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Uncrewed Maritime Systems

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One of the most significant military changes thus far in the 21st century has been the development of unmanned (also referred to as *uncrewed*) systems. This technology has evolved rapidly – from toy remote-controlled cars to assets adapted and adopted by state military forces. As technology improved, the unmanned systems were not just on the ground, but in the air, on water and under water. The variety of unmanned vehicles is astounding, getting both smaller and larger. They now range from the size of a bumblebee to the size of a submarine.

Although the technology is still evolving, a significant stage in the development of unmanned assets is their integration into operations. The existing systems are now useful enough to support combatants in the field, and they are increasingly being tested and incorporated into fighting forces. In early October 2022, for example, the Royal Netherlands Army announced that it had deployed four armed Tracked Hybrid Modular Infantry Systems (or THeMIS) unmanned ground vehicles (UGV) to Lithuania with the Robot and Autonomous Systems (RAS) Unit for what military officials characterized as the first known Western operational experiment involving armed UGVs.[1] These systems can be outfitted with machine guns, grenade launchers and anti-tank missiles, and thus can serve as support for other forces. Even if unarmed these UGVs are useful because they can reduce the physical strain on soldiers by transporting supplies, including heavy weaponry, water and ammunition. The Estonian Defence Forces have already deployed the unarmed variants of the UGV for logistics support alongside Estonian soldiers in Mali as part of *Operation Barkhane*, a French-led counterinsurgency operation. Unarmed UGVs have also been used in Ukraine for casualty evacuations. And photos suggest that the Russian military has deployed the heavily armed Uran-9 robot tank to support units in Ukraine's Luhansk region.

The development of unmanned aerial vehicles (UAVs), unmanned surface vehicles/vessels (USVs) and unmanned underwater vehicles/vessels (UUVs) offers navies a new range of capabilities. As technology advances, unmanned systems will become more capable and, in most cases, more autonomous. As systems are developed for offence, there will need to be developments on defence. Defending against enemy forces will become more complicated as the systems and actors proliferate.

This article will briefly discuss examples of unmanned systems *in the maritime arena*, and point out the challenges and concerns inherent in the employment of these systems. The changes are occurring so rapidly that this article can only provide a snapshot of what is happening in the development and use of these systems. Note that the article will generally focus on the Atlantic/Western arena and not on developments by China. It will not focus on Canada – if you are interested in what the Royal Canadian Navy is doing with regard to these systems, please see

[1] Jared Keller, "NATO Countries are Getting Serious about Sending Armed Robots into Battle," Task & Purpose, 16 October 2022, https://taskandpurpose.com/tech-tactics/nato-unmanned-ground-vehicle-combat-robots-russia/

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Unmanned Aerial Vehicles

Over the past 20-25 years, unmanned aerial vehicles (UAVs) have been developed, adapted and adopted for military use. Where once they were simple reconnaissance tools, unmanned aerial vehicles/systems (UAV/UAS) – which some people refer to as drones – have taken on an array of sophisticated military applications. The use of armed American systems, like Predator and Reaper UAVs, in Afghanistan and Iraq (and Pakistan and Somalia) illustrated a real shift in military technology and use of unmanned systems.

Given that the recent conflicts in which the West/NATO has been involved – i.e., Afghanistan, Iraq and Syria – had little maritime emphasis, it is not surprising that most of the attention has been on UAV use by ground and air forces. Nonetheless, the benefits to maritime forces are clear. They offer enhanced maritime awareness, long-range surveillance extending situational awareness beyond the range of a ship's onboard sensors, target acquisition, air-borne early warning, aerial refueling,[2] and they can also be used for resupply and/or transport of materials. These capabilities traditionally required aircraft flying off carriers or helicopters based on warships but now UAVs offer ships some of the same benefits often at less cost and greater sustainability.

Utilizing UAVs for anti-submarine warfare is also becoming possible. In anti-submarine warfare, surface ships are trying to detect and track submarines, without putting the ship and crew in harm's way. This involves collecting information from ship sonars as well as from sonobuoys (buoys that can detect sounds underwater and transmit information about them) and dipping sonars operated by aircraft (usually helicopters in the case of Canada). There are indications that UAVs are being designed to undertake sonar dipping with a small diameter cable, which will relieve manned aircraft of the duty.[3]

In addition to increasing the range of surveillance, extending the reach of warships and taking on tasks related to anti-submarine warfare, there are other benefits of UAVs for navies. UAV capabilities can be dispersed broadly across a fleet. It is no longer the case that only large ships can have aerial capability – small ships can carry light UAVs, and large ships can carry large UAVs (or many small systems). The variety of systems means some warships can have several systems on board, and these systems could be launched simultaneously in multiple directions. In a combat situation this improved tactical picture could help ensure effective defence.

