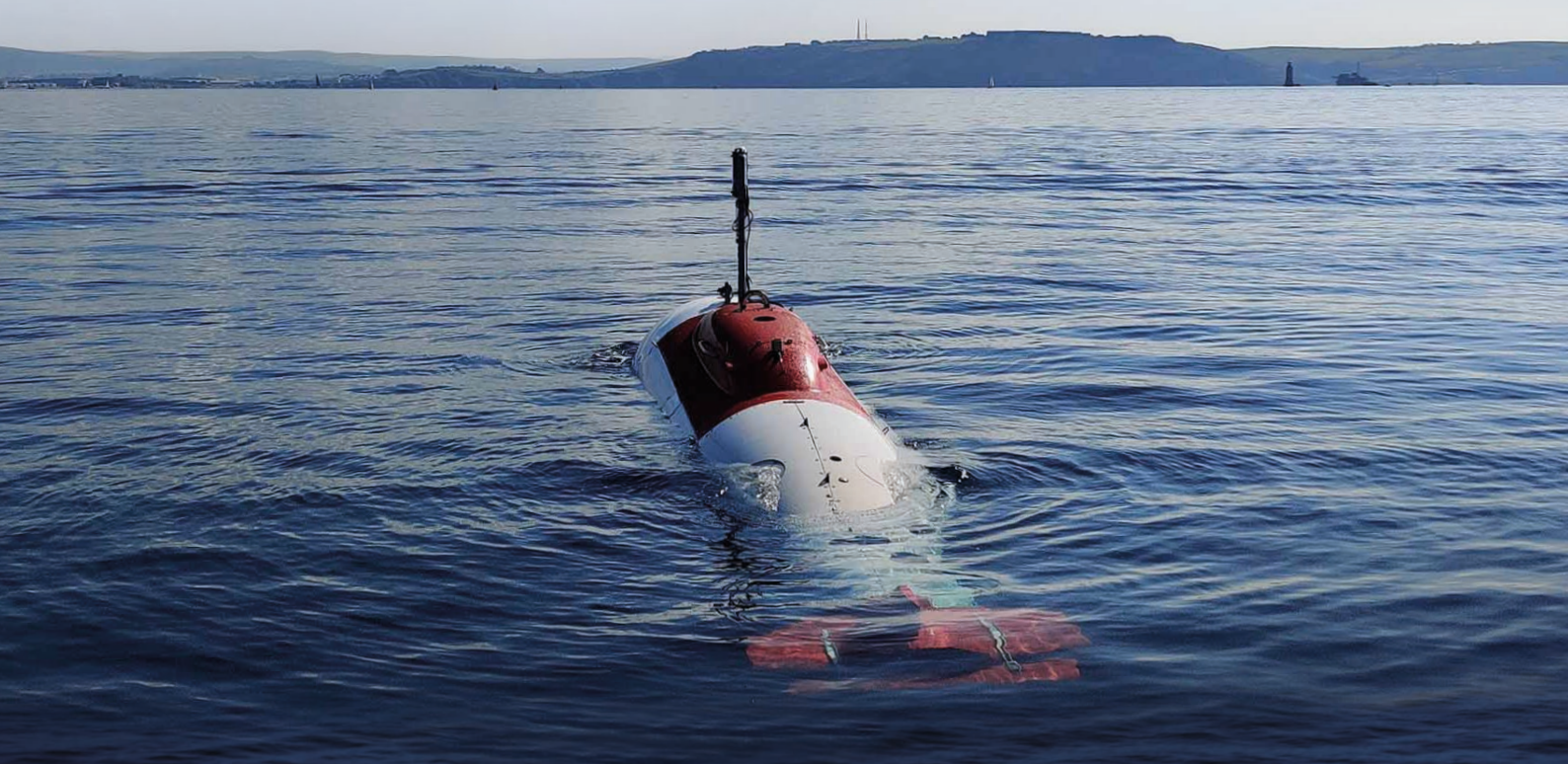
DRONE WARS

THE NEXT WAVE

The use of military drones in the world's oceans



Drone Wars UK is a small British NGO established in 2010 to undertake research and advocacy around the use of armed drones and other military technologies.

