made the distinction between data collection for research purposes and for exploration purposes, in practice it may be difficult to determine when UMVs are engaging in research or in some other endeavor.[159]

Before IMO regulation goes into effect, alternative mechanisms aside from the formal adoption of new regulations or revisions to existing Conventions could help to informally regulate autonomous vessels. Circulars agreed upon by IMO members that clarify some of the important legal questions around UMV operation could provide interim guidance for the development of this field.[160]

3. National UMV Law

In addition to international law, UMVs will be subject to the laws of their flag states. Different flag states have dramatically different approaches to these standards, creating a globally fragmented approach to maritime vessel regulation. The most notorious example of differences in flag state regulation and enforcement is in the case of flags of convenience.[161] Certain countries, generally those with relatively lax safety laws, low enforcement capability, or favorable tax status, allow interested vessels to easily register in their countries.[162] Countries seeking to increase revenue through vessel registries may ultimately target UMVs with favorable regulation.

Flag choice may become an important decision for operators of UMVs. Today, certain countries already target

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155 *See* UNCLOS, *supra* note 143, at art. 37–39 (transit passage); *id.* at art. 55–58 (resource use); *International and Regional Fisheries Management Organizations*, NOAA, https://www.fisheries.noaa.gov/international-affairs/international-and-regional-fisheries-management-organizations [https://perma.cc/6M4D-JTW9] (fisheries).

156 *See* NOAA, *supra* note 137.

157 UNCLOS, *supra* note 143, at pt. XIII.

158 *Id.* art. 246.

159 *See* Bork et al., *supra* note 33, at 304.

160 Ringbom, *supra* note 6, at 160.

161 *See generally* ENV'T JUST. FOUND., OFF THE HOOK: HOW FLAGS OF CONVENIENCE LET ILLEGAL FISHING GO UNPUNISHED (2020), https://ejfoundation.org/resources/downloads/EJF-report-FoC-flags-of-convenience-2020.pdf. [https://perma.cc/C3JA-BT8L] (discussing how flags of convenience facilitate illegal, unreported and unregulated fishing).

162 *Id.* at 9–11, 14.

specific types of vessels for registration: the Marshall Islands, for instance, targets private yachts over twelve meters and less than twenty years old.[163] Savvy countries seeking to expand their ship registries may eventually wish to target UMVs and other types of marine robots by creating a favorable regulatory landscape for these vessels. This type of forum shopping is an accepted feature of vessel registration, but one that may ultimately undermine national ability to regulate UMVs effectively.

4. US Law

The United States is slowly responding to the rise in marine robotics, and much of the regulatory landscape is still being developed. Congress recognized the importance of this area and initiated agency research on UMVs through the 2018 Commercial Engagement Through Ocean Technology Act, which tasked NOAA with coordinating with the Navy to research, develop, and use UMVs in their operations.[164]

While NOAA and the US Navy are relatively early movers in using UMVs, regulating UMVs will fall primarily to the US Coast Guard (USCG).[165] The Coast Guard began early stages of rulemaking on autonomous vessels with a Request for Information in August of 2020.[166] This was a broad call, asking for information from stakeholders on many questions related to the integration of new UMVs into the existing maritime regulatory system.[167] This early Request For Information (RFI) was devoted to the use of autonomous technologies for commercial purposes.[168]

Most comments in response to the USCG's RFI focus heavily on how UMVs will interact with existing maritime safety regulations. These safety regulations are primarily codified as part of the Convention on the International Regulations for Preventing Collisions at Sea (COLREGs) and Inland Navigation Rules.[169] Industry and academic commenters believe that these

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163 *About Us*, MARSHALL ISLANDS YACHT REGISTRATION, https://www.marshall-islands-yacht-registration.com/about-us.html [https://perma.cc/9P6F-QMHQ].

164 33 U.S.C. § 4102(c)(1).

165 Other agencies, including EPA, Department of Commerce, and Department of Transportation also govern smaller aspects of marine robotic operation.

166 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).

167 *Id.*

168 *Id.* A distinction that other federal agencies were quick to jump on, wanting to make sure that any initial Coast Guard rulemaking did not apply to government actions.

169 COLREGs, *supra* note 133; 33 C.F.R § 83.01–.02 (2022).

regulations may need to be significantly modified to accommodate autonomous vessels.[170]

COLREGs, in many places, are based around actions required of crewmembers on board vessels. For instance, regulations require a lookout onboard all vessels.[171] This lookout is responsible not only for ensuring that the vessel is traveling safely and communicating via radio with others, but also responding in the event of an oil spill.[172] Determining whether a UMV meets this lookout requirement if there is not a human onboard, either through sensors that act as a human equivalent or through remote monitoring by humans onshore, will be critical in understanding how COLREGs requirements apply to UMVs.[173] Existing case law can help to provide some clarity on how various COLREGs manning terms have been interpreted in the past.[174]

Some technology developers argue that compliance with COLREGs is possible through programming autonomous vessels.[175] The US Navy piloted a Ghost Fleet vessel that was able to safely cross the Atlantic while complying with COLREGs requirements.[176] While this may be possible, ultimately, COLREGs likely will need to be updated in many different areas, for instance around manning and lookout requirements, to accommodate unmanned vessels.[177] Some worry that adjusting COLREGs' safety requirements to accommodate unmanned vessels will have a spillover effect by reducing crew on manned vessels, lowering safety standards across the board.[178]

COLREGs are further enhanced in busy port areas by Vessel Traffic Services (VTS).[179] UMVs must be able to integrate into existing VTS rules and interact effectively with

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[170] *See, e.g.*, NAT'L ACADS. SCI., ENG'G, & MED., *supra* note 9, at 40; *see also* Allen, *supra* note 16, at 502–05, 509.

[171] 33 C.F.R. § 83.05.

[172] *See* 33 C.F.R. § 155.5030.

[173] *See* Allen *supra* note 16, at 500–01; NAT'L ACADS. SCI., ENG'G, & MED., *supra* note 9, at 159 n.74.

[174] *Id.*

[175] *Id.* at 136–38.

[176] Megan Eckstein, *Program Office Maturing USVs, UUVs With Help From Industry, International Partners*, USNI NEWS (June 23, 2020, 5:27 PM), https://news.usni.org/2020/06/23/program-office-maturing-usvs-uuvs-with-help-from-industry-international-partners [https://perma.cc/BV8U-GNRW].

[177] For a full list of areas where current COLREGs may conflict with autonomous vessel operation, see Craig H. Allen Sr., Comment Letter on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies into the Maritime Transportation System (Aug. 24, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0004.

[178] *Id.*

[179] *See Vessel Traffic Services*, U.S. COAST GUARD, https://www.navcen.uscg.gov/vessel-traffic-services [https://perma.cc/E56H-6S4G].

nonautonomous vessels as well as other UMVs. Realistically, it may be some time before vessels are able to be completely unmanned in these areas due to the existing complexity of vessel operation.[180] This includes not only a high volume of other vessel traffic but large heterogeneity in the types of vessels operating, from large cargo ships to jet skis to human swimmers.

Beyond core safety regulations, the United States has several other regulations that place light limits on what vessels can do on the ocean. In general, certain types of extractive and commercial activities must be permitted, such as fishing, oil drilling or mining.[181] Activities that may negatively impact the environment, either by harming marine mammals or discharging pollution, also require permits and environmental impact assessments.[182] These regulations will only apply to UMVs engaging in specific types of marine activities but will not apply more generally.

Functionally, determining how UMVs can operate in compliance with existing regulations is usually done on a case-by-case basis, requiring technology developers to meet with a cross-section of government agencies and other stakeholders.[183] This approach makes sense right now but will not be sustainable in the future with the increase in numbers of these types of vessels and a greater heterogeneity of operators.

B. Private Governance

Outside of the formal governance mechanisms created by national and international regulatory frameworks, private governance and other informal mechanisms may be the early drivers of how UMVs are governed. The private sector is already developing its own methods of informally governing marine robotics in the absence of formal regulation from governments. The American Bureau of Shipping, for example, has developed

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[180] *See generally* Marine Exch. of S. Cal. & Vessel Traffic Serv. of L.A. & Long Beach, *supra* note 65 (discussing the complexity of vessel activity in the waters around Los Angeles and the Port of LA).

[181] *See generally* Magnuson-Stevens Fishery Conservation and Management Act, 16 U.S.C. §§ 1801–1883 (providing for the conversation and management of fisheries); 33 C.F.R. §§ 140–147 (2022) (outlining permitted OSC activities as applied to OCS facilities, vessels, and other units).

