The Role of Uncrewed Systems in Addressing Climate Challenges

Figure 1: Soldier at Schofield Barracks, Hawaii using Tactical Handheld Automated Navigational Mapping and Observation System (THANOS). February 4, 2021. Photo by Staff Sgt. Thomas Calvert.

By: Marina Lesse, Kristen Fletcher, and Theresa Milio
Naval Postgraduate School
Energy Academic Group / Climate & Security Network

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Overview

As the world grapples with myriad climate change impacts, states are exploring and calling for a variety of actions to address the increasing challenges. Some states have pledged to reduce harmful greenhouse gas emissions while advancing science and monitoring to better understand existing and future climate change. The U.S. has several Executive Orders that aim to reach a government-wide Net-Zero emissions goal by 2050 and call for better scientific understanding and resulting adaptation.[1] Uncrewed systems (UxS) have the potential to assist scientists, policy-makers and responders addressing these challenges.[2] These systems not only have the potential for lowering the governments overall fuel use, but also can provide a better understanding and increase data collection of the changing climate and environment in which the systems operate. This paper provides an analysis of the intersection of UxS and climate change to provide a foundation for understanding the role of UxS in addressing climate change impacts and other challenges.

Part I

In Part I, this report provides an analysis of the intersection of UxS and climate change to provide a foundation for the use of these systems in climate mitigation and adaptation and how UxS (whether fossil fuel-based or electrified) fit within the current U.S. net-zero emissions goals. When relevant, the report includes key examples of the use of UxS for these efforts, showing progress made toward technologically advanced UxS. Part I concludes with recommendations for policies that can solidify and strengthen the role of UxS in climate change actions.

Environmental Monitoring

The usage of uncrewed systems is increasing in all sectors including private, commercial, government. While the military has been studying the utility of uncrewed aerial assets since World War 1, the applications of UxS operating in all domains have increased. The monitoring and gathering of data relevant to climate change through the usage of UxS is also increasing.[3] These systems provide accessibility to environments and areas that were previously unreachable through traditional means, at a comparably less expensive cost than alternative monitoring

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[1] Exec. Order No. 14057, (2021), https://www.whitehouse.gov/briefing-room/presidential-actions/2021/12/08/executive-order-on-catalyzing-clean-energy-industries-and-jobs-through-federal-sustainability/.

[2] In this report, authors refer to uncrewed systems or UxS as the generic term for systems used in air, on land, and in water that are robotic and/or autonomous.

[3] For an example, see National Oceanic and Atmospheric Administration, NOAA Science Report features new data-gathering drones, advances in wind, weather and water forecasts, March 29, 2023, https://research.noaa.gov/2023/03/29/noaa-report-highlights-2022-climate-weather-ocean-research-advances/.

systems.[4] The increase of environmental data being collected also helps in understanding how the environment is affected by climate change, allowing for more accurate predictions of what may happen in the future.

For example, while weather balloons have been consistently used for meteorological observances, the stand-alone tool is typically not able to perform any maneuverability, nor be reused or even recovered. To increase the range and accessibility of data, researchers and developers pair platforms together. Some weather balloons now launch small Unmanned Aerial Systems (sUAS) that collect high resolution data, increasing the resolution of weather modeling.[5] Other applications of small drones include forest monitoring, agriculture, and waterway observations. Unmanned Aerial Vehicles (UAVs) can be utilized in monitoring the regeneration of forests, collecting important data, especially in the face of droughts caused by climate change.

Some drones produce no operational carbon footprint which contributes to climate change mitigation efforts. The Saildrone systems, which are currently in use by the U.S. Navy, utilize both ocean and wind currents as well as solar energy to navigate and operate in the ocean. These Uncrewed Surface Vehicles (USVs) can carry important sensors used to collect ocean data. Further mitigating against climate change, these vehicles have been demonstrated to conduct important data collection and infrastructure security for offshore wind farms, a renewable energy source important in transitioning away from fossil fuels [Figure 2]. The USVs have the capability of staying on mission between six to 12 months at a time, further boasting its energy and operational efficiency.[6]

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[4] Salvatore Manfreda, Matthew McCabe, "On the Use of Unmanned Aerial Systems for Environmental Monitoring," *Remote Sensing* 10(4), (April 2018): 641, https://www.mdpi.com/2072-4292/10/4/641.

[5] Travis Schuyler, S.M. Iman Gohari, "Using a Balloon-launched Unmanned Glider to Validate Real-Time WRF Modeling," *Sensors* 19(8), (April 2019): 1914, https://www.mdpi.com/1424-8220/19/8/1914.

[6] "Ocean Drones with Zero Operational Carbon Footprint Helping to Mitigate Climate Change," Saildrone, August 25, 2021, https://www.saildrone.com/media-room/press-releases/ocean-drones-with-zero-operational-carbon-footprint-helping-to-mitigate-climate-change.

Figure 2: Saildrone operating in an offshore wind farm

Systems like these are important not only in their low to no greenhouse gas (GHG) emissions during operations, but also to continue to assess the ocean through important data collection. Increases in the uncrewed ocean platforms will help researchers understand the ocean environment, an indispensable and interconnected system that is important in the critical parameters on Earth such as regulating temperature and the long-term sustainability of the planet.[7] The Saildrone units have studied the diurnal variability of temperatures and surface temperature of the water in high latitudes. The drones were able to enter an environment that is difficult to study utilizing conventional methods such as icebreakers or satellite remote sensing. The study contributed results indicating there are significant warming events occurring in the Arctic at much higher rates than anywhere else on the planet.[8]

<u>Role of UxS in Climate Change Mitigation and Adaptation</u>

Climate scientists have concluded that climate change is caused by anthropogenic activities, especially the burning of GHGs which have caused global warming to increase by an

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[7] Larry Mayer, "Uncrewed Surface Systems Facilitating a New Era of Global Ocean Exploration," *The International Hydrographic Review* Volume 29, (May 2023): pages 42-55, https://ihr.iho.int/articles/uncrewed-surface-systems-facilitating-a-new-era-of-global-ocean-exploration/.
[8] Chong Jia and Peter Minnett, "Significant Diurnal Warming Events Observed by Saildrone at High Latitudes," *Journal of Geophysical Research: Oceans* Volume 128 (January 2023), https://doi.org/10.1029/2022JC019368.

average of 1.1°C from 1850-1900 to 2011-2020.[9] Identifying and quantifying the sources and amount of emissions being produced is a critical factor to understanding how to mitigate climate change. In addition to environmental monitoring and data collection, UxS can contribute to GHG monitoring. UAVs can be uniquely equipped with high-performance sensors to monitor and map methane (another type of GHG) at the local level.[10] Contributing to the tracking and understanding of methane emissions is particularly valuable. According to the U.S. Environmental Protection Agency (EPA), methane is the "second most abundant anthropogenic GHG after [CO_2], accounting for about 16% of global emissions. Methane is more than 28 times as potent as carbon dioxide at trapping heat in the atmosphere" and has 80 times the warming power of CO_2 over its first 20 years in the atmosphere.[11]

Even systems built to mitigate and reduce GHG emissions are not free from emissions themselves. Carbon capture technology can be applied to many different applications such as on coal combustion plants. Although carbon dioxide (CO_2) may be scrubbed from the air, other potentially harmful gases may continue to be emitted. To measure emissions and quantify the impact of the carbon capture, small drones can be used to monitor ammonia gas emissions (another type of GHG) from exit stacks connected to a carbon capture system. Often, the capability of precise measurement is absent through traditional means making the sUAS a viable alternative method for emissions measurements, with a unique capability of flying close to exhaust stacks to take more accurate measurements of the GHG emissions.[12] Other implementation examples of methane monitoring includes monitoring in the Arctic utilizing UAVs as an improvement to existing monitoring tools. Specifically, these methods help protect