Thus far, the use of UAVs as weapons has not been discussed. While the Royal Canadian Navy/Canada does not utilize *armed* UAVs, other countries do. UAVs are becoming potent assets in conflict and will become even more potent in the future. This article is just examining uses that have a *maritime* element, but even so, examples of recent use in this environment can easily be found. In the conflict in Ukraine, for example, UAVs have been used to inflict damage on the headquarters of the Russian Black Sea Fleet and a naval airbase in Crimea. According to intelligence reports, these attacks have led the Russian Navy to relocate its submarines from

[2] The United States, for example, has used the MQ-25 Stingray to refuel jets flying from aircraft carriers.
[3] Alix Valenti, "Thales Working on Dipping Sonar Technology for UAVs," *Naval News*, 25 October 2022, Thales Working on Dipping Sonar Technology for UAVs - Naval News.

Crimea to a base in Novorossyisk, Russia.[4] As well as attacking Russian naval bases, Turkish medium-altitude long-endurance unmanned combat aerial vehicles (Bayraktar) were used by Ukraine to help re-take Snake Island and to sink Russian navy patrol boats – and possibly to distract the Black Sea Fleet flagship RFS *Moskva* before it was hit with missiles.[5] Russia has responded with Iranian-developed Shahed-136 drones to attack targets in ports in Ukraine (as well as targets in cities, but this article is focusing on the *maritime* elements). Although full details are not available, in an exercise off California in April 2021, as part of its Super Swarm project, the US Navy destroyed a surface vessel conducting a simulated attack with a swarm of drones to illustrate that it could be done and to develop tactics to defend against such an attack.[6]

In October 2022 workers on Norwegian offshore oil platforms noticed UAVs circling around the platforms. This led to concern that these UAVs could be used by Russia to target/damage energy production or transport facilities. In response, Norway deployed warships to patrol the areas around offshore platforms.[7] This illustrates the flipside of armed UAVs – as they can be armed to attack, they must be defended against. So, states are developing the means and training to defend against UAV attacks. For example, in late October 2022, a German Navy frigate successfully countered drones at short and very short range with a shipboard laser weapon system.[8]

Unmanned Surface Vehicles/Vessels

Like aerial vehicles, the technology relating to unmanned surface vessels (USVs) is developing rapidly. And, like UAVs, USVs can provide a variety of benefits to a naval fleet. They have already been used in mine and counter-mine operations, force and port protection and counter-terrorism/narcotics operations. There have been USVs exercises to track and attack submarines, conduct surveillance in support of maritime operations, map 'patterns of life' in a particular area (to establish out-of-the-ordinary behaviour), and conduct amphibious assault.

A growing use for USVs is in training exercises to defend against attack. Navy ships, particularly when in port or close to shore, are vulnerable to attacks from small fast explosive-laden boats, increasingly unmanned vessels. In this situation the time to identify a threat and react to it is very limited. To address this, USVs designed to mimic small fast attack boats have been used by many navies – including Canada's – to simulate an attack and train for a response.

Much of the early research on USVs focused on de-mining, an activity that puts both ships and personnel at risk. If de-mining can be conducted by USVs, this will lessen the threat to traditional assets. Progress has been made on these systems and several states have either developed or adopted them already. As an example, in early October 2022, a demonstration of a

[4] Hugo Bachega and James Gregory, "'Massive' Drone Attack on Black Sea Fleet – Russia," BBC News, 29 October 2022. According to "Uncrewed vessel washes up in Crimea," *Insurance Marine News*, 23 September 2022. Uncrewed vessel washes up in Crimea | Insurance Marine NewsTweet

[5] Bayraktar TB2 is a medium-altitude long-endurance (MALE) unmanned combat aerial vehicle (UCAV) capable of remotely controlled or autonomous flight operations. In general, the UCAVs are monitored and controlled by an aircrew in a ground control station, including weapons employment. It is manufactured by a Turkish company.

[6] Gidget Fuentes, "Fleet Exercise Includes Live Missile Shoot as Navy Pairs Crews with Unmanned Systems," *USNI News*, 20 April 2021.

[7] Mark Lewis, "Unidentified drones over Norway's offshore platforms fuel fears of Russian threat," PBS 23 October 2022, https://www.pbs.org/newshour/world/unidentified-drones-over-norways-offshore-platforms-fuel-fears-of-russian-threat

[8] "German Frigate Sachsen Engages Drones with Laser Weapon," *Naval News*, 27 October 2022.