[182] National Environmental Policy Act of 1969, 42 U.S.C. §§ 4321–4370; Marine Mammal Protection Act of 1972, 16 U.S.C. §§ 1361–1423.

[183] Sean T. Pribyl, *From Sail to Steam to . . . the Stars? How Innovation in the Commercial Space Industry Is Impacting the Maritime Sector and Coast Guard*, GCAPTAIN (Aug. 3, 2021), https://gcaptain.com/commercial-space-exploration-maritime-and-coast-guard-impacts/ [https://perma.cc/DYW9-UF6N] (describing the measures taken by Space-X to develop protocols for using their UMVs, including meeting with Coast Guard, Air Force, pilots, port officials and vessel traffic service).

guidelines to shape how various ship-based systems can be developed to be compatible with autonomous operation and new hybrid autonomous support systems.[184]

Insurance is critical for all vessels on the ocean. Accidents are a given at sea, and the principles of these private governance systems are well established when it comes to manned vessels. Insurance company standards, for instance, form such an important backbone of the maritime industry that decisions not to issue policies can amount to "economic warfare."[185]

The initial risk and uncertainty around UMV use may make it difficult to obtain insurance policies. Apportioning liability when UMVs are involved is likely to initially be more challenging due to complicated questions around determining causation and fault. No UMVs have yet been a part of a major collision at sea, but it is only a matter of time before this happens.[186] Some have suggested that owners and operators of UMVs should be held to strict liability standards for any damages they cause.[187]

Even attempts to decrease uncertainty before vessels become fully autonomous by using remote operation as a risk reducing intermediate step raises its own questions about liability.[188] For instance, in collision avoidance situations, the communication delay between a vessel and its remote operators is likely to be significant enough to seriously impede the effectiveness of remote control.[189] This is a foreseeable issue and may raise potential tort liability for these types of vessels. Anecdotally, marine companies are concerned that switching to autonomous vessel technologies may raise insurance prices at least temporarily.[190] However, reduced personal injury claims from injured crew combined with better storm avoidance may decrease costs.[191]

In response to these concerns, insurance companies have also been relatively early movers in providing guidance on autonomous vessels. For example, Lloyd's Register, both a

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[184] James A. Watson, Am. Bureau of Shipping, *supra* note 71.

[185] Richard L. Kilpatrick Jr., *Marine Insurance Prohibitions in Contemporary Economic Warfare*, 95 INT'L L. STUD. 272, 273 (2019).

[186] SAVITZ ET AL., *supra* note 108, at 5.

[187] Allen, *supra* note 177.

[188] *See, e.g.*, James A. Watson, Am. Bureau of Shipping, *supra* note 71 (advocating for the use of Remote Control and Operations Centers for autonomous vessels).

[189] Ringbom, *supra* note 6, at 156.

[190] Haikkola, One Sea/DIMECC, *supra* note 53.

[191] Gard AS P&I Club, Comment Letter on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies into the Maritime Transportation System (Oct. 13, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0028.

classification society and the single largest marine insurance company, issued guidance on autonomous vessels in 2016 that provides a process for identifying, mitigating, and classifying the risks associated with UMV operation.[192] Other insurance companies have already thought through the regulation of UMVs in depth as well.[193]

Beyond insurance, classification agencies play a similarly important role in regulating marine industries, particularly when it comes to larger shipping and commercial vessels. Classification societies are independent nongovernmental organizations responsible for developing standards and certifying that vessels meet these standards, primarily for insurance purposes, for instance the American Bureau of Shipping.[194] Major classification societies have already created their own guidelines on autonomous vessels.[195] While these guidelines remain in many ways vague, they are early attempts to identify key issues related to UMVs and provide consistent guidance to other maritime sectors.

These private governance avenues will be critical in determining how UMVs are deployed and governed in the years before formal national and international regulations are issued. This is a particularly effective mechanism when it comes to addressing safety and liability issues, both areas that insurance companies and classification societies are heavily focused on. Other larger questions, like whether UMVs should be classified as vessels or what constitutional or regulatory limits on their operation may exist, are less likely to be addressed through private governance avenues.

C. Failures in UMV governance

Existing regulations provide little guidance on how UMVs should be operated. Instead, approaches to UMV regulation are slow, fragmented and overly focused on specific

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[192] *See* LLOYD'S REGISTER, CYBER-ENABLED SHIPS: SHIPRIGHT PROCEDURE–AUTONOMOUS SHIPS 4–5 (2016), http://info.lr.org/l/12702/2016-07-07/32rrbk [https://perma.cc/UX8X-W6W2].

[193] Gard AS P&I Club, *supra* note 191.

[194] *See, e.g.*, Rishab Joshi, *The Importance of Classification Societies in the Maritime Industry*, MARINE INSIGHT (June 25, 2021) https://www.marineinsight.com/maritime-law/the-importance-of-classification-societies-in-the-maritime-industry/ [https://perma.cc/F66R-GVZV].

[195] *See generally, e.g.*, DNV GL, CLASS GUIDELINE, AUTONOMOUS AND REMOTELY OPERATED SHIPS (2018), https://rules.dnv.com/docs/pdf/DNV/cg/2018-09/dnvgl-cg-0264.pdf [https://perma.cc/BZY6-X4MN] (providing comprehensive guidelines on DNV GL's autonomous and remotely operated ships).

types of actors. The gaps created by existing governance regimes allow many UMVs to operate without any meaningful oversight.

1. UMV Regulation is Outpaced by Technological Innovation

UMV regulation is currently characterized by a relatively slow and cautious approach: IMO, for instance, does not anticipate having concrete rules governing autonomous ships until the 2030s.[196] There is already a significant gap between the types of automation occurring on ships on a smaller scale, whether monitoring engine rooms or steering the boat with autopilot systems, and regulatory policy.[197] The current approach of making case by case determinations as these systems emerge will not continue to be effective with rapid increases in technological advancements and their uptake by the marine sector.

Some of this pace is dictated by an attitude that autonomous operation of ships is not technologically or politically feasible in the near term.[198] This is a myopic approach. Current trials of both small and large commercially viable UMVs in recent years has shown that UMV operation is technologically feasible with capabilities improving almost exponentially.[199] Regulation must move faster to be able to effectively handle the realities of marine robotics.

More legitimate reasons for the slow pace of regulation stem from caution: the IMO has explained that it is acting cautiously to ensure that the regulations adopted are effective and appropriate.[200] Other industry actors agree, noting that caution is warranted given the potential costs of automation on safety and marine workforce.[201]

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[196] Craig Eason, *No Rules on Autonomous Ships for Another 10 Years—At Least*, FATHOM WORLD (June 27, 2020), https://fathom.world/no-rules-on-autonomous-ships-for-another-10-years-at-least/ [https://perma.cc/N49P-GAF2].

[197] *Id.*

[198] Ringbom, *supra* note 6, at 154 ("The prospect of a fully developed autonomy, in which a ship undertakes an entire voyage totally without human supervision or involvement, is hardly realistic in the short term."); Allen, *supra* note 16, at 479 ("A.P. Moeller-Maersk Chief Executive Officer Søren Skou expressed his company's assessment that '[e]ven if the technology advances, I don't expect that we will be allowed to sail around with 400-meter long containers ships weighing 200,000 tonnes without any human beings on board.'" (alteration in original)).

[199] *See, e.g.*, DEAN ET AL., *supra* note 67 (discussing autonomous vessels trialed to date).

[200] INT'L MAR. ORG., REGULATORY SCOPING EXERCISE FOR THE USE OF MARITIME AUTONOMOUS SURFACE SHIPS (MASS) 4 (2018).

[201] Transp. Trades Dept., AFL-CIO, Comment Letter on Request for Information on Integration of Automated and Autonomous Commercial Vessels and

The pace of change is also limited by regulatory systems themselves. Amending applicable instruments or creating new standards and then waiting for actors to come into compliance with them will take a significant amount of time. This, in some ways, emphasizes the need for more rapid regulatory response. If it takes ten years from when a standard is promulgated to when changes begin to be seen on vessels, many of these changes should be made sooner rather than later to avoid regulatory gaps.[202]

Despite the justifications for a slow approach to UMV regulation, regulation that lags behind innovation has several major consequences for the maritime sector. The delay in adoption of formal governance regimes disincentives commercial investment and government adoption due to uncertainty about what regulatory regimes will ultimately look like. Some companies cite regulatory uncertainty specifically as the largest barrier to implementation of autonomous systems, ahead of technical challenges and other logistical concerns.[203] The slow pace of developing governance mechanisms for UMVs also potentially allows illegal actors to use emerging robotic technologies to their advantage: while government enforcement agencies are still debating how to operate UMVs legally, drug traffickers are beginning to use these same technologies to exploit enforcement gaps.[204] Temporary measures could potentially work to mitigate some of these consequences, but they have not yet been a major focus of national or international regulators.