[9] IPCC, 2023: Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee, and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 1-34, doi: 10.59327/IPCC/AR6-9789291691647.001.
[10] Jacob Shaw and Adil Shah, "Methods For Quantifying Methane Emissions Using Unmanned Aerial Vehicles: A Review," *Philosophical Transactions of the Royal Society A* 379 (May 2021), https://doi.org/10.1098/rsta.2020.0450.
[11] U.S. Environmental Protection Agency, Importance of Methane, November 1, 2023, https://www.epa.gov/gmi/importance-methane.
[12] Travis Schuyler and Bradley Irvin, "Application of a Small Unmanned Aerial System to Measure Ammonia Emissions from a Pilor Amine-CO_2 Capture System," *Sensors* Volume 20, No. 23 (December 2020): 6974, DOI:10.3390/s20236974.

fragile vegetation and soil structures in the Arctic wetlands, areas associated with ecosystem impacts due to climate change [Figure 3].[13]

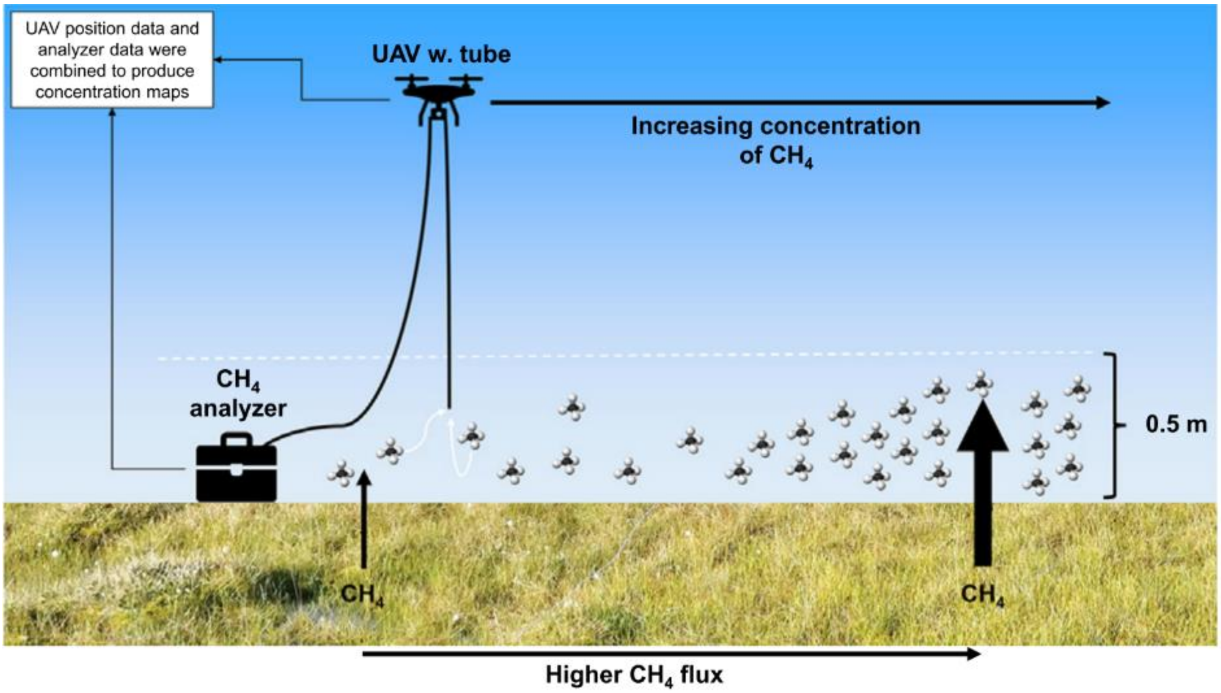

Figure 3: Example of UAV being utilized to measure methane GHG emissions in the Arctic wetland.[14]

UxS Carbon Footprint & Fuel Usage Analysis

In addition to being a low cost and economic alternative system to those of larger systems, UxS have the potential to be more fuel efficient and even fuel independent, further mitigating the harmful GHG emissions associated with those larger systems that are often solely dependent on fossil fuels. New UxS have the potential to harness the increasing amount of alternative fuel as well as the increased efficiency of batteries. Studies have analyzed the efficiency and range of UxS powered by electricity versus those powered by fossil fuel. These studies have mainly consisted of "last-mile" studies of delivery companies that compare the fuel and cost of a typical delivery truck and integrating a drone or UAS into the logistical pathway. Other studies include the carbon footprints of UxS with that of crewed vessels such as cargo ships or larger aircraft.

[13] Johan Scheller and Mikhail Mastepanov, "Toward UAV-based Methane Emission Mapping of Arctic Terrestrial Ecosystems", *Science of the Total Environment* 819 (January 2022): 153161, http://dx.doi.org/10.1016/j.scitotenv.2022.153161 0048-9697.
[14] Ibid.

Drones or UAVs are integrated into the "last-mile delivery" of operations, which most widely is defined as referring to the logistical activities involved in the distribution of shipments from a central depot in an urban environment to the consumer.[15] The delivery sector has studied this integration for both cost and environmental benefits. Because current technologies often inhibit the range of these systems, a teaming approach is favored when conventional transportation systems are used in tandem with the uncrewed systems. Like other studies, this study incorporated path mapping and efficient route modeling to quantify the potential emissions and energy savings of the systems. The study was able to model the carbon emissions reductions for various traffic route loads both with and without the incorporation of UAVs, concluding that UAVs have the potential to have energy sustainability benefits [Figure 4].[16]

Number of customers	Number of vehicles		Number of reduced vehicles	CO_2 emission (kg)				CO_2 emission reduction	
	Without UAV	With UAV		Without UAV	With UAV			(kg)	(%)
					Vehicle	UAV	Total		
200	2	2	0	467.8864	428.1870	0.2913	428.4783	39.4081	9.20
300	3	2	1	590.1355	492.7773	0.3523	493.1296	97.0059	19.67
400	4	3	1	687.4937	621.0128	0.4561	621.4689	66.0248	10.62

Figure 4: Comparison of CO_2 emissions of using UAVs and not using UAVs.

Another study approached the entire GHG life cycle of incorporating drones in "last-mile delivery" which is often the most carbon intensive and least energy efficient portion of the delivery cycle. The researchers further studied the usage of both robotic package delivery as well as autonomous vehicles. While not all applications of the model produced GHG emissions

[15] Nils Boysen and Stefan Fedtke, "Last-mile Delivery Concepts: A Survey From an Operational Research Perspective," OR Spectrum Volume 43, (September 2020): pages 1-58, https://link.springer.com/article/10.1007/s00291-020-00607-8.
[16] Yuyu Li and Wei Yang, "Impact of UAV Delivery on Sustainability and Costs under Traffic Restrictions," *Mathematical Problems in Engineering* Volume 2020, no. 9437605 (August 2020): 15 pages, https://www.hindawi.com/journals/mpe/2020/9437605/.

saving potential, assorted sizes of Battery Electric Vehicles (BEVs) were concluded to have to have lower emissions than the Internal Combustion Engine vehicles (ICEV) [Figure 5].[17]