USV to the UK Ministry of Defence successfully illustrated autonomous mine-hunting technology in real conditions off the coast of Scotland – i.e., differing depths, currents and tidal streams, and in simulated minefields seeded with mine-like objects.[9]

Another use of USVs is for patrol. A USV can patrol and monitor the ocean approaches continuously, collecting data on activity in the littoral regions. Australia is exploring the possibility, with industry and thinktanks, of converting manned patrol boats to USVs. Austal Australia was given a de-commissioned *Armidale*-class patrol boat to commence planning, modification, and test and evaluation of autonomous and remotely operated systems. This is part of the Patrol Boat Autonomy Trial (PBAT), an attempt to "establish robotic, automated and autonomous elements on a patrol boat, providing a proof-of-concept demonstrator, for optionally crewed or autonomous operations for the RAN [Royal Australian Navy] into the future."[10]

We can see how USVs are joining the order of battle by looking at recent events in both Yemen and Ukraine. Remote-controlled boats carrying explosives have been used extensively during the civil war in Yemen to attack Saudi (or United Arab Emirate) ships. For example, in 2017 an unmanned boat packed with explosives rammed the Saudi frigate *Al-Madinah* off Yemen, killing two sailors and damaging the ship.[11]

In the war in Ukraine, USVs have also made an appearance. In April 2022, the United States said it was supplying an unspecified number of "unmanned coastal defense vessels" to Ukraine.[12] In September 2022, the international media reported that one (and possibly two) improvised USVs, approximately the size of a kayak, washed up on the shoreline outside the Russian Navy base in Sevastopol, Crimea. (The vessel was not of the type that the United States provided.) Photographs of the craft show a surface drone made from commercial watercraft parts that was possibly laden with explosives. It was fitted with a camera, infra-red sensors, communications antenna, bow-mounted sensors and waterjet propulsion (similar in style to the propulsion of a Sea-Doo) for speed.[13] In October 2022, similar Ukrainian USVs (and UAVs were involved as well) carried out attacks on the Russian Black Sea Fleet again, reportedly damaging several ships. An interesting aspect of this attack is that the video feed from one of the USVs is available online for viewing.[14]

It is not clear what happened to the first craft found in September, and why it ended up on shore, but it is the first known example of such a vessel being used in the Black Sea as part of the war between Russia and Ukraine. As the second incident illustrates, it is probable that the USV was being used for targeting and/or attack (since it likely contained explosives). Given these USVs have a very low-profile, they would be a less risky, stealthy alternative to a UAV as they would

[9] "Elbit Systems UK's Seagull™ USV Achieves 100% Success Rate in Royal Navy's Mine Hunting WISEX Trials," Navy Recognition, 11 October 2022.
[10] "Austal to Conduct Patrol Boat Autonomy Trial for Royal Australian Navy," *Naval News*, 5 October 2022.
[11] Kyle Mizokami, "Suicide Strike on Saudi Frigate was a First Carried out by Drone Boat," *Popular Mechanics*, 21 February 2017.
[12] As noted in Kris Osborn, "United States Sends Drone Boats to Ukraine," Warrior Maven, Center for Military Modernization, 20 April 2022.
[13] See David Hambling, "Russia Finds Mystery Vessel on Crimean Beach: Is It a New Ukrainian Attack Drone?" *Forbes*, 22 September 2022; "Mysterious Uncrewed Vessel Washes Up in Russian-Occupied Crimea," *Maritime Executive*, 21 September 2022 [Mysterious Uncrewed Vessel Washes Up in Russian-Occupied Crimea (maritime-executive.com)]; "Uncrewed vessel washes up In Crimea," *Insurance Marine News*, 23 September 2022; H.I. Sutton, "Suspected Ukrainian Explosive Sea Drone Made From Recreational Watercraft Parts," *USNI News*, 11 October 2022.
[14] Tayfun Ozberk, "Analysis: Ukraine Strikes with Kamikaze USVs – Russian Bases Are Not Safe Anymore," *Naval News*, 30 October 2022.

be able to linger very low in the water so as not to be seen. Russia announced that it had destroyed the original vessel(s), undoubtedly because it carried explosives, but the second attack illustrated that there are more USVs in the Ukrainian arsenal.

Yemen and Ukraine are not the only theatres in which unmanned surface vessels have been used. The Iran Revolutionary Guard Corps Navy has developed fast surface attack vessels, and may have provided the Houthis in Yemen with USVs and the training to use them. It is interesting, however, that thus far these attack USVs tend to be adaptations of crewed boats and retain a place for a pilot, and therefore could also be used for other operations. This contrasts with the version found in Crimea which was specifically designed to be uncrewed, and its small size and low profile would make it difficult to observe and/or destroy.