2. UMV Regulation is Fragmented Across Jurisdictions

Not only has the approach to regulating marine robots been slow, but it has also been fragmented. In lieu of IMO regulation, domestic laws and policies around UMV use will dictate the landscape. Functionally, this means a variety of

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Vessel Technologies into the Maritime Transportation System (Oct. 13, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0036.

[202] *See* Ed Wendlandt, Radio Tech. Comm'n for Mar. Servs. (RTCM), Comment Letter on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies into the Maritime Transportation System (Oct. 12, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0017 [https://perma.cc/85PK-BASY] (noting that "it may take a decade or more from the time a change to an ITU standard is initiated, to the time consequential changes to relevant IEC standards are made, and then until compliant equipment becomes available on ships").

[203] Patrick Parsons, Am. Waterways Operators, Comment on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies into the Maritime Transportation System (Oct. 13, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0024.

[204] SAVITZ ET AL., *supra* note 108, at 3, 9.

different outcomes and approaches between countries.[205] The European Union has been an early mover, funding autonomous vessel development and creating specific test sites for vessels to use.[206] As countries move forward without international guidance, national regulatory regimes are evolving rapidly to accommodate these new technologies. By the time international regulation is finally complete, existing national regulation may be incompatible with global efforts. Harmonizing approaches early on is essential to ensuring effective governance and avoiding the problem of patchwork regulation that plagues so much of maritime law.

Regulatory fragmentation is happening not just at the international level, but within countries. In the United States, individual agencies are developing their own approaches to managing UMVs and other emerging technologies. NOAA's current plan to develop their own Best Management Practices in lieu of guidance from the Coast Guard is early evidence of this fragmentation.[207] The longer regulation takes to be enacted, the more individual entities will develop their own regulatory mechanisms that may or may not be consistent with what is ultimately enacted by the Coast Guard or the IMO. While federal agencies have made statements about their wish to coordinate with one another (and in some cases, Congress has required this coordination), it is not clear that these activities are happening rapidly enough to prevent divergent regulatory systems from being created.[208]

An incohesive regulatory environment is a problem for both agencies and the private sector. Lack of regulatory certainty prevents large capital investment in UMV development.[209] This effect is particularly stark in ocean industries, where government agencies are often major customers of marine robotics companies. NOAA, the Coast Guard, and the Navy all rely on private sector innovation in addition to their own technology development to supply resources necessary to carry out agency operations at sea.[210] The

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[205] *See, e.g.*, Gard AS P&I Club, *supra* note 191 (discussing different national approaches to determining COLREG compliance).

[206] *See generally* EUR. UNION COMM'N, EU OPERATIONAL GUIDELINES FOR SAFE, SECURE AND SUSTAINABLE TRIALS OF MARITIME AUTONOMOUS SURFACE SHIPS (2020) (recommending a regulatory framework for UMVs among European Union countries).

[207] *See* NOAA, *supra* note 137.

[208] *See id.*

[209] *See* SAVITZ ET AL., *supra* note 108, at 3.

[210] NAT'L ACADS. SCI., ENG'G, & MED., *supra* note 9, at 29–41 (discussing the Coast Guard's adoption of technology developed by the private sector).

procurement potential of these technologies is an important economic factor for the private marine sector.

As regulations evolve, technologies procured early may be grandfathered into new regimes, raising concerns about how and if they meet regulatory requirements. Commercial uncertainty is a critical impediment to success going forward. Commercial technology innovation depends on predictable markets to sell their products. The potential customer pool for marine robotic technologies is inherently limited and different national regulatory regimes may limit this pool even further.

3. UMV Regulation Ignores Major Potential UMV Impacts

Proposals for UMV regulation also fail to look holistically at the landscape of UMV use and address the myriad potential legal challenges that it raises. The focus on updating safety regulations to accommodate UMVs is important, but it is only a small fraction of the legal issues that must be addressed to create effective UMV regulation. For instance, beyond safety measures, private sector concerns about UMVs include the need for robust security measures. Cyber security is a critical issue to address for UMVs. One of the most important aspects of UMVs is they move oversight of vessels from directly on the ship to an operations center on land.[211] Even those UMVs that are operating completely autonomously are likely to have some degree of human oversight from operations hubs. Transmitting information securely between UMVs and the shore then becomes a critical concern.

In addition, UMVs can be more easily captured than manned vessels. Small UMVs can be easily picked up, either intentionally or unintentionally, by other vessels. This has happened already, with different fishermen capturing both presumed US Navy and Chinese UMVs.[212] For more sensitive missions, the ease of capture of these small devices raises important security concerns about the data available on the devices. Larger UMVs, those ultimately replacing manned cargo ships, are likely to be attractive targets for pirates. Without crews to defend them, it may be much easier to capture large autonomous ships. In addition, industry leaders are seriously

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[211] *See* Ringbom, *supra* note 6, at 149, 157, 159.

[212] *See* Rachel Zhang & Laura Zhou, *Chinese Fishermen Find Drone Ship 'Used for Spying by a Foreign Country,'* S. CHINA MORNING POST (Apr. 16, 2021, 9:00 PM), https://www.scmp.com/news/china/military/article/3129897/chinese-fishermen-find-drone-ship-used-spying-foreign-country [https://perma.cc/P7NS-SEJZ].

considering both the cybersecurity and security issues raised by the advent of large autonomous ships, though relatively little attention has been paid to the smaller classes of UMVs.[213]

Beyond security concerns, new methods of UMV surveillance implicate important privacy protections. In the United States, those protections stem primarily from the Fourth Amendment, the reach of which is notoriously weak at sea.[214] Vastly increasing the number of surveillance devices in the world's oceans is already spurring a cultural shift from historical norms, which hinged on the understanding that anything done on the oceans was unlikely to be seen by anyone else, to a much more transparent ocean where new privacy concerns may be raised.[215] Many have argued that the Fourth Amendment is already unconstitutionally applied to benefit law enforcement at sea.[216] UMVs will strain this already weak legal regime even further; however, these issues remain largely unaddressed by the marine community.[217]

UMVs also raise new questions of jurisdiction. While current vessels are subject to the jurisdiction of their flag state as well as that of the coastal nation whose waters they are

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[213] *See, e.g.*, Nir Ayalon, *Cybersecurity and Automation in Shipping*, SEATRADE MAR. NEWS (Feb. 21, 2022), https://www.seatrade-maritime.com/opinions-analysis/cybersecurity-and-automation-shipping [https://perma.cc/7L7C-FUKZ].

[214] *See generally* Annie Brett, *Secrets of the Deep: Defining Privacy Underwate*r, 84 MO. L. REV. 47 (2019) (examining privacy concerns and trade secret protections from underwater surveillance and arguing that given the widespread use of drones, privacy protections must be strengthened).

[215] The case of Global Fishing Watch, a "map [which] is the first open-access online platform for visualization and analysis of vessel-based human activity at sea," demonstrates the power of this transparency. GLOBAL FISHING WATCH, https://globalfishingwatch.org [https://perma.cc/8TSA-RQK9]. Being able to track fishing vessels globally in real time has important policy benefits but has also raised concerns for members of the fishing community about the privacy consequences of having their locations broadcast in near real-time to the world. *See id.*

[216] *See generally* James S. Carmichael, *At Sea with the Fourth Amendment*, 32 UNIV. MIAMI L. REV. 51 (1977) (presenting development of the law regarding searches at sea and how there is a trend towards applying strict scrutiny on searches based on consitutional grounds); Linda A. Newland, *Searches and Seizures at Sea: Trying to Balance Governmental Interests Against the Fourth Amendment*, 16 TUL. MAR. L.J. 319 (1992) (discussing Fourth Amendment implications of unreasonable searches and seizures of private vessel in international waters); Daniel L. Cullum, *The Fourth Amendment and Maritime Drug Searches: Is There a "Legitimate Expectation of Privacy" on Vessels at Sea?*, 1994 UNIV. CHI. LEGAL F. 367 (1994) (addressing Fourth Amendment standards as related to privacy interest in areas of a vessel); Megan Jaye Kight, *Constitutional. Barriers to Smooth Sailing: 14 U.S.C. § 89(a) and the Fourth Amendment*, 72 IND. L.J. 571 (1997) (examining the power vested in the Coast Guard and the Fourth Amendment in consitutional challenges addressed by the courts).