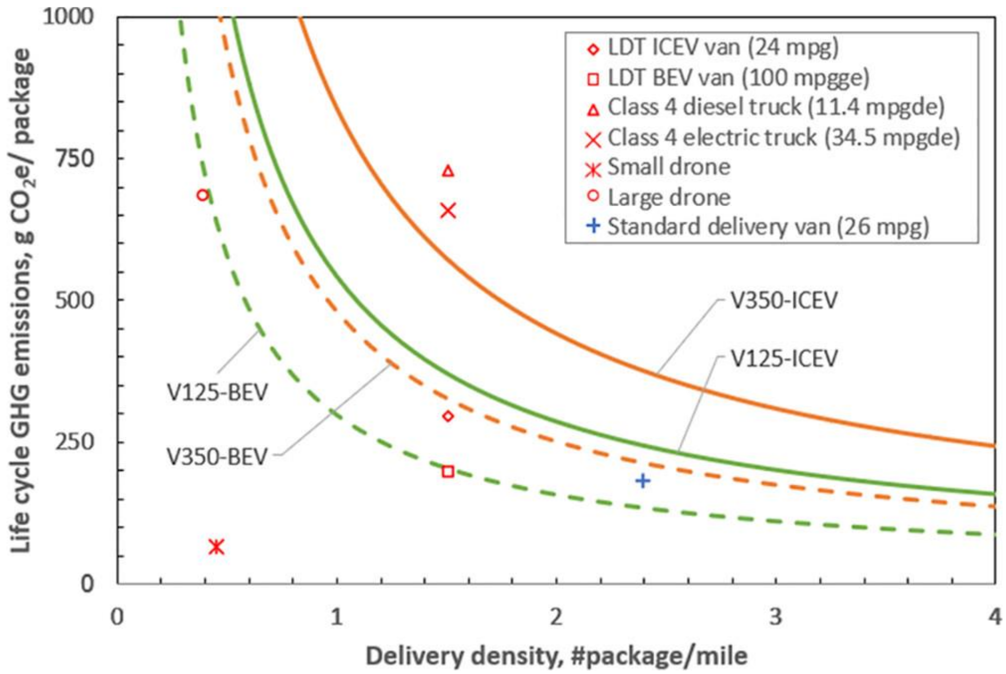

Figure 5: GHG emissions vs delivery density. Solid line = internal combustion engine, dashed line = battery electric. Vehicle size and fuel source account for the majority of overall greenhouse gas emissions.

Other applications of uncrewed systems include scalability from small systems to cargo ships. Studies have shown that the unmanned autonomous shipping vessels improve both the operational flexibility in the absence of a crew as well as improved energy efficiency.[18] The adoption of such systems will prove valuable to the maritime community with lower emissions and energy costs.[19]

The development of dual technology of systems offers translatability into military operations. While a "last-mile drone" may not have a role to play in the military, the concepts of

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[17] Luyao Li, Xiaoyi He, "Life Cycle Greenhouse Gas Emissions for Last-Mile Parcel Delivery by Automated Vehicles and Robots," *Environmental Science & Technology* Volume 55 (August 2021): pages 11360-11367, doi: 10.1021/acs.est.0c08213.

[18] Olakunle Oloruntobi and Kasypi Mokhtar, "Sustainable Transition Towards Greener and Cleaner Seaborne Shipping Industry: Challenges and Opportunities," *Cleaner Engineering and Technology* Volume 13, (April 2023): 100628, https://doi.org/10.1016/j.clet.2023.100628.

[19] Floris Goerlandt, "Maritime Autonomous Surface Ships from a Risk Governance Perspective: Interpretation and Implications," *Safety Science* Volume 128 (August 2020), https://doi.org/10.1016/j.ssci.2020.104758.

fuel efficiency within UAVs exists. For example, Vanilla UAS currently holds the world record for the longest unrefueled flight of any aircraft. This ultra-long endurance Intelligence, Surveillance, and Reconnaissance (ISR) aircraft has flown for just over 8 days straight without the need to refuel. Although the platform does use GHG emitting fuel, it has the potential to perform ISR missions more efficiently than a crewed aircraft, leading to overall reduction in emissions.[20] The U.S. Navy has plans to integrate the Boeing MQ-25 Stingray into the carrier air wing. The uncrewed aerial tanker promises to increase the strike range of the fleet's strike fighters attached to the aircraft carriers up to about 400 nautical miles, boasting a payload of about 15,000 pounds of fuel, further increasing the efficiency of the aircraft it will refuel.[21]

However, while the military is eager to adopt UxS and integrate them into the fleet, there is a potential for reducing overall DOD emissions by adopting platforms that produce no to net-zero amounts of GHG emissions. Moving away from fossil fuel requirements in systems to renewable and battery-operated systems is a benefit not only for decarbonization efforts, but also for monetary and logistic constraints that tend to exist for the systems utilizing JP-5 type fuel. There are measurable advantages to utilizing batteries and other fuel cells for drones such as high energy efficiency, low noise, and low to no GHG emissions during operations.[22]

Another example of an autonomous system includes a UAV that harnesses solar energy and charging stations held in building envelopes leading to a net-zero operation.[23] This modeled system demonstrated that a system utilizing both renewable energy sources as well as pathway optimization as well as excess electricity generation, could simulate an elimination of GHG emissions. The pathway optimization emphasized the preference for a minimum-energy trajectory pathway. This model also incorporated charging stations along the drone's pathway to facilitate energy efficient pathways to the destination.

There is a wide range of models and techniques for assessing fuel and energy efficiency of UxS. Data availability and parameter cohesion of systems continues to be an issue when measuring the efficiency of systems, especially in the military focus. While research exists on UxS energy efficiency, much of the research focuses on drones, specifically in terms of delivery

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[20] "Strategic Coverage – Tactical UAS" Vanilla Unmanned, 2021, https://static1.squarespace.com/static/5b89a45fa9e02897af6fe886/t/6536e7fb5fb2335f013a2ade/1698097148004/%28Aug+2023%29+Vanilla+Unmanned+Datasheet.pdf.

[21] Sam Lagrone, "MQ-25 Stingray Unmanned Aerial Tanker Could Almost Double Strike Range of U.S. Carrier Air Wing," U.S. Naval Institute, August 31, 2017, https://news.usni.org/2017/08/31/mq-25-stingray-unmanned-aerial-tanker-almost-double-strike-range-u-s-carrier-air-wing.

[22] Joshuah Stolaroff and Constantine Samaras, "Energy Use and Life Cycle Greenhouse Gas Emissions of Drones for Commercial Package Delivery," *Nature Communications* Volume 9 (February 2018), https://doi.org/10.1038/s41467-017-02411-5 .

[23] Mo ElSayed and Ahmed Foda, "Autonomous Drone Charging Station Planning Through Solar Energy Harnessing for Zero-Emission Operations," Sustainable Cities and Society Volume 86 (November 2022): https://doi.org/10.1016/j.scs.2022.104122.

services and includes a wide range of models. Within the available range of research, there is no agreed upon scientific method nor consensus of methods for measuring drone energy consumption. Although many models offer efficiency measurement, they should be used with caution as each model offers different benefits and focuses and should be considered with low accuracy of real-world modeling of UxS operations.[24]

Role of AI in Combatting Climate Change

A growing trend in technology is the development and integration of autonomy into many of the uncrewed systems being used in both the private and commercial sectors including military application. This includes the various artificial intelligence (AI) applications that range from autonomous navigation to large language models. Many of the AI applications can be directed towards climate change mitigation and prediction efforts. The role of these innovative technologies has immense potential in redefining how militaries can meet specific emissions goals and predict and adapt to the changing environment. Some of the efforts and studies of AI integration include the prediction of impacts on critical infrastructure caused by extreme weather events due to climate change.[25]

While AI has the potential to enable many positive outcomes including advancement in the understanding of climate change implications as well as solutions to mitigate those impacts, it should be understood that AI computing at high levels often requires large amounts of electricity to function.[26] This can potentially pose environmental concerns, especially considering the type of energy consumed to produce the needed large quantities of electricity, specifically for maintaining the required data centers associated with AI applications. After training is complete, the model moves into the inference stage. This stage produces outcomes based on input, and studies show that this stage uses a significant amount of energy to maintain. For example, Generative Pre-trained Transformer 3 (GPT-3, the platform associated with ChatGPT) reportedly used approximately 1,287 Megawatt hours (Mwh) for training, and a considerable amount more for the inference phase. For context, a 40 Watt (0.04 kilowatt) lightbulb that is on for 5 hours consumes 0.20 kilowatt hours (kWh) of electricity, with 1 MWh equaling 1,000 kWh. The equivalent amount of energy used to train the GPT-3 is equal to

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[24] Juan Zhang and James Campbell, "Energy Consumption Models for Delivery Drones: A Comparison and Assessment," Transportation Research Part D Volume 90 (2021): https://torpedo.nrl.navy.mil/tu/ps/doc.html?vol=90&dsn=19625722&ssn=2753&iss=C&st=JRNAL.