In part to counter Iranian influence, the US Navy (USN) 5th Fleet established an unmanned systems and artificial intelligence task force in September 2021 to integrate new technologies into USN operations across the Middle East.[15] In cooperation with regional partners, Task Force 59 is based at operational hubs in Bahrain and Aqaba, Jordan, to integrate new unmanned systems and artificial intelligence (AI) into maritime operations. Task Force 59 has been set up to collect and use unclassified systems which simplifies the process of adapting collection methods and sharing information. Additionally, unlike many slow procurement systems, the task force has been given the mandate to try different unmanned systems and AI providers and quickly bring different platforms into the 5th Fleet.[16] According to Vice Admiral Brad Cooper, Commander of US Naval Forces Central Command, US 5th Fleet and Combined Maritime Forces, "[o]ur goal is a distributed and integrated network of systems operated with our partners to significantly expand how far we can see."[17] Cooper stated that "the United States and its allies want a force of 100 unmanned surface vessels patrolling waters from the Red Sea into the Persian Gulf" by summer 2023.[18] In January 2022, as part of the International Maritime Exercise 22, a large unmanned maritime exercise was held with more than 50 unmanned systems from 10 states. The goals were to connect these USVs and to create a unified picture – both successful.[19]

As new systems are developed by states, this raises the question of how naval forces will be able to act together to maximize the effectiveness of their systems. There have been, therefore, a number of naval exercises recently to practice working with other naval systems. In a one-day exercise on 7 October 2022, USN (and a US Coast Guard ship as well) and Royal Navy (RN) ships conducted a bilateral exercise, Phantom Scope, in the Arabian Gulf. This exercise featured the use of unmanned systems – three Saildrone Explorer USVs – and artificial intelligence to enhance

[15] USN 5th Fleet's operating area includes the Arabian Gulf, Gulf of Oman, Red Sea, parts of the Indian Ocean, 21 countries and the Strait of Hormuz, Bab al-Mandeb and Suez Canal.
[16] Sam LaGrone, "Navy Wants 100 Unmanned Ships Monitoring Middle East Waters by Next Year," *USNI News*, 11 October 2022.
[17] Vice Admiral Brad Cooper quoted in US Naval Forces Central Command Public Affairs, "US, UK Navies Conduct Unmanned Exercise in Arabian Gulf," 7 October 2022, https://www.navy.mil/Press-Office/News-Stories/Article/3183025/us-uk-navies-conduct-unmanned-exercise-in-arabian-gulf/
[18] As quoted in Sam LaGrone, "Navy Wants 100 Unmanned Ships Monitoring Middle East Waters by Next Year," *USNI News*, 11 October 2022.
[19] Xavier Vavasseur, "IMX 2022: The Largest Unmanned Maritime Exercise in the World," *Naval News*, 8 February 2022. This article provides a list of USV/UUVs involved, with photos. https://www.naval news.com/naval-news/2022/02/imx-2022-the-largest-unmanned-maritime-exercise-in-the-world/

maritime monitoring by crewed ships and operators ashore.[20] In this exercise, the sensors on the USVs were able to locate and identify training aides in the water and relay visual depictions to the command centres. Another bilateral exercise (Digital Shield) was conducted between the USN and Israel in September 2022 to focus on enhancing maritime awareness using unmanned systems, among other things. In this exercise, Devil Ray T-38 and Saildrone Explorer USVs were used.[21]

These exercises illustrate the desire among states to increase their ability to work together to utilize this new technology effectively. This must happen on a multilateral as well as bilateral basis. NATO launched the Maritime Unmanned Systems Initiative in October 2018 to promote the use of unmanned systems in the alliance's naval operations. NATO has also been conducting exercises for this purpose. In September 2022 two NATO exercises – Exercises Robotic Experimentation and Prototyping using Maritime Uncrewed Systems 2022 (REPMUS22) and Dynamic Messenger 2022 (DYMS22) – were conducted to test training, readiness and the interoperability of new maritime unmanned systems (MUS). These exercises included air, surface and sub-surface assets. Dynamic Messenger was "the first full NATO operational experimentation exercise that specifically focuse[d] on integrating unmanned systems into the maritime domain, and more specifically NATO Task Groups at sea."[22] More than 18 ships, 48 unmanned assets and 1,500 personnel from 16 NATO member states participated. Two of NATO's Standing Naval Groups were part of this initiative, as were private sector and academic representatives.

An extremely interesting USV project has been initiated in the United States. In the No Manning Required Ship (NOMARS) Program, the Defense Advanced Research Projects Agency (DARPA), in partnership with industry, is examining an entirely new design for ships, a 'clean-sheet approach.' They are designing ships assuming that there will be no humans on board, ever. For the first time in history, this means that all design requirements associated with humans can be eliminated – i.e., no air, no living spaces, no food preparation or storage spaces, etc. Along with this, however, comes the issue of maintenance. If there is no crew to perform maintenance, the ship needs to be reconsidered in terms of "power generation, propulsion, machinery line-up, and control schemes to ensure continuous functionality throughout a long mission in all weather, temperature, and sea states."[23] The ships – the prototype is named *Defiant* – will need to have redundancy, modularization and distributed hybrid power generation. This program is opening up the possibility for very different warships. The idea is to imagine, design and then demonstrate a completely unmanned ship that can illustrate performance and capability improvements, and that can operate alongside manned ships, or on its own.