[217] This may be explained by current UMV regulatory efforts that are being driven by the U.S. Coast Guard and other bodies who historically benefit from weak privacy protections on the oceans.

operating in,[218] UMVs add an additional element of remote control. If operational centers are located in a different jurisdiction than the flag state, this may introduce additional options for the applicable jurisdiction of the vessel.[219]

Current discussions of UMV regulation fail to engage with these concerns, or with the additional environmental and workforce questions that increased autonomy in the oceans raises.[220] While widening the lens to include additional regulatory impacts may not help with the existing issues with slow movement by regulatory agencies, incorporating a more holistic understanding of potential UMV impacts is essential for effective regulation moving forward.

III. PRINCIPLES FOR REGULATING UMVS

Several areas of UMV regulation are already being well addressed, primarily in safety, as discussed above. However, major gaps exist. The current regulatory landscape raises fundamental questions about how UMVs can and should be regulated. Either under existing frameworks or through new regulatory initiatives, many of the legal aspects of UMV deployment must be more effectively addressed going forward.

UMVs are already active in the oceans and need better governance now, not decades in the future. The landscape of UMV use is varied, and regulation must be able to accommodate this variety. Regulators should recognize that in the next decade, the focus for UMVs will be more on development and likely less on deployment, with several countries establishing specific areas solely for testing autonomous vessels.[221] Regulatory regimes must consider how to regulate UMV testing and experimentation as well as final implementation.[222]

This Part provides an overview of the major legal challenges raised by UMVs outside of the core proposals to

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218 *Jurisdiction Over Vessels*, NOAA, https://www.gc.noaa.gov/gcil_jurisdiction.html [https://perma.cc/HM4T-RMWB].

219 *See* DNV GL USA, Inc., *supra* note 129 (noting that remote control centers "controlling a fleet of ships will most likely be in three different time zones . . . [and] will therefore be in different jurisdictions," which affords an opportunity to forge "a new international agreement" regarding jurisdiction).

220 The environmental and workforce impacts of UMVs and the existing governance gaps in these areas are discussed further in a different part of this article. *See infra* Part III.

221 Norway's designated test fjord is by far the most charismatic of these sites. *See Test Site for Autonomous Vessels*, KONGSBERG (Oct. 5, 2016), https://www.kongsberg.com/maritime/about-us/news-and-media/our-stories/test-site-for-autonomous-vessels/ [https://perma.cc/G8A9-DPAT].

222 NAT'L ACADS. SCI., ENG'G, & MED., *supra* note 9, at 4.

update COLREGs and other marine traffic schemes, identifies key governance gaps that should be addressed, and proposes principles for regulation of UMVs moving forward. These proposals are tailored specifically for US regulation, though the fundamental principles apply equally to other national and international proposals. It focuses on the US Coast Guard as the lead agency regulating UMVs but recognizes that other agencies may ultimately play ultimately play complementary roles in UMV regulation.

A. Regulation Should be Based on Type of UMV

The majority of UMVs in use today are relatively small, noncommercial vehicles that are very different than the autonomous surface ships that are taking up most regulatory attention.[223] It is critical that regulatory bodies not overlook regulation of early UMVs just because they are relatively small or low risk compared to large, complex MASS. It will likely be decades before fully autonomous cargo ships are in use, but a wide variety of other types of UMVs are already in routine use and growing exponentially. Regulators must recognize these UMVs when drafting and creating legislation.

International and national maritime laws apply to all vessels, regardless of their operator. In certain cases, these regulations can either be relaxed or tightened for specific types of actors, however the same basic principles apply across the board.[224] In looking at regulation of UMVs, putting UMVs into the broad vessel category in some cases would help achieve regulatory goals and in others would likely hinder effective outcomes. UMV regulation should take these differences into account, delineating between different types of UMVs rather than attempting to regulate the diverse landscape of UMVs as one monolith.

The regulation of aerial drones provides some insight here. It is insight that many in the maritime world are already familiar with, given that many marine entities were early adopters of Unmanned Aerial Systems (UAS).[225] Many of the issues facing UMVs have already been addressed with aerial

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[223] *See, e.g.*, *1977—Astounding Discoveries*, *supra* note 28.

[224] For instance, militaries routinely exempt themselves from COLREGs requirements. *See* Allen, *supra* note 16, at 510 (noting the Secretary of the Navy's has exempted several UMVs from requiring that they comply with COLREGs). Meanwhile, nations often impose stricter safety and inspection requirements on commercial vessels than recreational vessels.

[225] *See, e.g.*, NAT'L ACADS. SCI., ENG'G, & MED., *supra* note 9, at 45–52 (describing the Coast Guard's use of aerial drones).

systems, from debate over whether the FAA's aircraft definition includes small drones to complex technical safety discussions on how best to integrate new UAVs into existing airspace management frameworks. These provide an important starting point for discussions around UMV regulation.

Congress led early UAS regulation with the 2012 FAA Modernization and Reform Act.[226] This split aerial drones into three major categories: public, civil, and recreational.[227] FAA then further split drone regulation up by size, going through a rulemaking specifically for small UAS (under fifty-five pounds).[228] The small UAS rule provides an interesting template for small UMVs. The small UAS rule applies to both public and civil drones but provides an additional carve out that exempts purely recreational use from most of the requirements of the rule.[229] Small UAS operation is subject to certain limitations not only in the size of the drone, but also the speeds, altitude, and times at which they can be operated.[230] Operators must complete knowledge testing, obtain a remote pilot (drone) certification, and register any drones they use with the FAA.[231] Recreational users are exempt from remote pilot certification and other requirements of the small UAS rule if they comply with stricter operational requirements, including using drones only within line of sight and below four hundred feet above ground level.[232]

Additionally, and analogous to the maritime environment, these aerial drones have restricted operational zones: they must fly at or below four hundred feet above ground level (AGL) within controlled airspace (Class B, C, D, and E) only when they have prior authorization/notification to the FAA via their Low Altitude Authorization and Notification Capability system (LAANC).[233] Within uncontrolled airspace (Class G), they must simply fly at or below four hundred feet AGL.[234] This regulatory framework aims to reduce the likelihood of collisions between traditional aircraft and drones. Additionally, there is

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226 FAA Modernization and Reform Act of 2012, Pub. L. No. 112-95, §§ 331–36, 126 Stat. 73–77 (codified as amended at 49 U.S.C. §§ 44801–04).

227 *Id.*

228 *Id.* § 336.

229 14 C.F.R. § 107.1(b)(2) (2021).

230 §§ 107.29, 107.51 (2021).

231 §§ 107.13, 107.67.

232 49 U.S.C. § 44809.

233 FAA AIR TRAFFIC ORG., LOW ALTITUDE AUTHORIZATION AND NOTIFICATION CAPABILITY: USS PERFORMANCE RULES 11 (2022), https://www.faa.gov/sites/faa.gov/files/uas/programs_partnerships/data_exchange/laanc_for_industry/LAANC_USS_Performance_Rules.pdf [https://perma.cc/M4XH-8EM8].

234 *Recreational Flyers and Modeler Community-Based Organizations*, FAA, https://www.faa.gov/uas/recreational_fliers/ [https://perma.cc/5DMF-3ULQ].

an upcoming requirement for drones to broadcast their position, altitude, and velocity information via the remote ID network by 2023.[235]

This model, regulating by user type as well as size of the vehicle, is one that the Coast Guard should draw upon for UMV regulation. UMVs should be categorized based on relative risk posed based on the size, speed, and function of the vessels.[236] This conforms with existing regulation that imposes stricter requirements on certain types of vessels. Certain UMV types might indicate the need for education and licensure. Equally important to the size of the vessel is the location and how it is moving. The Coast Guard should look to have position, speed, and directional information broadcast so other UMVs, and traditional vessels, can avoid collisions. Moreover, there should be some "controlled areas" where UMV movement is presumptively barred without a risk mitigation plan and advanced Coast Guard approval.