[25] Dr. Sandro Carniel and Fabio Lissi, "Climate Change and Security: The Role of New Technologies at NATO," *Sea Technology,* November 2023, pages 10-14 https://lsc-pagepro.mydigitalpublication.com/publication/?m=60787&i=808141&p=14&ver=html5.

[26] Delger Erdenesanaa, "A.I. Could Soon Need as Much Electricity as an Entire Country," *New York Times*, October 10, 2023, https://www.nytimes.com/2023/10/10/climate/ai-could-soon-need-as-much-electricity-as-an-entire-country.html?campaign_id=9&emc=edit_nn_20231011&instance_id=104913&nl=the-morning&regi_id=176535770&segment_id=147032&te=1&user_id=8c52866eb9f109cd4e04f1bbe8fe4fe6.

approximately 257,400 40W lightbulbs switched on for 5 hours. According to the U.S. Energy Information Administration, the average U.S. household purchased or used about 10,791kWh annually in 2022.[27] One of the biggest sources of AI energy consumption is during the training phase of the system when large data sets are used to create desired functions for the AI model. Additionally, by the year 2027 the AI servers could potentially consume about the same amount of energy consumed by some countries such as Argentina, the Netherlands, and Sweden at about 85 to 134 TWh annually.[28] With energy demands for these systems being as high as noted, it should be understood that carbon emissions associated with the energy sources will continue to be high until renewable and low or no emission sources of energy are adopted.

Although some AI models require the same amount of electricity and energy as a small city, it should also be noted that future improvements in hardware and software including training algorithms will improve the systems' energy efficiency. While improvements in hardware and software may initially improve their efficiency, the increased efficiency may cause the demand in the usage to increase as well, flattening any mitigation of the high energy cost. This type of demand elasticity is known as Jevons Paradox, where an improvement in efficiency leads to an increase in demand. For example, as fuel efficiency increase, it tends to lead to an increase in demand therefore an equilibrium or even increase in fuel usage and not a decrease.[29] This type of paradox can be applied more broadly to the expected energy demand of UxS and other autonomous systems as they become more integrated into use.

Net Zero Goals & Electrification

The research findings noted above show that UxS reliant on fossil fuels may reduce emissions if they replace a system that requires more fuel and if the number of systems stays stable rather than increases over time. If these elements are not met, there is a question whether they will help meet net zero goals and whether policies toward electrification can change the trend. Primarily, two options exist to increase the operating time of UxS: refuel at regular intervals or employ a power source that increases the system's capacity. The former requires a type of external refueling station, regular landing of the system and, as a result, decreasing mobility and increasing costs.

Electrifying UxS depends on a variety of factors including its size, purpose and anticipated use, and the environment in which it operates. Electrifying UxS can "improve the

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[27] "How Much Electricity Does an American Home Use?" Energy Information Administration, 2023, https://www.eia.gov/tools/faqs/faq.php?id=97&t=3.
[28] Alex de Vries, "The Growing Energy Footprint of Artificial Intelligence," Joule Volume 7 (October 2023): pages 2191-2194 DOI: https://doi.org/10.1016/j.joule.2023.09.004.
[29] Tabrez Syed, "The Demand Elasticity Paradox: More than Meets the AI," Artificial Intelligence in Plain English, July 24, 2023, https://ai.plainenglish.io/the-demand-elasticity-paradox-more-than-meets-the-ai-1e87e63a4cfa.

efficiency and effectiveness of military operations while also substantially reducing the environmental footprint, fully burdened cost of fuel and risk to human life."[30] While combustion engines remain a favored power system for most military and commercial UAVs, electrical systems offer a higher efficacy and tend to be more reliable, with the added benefit of having low to no greenhouse gas emissions and low noise."[31] There is also room for new architectural design to maximize the benefits of electrification and reduce the disadvantages of trying to electrify an existing platform with space, technological and other constraints. While "these vehicles may not be a reality for quite some time," removing the need for essential systems for a crew allows for unique possibilities for engineers to imagine the next generation of low-emission UxS.[32]

The World Economic Forum estimates that drones in the transportation sector alone could reduce carbon emissions by up to 4.5 billion tons per year.[33] However, the power source will have a major impact. Table 1 shows some of the options for powering UxS and their shortfalls.

Power source	Shortfall
Batteries	Low recharge cycles; low energy density; low flight time in comparison; recharge period significantly longer than others; dangerous to the environment and/or operators; limited flight time thus limited applications.
Hydrogen FCs	Larger size; limited by availability of hydrogen gas and gas tank size; quite expensive; lower energy efficiency compared to batteries due to complex power management requirements; hydrogen extraction process increases refuel time;
Combustion engine	Heavier; larger size; noisy; complex maintenance;
Solar power	Large surface required for solar panels; requires sunlight; much heavier than others; significantly larger cost than others; maximum power point tracking (MPPT) algorithm is required.

Table 1. Summary of the shortfalls of different UxS power sources[34]

[30] Ben Chiswick, "How Electrification and Autonomy Can Unlock the Potential of Unmanned Ground Vehicles," Mobility Engineering, May 1, 2023, https://www.mobilityengineeringtech.com/component/content/article/48022-how-electrification-and-autonomy-can-unlock-the-potential-of-unmanned-ground-vehicles.
[31] Ashleigh Townsend, Immanual Jiya, Christiaan Martinson, Dmitri Bessarabov, Rupert Gouws, "A comprehensive review of energy sources for unmanned aerial vehicles, their shortfalls and opportunities for improvements," Heliyon, Volume 6, Issue 11, November 2020, https://www-sciencedirect-com.libproxy.nps.edu/science/article/pii/S2405844020321289?via%3Dihub.
[32] *Id.*
[33] World Economic Forum, The Future of the Last-Mile Ecosystem, 2020, https://www3.weforum.org/docs/WEF_Future_of_the_last_mile_ecosystem.pdf.
[34] Townsend, et. al.

Fuel and renewable energy advancements are crucial factors as well. In 2023, French company VoltAero flew its hybrid-electric aircraft on sustainable aviation fuel for the first time.[35] A Canadian start-up, Solar Ship, Inc., is developing solar powered hybrid airships that can run on solar power alone.[36] A platform such as this deliver humanitarian assistance and disaster relief supplies to remote locations without needing fuel or infrastructure. In addition, the ship's solar cells along with the large volume of the envelope allow the hybrid airship to be reconfigured into a mobile shelter that can recharge batteries and other equipment.

Current U.S. policy requires movement toward these alternative power sources. Executive Order 14057 on catalyzing American clean energy industries and the accompanying Federal Sustainability Plan lays out targets for emission reductions through 2050. They are:

- 100% Carbon Pollution-Free electricity by 2030;
- 100% Zero-emission vehicle acquisitions by 2035 including 100% light-duty acquisitions by 2027;
- Net-Zero emissions buildings by 2045, including a 50% reduction by 2032;
- Net-Zero emissions procurement by 2050; and,
- Net-Zero emissions operations by 2050, including a 65% reduction by 2030.

Part of reaching these goals includes analysis of operational emissions and life-cycle emissions of both fossil fuel-powered and electric UxS. This must include accurate accounting of current GHG emissions; conducting this in the research setting will reduce the danger of revealing strategic information about platforms or operations.[37]

The best-known methodology to monitor GHG emissions is from the National Inventory Reports that states submit to the UN Framework Convention on Climate Change (UNFCCC). Each National Inventory includes a specific category available to report emissions from military fuel use; this is further broken down into stationary emissions, for fuel use in buildings, and mobile emissions, for fuel use in vehicles. National Inventory Reports follow the same structure and methodology to ensure they are comparable.