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Written by Peter Burt
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Design by Chris Woodward
www.chriswoodwarddesign.co.uk

Drone Wars UK,
Unit 34, The Wincombe Centre,
Shaftesbury, SP7 9QJ

www.dronewars.net
info@dronewars.net

Cover image: MSubs S201 XLUUV is being trialled by the Royal Navy **Credit:** Royal Navy

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1 Introduction

In October 2020, hair-raising scare stories appeared in the UK's tabloid newspapers reporting that an alleged Russian 'spy boat' had been found off the coast of the Scottish island of Tiree. The uncrewed solar powered craft was said by naval sources to be a clone of the US Liquid Robotics *Wave Glider* sea drone and there was speculation that it may have been monitoring submarine movements off the coast of Scotland.[1]

Although we usually tend to think of drones as small uncrewed aircraft flying in the sky, uncrewed 'drone boats' and submersible underwater drones have long been in existence and are increasing in their military importance. Networks of such drones are now being used by the larger military powers to gather data from the world's oceans – particularly in politically and militarily sensitive regions. While these drones are said to be used to gather hydrographic data, there is strong suspicion that the data collected will have dual-use functions in both oceanographic research and anti-submarine warfare.[2]

The world's oceans play an essential role in the global economy, with shipping representing 90 per cent of international trade in raw material and manufactured goods.[3] The seas are also an important component of the energy economy, as a source of offshore oil, gas, and wind power and also in terms of energy transfer, with tankers transporting more than half of the world's oil and seabed electricity interconnectors and gas pipelines also playing a key role. Other seabed infrastructure includes submarine telecommunications cables which transmit the vast majority of the world's data and are essential for routing internet traffic.

Sabotage of the Nord Stream gas pipelines in the Baltic Sea in September 2022 showed that undersea infrastructure is now a target during war fighting. Both offensive and defensive operations in this area are emerging as an important

1 Joe Davies: 'Searching for submarines? Unmanned US 'spy ship' powered by solar energy and designed to avoid detection is found off the coast of Scotland'. Mailonline, 10 October 2020. **https://www.dailymail.co.uk/news/article-8827043/Unmanned-spy-ship-powered-solar-energy-designed-avoid-detection-Scotland.html**

2 H.I. Sutton: 'Underwater Drone Incidents Point to China's Expanding Intelligence Gathering'. RUSI Commentary, 15 January 2021. **https://rusi.org/explore-our-research/publications/commentary/underwater-drone-incidents-point-chinas-expanding-intelligence-gathering**

3 'Shipping and World Trade: World Seaborne Trade'. International Chamber of Shipping. **https://www.ics-shipping.org/shipping-fact/shipping-and-world-trade-world-seaborne-trade/**

element of naval activity alongside more traditional roles such as upholding navigation rights, securing maritime trade routes, and undertaking combat operations against crewed ships and ports. Increasingly drones and uncrewed craft are being used for such operations.

This study reviews the development of maritime drones – drones operating on, under, or over the ocean – by the world's major military powers and in particular, details the UK's efforts to develop maritime drone capabilities. Importantly, it also examines three specific case studies (the Black Sea, the Arabian Gulf, and the South and East China Seas) where maritime drones have already been deployed and are playing an important role in naval force projection.

For the purposes of this study we are defining 'maritime drones' as any remotely operated or autonomous vehicle which operates in the maritime domain: either on the surface (sometimes known as uncrewed surface vehicles, or USVs), underneath the surface (underwater uncrewed vehicles, or UUVs), or overhead in the sky above the sea (uncrewed aerial vehicles, or UAVs). Not all maritime drones fit easily into one of these categories: for example, some glider drones can loiter at depth underwater and then surface to transmit data,[4] and other drones are able to operate in more than one domain, such as the *C-Ray* amphibious drone which can operate on land or water,[5] and the Flying Sea Glider under development by the US Office of Naval Research, which is intended to fly into the water and then turn into a subsurface vehicle.[6] These systems can be either remotely operated by a human controller, or operate autonomously through computer control systems, or both: switching between human and autonomous operation depending on the role they are playing and the situation they are in.