Some argue that we should draw the line by considering whether UMVs are "capable of navigat[ion]" or actively propelled.[237] Others add to this the size and function of the UMVs, all of which serve to dictate the potential consequences of a collision.[238] UMVs over a certain size and capable of "transportation" are more likely to be considered vessels and fall under existing legal frameworks. These UMVs will need additional regulation beyond what is in place, but it is also essential that smaller UMVs that would not otherwise be considered vessels have some regulatory frameworks in place. Size categories then could be based around the interpretation of what is considered a vessel: UMVs that are large enough to be considered vessels would be subject to the full weight of existing international requirements in addition to UMV specific regulation. UMVs that are too small to be considered vessels and without major propulsion could be regulated akin to small UAS: subject to some training and operational limitations, but not subject to the full requirements of large UMVs like MASS.

Certain extremely low risk, recreational UMVs that are unlikely to fall under the UNCLOS or Coast Guard definition of a vessel should be subject to similar carve outs to those created for recreational aerial drone use. Small, tethered recreational

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[235] This will function in a similar way to existing marine AIS, requiring that basic information about drones be available to others for safety purposes. 14 C.F.R. § 89.110 (2021).

[236] SAILDRONE, Inc., *supra* note 139.

[237] Bork et al., *supra* note 33, at 323 n.73.

[238] *Id.* at 307–08.

ROVs, for instance, pose very little risk to other people or vessels. The regulatory history of drones reveals the importance of not underestimating the impacts of relatively small commercially available units. These were the first types of aerial drones widely available; the missteps in their regulation, and subsequent outcry, has characterized the entire regulatory approach to aerial drones going forward.[239] Creating avenues to ensure that small recreational UMV users comply with basic marine safety principles without having to meet onerous international standards is likely the best approach.

Creating clear legal distinctions between regulatory categories of UMVs is essential to ensure commercial predictability and spur continued investment in this type of technological development.[240] The desire for certainty in this sphere has led other agencies, primarily NOAA, to begin the process of developing their own Best Management Practices to oversee autonomous vessel deployment.[241] This reflects the already fragmented approach to autonomous system deployment.[242] While an understandable response to the lag between the rapid adoption of these new technologies and a regulatory scheme for them to operate in, different agencies creating different standards for UMV deployment will continue to complicate an already fragmented landscape. The Coast Guard should create a unified approach to UMV regulation that applies across sectors and agencies.

Consistency is essential not only for investment and innovation in this area, but to ensure that marine robotic technologies are employed to their full potential. NOAA, for instance, has had an ad hoc approach to UMV deployment that has been relatively successful, but it recognized the potential downsides of that approach and has recently centralized operations to create a unified approach to UMVs.[243]

B. Regulation Should Be Performance Based

Technology-specific regulation in the maritime sector currently impedes innovation and promotes regulatory inefficiency. The language dictating human manning

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[239] *See, e.g.*, Takahashi, *supra* note 4, at 113; Froomkin & Colangelo, *supra* note 4, at 48; *see generally* Smith, *supra* note 4 (discussing state legislative attempts to regulate police use of drones as enforcement tools).

[240] NOAA, *supra* note 137.

[241] *Id.*

[242] *See* NAT'L ACADS. SCI., ENG'G, & MED., *supra* note 9, at 70–80 (discussing different agencies varying approaches to autonomous system deployment and governance).

[243] *Id.* at 80.

requirements in UNCLOS and COLREGs, for example, prevents regulation from applying to new autonomous technologies. Performance-based standards can provide the flexibility needed for regulatory structures to keep pace with rapidly changing technological developments.

Current Coast Guard regulation is primarily technology based, using language that writes specific technologies directly into regulation. As one example, the Howard Coble Act of 2014 requires the Coast Guard to continue to maintain Loran-C towers.[244] Once the cornerstone of navigational technology, Loran was decommissioned in 2010 after the cheaper, more accurate GPS systems became universally used for navigation.[245] Despite the fact that maintaining obsolete Loran towers nationally costs the Coast Guard millions of dollars a year, they are unable to stop doing so because the technology-based regulation delivered by Congress requires specifically that they continue to maintain Loran-C towers.[246]

The Coast Guard recognizes the inefficiencies of the current system, noting that they "must promote a shift from a rules-based regulatory structure in the maritime environment to a risk and principles-based regulatory structure to keep pace with emerging issues and technology advancements, such as electronic and autonomous systems."[247] Performance goals (e.g. maintaining navigation infrastructure) allow the details of how goals are met to be determined by agencies, or regulated entities, and altered relatively easily as technologies change. This increases flexibility and opportunity for innovation while also ensuring that baseline standards are met.[248] The IMO has recently transitioned to using "goal-based standards" as regulatory mechanisms.[249] Industry players are also supportive of the shift to goal-based regulation.[250]

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[244] *See* 14 U.S.C. § 914.

[245] Mike M. Ahlers, *World War II-Era Navigation System Shut Down*, CNN (Feb. 8, 2010, 9:25 PM), http://www.cnn.com/2010/TECH/02/08/loran.navigation.shutdown/index.html [https://perma.cc/98FP-ZKV9].

[246] *Id.* By contrast, a performance-based regulation in this case might require the Coast Guard to continue to maintain essential navigation infrastructure or something similar without dictating a specific technology requirement.

[247] U.S. DEP'T OF DEF., UNITED STATES COAST GUARD MARITIME COMMERCE STRATEGIC OUTLOOK 1, 29 (2018).

[248] *See* Ringbom, *supra* note 6, at 164.

[249] *Id.*

[250] *See, e.g.*, DNV GL USA, Inc., *supra* note 129; Gard AS P&I Club, *supra* note 191 ("Coast Guard should consider that national regulation of autonomous ships should be in the form of goal-based framework regulation accomplished through the use of industry-specific technical standards and codes of conduct for autonomous ships, some of which are already available as guideposts, rather than through prescriptive regulation.") (internal citation omitted).

This principles-based approach requires a full assessment of potential risk factors before regulatory goals are established. Many of the risk factors autonomous ships will experience have been identified, aggregated, and discussed.[251] One such metasummary of these efforts illustrated twenty-three human-related factors, twelve ship related factors, eight environmental factors, and twelve technological factors.[252] What is missing are identifiable principles or quantifiable benchmarks to compare with. One approach might be to have an "acceptable rate" of risk, another might be to have an equivalent amount of risk, and, yet another might be to require a lower risk profile than currently exists with manned maritime vessels.

The most prudent approach would be that the adoption of revolutionary technology, like autonomous vessels, should not occur unless there is a concomitant reduction in errors and accidents. Safety should be the primary factor, and all goal-based regulations should keep this as the primary focus.[253] Any ancillary benefits for reduced costs, operational advantages, and environmental benefits are important, but secondary concerns. This is especially true when the technology has the potential to greatly disrupt the shipping industry and while there are likely numerous potential benefits there will also be numerous detriments—including job losses.[254] Balancing these benefits and risks is particularly difficult in cases like this, when many of the risks from this emerging technology cannot be fully known.[255] Intelligent risk management should consider the operating context and autonomy level employed at the time.[256] For instance, if a vessel operating fully autonomously has a critical fault with a particular subsystem, it could revert to remote-controlled operation and return home for repairs. In such cases the regulatory framework should be flexible enough to accommodate multiple levels of operation.

Establishing goal-based regulation allows for flexibility and may be able to draw on the important role of classification

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[251] *See generally* Cunlong Fan et al., *A Framework to Identify Factors Influencing Navigational Risk for Maritime Autonomous Surface Ships*, 202 OCEAN ENG'G 1 (2020) (defining human-related, ship-related, environment-related, and technology-related factors that influence autonomous ships).

[252] *Id.*

[253] *See* Floris Goerlandt, *Maritime Autonomous Surface Ships from a Risk Governance Perspective: Interpretation and Implications*, 128 SAFETY SCI. 1, 1 (2020).

[254] *See infra* Section III.E.

[255] Ingrid Bouwer Utne et al., Risk Management of Autonomous Marine Systems and Operations 1, 5 (Sept. 25, 2017) (unpublished manuscript), https://asmedigitalcollection.asme.org/OMAE/proceedings-abstract/OMAE2017/57663/V03BT02A020/280986.