As noted by the International Military Council on Climate and Security, in practice, National Inventory Report data on the military sector emissions are not useful for assessing and quantifying military emissions. It notes that the "methodology is not designed to be applied to specific organizations (i.e., defense agencies). It does not cover emissions generated outside the national territory, in international waters and airspace. The subcategories dedicated to military

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[35] VoltAero flies hybrid-electric aircraft on SAF for the first time, Military & Aerospace Electronics, Sept. 24, 2023, https://www.militaryaerospace.com/commercial-aerospace/article/14299314/voltaero-flies-hybridelectric-aircraft-on-saf-for-the-first-time.
[36] Solar Ship, December 2023, https://www.solarship.com/.
[37] International Military Council on Climate and Security, "Decarbonized Defense: The Need for Clean Military Power in the Age of Climate Change," June 2022, at page 10, https://imccs.org/wp-content/uploads/2022/06/Decarbonized-Defense-World-Climate-and-Security-Report-2022-Vol.-I.pdf.

fuel use emissions include other types of civilian emissions not specified elsewhere, making the data unreliable."[38] Thus, the ability to accurately track and calculate military emissions is a necessity in reaching net zero, whether by using uncrewed or crewed systems.

Policy Recommendations

Uncrewed systems such as drones and other systems utilizing artificial intelligence have the potential to mitigate and combat climate change. Many platforms serve as important data collecting units, helping researchers and scientists better understand the global biosphere. Many UxS can further play a role in mitigation through the development of efficient operations through route planning and utilization of renewable energy sources; both have the potential to lower harmful GHG emissions. However, fuel analysis models are not well developed for comparison of UxS and conventional systems such as ships and aircraft. Most literature covers delivery trucks and UAVs. While current research on "last-mile delivery" is promising, further development of standardized methodologies is needed to quantify the potential emission and efficiency benefits of using UxS. Additionally, Artificial Intelligence at large scales currently requires an immense amount of energy, pulling from the community grid that is often still dependent on fossil fuels. The following policy and research recommendations may help to meet some of these challenges.

- **Develop an UxS Sustainability Plan.** The 2022 U.S. Department of Defense Sustainability Plan notes that the Department "strongly supports the deployment of sustainable, clean energy technologies to support installation resilience and recognizes that in some cases DoD's scale can drive uptake of new and promising technologies."[39] The Plan also notes DoD's efforts to meet the goal of 100% acquisition of zero-emission vehicles and accelerating the development of charging infrastructure. There is no such policy directed to the sustainability of UxS. By adopting such a plan, DoD can assess the role that UxS may have in emissions reductions and address the existing opportunities embedded in UxS research and development to advance sustainable UxS.

- **Operationalize the use of procurement to drive demand for electrified UxS.** According to the Sustainability Plan, DoD is "leveraging its purchasing power to increase the sustainability of its supply chain and achieve net-zero emissions from procurement by

[38] Ibid.
[39] U.S. Department of Defense Sustainability Plan, 2022, https://www.sustainability.gov/pdfs/dod-2022-sustainability-plan.pdf.

2050."[40] Explicitly applying these policies to UxS could shift the trend toward alternatively powered UxS to answer the challenges noted above.

- **Expand international treaties and agreements to address the role of UxS in meeting climate challenges.** As previous legal analyses have shown, there are few international agreements that directly address UxS and often, UxS are governed by laws and policies drafted decades ago and with crewed systems in mind. Such agreements can produce an international effort toward reduced emissions from UxS, both operational and life cycle emissions, and tackle related problems such as environmental impacts of expendable systems, navigational hazards related to abandoned systems, use in environmentally sensitive areas such as polar regions, and improved composition of UxS to reduce the use of plastic and forever chemicals.

Part II

Part II provides a related legal analysis of whether UxS are considered ships or vessels for purposes of international law. This analysis advances the understanding of how UxS will be treated as they are used for multiple uses such as addressing climate challenges across the globe. Part II concludes with suggested research questions that address legal gaps in defining UxS.

Legal Analysis: Defining UxS in the Maritime Environment

As unmanned systems (UxS) permeate the maritime environment, it becomes increasingly evident that existing policy lags far behind technological advances. Taking effect in 1982, the most commonly accepted regulatory policy on the high seas is the United Nations Convention on the Law of the Sea (UNCLOS).[41] UNCLOS provisions have an underlying assumption that ships and vessels (terms used interchangeably in the agreement) must be manned.[42] Because UNCLOS fails to explicitly define either of these terms, it is unclear whether or not its provisions apply to unmanned maritime systems, which could also be interpreted as devices. Lacking an international classification of UxS as ships or vessels, the precedents that nations set through their own domestic policies and treatment of UxS become increasingly

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[40] Ibid.
[41] UN General Assembly, Convention on the Law of the Sea, Article 29. (1982). https://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf .
[42] Laws that imply crewing or apply questionably to UxS are detailed extensively in this article. Comite Maritime International. (2018). CMI International Working Group Position Paper on Unmanned Ships and the International Regulatory Framework. *Comite Maritime International*. https://comitemaritime.org/wp-content/uploads/2018/05/Summary-of-Responses-to-the-CMI-Questionnaire.docx.

important in determining treatment of UxS in the maritime environment.[43] Whether UxS are considered ships or vessels, or if they fall into a separate category, dictates whether UxS are required to follow certain rules and whether they receive specific protections. The development of technology, its productive use, and the safety of the maritime environment depend on the existence and implementation of clear laws and policies. Part II explores the following key elements of the classification of UxS in the maritime environment:

1) Current international and Five Eyes Alliance (FVEY) members' definitions of vessels and ships;
2) Whether UxS fall within these definitions;
3) Current international and FVEY classifications of UxS, or lack thereof; and
4) The implications of these classifications (or lack thereof).

In the context of recent seizures of U.S. UxS by Iran and China, the classification of these systems is relevant and time sensitive.[44,45] The findings of this report elucidate the terminology used and precedents set by FVEY countries to clarify the legal environment and how UxS will be treated under international law. This analysis becomes even more relevant as state boundaries shift around the world. Recently, the U.S. announced the extension of the outer limits of its continental shelf.[46] The U.S. has extended continental shelf (ECS) in seven offshore areas including the Arctic, Atlantic (east coast), Bering Sea, Pacific (west coast), Mariana Islands, and two areas in the Gulf of Mexico. The ECS is approximately one million square kilometers, an area about twice the size of California. The State Department notes that the U.S. "may also have ECS in other areas, and the U.S. ECS Project continues to analyze available data and undertake analysis in a range of areas."[47]

Research relevant to this analysis includes a plethora of legal and policy, from treaties to military handbooks to ship registration regulations. For this report, a nation has defined the terms "ship" or "vessel" when the term(s) is included in the laws or policies that apply broadly to their coastal waters, territorial waters, or exclusive economic zone, promulgated by the regulatory

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[43] Michael Schmitt and David Goddard, "International Law and the Military Use of Unmanned Maritime Systems," International Review of the Red Cross Volume 98, no. 902 (July 2017): pages 567-592 https://doi.org/10.1017/s1816383117000339.

[44] "Iran Seizes and Later Releases Two U.S. Navy Unmanned Surface Vessels," (2022, September 4). *The Maritime Executive,* September 3, 2022. https://maritime-executive.com/article/iran-seizes-and-later-releases-two-u-s-navy-unmanned-surface-vessels.

[45] M. Taylor Fravel, "The Implications of China's Seizure of a U.S. Navy Drone" The National Bureau of Asian Research, December 15, 2016, https://www.nbr.org/publication/the-implications-of-chinas-seizure-of-a-u-s-navy-drone/.