US Naval Forces Central Command (NAVCENT) began operating the Saildrone Explorer unmanned surface vessel (USV) in the Arabian Gulf in Jan 2022 **Credit:** US Navy

4 David B. Larter: 'With the submarine threat on the rise, the US Navy looks to autonomous water sensor drones'. Defense News, 17 February 2021. https://www.defensenews.com/naval/2021/02/17/with-the-submarine-threat-on-the-rise-the-us-navy-looks-to-autonomous-water-sensor-drones/

5 'Prehistoric sea creature-like robot can navigate surf, crawl up onto the beach'. Military Times, March 2023. https://www.militarytimes.com/video/2023/04/10/prehistoric-sea-creature-like-robot-can-navigate-surf-crawl-up-onto-the-beach/

6 Joseph Trevithick: 'The US Navy Has Created Its First Ever Underwater Drone Squadron'. The Drive, 29 June 2019. https://www.thedrive.com/the-war-zone/14733/the-us-navy-has-created-its-first-ever-underwater-drone-squadron

2 | Background and context

Explosive-laden boats were first used in warfare as long ago as 1863 in the American Civil War, and 'fireships' – ships set on fire and allowed to drift into enemy fleets – have been used in naval warfare since ancient times. Uncrewed ships were used by the military in the 1920s as remote controlled target craft, and later in World War II for minesweeping.[7] The first UUV was developed in the 1950s, when the University of Washington developed the Special Purpose Underwater Research Vehicle (SPURV) to collect oceanographic data and conduct research in Arctic waters.[8] Subsequently UUVs have been widely used in oceanographic research and in the offshore energy and construction sectors, where they are routinely used to survey and inspect underwater infrastructure and undertake maintenance functions. The US Navy began using UUVs in the 1990s to detect and disable mines, and the first wartime use of a UUV reportedly took place during the 2003 Iraq War when a *Remus* UUV was used to help clear mines from the area around the port of Umm Qasr.[9]

Maritime drones are a fraction of the cost of a conventional destroyer or submarine and represent a new vision of naval warfare that exchanges small numbers of high-value military assets for large numbers of cheaper, flexible, and simpler platforms which, working together in co-operation, have a greater overall capability. According to this vision, the vehicles would be modular, able to carry a number of payloads such as weapons, sensors, or smaller drones depending on the mission, and work as a connected network using artificial intelligence computing methods to stay in touch with other members of the fleet and with human controllers. An adversary would be overwhelmed with a multitude of small targets instead of a few large warships.

Such drones can gather information about the ocean more cheaply than larger crewed vessels, and may also be able to access areas that would be too

7 H. I. Sutton: 'A brief history of Explosive Boats'. Covert Shores, 22 February 2017. http://www.hisutton.com/Explosive_boats.html

8 Salimzhan A. Gafurov and Evgeniy V. Klochkov: 'Autonomous Unmanned Underwater Vehicles Development Tendencies'. Procedia Engineering. Proceedings of the 2nd International Conference on Dynamics and Vibroacoustics of Machines, 15-17 September 2014. Vol 106, p141–148. https://www.sciencedirect.com/science/article/pii/S187770581500942X

9 'The History of Underwater Drones'. Droneblog. https://www.droneblog.com/the-history-of-underwater-drones/

shallow or narrow for a larger ship. They are not bounded by the limits of human personnel and can undertake assignments that humans find demanding, such as deep diving or an extended submarine mission. They are also more easily able to loiter undetected than a larger ship, allowing data to be collected over a longer time period, and can also allow potentially dangerous objects to be examined remotely, reducing risks. As such, they have a number of potential military roles (see Table 1).

Table 1: Military roles of maritime drones[10]

Intelligence gathering, surveillance, and reconnaissance (ISR).
Time-critical strike.
'Probing' into hostile waters.
Mine-hunting.
Anti-submarine warfare.
Communication relaying.
Force protection against special operations forces and divers.
Oceanographic mapping and research.
Surveying, maintenance, or sabotage of underwater infrastructure.
Underwater salvage.
Political messaging to show domination or defiance.

Within the world's vast oceans, certain locations are particularly strategically important for both military and civilian purposes. These include the Arabian Gulf, the Red Sea, areas around disputed islands in the South and East China Seas, the Greenland-Iceland-UK Gap, the Baltic Sea and the English Channel. These areas often represent choke points and are both crowded with marine traffic and focal points for concentrations of underwater infrastructure. Drone networks are an attractive option for military planners when undertaking surveillance and reconnaissance operations in such areas.

Although it is sometimes claimed that oceans are an 'uncluttered' setting, with relatively few civilians and civilian objects and a correspondingly lower risk of harm to civilians from automated weapon systems, it should be remembered that increasingly autonomous technologies are likely to be found in both these more cluttered areas as well as the relatively empty parts of the marine environment.

Some limitations facing maritime drones

While advocates argue there are real advantage in the use of maritime drones, there are important factors that limit the use of drones at sea. Ocean currents and strong winds, the presence of other ships bringing the risk of collision, and the sensing of the surrounding environment are all more challenging when operating maritime drones than with conventional airborne drones. Power, communication, and navigation are particularly acute problems, especially for drones operating underwater.