[20] US Naval Forces Central Command Public Affairs, "US, UK Navies Conduct Unmanned Exercise in Arabian Gulf," 7 October 2022. https://www.navy.mil/Press-Office/News-Stories/Article/3183025/us-uk-navies-conduct-unmanned-exercise-in-arabian-gulf/

[21] "U.S. and Israel Complete Unmanned Exercise in Gulf of Aqaba," Media Release, NAVCENT Public Affairs, 22 September 2022.

[22] Tayfun Ozberk, "Dynamic Messenger 22: 'Unmanned' Systems Meet 'Manned' Assets," *Naval News*, 25 September 2022. Royal Navy, "Royal Navy leads "Game-changing" NATO tech experiments," 10 October 2022, https://www.royalnavy.mod.uk/news-and-latest-activity/news/2022/october/10/20221010-royal-navy-leads-game-changing-nato-tech-experiments.

[23] Defense Advanced Research Projects Agency (DARPA, "No Manning Required Ship (NOMARS) Program to Build, Test, Demonstrate First Ship: DARPA Selects Serco Inc. for Novel Design Named Defiant," Outreach DARPA, 22 August 2022, https://www.darpa.mil/news-events/2022-08-22

Unmanned Underwater Vehicles/Vessels

Unmanned underwater vessels (UUVs) are the most recent unmanned systems to be developed – although it should be noted that some civilian agencies have been using remote-controlled UUVs for years.[24] The technology is difficult for these systems – and effective communication in particular is challenging, but essential. It should be noted that there can be some overlap with the USV technology as states look to develop systems that can operate both on the surface and underwater. The Royal Navy/Royal Marines, for example, are seeking an Uncrewed Surface and Subsurface Vessel (USSV) prototype for maritime commando operations.[25] The stated need is for a vessel that can transition from surface to sub-surface while deployed so cargo/supplies can be transported to forward bases, remote islands, or into dangerous environments to reduce the threat to manned transport.

Despite the technical difficulties, the development and adoption of UUVs has been rapid. They are beginning to be used for a variety of missions. The USN's "Unmanned Undersea Vehicle (UUV) Master Plan," identifies the following missions:

- intelligence, surveillance and reconnaissance;
- mine countermeasures;
- anti-submarine warfare;
- inspection/identification;
- oceanography;
- communication/navigation network nodes;
- payload delivery;
- information operations; and
- time-critical strikes.[26]

In addition to these missions, a new role for UUVs has become apparent in recent months – monitoring and protection of underwater infrastructure to protect national security. In September 2022 the Nord Stream pipelines running under the Baltic Sea were sabotaged, disrupting gas flows from Russia to Western Europe (which had already been disrupted for political reasons). While answers to the questions of who did this and how have not been publicly answered, this incident magnified concerns that sub-sea infrastructure is vulnerable. States are working to develop ways to monitor and protect sub-sea communication cables. The French Navy, for example, conducted its first operation as part of its exploratory seabed control capability with a UUV in October 2022 (the HUGIN Superior deep-sea underwater drone).[27]

UUVs are already being adopted that can locate, track, identify, target and destroy enemy submarines or sea mines. Some UUVs have been developed to be launched from submarines. (So

[24] For example, the wreckage of one of the lost ships of the Franklin expedition was found by Parks Canada in September 2014 using a UUV.
[25] Inder Singh Bisht, "Royal Navy Seeks Unmanned Surface and Subsurface Vessel," The Defense Post. 5 October 2022, https://www.thedefensepost.com/2022/10/05/royal-navy-unmanned-vessel/
[26] US Department of the Navy, "The Navy Unmanned Undersea Vehicle (UUV) Master Plan," US Navy, 9 November 2014.
[27] "Mission CALLIOPE: First Seabed Control Operation," *SeaWaves Press*, 21 October 2022, Mission CALLIOPE: First Seabed Control Operation (seawaves.com)

far UUVs can be launched from submarines, but the recovery of them is still a work in progress.) Ironically, defensive UUVs will be necessary to counter UUV attack swarms. Submarines are designed to engage other submarines or other large assets, and they cannot expend their limited supply of torpedoes to deal with small, but possibly lethal, UUVs. Plus submarines do not tend to have close-in-weapons defence which makes them vulnerable to a small UUV. There is, thus, a possible need for single-use interceptor UUVs to be launched for the defence of submarines, perhaps to decoy incoming torpedoes and/or destroy them.