[46] U.S. Department of State, Announcement of U.S. Extended Continental Shelf Outer Limits, December 19, 2023, https://www.state.gov/announcement-of-u-s-extended-continental-shelf-outer-limits/. Maps are available at https://www.state.gov/the-us-ecs/.

[47] Ibid.

body in charge of that area (e.g., the U.S. Code of Law, the Canada Shipping Act of 2001, etc.). Specific treaties often have narrow definitions that only make sense in their specific context which don't necessarily offer clarity of legal treatment for UxS.[48] Given the ambiguity among states' treatment of UxS, a broader approach to researching the issue is needed including examining a wide variety of documents and statements to gauge nations' stances on the status of UxS as ships or vessels.

Definitions of "Ship" and "Vessel" Among FVEY Nations

UNCLOS provisions apply to either "vessels" or "ships," neither of which are defined in the policy. Many nations have delineated between the two terms. As the IMO considers rules to fill the gaps under UNCLOS, it is necessary to understand the current global consensus on the definitions of these terms and whether a common definition may be attained.[49] In the absence of international agreement, the precedent set by nations' definition of "ship" or "vessel" and whether UxS is included will influence the definition that the IMO eventually uses in its rules. This report focuses on FVEY countries, as they are incorporating UxS technology into their fleets and exert significant political influence internationally.

Vessels

Ships and vessels are referred to interchangeably in UNCLOS and lack formal definitions. It is useful, however, to note that the term "vessel" has been defined in other internationally accepted policies. The Convention on the International Regulation for Preventing Collisions at Sea (COLREGs) defines a vessel as "includ[ing] every description of watercraft, including non-displacement craft, wing-in-ground-effect (WIG) craft and seaplanes, used or capable of being used as a means of transportation on water."[50] The following section discusses FVEY definitions for the term "vessel."

In the U.S. Code, "vessel" is defined broadly in Title 1 as "every description of watercraft or other artificial contrivance used, or capable of being used, as a means of transportation on water."[51] "Vessel" is also defined in U.S. Code Title 47 and is equated to the term "ship," and

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[48] Simon McKenzie, "When is a Ship a Ship? Use by State Armed Forces of Un-crewed Maritime Vehicles and the United Nations Convention on the Law of the Sea," *Melbourne Journal of International Law* 21, no. 2 (2020): https://doi.org/10.31228/osf.io/a7xtc.
[49] International Relations and Defence Committee. (2021). *Corrected oral evidence: UNCLOS: Fit for purpose in the 21st century?* (HL 2021). [Online]. London. [Accessed 03 June 2023]. https://committees.parliament.uk/oralevidence/3000/pdf/.
[50] International Maritime Organization. (1972, October 20). *Convention on the International Regulations for Preventing Collisions at Sea.* Rule 3. https://opanalytics.ca/courses/mod/page/view.php?id=7#:~:text=(a)%20The%20word%20%E2%80%9Cvessel,means%20of%20transportation%20on%20water.
[51] Rules of Construction, 1 U.S.C.§ 3. (1947). https://www.law.cornell.edu/uscode/text/1/3.

uses the exact wording as the first definition except that it excludes aircraft.[52] Interestingly, even in the same code of law, there is ambiguity regarding the distinction between a "vessel" and a "ship."

In the U.K., the Merchant Shipping Act of 1894 defines a vessel as "includ[ing] any ship or boat, or any other description of vessel used in navigation," circularly using the term vessel in its own definition.[53] The more recent Merchant Shipping Act of 1995 does not include a definition for the term "vessel."

Australia has two main legislative frameworks– one for ships that travel internationally (Regulated Australian Vessels) and another for ships that operate exclusively within the Australian Exclusive Economic Zone (Domestic Commercial Vessels). Regulated Australian Vessels fall under the Navigation Act of 2012, while Domestic Commercial Vessels are regulated by the Marine Safety National Law Act of 2012.[54] The Navigation Act defines a vessel as "any kind of vessel used in navigation by water, however propelled or moved, and includes the following: (a) a barge, lighter or other floating craft; (b) an air-cushion vehicle, or other similar craft, used wholly or primarily in navigation by water."[55] In the Marine Safety National Law Act, a vessel is defined as "a craft for use, or that is capable of being used, in navigation by water, however propelled or moved, and includes an air-cushion vehicle, a barge, a lighter, a submersible, a ferry in chains and a wing-in-ground effect craft."[56] It is notable that the first Navigation Act defines "vessel" circularly, using the term in its own definition, while the Marine Safety National Law does not.

The Canada Shipping Act of 2001, the umbrella act under which more specific maritime provisions fall, defines a vessel as "a boat, ship or craft designed, used or capable of being used solely or partly for navigation in, on, through or immediately above water, without regard to method or lack of propulsion, and includes such a vessel that is under construction. It does not include a floating object of a prescribed class."[57] New Zealand's primary marine policy, the Maritime Transport Act of 1994, does not provide a definition for the term "vessel."

[52] Definitions, 47 U.S.C. § 153. (1954). https://www.law.cornell.edu/uscode/text/47/153#:~:text=The%20term%20%E2%80%9Caffiliate%E2%80%9D%20means%20a,or%20control%20with%2C%20another%20person.

[53] Merchant Shipping Act of 1894, c. 60 sec 742. https://www.legislation.gov.uk/ukpga/1894/60/pdfs/ukpga_18940060_en.pdf.

[54] Australian Maritime Safety Authority. *Advisory note—The scope of the National System: Regulated Australian vessels and domestic commercial vessels*. (2015). https://www.amsa.gov.au/vessels-operators/domestic-commercial-vessels/advisory-note-scope-national-system-regulated.

[55] *Navigation Act 2012.* (Cth). Pt IV div 1. https://www.legislation.gov.au/Details/C2012A00128.

[56] *Marine Safety National Law Act 2012.* (Cth). Pt I div 8. https://www.legislation.gov.au/Details/C2016C00377.

[57] *Canada Shipping Act 2001,* RSC 2001. C Interpretations, s 2. https://laws-lois.justice.gc.ca/eng/acts/C-10.15/page-1.html#h-50749.

Ships

The term "ship" is not defined in UNCLOS but is defined in the International Convention for the Prevention of Pollution from Ships (MARPOL). MARPOL defines ships as "a vessel of any type whatsoever operating in the marine environment…."[58] While this is an example of an international definition in the absence of one in UNCLOS, it is much broader than usual, as pollution regulations aim to include as wide a range of watercraft as possible. Each of the FVEY countries also has a definition for the term "ship."

In the U.S., "ship" and "vessel" are defined interchangeably in the U.S. Code of Law as mentioned in the previous section on vessels. The only difference between the definition of "vessel" and that of a "vessel or ship" is that ships do not include aircraft.[59]

The U.K.'s Merchant Shipping Act of 1995 defines "ship" as "every description of vessel used in navigation."[60] Since the Merchant Shipping Act of 1995 does not define a vessel, we can assume that it references back to the 1894 act, which does define the term. Problematically, the 1894 definition of "vessel" is a "ship… used in navigation."[61] As a result, a ship is a type of vessel, while a vessel is also a type of ship under U.K. law.

Neither of Australia's main governing maritime policies, the Navigation Act of 2012 and the Marine Safety National Law Act of 2012, contain a definition for ship.[62] The Australian Shipping Registration Act of 1981, however, does provide a definition for "ship" as "any kind of vessel capable of navigating the high seas…" and includes various examples to clarify items that can be defined as ships.[63]

In the Canadian Shipping Act of 2001, there is no provided definition for "ship." In the Canada Marine Act, a regulation administered by Transport Canada (the government's commercial regulatory body), it is defined as "every description of vessel, boat or craft designed, used or capable of being used solely or partly for marine navigation, whether self-propelled or not and without regard to the method of propulsion, and includes a sea-plane and a raft or boom of logs or lumber."[64] In New Zealand, under the Maritime Transport Act of 1994, "ship" is

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[58] International Maritime Organization. (1973). *International Convention for the Prevention of Pollution from Ships.* Art 2 sec 4. https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/ConferencesMeetings/Documents/MARPOL%201973%20-%20Final%20Act%20and%20Convention.pdf.