10 'The Weaponization of Increasingly Autonomous Technologies in the Maritime Environment: Testing the Waters'. UNIDIR, 31 August 2015. https://www.unidir.org/publication/weaponization-increasingly-autonomous-technologies-maritime-environment-testing-waters

Power and energy density are a particular challenge when operating drones at sea, and limitations in power generation and storage are currently the main obstacles holding back the development of uncrewed underwater vehicles. Power factors limit the endurance and speed at which a drone can travel, and even under ideal conditions, military drones may only be able to spend no more than a day underwater and move at just a few knots. This means that they will need to be recovered by a crewed ship for recharging or be left to drift with the ocean currents, which may effectively mean treating them as disposable systems if a recovery ship is not able to retrieve them.

Maritime drones are often powered by Lithium-ion Fault Tolerant (LiFT) batteries which have a high energy density, and research is actively under way into improving the lifetime, energy density, safety, and charging speed of such batteries. An alternative approach is to enable the drone to recharge at an underwater charging station, and innovative proposals have been put forward for underwater charging stations which can harvest energy by exploiting temperature differences between warmer water at the ocean surface and colder water deeper down.[11]

Unpowered glider craft employ variable-buoyancy propulsion which causes them to repeatedly sink to depths of as much as 1000 metres and then rise to the surface again by inflating and deflating a reservoir filled with pressurized oil. With the assistance of large wings, this allows them to glide forward and operate for months on end, travelling over considerable distances. However, they are not fast or agile and are only suitable for tasks where they can be left to drift and operate alone.

Several factors hinder communication between the drone and its controller and other systems when operating underwater. Electromagnetic radiation techniques such as radio waves are not suitable for carrying out underwater communication as they become distorted and delayed when travelling through water. Even very low frequency radio waves, which require large antennae and a high transmission power, can only pass through sea water to a depth of around 20 metres. Optical techniques such as Lidar (which operates on the same principle as radar, using laser light instead of radio waves) do not suffer from such high attenuation but are prone to scattering. To communicate effectively via radio, an underwater drone will need to surface periodically to receive and transmit signals or return to a home base to download data.[12]

Uncrewed underwater vehicles can use acoustic waves to communicate underwater. Acoustic waves move relatively slowly through water and their transmission is delayed by a couple of seconds, posing difficulties for time-critical communication. The bandwidth available for communication is limited and underwater acoustic communication is also hindered by propagation and reflection, refraction, and fading and absorption of the signal. These conditions scatter and degrade the signal, making underwater communication difficult and prone to delay. At present acoustic communication can be used over operationally relevant distances, but only at low bandwidth. Short range communications of higher capacity can be based on LED or laser systems, and radio aerials or towed arrays – floating towed radio transceivers – can be used to communicate when at or near the surface.

11 Jeremy Hsu: 'These Underwater Drones Use Water Temperature Differences To Recharge'. IEEE Spectrum, 3 September 2020. **https://spectrum.ieee.org/renewable-power-underwater-drones**

12 Lokesh Bommisetty, Samskruthi Gaddam, Nomula Prakash Reddy, Shaik Basharath and Bharath Are: 'CDMA for Underwater Acoustic Communication'. Arxiv, 20 November 2021. **https://arxiv.org/pdf/2111.10581.pdf**

For similar reasons standard methods of navigation such as GPS do not work underwater. UUVs may use acoustic positioning techniques, but these face the same problems as acoustic communication because they use the same systems.

The difficulties in maintaining communication with drones operating underwater makes autonomous systems, able to operate independently of external human control, an attractive military option. Autonomous operation also has advantages in terms of secrecy and stealth, and reduces opportunities for jamming or hacking of the system, but has the down side of limiting opportunities for mission updates and locating, tracking, and status monitoring of the drone.[13]

13 'The Weaponization of Increasingly Autonomous Technologies in the Maritime Environment: Testing the Waters'. UNIDIR, op cit.

3 The major military powers and maritime drones

China, Russia and the US have a highly competitive relationship in the field of military artificial intelligence, uncrewed systems, and autonomous technology, and are closely watching each other's moves in this respect. Each nation is actively developing such capabilities, including systems for use in the maritime domain, with Russia lagging somewhat behind China and the US. This section will briefly examine the current state of development of maritime drones by the three major global military powers. However, when reading this section it should always be remembered that the release of information about emerging military capabilities is carefully controlled by governments, and that they will publicise certain programmes to further their own purposes while ensuring that other sensitive programmes remain secret. The following review is based on open source information and is therefore unlikely to represent a fully comprehensive assessment of capabilities.