[256] *Id.* at 3, .

societies in maritime vessel development.[257] The Coast Guard and other regulatory bodies can set performance-based regulatory goals that classification societies detail how to achieve through more technical standards.[258] Classification societies and other private actors are able to move more rapidly and adapt their standards over time efficiently in response to emerging technologies and new regulatory concerns. The IMO's International Safety Management Code is a potential example of regulatory goals framed at the right level of specificity to allow flexibility and innovation in the face of new developments.[259]

Approaches that focus on developing performance standards to address regulatory goals and desired functions of new technology, not specific technologies themselves, is an approach being adopted throughout the landscape of emerging technology regulation. Some have argued that the Coast Guard and other governing bodies should outsource the development of these standards to third parties to try to improve the current slow pace of regulation.[260]

C. *Regulation Should Address Environmental Concerns*

UMVs raise new environmental questions. Marine robots by their nature will break down at sea.[261] Larger MASS will likely be worth repairing and recovering but smaller vessels are currently left to drift and eventually break up.[262] This is cheaper and more efficient for operators than expending the resources needed to recover UMVs at sea. The Coast Guard, for instance, is prioritizing UMVs that are "[a]ffordable enough to be launched on one-way missions" and never retrieved.[263] This may increase operational efficiency for the Coast Guard, but the environmental impacts of abandoning UMVs at sea must be addressed. Similarly, many of the scientific floats deployed in the world's oceans are not designed to return to shore.[264] Instead, once they reach the end of their lifespans they continue drifting until they either wash up on shore or sink.[265] Addressing end of life issues is essential for UMV regulation going forward.

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[257] For discussion of the potential role of classification societies in governing UMVs, see *supra* Part II.

[258] Utne et al., *supra* note 255, at 1–2.

[259] *Id.*

[260] Patrick Parsons, Am. Waterways Operators, *supra* note 203, at 3.

[261] *See* Glenn Wright, GMATEK, *supra* note 63.

[262] *See, e.g.*, *Argo's Status*, *supra* note 34.

[263] NAT'L ACADS. SCI., ENG'G, & MED., *supra* note 9, at 36.

[264] *See, e.g.*, *Argo's Status*, *supra* note 34.

[265] *Id.*

UNCLOS and the International Convention for the Prevention of Pollution from Ships (MARPOL) have provisions prohibiting marine dumping. In particular, dumping plastics is illegal throughout the oceans.[266] Arguably, deploying UMVs, all of which have significant plastic components, with the intent that these UMVs never be retrieved, is already in violation of MARPOL's provisions. It is essential that these measures be more thoroughly considered when it comes to UMV disposal. Regulators should weigh the importance of preventing marine litter with the reality that many small UMVs may malfunction and make retrieval infeasible.

Beyond vessel abandonment, some agencies worry that the rise of automation and UMV use generally will lead to increased maritime accidents, oil spills, and other types of environmental harm.[267] Some early work has been done to draw on lessons from human failures in aviation to better inform marine uptake of autonomous technologies.[268] Policymakers and technology developers must build upon these efforts to ensure that technology deployment is as safe as possible. On the other hand, oil spill response is potentially a prime use case for UMVs. The environmental impacts of marine robots have not been effectively evaluated. Future regulation must consider how UMVs fit into existing environmental and maritime dumping regulation.

Salvors, for instance, play an important role in decreasing the likelihood of vessels left to drift at sea by helping to save boats that have been in major accidents in return for a portion of the vessel's value if and when their efforts are successful. Larger UMVs may be attractive salvage targets if they are in accidents due to their high values.[269] The Coast Guard should clarify whether existing salvage regulations will also apply to UMVs.[270]

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[266] International Convention for the Prevention of Pollution from Ships (MARPOL) Annex V, *adopted* Nov. 2, 1973, 1340 U.N.T.S. 263 [hereinafter MARPOL].

[267] Wash. State Dep't of Ecology Spills Prevention, Preparedness, & Response Program, Comment Letter on Request for Information on Integration of Automated and Autonomous Commercial Vessels and Vessel Technologies into the Maritime Transportation System (Oct. 13, 2020), https://www.regulations.gov/comment/USCG-2019-0698-0037 ("With even less people to perform maintenance, respond to incidents, and provide assistance to maintaining effective watches, the risks of accidents like oil spills increases.").

[268] Felski & Zwolak, *supra* note 59, at 9.

[269] *See generally* RONALD O'ROURKE, CONG. RSCH. SERV., R45757, NAVY LARGE UNMANNED SURFACE UNDERSEA VEHICLES: BACKGROUND AND ISSUES FOR CONGRESS (2002), https://sgp.fas.org/crs/weapons/R45757.pdf (discussing the cost of Naval UMVs).

[270] Gard AS P&I Club, *supra* note 191.

D. Regulations Should Consider New Actors and Uses of UMVs

In general, the discussion around UMV regulation is focused on large commercial vessels transitioning their existing operations to use more autonomous technologies.[271] This leaves out important categories of UMV operators, including government entities, scientists, and other private individuals. It also ignores classes of UMVs that are undertaking new types of projects that were previously infeasible for manned ships. New forms of resource extraction and other types of operation are possible with the advent of UMVs. Because these activities are only newly possible, existing regulations were not crafted to govern them leading to large and potentially harmful governance gaps.

1. Deep-Sea Mining

Significant discussion around these new uses is in relation to deep-sea mining. Deep-sea mining is only practically and economically feasible with UMVs, and UMVs are catalyzing new capabilities for resource extraction.[272] While enacted before UMVs were developed, UNCLOS does create a regime to govern allocation of seabed resources in areas beyond national jurisdiction.[273] This framework was created when UNCLOS was drafted in the 1980s and has yet to be finalized, though the International Seabed Authority has been attempting to develop concrete rules governing seabed mining for decades.

In 2021, Nauru officially spurred acceleration of this process by requiring that the International Seabed Authority issue final rules to govern deep-sea mining by 2023.[274] This acceleration is in Nauru's economic interest, as this small island state relies on the income from potential deep-sea mining, but many worry that not enough is known scientifically about deep-sea ecosystems to ensure mining is carried out in ways that

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[271] *See supra* Section II.A.2. As evidenced by the IMO's regulatory scoping focused on large, autonomous commercial surface vessels, and the US Coast Guard's RFI that deals only with commercial vessels.

[272] *See generally* Jeff A. Ardron et al., *Incorporating Transparency into the Governance of Deep-Seabed Mining in the Area Beyond National Jurisdiction*, 89 MAR. POL'Y 58 (2018) (explaining how good practices in transparency for deep-seabed mining leads to many better outcomes).

[273] UNCLOS, *supra* note 143, art. 142.

[274] Kate Lyons, *Deep-Sea Mining Could Start in Two Years After Pacific Nation of Nauru Gives UN Ultimatum*, GUARDIAN (June 30, 2021, 2:04 AM) https://www.theguardian.com/world/2021/jun/30/deep-sea-mining-could-start-in-two-years-after-pacific-nation-of-nauru-gives-un-ultimatum [https://perma.cc/XZP9-ETGS].

minimize ecosystem damage.[275] While scientists and conservation groups hoped that limits in technological capacity would slow the development of deep-sea mining, robust autonomous technologies have made deep-sea mining a practical possibility now.

2. Law Enforcement

Outside of deep-sea mining, law enforcement agencies, primarily the Coast Guard and other nations' equivalents, are already turning to the promise of UMVs in many of their operations. In the United States, it is critical that meaningful constitutional limits are put in place to protect individual rights at sea. Conversation around aerial drones is heavily centered around what limits the Fourth Amendment places on their use.[276] While the ocean presents a very different case than the airspace above people's homes, the Fourth Amendment still applies. Many argue that Fourth Amendment limits are already unconstitutional when applied to the ocean.[277] Adding UMVs to this mix has the potential to exacerbate this issue. UMVs are already being used for military surveillance and law enforcement use is increasing as the Coast Guard and others turn to UMVs.[278] Regulation of UMVs should help to define clearer lines that protect Fourth Amendment rights for those at sea. Surveillance on the private areas of a ship, for instance, should be limited, if possible, to protect the privacy of crew living quarters.

3. Environmental Protection

In other areas, there is not even a rudimentary framework for governing the new types of operations made possible by UMVs. In the environment, for instance, there has been a dramatic rise in private sector actors developing robotic technologies aimed to actively intervene in marine ecosystems. From projects to remove plastics from the ocean, to ocean iron

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[275] Eric Lipton, Secret Data, Tiny Islands and a Quest for Treasure on the Ocean Floor, N.Y. TIMES (Aug. 29, 2022), https://www.nytimes.com/2022/08/29/world/deep-sea-mining.html [https://perma.cc/QN3D-LNQP].

[276] *See, e.g.*, MCNEAL, *supra* note 4, at 5; Kaminski, *supra* note 4, at 59–60, 71; Takahashi, *supra* note 4, at 80, 93; John Pavletic, *The Fourth Amendment in the Age of Persistent Aerial Surveillance*, 108 J. CRIM. L. & CRIMINOLOGY 171, 177, 182, 195–96 (2018).