Like aerial and surface systems, as the technology develops, multiple types and sizes of UUVs are being produced. The USN UUV Master Plan divides them into four classes:

1. Man-portable: 25-100 lb displacement; 10-20 hours endurance; launched from small water craft manually (eg., Mk 18 Mod 1 Swordfish UUV);
2. Lightweight: up to 500 lb displacement; 20-40 hours endurance; launched from RHIB using launch-retriever system or by cranes from surface ships (eg., Mk 18 Mod 2 Kingfish UUV);
3. Heavyweight: up to 3,000 lb displacement; 40-80 hours endurance; launched from submarines;
4. Large: up to 10 long tons displacement; launched from surface ships and submarines.[28]

To give an illustration of the sizes now under development, Russia has developed a UUV that weighs about 100 metric tons, referred to as the Poseidon Status 6 or Doomsday Torpedo, an autonomous, nuclear-powered UUV capable of delivering both conventional and nuclear payloads.[29] Other countries are also working rapidly on developing and adopting all sizes of UUVs. For example, the USN is already deploying early models of its Razorback medium-sized UUV and is in the process of procuring an upgraded model. As well, the USN is in the process of developing five robotic Extra Large Unmanned Undersea Vehicles (XLUUVs) that can lay undersea mines, as well as prevent enemies from accessing waterways and coasts.[30] Although there have been delays and cost increases, all of these XLUUVs are scheduled to be complete some time in 2024.

In September 2022, the British announced that the Royal Navy had acquired three new REMUS 100 UUVs.[31] And, in a final example here, on the *Kormoran II*-class mine-hunting ships it is building, Poland will include an unmanned underwater capability to assist in sub-sea search and survey missions in the Baltic and North Seas.[32]

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[28] US Department of the Navy, "The Navy Unmanned Undersea Vehicle (UUV) Master Plan," US Navy, 9 November 2014.

[29] See Ryan Morgan, "Russia Activates 'Doomsday' Submarine Armed with Nuke Torpedoes," *American Military News*, 12 July 2022.

[30] The model is based on Boeing's Echo Voyager, with differences in batteries and payload. This project is experiencing problems with delays and cost overruns. Jonathan Lehrfeld, "Navy Behind Schedule, Over Budget on Robot Subs," *Navy Times*, 5 October 2022, https://www.navytimes.com/news/your-navy/2022/10/05/navy-is-behind-schedule-and-overbudget-on-robot-subs-report-says/

[31] Alie Peter Neil Galeon, "UK Royal Navy Procures Three Unmanned Underwater Vehicles," *Naval News*, 22 September 2022. REMUS 100 has a side-scan sonar which allows for autonomous underwater surveillance, and can cover a large area in missions that can last as long as 10 hours.

[32] "Kongsberg to Provide HUGIN AUVs and Related Systems to Polish Navy's Minehunters," *Naval News*, 12 October 2022. France is also considering the system. See "DGA Selects Kongsberg's Hugin AUV for the French Navy," *Naval News*, 21 October 2022. There is also discussion about Poland purchasing Saab's Double Eagle UUV

Considerations about Unmanned Systems

There are many considerations and challenges that are inherent in the development and adoption of most new military-use systems, and this is the case with unmanned technology. First, perhaps the most significant consideration is that in the near future these systems will go from simply being *unmanned* to being *autonomous*, and indeed as a few of the examples mentioned earlier illustrate, some autonomous systems are already in use. The difference is stark – consider the Predator drone strikes that the United States conducted during operations in Iraq and Afghanistan. At the time, these drones were operated by a human being sitting at a US Air Force base in the United States. The operator could observe a person or place in real-time through the Predator's camera. When ready, the operator pushed a button to fire on the target. Although there are variations within the category, an unmanned system is like this example – there is an operator in control who gives commands in real-time. An autonomous system, however, is generally pre-programmed to perform a certain task. Once programmed, it can go on its way without someone controlling it remotely. (Someone could be *monitoring* it, but they would not be controlling it.) The USN has been working on unmanned autonomous vessels for years, as have China and Russia, and all have made significant advances. For example, in early 2019, the USN's 40.2 metre (132 foot) Medium Displacement Unmanned Surface Vessel (MDUSV), *Sea Hunter*, became the first ship to navigate autonomously from San Diego to Pearl Harbor, Hawaii, and back. This was done without a single crew member onboard, except brief boardings by personnel from an escort vessel to check electrical and propulsion systems.