United States of America

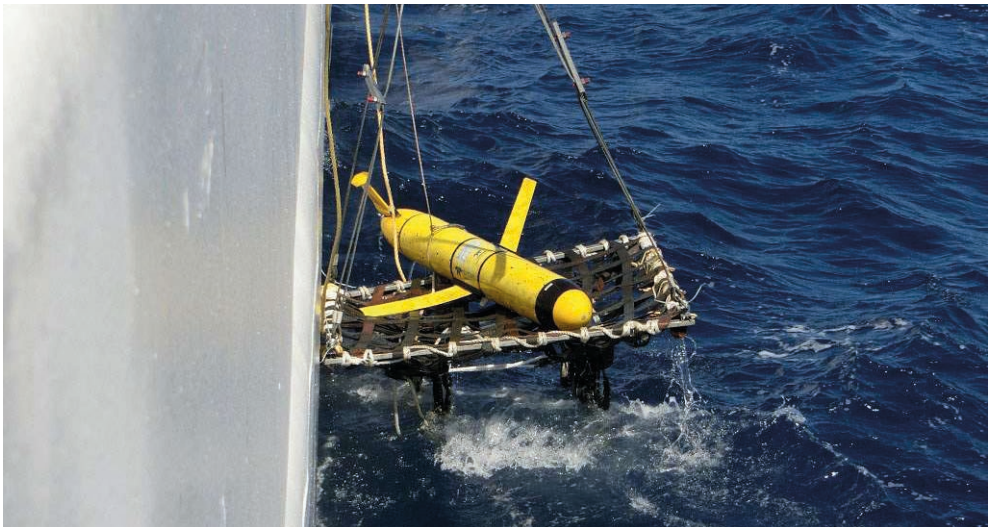
The US Navy sees autonomous uncrewed surface and subsurface vessels as important components of its future forces, and in 2019 made a budget request for $US 3.7 billion for future autonomous uncrewed vehicle programmes.[14] Different types, classes, and sizes of vessels will host a variety of sensors and payloads allowing them to conduct a range of missions. The US Navy hopes eventually to operate a widely dispersed but interconnected fleet with a mix of crewed and uncrewed platform types. Over the last decade the US has been experimenting with uncrewed maritime drones and is now beginning to introduce them into military operations.

The US Navy first experimented with sea-launched uncrewed aircraft from aircraft carriers in 1969 during the Vietnam War. More recently the experimental Northrop Grumman X-47B drone was built to test and demonstrate an uncrewed air system and in 2013 was successfully launched from and landed on an aircraft

14 Leona Alleslve: 'NATO Anti-Submarine Warfare: Rebuilding Capability, Preparing For The Future'. NATO Parliamentary Assembly Science and Technology Committee, 13 October 2019. https://www.nato-pa.int/download-file?filename=/sites/default/files/2019-10/REPORT%20150%20STC%2019%20E%20rev.%201%20fin%20-%20ANTI-SUBMARINE%20WARFARE.pdf

carrier deck. The Boeing MQ-25 *Stingray* drone was eventually developed as the US Navy's first carrier-based uncrewed aircraft, operating as a refuelling tanker with a secondary ISR role. The Navy plans to buy more than 70 such drones, expanding its role and gaining operating experience through the 2020s and in future decades flying more capable aerial drones from aircraft carriers.[15] Experiments have also been conducted with MQ-9A *Reaper* drones to drop sonobuoys (small buoys with a sonar sensor that are dropped from aircraft or ships) at sea to assist with submarine hunting.[16]

The US Navy has been deploying uncrewed Littoral Battlespace Sensing Gliders – an uncrewed boat – operationally at sea since 2012. The glider is an autonomous reconnaissance sensor platform used for gathering oceanographic data.[17] In 2016 a Chinese Navy vessel seized one of the gliders in the South China Sea close to the Philippines. The glider was subsequently returned, with China claiming it had been a hazard to navigation.