[59] Definitions, 47 U.S.C. § 153. (1954). https://www.law.cornell.edu/uscode/text/47/153#:~:text=The%20term%20%E2%80%9Caffiliate%E2%80%9D%20means%20a,or%20control%20with%2C%20another%20person.

[60] Merchant Shipping Act of 1895, c. III sec 313. https://www.legislation.gov.uk/ukpga/1995/21/data.pdf.

[61] Merchant Shipping Act of 1894, c. 60 sec 742. https://www.legislation.gov.uk/ukpga/1894/60/pdfs/ukpga_18940060_en.pdf.

[62] *Marine Safety National Law Act 2012.* (Cth). Pt I div 8. https://www.legislation.gov.au/Details/C2016C00377.

[63] *Shipping Registration Act 1981.* (Cth). Pt I sec 3. https://www.ilo.org/dyn/natlex/docs/ELECTRONIC/88621/101412/F-915920895/AUS88621%202019.pdf.

[64] *Canada Marine Act,* RSC 1998. C Interpretation, s 2. https://laws-lois.justice.gc.ca/eng/acts/c-6.7/FullText.html.

defined as “every description of boat or craft used in navigation, whether or not it has any means of propulsion…” and include examples of items that are to be considered ships.[65]

Complexity of Defining UxS

Given that the FVEY countries have defined "vessel" and "ship,” the next step in the analysis is whether UxS fall within these definitions and can be categorized as such. Every country, excluding New Zealand and Australia’s Marine Safety National Law, uses the term “vessel” in their definition of a ship, so this analysis will focus on how an UxS can be classified as a vessel. New Zealand’s definition for “ship” will be used because its law lacks a definition for “vessel.” Most seem broad and inclusive of UxS at the surface level, but there are various nuances within each definition.

The first issue arises in the existence of multiple definitions of “vessel,” which use the term to define itself. The circular nature of these definitions makes it difficult to determine whether they are inclusive of UxS. To ascertain whether UxS are vessels, other requirements that are common between all FVEY definitions may help, regardless of whether they use the word “vessel.” The main specifications are that (1) a vessel is in or on the water in some capacity and (2) they are either capable of or are being used for navigation or transportation. There is little debate over whether UxS satisfies the first condition of being in or on the water. The second condition, what classifies use for navigation or transportation, is less clear.

For example, in the U.S. Code of Law’s definition of “transportation” provided in Chapter 51, Transportation of Hazardous Material– “the movement of property and loading, unloading, or storage incidental to the movement.” Purely based on the U.S. definition of “vessel” and this definition of “transportation,” a small UxS that looks nothing like a typical vessel could be defined as such, even if all it is “transporting” is a small sensor, like the Wave Glider.[66] However, a narrow definition of “transportation” could have excluded the Wave Glider if it implied the carrying of people or goods, or had some implication or requirement of the intentional movement of objects from a start point to an end point (which a sensor does not necessarily do). The way “navigation” is defined could also exclude various UxS; there are certain propulsion requirements for navigation that may not be met because some UxS move passively through their environment.

It has been up to individual nations to interpret these definitions (determining whether UxS are registered as ships or vessels) and apply their existing policies to them or create new provisions specifically for UxS. The following section will outline the ways in which FVEY

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[65] Maritime Transport Act 1994. Pt 1 sec 2. https://legislation.govt.nz/act/public/1994/0104/latest/DLM334660.html.
[66] “The Wave Glider | How It Works,” Liquid Robotics, Inc., July 27, 2022, https://www.liquid-robotics.com/wave-glider/how-it-works/.

countries have integrated UxS into a policy framework that was written before the existence of such systems.

Classifications of UxS Among FVEY Nations

Pending international clarification, states self-determine if UxS are included under existing policy[67] A study has been conducted by Comite Maritime International in which they asked seventeen countries a series of questions about the status of unmanned ships.[68] While this study outlined the ways in which different countries interpreted their laws in regard to larger UxS, such as cargo ships, it did not show more broadly how countries are integrating various types of UxS into their policy framework through recent policies, regulations or other actions. This section will outline the provisions promulgated and actions taken by nations to make clear their views on UxS and how such systems fit into an environment of ships and vessels.

Existing Classifications

The U.S. has explicitly stated in an official publication that UxS are considered ships and are granted the associated rights. In the 2022 Commander's Handbook on the Law of Naval Operations, UxS are said to have the ability to "operate independently as a ship" and to "exercise any internationally lawful use of the seas."[69] UxS are clearly defined as "ships," therefore, they fall under the regulatory regime of UNCLOS and other relevant laws. Additionally, the handbook states that UxS "engaged exclusively in government, noncommercial service are sovereign immune craft," solidifying the position that the rights afforded to conventional crewed ships under UNCLOS also apply to UxS.[70] The U.S. has integrated UxS into an existing policy framework that was created with only crewed vessels in mind.

The U.K., while lacking an explicit regulation declaring UxS as vessels, has considered how the modern technology fits into the existing UNCLOS framework. In an International Relations and Defence Committee meeting on UNCLOS and modern uses of the sea, the conclusion reached was that the provisions ought to be interpreted on a "principle of equivalence." This means that if this technology meets the given safety requirements for conventionally crewed ships, they too, should be considered ships and given the associated

[67] McKenzie, "When is a Ship a Ship? Use by State Armed Forces of Un-crewed Maritime Vehicles and the United Nations Convention on the Law of the Sea."
[68] Comite Maritime International. (2018). CMI International Working Group Position Paper on Unmanned Ships and the International Regulatory Framework. *Comite Maritime International*. https://comitemaritime.org/wp-content/uploads/2018/05/Summary-of-Responses-to-the-CMI-Questionnaire.docx.
[69] U.S. Department of Navy, Office of the Chief of Naval Operations. *The Commander's Handbook on the Law of Naval Operations.* Sec 2.3.4. (2022). https://usnwc.libguides.com/ld.php?content_id=66281931.
[70] Ibid.

rights. In 2021 alone, the U.K. registered 23 UxS as vessels.[71] In its Maritime 2050 Strategy, the Department for Transport aimed to be a leader in the "uptake of smart shipping technologies" and in being the "register authority for autonomous and semi-autonomous vehicles," indicating that it views UxS as ships or vessels capable of registration as such.[72] The U.K. is setting a strong precedent by integrating UxS under their policy as vessels.

The Australian Maritime Safety Authority has consistently referred to UxS as "vessels" when referencing them, and has stated that "currently, these vessels are subject to the same regulatory framework as other vessels, including for survey standards and crewing requirements."[73] They state explicitly that because of the broad definition of "vessel" in the Navigation Act of 2012 and the Marine Safety National Law Act of 2012, these regulations apply to UxS. Australian authorities have solidly stated that UxS fall under the same regulatory regime as conventional vessels and have set a precedent that they are to be treated as vessels.