Related to increased autonomy are legal and ethical concerns about responsibility for mistakes or malfunctions. If an autonomous system goes awry and kills someone or a USV rams or sinks a civilian ship, the lines of responsibility/culpability and liability are unclear. As discussed below, this illustrates the need for policy and laws governing the use of autonomous systems.

Second, the navies of Western countries are all experiencing personnel shortages and using unmanned ships has the potential to solve this problem. In the long term, it is possible that unmanned systems will replace crewed warships. The US NOMARS program is a major step along this path.

Third, having said this, however, it must be said that 'unmanned/uncrewed' technology does not mean that there are no personnel involved. Unmanned systems require a team of personnel to operate them, to launch/recover them and to maintain them. The systems themselves may be unmanned but they have substantial support teams that go with them. The personnel who are responsible for operating and maintaining these systems will require different skill sets than the usual crews on warships – i.e., these are extremely technical assets and the crews will need to be proficient in electronics, computer software and hardware and cyber-security. Furthermore, recruiting personnel with skills in operating and maintaining the systems will be challenging in tight labour market conditions.

Alternatively, the systems can, and often are, maintained by the companies that manufacture them. But this means that warships (and naval bases) will need to accommodate industry representatives if the systems are maintained by the manufacturers. Aside from accommodations

for the ships. Joe Saballa, "Poland Buys More Advanced Naval Mine-Hunting Vehicles from Saab," The Defense Post, 21 October 2022.

and the cost of contracting-out, questions have been asked about the use of contract service providers in combat. These questions began when the United States started out-sourcing maintenance on important assets (and other services as well) in Iraq. For example there are questions of where worker loyalty lies (to the country they're serving or to the company that employs them), questions about whether corporate employees are willing to serve in combat zones, questions about application of the laws of warfare to non-state actors, questions about liability if things go wrong, etc.

Fourth, depending on the system, there *may* be cost savings to using unmanned systems. This could be the case in several aspects. First, depending on their size and complexity, the purchase price might be much lower than other assets. Thus, a warship can deploy many small UAVs for the price of a single helicopter.[33] Second, another cost saving could be human lives. Human losses could be reduced by utilizing an unmanned system in certain circumstances. If an unmanned system is used there is no risk to personnel if it sinks, crashes or is shot down. A third consideration is the financial cost associated with personnel. Personnel costs are significant – for Canada these costs make up a major part of the defence budget – so reducing personnel means reducing the costs of salaries, pensions and benefits. It should be noted, however, that unmanned systems are not always cheap – the US Navy Global Hawk surveillance drone shot down by Iran in June 2019, for example, cost more than a basic F-35 fighter jet.[34] As well, there has been controversy about the cost of the US XLUUVs which is now estimated to be (US) $621 million for five of them.[35]

Fifth, while lower costs sound good in theory, there is a downside to this as well. As has been seen recently, Russia has used swarms of UAVs to attack cities in Ukraine. It is rumoured that Russia has bought thousands of Iranian UAVs to use in its war in Ukraine because they cost only about (US) $20,000 each, a price which is much cheaper than regular military missiles.[36] The point here is that if these systems are relatively inexpensive, this will make them affordable not only to the militaries of powerful countries, but also to smaller states. Whereas a small state might not be able to buy fighter jets or submarines, it may be able to buy lethal unmanned systems. These systems may not produce the effect of a single large weapon, but they can kill, maim and destroy just the same. As well, if the price is low, non-state actors such as insurgent groups, criminal organizations and terrorists will be able to afford the systems. This will increase the number of threat actors. Military forces will now have to protect themselves not just from other state-based forces, but from any individual or organization that can afford to buy, arm and operate an unmanned system.

Sixth, depending on the ships on which they are deployed, there may be challenges to find space for storage of large unmanned systems. Some of the larger UAVs have been built to have folding wings or blades so they can be accommodated in existing hangars, but others have not. Like most technology, these systems cannot be left exposed to salt water and salt air so they must be accommodated somewhere to avoid damage to the systems.

Seventh, there may be challenges integrating the data these systems generate with a ship's

[33] See Constantine Atlamazoglou, "NATO Navies are Teaming up for the First Time to Practice Using Drones to Hunt Submarines and Other Undersea Threats," *Business Insider*, 21 October 2022.
[34] "The Drone Iran Shot Down Was a $220M Surveillance Monster," *Wired*, 20 June 2019.
[35] Jonathan Lehrfeld, "Navy behind Schedule, Over Budget on Robot Subs," *Navy Times*, 5 October 2022.
[36] See Aaron D'Andrea, "'Game-changing' Drone Warfare in Ukraine May Tee Up New Phase of Conflict: Official," Global News, 21 October 2022.

combat management system and data from other sources. These new systems are proficient at gathering data, but this data is of little use if it cannot be accessed. It can be difficult to integrate data if one system has advanced technology (UAVs/USVs/UUVs) and another legacy system does not. There must be a way to collect the data, transmit it and analyse it. This means that navies will face growing pressure to update onboard ship systems and utilize the latest data analytics technologies to process incoming sensor data. We likely will see navies working toward the adoption of AI systems to analyse data.