[277] *See, e.g.*, Cullum, *supra* note 216, at 368, 380; Newland, *supra* note 216, at 325–26; Carmichael, *supra* note 216, at 76–77, 80; Kight, *supra* note 216, at 575–80, 585; Howard S. Marks, *The Fourth Amendment: Rusting on the High Seas?*, 34 MERCER L. REV. 1537, 1540–41, 1545, 1548, 1552–55, 1560 (1983).

[278] *See generally* NAT'L ACADS. SCI., ENG'G, & MED., *supra* note 9 (discussing Coast Guard's use of unmanned systems for its missions).

fertilization efforts intended to sequester carbon dioxide, nongovernmental actors are using UMVs to reshape the landscape of environmental intervention.[279] These new technology projects are seen by many as a critical hope in human efforts to mitigate increasing environmental degradation.[280] The potential economic and ecosystem benefits of these interventions are high, ranging from combatting climate change to supplying needed protein for a growing global population.[281] The potential costs, however, may be even higher. Historical human attempts to mitigate damage and improve the environment have often instead caused irreparable harm.

Ocean ecosystems are facing unprecedented threats, from climate change to coral bleaching to illegal fishing.[282] The extent of these impacts has galvanized global support and catalyzed a new wave of ocean technologies that seek to mitigate environmental damage and restore, or improve, ocean conditions. Nowhere has enthusiasm been greater than around proposed solutions to ocean plastic pollution, many in the form of large-scale projects. The Ocean Cleanup, for instance, launched a giant boom system in 2018 to great fanfare with the goal of sweeping up plastics in the ocean.[283]

Decreasing costs and increasing capabilities of UMVs are enabling these projects, which may have significant negative impacts on marine ecosystems. The Ocean Cleanup has relatively limited consequences, ranging from small scale introduction of plastics into the ocean (when the prototype broke) and local disruption of ecosystems (assuming the system is never deployed globally). Other technology interventions may not be so mild, from geoengineering options that aim to alter oceanic conditions to mitigate climate change to genetic recovery

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[279] *See* Raphael Sagarin et al., *Iron Fertilization in the Ocean for Climate Mitigation: Legal, Economic, and Environmental Challenges* 1, 2 (Nicholas Inst. for Env't Pol'y Sols., Duke Univ., Working Paper No. NI WP 07-07, 2007), https://nicholasinstitute.duke.edu/sites/default/files/publications/iron-fertilization-in-the-ocean-for-climate-mitigation-legal-economic-and-environmental-challenges-paper.pdf [https://perma.cc/787R-72LU].

[280] OECD, RETHINKING INNOVATION FOR A SUSTAINABLE OCEAN ECONOMY 3 (2019).

[281] *See, e.g.*, U. Rashid Sumaila et al., *Fishing for the Future: An Overview of Challenges and Opportunities*, 69 MAR. POL'Y 173, 173–74 (2016); Albert C. Lin, *The Missing Pieces of Geoengineering Research Governance*, 100 MINN. L. REV. 2509, 2525, 2558, 2567, 2575 (2016).

[282] LAURETTA BURKE ET AL., WORLD RES. INST., REEFS AT RISK REVISITED V (2011); Dana D. Miller & U. Rashid Sumaila, *IUU Fishing and Impact on the Seafood Industry*, *in* SEAFOOD AUTHENTICITY AND TRACEABILITY 92–93 (2016).

[283] *System 001–First Ocean Cleanup System*, OCEAN CLEANUP, https://theoceancleanup.com/milestones/system001/ [https://perma.cc/2DCB-XPVE].

projects relying on UMVs to collect and potentially move threatened species to new ecosystems.

These projects currently operate in a grey area under most US and international laws and consequently have very little regulatory oversight. The Ocean Cleanup, for instance, was self-labelled a research mission and operates under the Law of the Sea's Freedom of Scientific Research.[284] A close reading of UNCLOS shows that this is a misinterpretation of what is considered scientific research.[285] Similar issues are raised by other types of marine technology projects.[286]

Private sector robotic technology interventions are a major shift from historical models of ocean governance. This shift manifests both as to the parties driving these interventions and in the aims of these projects. Such large-scale interventions were once primarily the province of governments. While wealthy philanthropists and others have made significant contributions to land-based conservation efforts, historically private efforts to conserve marine ecosystems have been limited in scope.[287] The cost, expertise, and motivation needed to make significant changes to ocean conditions precluded private actors from engaging in large-scale environmental alteration.[288] While corporate action has been an important feature of ocean governance,[289] the rise of large-scale direct action by private parties to remediate and improve ocean conditions is relatively new.[290]

The scope and goals of technology interventions in the ocean are also pushing into new territory for environmental management. The majority of federal environmental regulation has been based around conservation of existing ecosystems; for instance, through pollution control or environmental species protection.[291] Some environmental laws deal with remediation efforts, most notably the Comprehensive Environmental Response, Compensation and Liability Act, but these are limited

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[284] *See* Rozemarijn Roland Holst, *The Netherlands: The 2018 Agreement between The Ocean Cleanup and the Netherlands,* 34 INT'L J. MARINE & COASTAL L. 351, 353 (2019).

[285] *Id.* at 355.

[286] *See generally* Annie Brett, *Environmental Silver Bullets*, ECOLOGY L. Q. (forthcoming 2022).

[287] *Id.*

[288] *Id.*

[289] *See* Michael P. Vandenbergh, *Private Environmental Governance*, 99 CORNELL L. REV. 129, 135–36, 154, 156 (2013).

[290] *See id.* at 133.

[291] *See e.g.* Clean Water Act, 33 U.S.C. §§ 1251–1387 (regulating water pollution); Endangered Species Act, 16 U.S.C. §§ 1531–1544 (regulating endangered species).

in scope.[292] NEPA's procedural safeguards apply only to major federal actions.[293] While this also includes private projects that require federal permits, many environmental technology projects operate in areas where no permits are needed and are thus outside of NEPA's reach.[294] Large-scale efforts to restore or improve marine ecosystem conditions through the use of new technology tools are left free to operate with little to no regulatory oversight.[295] The impacts of these projects, both individually and when viewed cumulatively, demand a more comprehensive governance approach.

UMV regulation should consider the many different ways that UMVs are being used and attempt to fill regulatory gaps by creating mechanisms to hold UMV operators accountable for environmental and other damage that they may cause. UMV regulation should additionally impose light environmental impact assessment requirements for projects actively aiming to alter ocean ecosystems.

E. UMV Regulation Should Draw on Regulation of Parallel Robotic Advancements

Policymakers should look outside of marine contexts to other areas of emerging technology that can provide key insights into what an effective regulatory landscape for UMVs should look like. Understanding human-machine interactions, for example, will be essential to developing UMV systems that are as safe and efficient as possible. Current evidence suggests that the relatively low levels of automation already present on vessels with human crew, for instance advanced autopilot systems, are confusing to mariners.[296] This confusion is already a major reason for vessel collisions, a trend that will only continue as automation onboard vessels becomes more advanced.[297]

Likewise, significant discussions are occurring in other fields about the future of work. In general, the cultural and workforce impacts of increased use of UMVs have been recognized but only at a cursory level.[298] Union representatives,

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292 S*ee* *Superfund: CERCLA Overview*, U.S. ENV'T PROT. AGENCY, https://www.epa.gov/superfund/superfund-cercla-overview [https://perma.cc/LWM5-HSPK] (providing an overview of the environmental law's remediation efforts).

293 *See* 42 U.S.C. §§ 4321–4347; 40 C.F.R. § 1508.18 (2022).

294 Brett, *supra* note 286.

295 *Id.*

296 Felski & Zwolak, *supra* note 59, at 5, 9.

297 *Id.* at 9.

298 *See, e.g.*, Hadi Ghaderi, *Wider Implications of Autonomous Vessels for the Maritime Industry: Mapping the Unprecedented Challenges*, *in* 5 ADVANCES IN

in particular, have criticized current regulatory efforts for their lack of attention to key questions around the effect of UMVs on the merchant mariners.[299] This attention is particularly important now, as UMV use is rising in the face of a rapidly declining merchant marine workforce. Despite protectionist laws designed to ensure the United States retains a sufficiently trained merchant marine in the event of war, the US merchant marine is dwindling rapidly.[300]

The advent of autonomous ships will likely decrease the number of working merchant mariners. How much of a reduction is currently open to debate.[301] Moreover, the character of maritime jobs will change significantly, with support personnel on shore and potentially onboard larger ships as they transition to full automation.[302] At the same time, there will be an increase in jobs developing and overseeing UMVs.[303]

Increased UMV use may fundamentally alter the relationship between mariners and the ocean. Today's Coast Guard and other merchant mariners spend lengthy periods of time at sea, becoming attuned to seafaring and marine conditions.[304] The level of knowledge gained through experience on the ocean is legally enshrined in COLREGs, several rules of which refer specifically to the "ordinary practice of seamen" as standards of conduct.[305]

TRANSPORT POLICY AND PLANNING 263, 285–86 (Dimitris Milakis, Nikolas Thomopoulos, & Bert van Wee eds., 2020) (recommending further study is needed on workforce issues).