Transport Canada has created a policy on the Oversight of small Maritime Autonomous Surface Ships (MASS).[74] Even in the title of the policy, they refer to the UxS as "ships," indicating that they will treat them as such in following legal discourse. Additionally, in a 2002 court case regarding an unmanned submersible device, a Canadian federal court applied the definition of vessel very widely, where the physical presence of a crew on board is not necessary to be classified as a vessel.[75]

New Zealand issued an Interim Technical Note (ITN) in 2020 to provide guidance for using UxS. The policy refers to the UxS consistently as ships, and provides viable pathways for registration, indicating New Zealand's view that UxS are indeed considered to fall under their definition of "ship."[76] The document acknowledges that UxS do not meet certain crewing and watchkeeping requirements laid out in other policies and regulations, in which case ship owners are able to apply for exemptions that will allow their UxS to be registered. Interestingly, the ITN excludes "remotely operated vehicles (ROVs) such as those used in subsea operations, which

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[71] International Relations and Defence Committee. (2021). *Corrected oral evidence: UNCLOS: Fit for purpose in the 21st century?* (HL 2021). [Online]. London. [Accessed 03 June 2023]. https://committees.parliament.uk/oralevidence/3000/pdf/.
[72] U.K. Department for Transport. *Maritime 2050– Navigating the Future.* (2019). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/872194/Maritime_2050_Report.pdf.
[73] Australian Maritime Safety Authority. *Autonomous vessels in Australia.* (2022). https://www.amsa.gov.au/vessels-operators/domestic-commercial-vessels/autonomous-vessels-australia.
[74] Transport Canada. *Tier I- Policy- Oversight of small Maritime Autonomous Surface Ships (MASS).* (2022). https://tc.canada.ca/en/marine-transportation/marine-safety-management-system-tp-13585-e-tier-i-policies/tier-i-policy-oversight-small-maritime-autonomous-surface-ships-mass.
[75] Comite Maritime International. (2018). Canada CMI Questionnaire on Unmanned Cargo Ships. *The Canadian Maritime Law Association*. (2018). https://comitemaritime.org/wp-content/uploads/2018/05/CMI-IWG-Questionnaire-Unmanned-Ships-CANADA.pdf.
[76] Maritime New Zealand. *Autonomous Ship Operation in New Zealand.* (2020). https://www.maritimenz.govt.nz/content/rules/interim-technical-notes/ITN-002-20.pdf.

during the mission are physically or wirelessly connected to the relevant support vessel from which they are controlled."[77] The exclusion of this kind of watercraft raises interesting questions and could offer some insight into what navigate means under New Zealand law. Perhaps these vessels are excluded because of the unreliability of their "ability to navigate." If there was any interference with their remote-control communications, this ability would be lost, as opposed to a pre-programmed UxS that does not need constant communication with a driver.

Every FVEY country has either explicitly labeled UxS as "ships" or "vessels," or indicated that they receive the same rights under UNCLOS. While it is unclear whether UxS fall under their legal definitions of "ship" and "vessel," these nations have made their interpretation of the law clear by stating so in policies or registering UxS as ships. FVEY nations are setting a precedent for UNCLOS to apply to UxS, giving them the same rights and responsibilities as conventional crewed vessels. These include innocent passage, due regard, and other rights, which have become increasingly relevant with UxS seizures like the 2016 USS Bowditch incident.[78] Without a legal regime establishing the way UxS must act and be treated, we run the risk of creating an unsafe maritime environment for commercial operation and elevating the potential for military escalation. FVEY countries have effectively established that having humans on a watercraft is not a prerequisite to it being a vessel or ship. While it is encouraging that all FVEY countries are considering UxS and setting a precedent for international law, many questions about their integration into the maritime environment remain. The following table offers a quick reference for these findings [Table 2].

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[77] Ibid.

[78] The National Bureau of Asian Research. (2021). *The Implications of China's Seizure of a U.S. Navy Drone - The National Bureau of Asian Research (NBR)*. The National Bureau of Asian Research (NBR). https://www.nbr.org/publication/the-implications-of-chinas-seizure-of-a-u-s-navy-drone/.

	Define vessel?	Define ship?	Circular "vessel" definition?[79]	Condition for being a "vessel" besides being in the water	Classify UxS as vessels or ships?
United States	Y	Y	N	Capable of transportation	Yes, in 2022 Commander's Handbook on the Law of Naval Operations, ship registration
United Kingdom	Y	Y	Y	Used for navigation	Yes, in International and Defence Committee meeting, ship registration
Australia	Y	Y	Y	Used for navigation	Yes, in a formal statement by the Australian Maritime Safety Authority
Canada	Y	Y	N	Capable of navigation	Yes, in Oversight of small Maritime Autonomous Surface Ships (MASS) Policy, legal precedent
New Zealand	N	Y	Y	Used for navigation	Yes, in a 2020 Interim Technical Note

Table 2: Summary of UxS Classifications

[79] This refers to whether the term "vessel" is used in its own definition.

<u>Recommended Research</u>

The research team identified several gaps related to defining UxS and recommends the following research questions to add clarity to international policy around UxS.

How will novel technology be integrated into existing policy? How will new policy be formulated to allow room for technological development?

While this research made clear that UxS can be considered vessels and/or ships despite definitional challenges in existing policy, questions remain about the extent to which this classification will apply. Certain UxS have a clear crewed counterpart, such as an unmanned cargo ship or frigate. Other UxS, however, will be novel technology in their appearance, use, and capabilities. It will be significantly more difficult to integrate UxS into existing policy when they do not have a crewed counterpart to which they can be compared. What this analysis has shown is that in FVEY countries, being labeled as a vessel does not necessitate a crew. What it has not shown is that all UxS, present and future, will be considered UxS by these nations. The extreme variability in these systems, much of it still unknown, will continue to pose legal and policy challenges.

What does it mean to "navigate" or to "transport?"

The Wave Glider can navigate without a means of mechanical propulsion and simply harnesses the wave energy surrounding it to move in its intended direction.[80] Technology is fundamentally changing the ways in which navigation happens and what it means to do so. Additionally, there is the question of whether the small sensors that the Wave Glider carries constitute "transportation." Seemingly simple terms leave ambiguity in how intentional navigation needs to be (to what extent is a device drifting with the waves "navigating"), by what means the navigation needs to occur (are there requirements for propulsion), and what degree of autonomy the navigation needs to occur at (does a remote control equate to an artificially intelligent craft). While a precedent has been set that UxS do indeed fall under the requirements of "navigating" and "transporting" enough to be considered vessels, New Zealand's decision to exclude UxS that are remote controlled shows that there will be much more nuance involved as modern technology emerges. Clear definitions of these terms will be necessary, as well as further classifications of UxS by degree of autonomy, networking capability, use, and a variety of other characteristics.

[80] Liquid Robotics, Inc., "The Wave Glider | How It Works."

How do non FVEY countries, especially U.S. adversaries, define UxS?

The ambiguity surrounding UxS can be taken advantage of by other nations to commit legally questionable actions. Without the protections given to crewed vessels and ships in UNCLOS, UxS are subject to unfair treatment by other hostile nations. The U.S. has already had two countries seize its UxS (China and Iran), with both countries claiming their actions were legal and justified. In future research, it would be interesting to uncover more about how these nations define UxS. If they do not consider UxS ships or vessels under their laws, UNCLOS would not apply. If they do, they were simply acting provocatively by seizing the UxS and taking actions they knew were legally ambiguous. While this report has shown that FVEY countries are setting a precedent of treating UxS as vessels legally, other nations may not be doing the same.

Conclusion

Climate mitigation requires identifying and quantifying sources and amounts of greenhouse gas emissions and UxS are already playing a significant role in environmental monitoring and data collection, including being equipped with high-performance sensors to monitor and map the most climate-damaging emissions. UxS are usually smaller and lighter than their crewed counterparts and, even if they rely on fossil fuels, they generally emit fewer emissions. However, to truly play a role in reducing emissions, UxS must move toward designs that are, ideally, electrified or, at a minimum, fueled with sustainable fuels as opposed to traditional high-emission fuels.

To enable these systems to best contribute to monitoring, mitigation and adaptation, gaps in governance structures must be addressed, particularly in the Arctic region where climate change is occurring faster than anywhere else on earth and countries are vying for valuable resources under melting sea ice. Related analysis shows the need for uniformity in defining UxS as vessels or ships for purposes of customary international law. This analysis is relevant for UxS used in climate change monitoring, mitigation, and adaptation and for other maritime uses.

Overall, these various systems can play a key role in helping scientists understand how the Earth is changing as well as mitigating against the effects of climate change caused by harmful GHG emissions through the usage of renewable and efficient technologies.