Eighth, as different navies develop their own systems, there will be increasing challenges for allied and/or friendly states to ensure that their systems are compatible and interoperable. Not only must the unmanned systems communicate with their state's ships, they must communicate with each other, and the systems of other allied/friendly states. Thus in the West we are already seeing increased NATO exercises focusing on this, as noted earlier. And, of course, along with this will be concerns about security of the systems. The systems rely on complex computer programs and will need to be supplemented with additional layers of cyber-security to protect against hacking. There have been numerous examples of ships that have had their GPS navigation systems spoofed – i.e., the coordinates have been altered – and ensuring that this does not happen to unmanned/autonomous systems will be crucial.

Ninth, as more unmanned technology gets adopted by navies – and indeed all military services – states will need to develop policy guidelines about how, where and why they will use them.[37] Collaboration with industry and academics as well as governments will need to happen to develop operational concepts and doctrine and promote the integration of these systems into operations. As well, alliances will need to develop common policies, and it would be useful to write international rules about the systems as they are being adopted. This technology will have implications for warfare, and in the past the development of technology with major influence on the conduct of warfare led to international agreements on the use and exploitation of the technology – the Hague Conventions of 1899 and 1907 and the Nuclear Non-Proliferation Treaty for example.

Tenth, as these systems proliferate, their use will complicate the operations of existing capabilities – both civilian and military. How will UAVs avoid civilian aircraft? Will air traffic controllers ensure that there is no conflict between jets arriving at a civilian airport and a military UAV that is launched in the vicinity? In other words, what will be done about air traffic management? What about deconfliction of underwater boats. Right now there is a system of waterspace management so states know where the submarines of friendly states are if they are in local waters. This is to avoid collisions. How will UUVs be deconflicted with submarines? Or will UUVs and USVs have sophisticated enough systems that they can avoid collisions? These questions will need serious consideration.

Conclusions

This article has only provided a brief snapshot of developments relating to unmanned systems. Changes are occurring rapidly in all environments – in the air, on the surface and under water. There are new developments almost every day. What is important here is not the specific details

[37] Australia's Patrol Boat Autonomy Trial (PBAT) is an example in that it has specifically announced its larger aims with the project. "Austal to Conduct Patrol Boat Autonomy Trial for Royal Australian Navy," *Naval News*, 5 October 2022.

of the unmanned assets, but how they affect naval forces in structure and employment. In terms of structure, these systems have already led to some organizational changes of naval forces. For example, in October 2022 South Korea announced that its naval headquarters will undergo a reorganization in which its three numbered fleets will be replaced with a Maritime Unmanned Forces Command. This command will consist of an unmanned surface vehicle flotilla, unmanned underwater vehicle flotilla and unmanned aerial vehicle flotilla.[38] Other countries will need to consider changes to their organizational structures as well. These systems may give support to the call for more distributed fleets – i.e., many small assets versus a small number of large assets.

The changes do not end there. These systems will not only affect the fleet assets and the organizational structure of navies, they will also affect procurement, personnel and training. They will affect budgets. The USN's proposed FY2023 budget requests (US) $549.3 million in research and development funding for large and medium USV-enabling technologies and (US) $60.7 million in additional funding for UUVs.[39] These numbers will continue to grow. According to some estimates, by 2030 sales of just UUVs are projected to increase 150% from the current (US) $4 billion.[40]

In terms of employment, the fact that these systems are rapidly entering into the naval order of battle will affect how battles are fought. The array of threats to naval forces has increased. There will still be enemy warships, missiles, torpedoes, pirates and criminals but now there is an additional smorgasbord of systems unfriendly actors can use to threaten naval forces.

These systems are here to stay. They will become more sophisticated and more ubiquitous as time passes. How navies adopt and react to them will define naval warfare in the future.

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[38] Juho Lee, "ROK Navy Announces Major Reorganization," Naval News, 31 October 2022.

[39] Congressional Research Service Report, "Navy Large Unmanned Surface and Undersea Vehicles: Background and Issues for Congress," 18 October 2022. Or see "Report on Navy Large Unmanned Surface and Undersea Vehicles," *USNI News*, 21 October 2022.

[40] Citing Angelos Tsereklas, managing director of SOTIRIA Technology, which creates underwater intelligence and security products. In Constantine Atlamazoglou, "NATO Navies are Teaming up for the First Time to Practice Using Drones to Hunt Submarines and Other Undersea Threats," *Business Insider*, 21 October 2022.