[299] Transp. Trades Dep't, AFL-CIO, *supra* note 201 (arguing that the USCG's 2020 RFI was "structured and written in a way to generate comments that extol the values of automation and supposed cost savings while giving short shrift to critical questions of safety and impacts to the maritime workforce").

[300] *Id.*

[301] *See* Allen, *supra* note 177 ("[S]ome shrinkage in the number of seagoing billets will be lost. A few shoreside 'operator' positions will open but, assuming such shoreside operators will control more than one vessel at a time and perhaps for longer 'watches' than seafarers typically stand, the trade-off will be less than 1:1. In the area of unintended consequences, if regulatory manning and watchstanding requirements are relaxed to accommodate autonomous vessels, that may spill over and lead to further moves to reduce manning on manned vessels."); *Increase in Autonomous Ships Won't Mean a Shortage of Jobs for Seafarers*, NAUTILUS INT'L (Dec. 2, 2018), https://www.nautilusint.org/en/news-insight/telegraph/increase-in-autonomous-ships-wont-mean-a-shortage-of-jobs-for-seafarers/ [https://perma.cc/L789-JTMB] ("[E]ven if as many as 3,000 autonomous or semi-autonomous ships are introduced by 2025, there will be 'no shortage of jobs for seafarers in the foreseeable future.'") (quoting HSBA HAMBURG SCH. OF BUS. ADMIN., SEAFARERS AND DIGITAL DISRUPTION 26 (2018), https://www.ics-shipping.org/wp-content/uploads/2020/08/ics-study-on-seafarers-and-digital-disruption-min.pdf [https://perma.cc/GU8V-X2H5]).

[302] *See, e.g.*, Glenn Wright, GMATEK Inc., *supra* note 63.

[303] *See, e.g.*, NAT'L ACADS. SCI., ENG'G, & MED., *supra* note 9, at 95 (discussing career paths in UMVs).

[304] *See, e.g.*, Glenn Wright, GMATEK Inc., *supra* note 63.

[305] *See, e.g.*, COLREGS, *supra* note 133, at r. 2.

Shore-based operators will have a very different understanding of ocean conditions. While many still argue the importance of UMV operators being trained in the same ways as mariners, there may still be a gap in how shore-based crew understand and interact with changing ocean conditions.[306] Understanding and adapting to changing ocean conditions is essential to minimize damage to vessels, and something that autonomous programming may be relatively bad at when compared to trained humans.[307]

The impacts of marine automation will likely also have impacts outside the marine industry. For instance, early pilots in Europe intend to replace larger ships with smaller, electric powered ones servicing smaller ports.[308] These ships will reduce the use of trucks on the road transporting goods between large port facilities and outlying areas.[309]

Some other cultural norms of seafaring will also be at risk with the move to UMVs. For instance, one of the most fundamental duties of mariners is that of helping vessels in distress.[310] Whether UMVs should be programmed to respond to distress calls, and, if so, how they can provide assistance, will be just one of the important cultural questions around UMV implementation to answer.[311]

F. UMVs Should Be Registered

Requiring that vessels globally register with national and international authorities is already an uphill battle.[312] However, it is an essential component of ensuring the effective regulation of the wide array of UMVs on the ocean. Currently vessel registration requirements are limited in many areas to certain sizes and types of commercial vessels. In the United States, recreational motorized vessels must be registered with state authorities, but these regulations often do not apply to UMVs.[313]

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[306] *See* James A. Watson, Am. Bureau of Shipping, *supra* note 71.

[307] *Id.*

[308] Radio Tech. Comm'n for Mar. Servs., *supra* note 202.

[309] *See id.*

[310] In some cases, this duty has been codified as a legal obligation.

[311] *See* Ed. Wendlandt, Radio Tech. Comm'n for Mar. Servs., *supra* note 202 (discussing the communications issues raised with autonomous vessel response to distress calls).

[312] *See* ENV'T JUST. FOUND., *supra* note 161, at 24.

[313] Each state regulates vessel registration slightly differently. *See, e.g.*, FLA. STAT. §§ 328.40–.80 (West, Westlaw current with laws, joint and concurrent resolutions and memorials through July 1, 2022, in effect from the 2022 2d Reg. Sess.) (requiring registration of recreational vessels in Florida and detailing the types of vessels subject to registration).

The upshot is that not only are there no registration mechanisms that allow for centralized assessment of UMV use, but also that UMVs are essentially exempted from most safety regulations required of registered vessels. The Coast Guard should create mechanisms, either building on existing state level vessel registration laws, or building on the Coast Guard's federal Documentation process, to require UMVs to register.

This process can build on the registration mechanisms created by the FAA requires for certain types of aerial drones. The registration scheme begins with a premise that all drones need to be registered, as they are part of the aviation landscape and can interfere with the safe operation of the skies (the FAA's mission is to protect those skies). The only blanket exception is if the drone is being used for recreational purposes and is under 0.55 pounds.[314] The purpose limitation is a critical factor for the FAA. If that same 0.55-pound drone was being used for a commercial purpose—say aerial mapping for a real estate company, thermal imaging for an engineering contractor, or your professional photographer taking pictures at your wedding—then the drone would have to be registered. Similarly, any drone weighing over 0.55 pounds and being used for recreational purposes still needs to be registered with the FAA. Here, the registration number connects the drone operator to the physical drone, which seems partly to allow traceability in case of accidents.

The FAA makes the process rather streamlined but attaches significant civil and criminal penalties if drone users do not comply with its regulations. For instance, failing to register a drone can incur a regulatory fine of up to $27,500, and the criminal penalties can be up to $250,000 and three years in prison.[315] One such unlucky Philadelphia, PA drone operator got stuck with a $182,000 fine from the FAA.[316]

Coast Guard regulations should follow these lines, providing mechanisms that require time-limited registration for certain classes of UMVs. Smaller UMVs, similar to smaller recreational drones, can have relatively little regulatory oversight, while larger UMVs may have more intensive requirements including risk-management analysis and other safety requirements.

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[314] *How to Register Your Drone*, FAA, U.S. DEP'T OF TRANSP. (June 3, 2022), https://www.faa.gov/uas/getting_started/register_drone/ [https://perma.cc/4D82-PK5V].

[315] *Id.*

[316] Jonathan Rupprecht, *FAA Slaps Drone Pilot with $182,000 Proposed Fine*, FORBES (Dec. 17, 2020, 9:30 AM), https://www.forbes.com/sites/jonathanrupprecht/2020/12/17/drone-pilot-received-182000-proposed-fine/?sh=11b6296e2fe0 [https://perma.cc/86ND-9ZAJ].

CONCLUSION

UMVs are dramatically expanding what humans can accomplish on the oceans.[317] However, investment and development in the UMV sector is undermined by regulatory uncertainty. Numerous UMVs are already in use around the world, operating in regulatory gray areas as operators await clarity from national and international regulatory bodies.[318] Stability for environmental, safety, workforce, surveillance, and other critical maritime areas is dependent on updating global regulation to include autonomous vessels.

Current efforts are beginning to address some of these challenges but a more comprehensive approach to UMV regulation is needed, not just to ensure that navigation and safety goals are met, but that understands the diverse impacts that UMVs may have on the oceans. Considering the full landscape of UMV uses and consequences highlights key areas where modifying existing regulations will likely not be enough to effectively govern UMV use. New regulatory frameworks, spearheaded by national governments in lieu of formal and timely action by the IMO, need to take into account new uses of UMVs and plan for environmental, workforce, and surveillance impacts. Private governance mechanisms, through ship classification societies as well as ISO standards, can help to quickly solidify norms around UMV operation. These formal and informal governance mechanisms should look outside of the maritime world to understand key principles for regulating emerging technologies more generally as well as how other analogous use cases, like that of aerial drones, may provide a model for UMV regulation. UMVs are already revolutionizing ocean operations. Regulation must catch up.

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[317] *See supra* Part I.
[318] *Id.*