A littoral battlespace sensing-glider (LBS-G) survey drone is deployed from a US Naval Oceanographic Office vessel **Credit:** US Navy

The US Navy's Unmanned Systems Directorate, or N99, was stood up in September 2015 with the task of assessing emerging technologies and applying them to uncrewed platforms,[18] and in February 2016 the Pentagon announced plans to spend $600 million over the next five years on the development of uncrewed underwater systems.[19]

In April 2021, the US 3rd Fleet conducted the Unmanned Systems Integrated Battle Problem 21 exercise in the Pacific Ocean to gain experience of integrating uncrewed systems into mainstream fleet operations. In September 2021 a special experimental unit, Task Force 59 was established with US Naval Forces Central Command in Bahrain with the objective of integrating uncrewed systems and AI into marine operations in the Middle East (see case study 2 below).[20]

15 David Axe: 'The U.S. Navy Is Finally Getting Carrier Drones. It Only Took 60 Years'. Forbes, 2 November 2021. **https://www.forbes.com/sites/davidaxe/2021/11/02/the-us-navy-is-finally-getting-carrier-drones-it-only-took-60-years/**

16 David B. Larter: 'Off the California coast, the US Navy tests hunting subs with an aerial drone'. Defense News, 18 January 2021. **https://www.defensenews.com/naval/2021/01/18/off-the-california-coast-the-us-navy-tests-hunting-subs-with-an-aerial-drone/**

17 'Littoral Battlespace Sensing Glider (LBS-G)'. Teledyne Brown Engineering. **https://www.tbe.com/what-we-do/markets/maritime-systems/current-programs/littoral-battlespace-sensing-glider**

18 N99 was subsequently closed in January 2017 as part of a wider move within the US Navy to move unmanned systems into technology development or domain-based warfare directorates.

19 Marjorie Greene: 'Unmanned Systems: A New Era for the U.S. Navy?' CIMSEC, 18 July 2016. **https://cimsec.org/unmanned-systems-new-era-u-s-navy/**

20 Richard Scott: 'Ghost Fleet'. Jane's Defence Weekly, 26 January 2022. **https://emagazines.janes.com/webviewer/#janesdefenceweekly26january2022/ghost_fleet** [subscription]

The highest profile uncrewed vessel yet developed for the US Navy is the *Sea Hunter* – an uncrewed ship that can cross the Pacific. Developed by the Defence Advanced Projects Agency (DARPA) and the Office of Naval Research (ONR) through the joint Anti-Submarine Warfare Continuous Trail Unmanned Vessel (ACTUV) programme, *Sea Hunter* was delivered by a Leidos-led industrial consortium and is a demonstrator version of a medium sized uncrewed ship that can run autonomously for 60 – 80 days at a time. Although focused mainly on submarine tracking and trailing, the US Navy hopes to use *Sea Hunter* for a range of mission types and the ship has taken part in a number of fleet exercises to develop tactics and techniques for crewed and uncrewed operations. *Sea Hunter* came into operation in 2019 and a second similar ship, *Sea Hawk*, was completed in 2021.[21]

Sea Hunter and *Sea Hawk* are assigned to the US Navy's Surface Development Squadron 1 (SURFDEVRON) which was set up to trial and develop a concept of operations for uncrewed vessels. Elsewhere in the Department of Defense the Strategic Capabilities Office set up 'Ghost Fleet Overlord' to research into the development of large uncrewed surface vessels. Two former commercial supply vessels – the *Libby L McCall* and the *Riley Claire* (renamed as *Ranger* and *Nomad*) – were adapted as test beds for autonomous and communications technologies. Among the tests conducted was the launch of a long range missile from *Ranger*. The two ships have now been transferred to SURFDEVRON for further tests along with two further USV ships, *Mariner* and *Vanguard*, and there are plans to expand the unit's fleet with more ships and prototypes.

Sea Hunter is a US Navy autonomous unmanned surface vehicle (USV) launched in 2016 by DARPA, now operated by US Office of Navy Research **Credit:** US Navy

The US Navy is also planning to develop a low cost Medium Unmanned Surface Vehicle (MUSV), with a reconfigurable mission capability which will be achieved using modular payloads – initially for intelligence, surveillance and reconnaissance and electronic warfare (EW) systems. MUSVs will be capable of semi-autonomous operation, with operators in-the-loop or on-the-loop. In July 2020 the Navy awarded a $34 million contract to L3 [Harris] Technologies for development of a MUSV prototype, with options to procure up to eight further ships.[22]

21 Richard Scott: 'Ghost Fleet', op cit.

22 Ronald O'Rourke: 'Navy Large Unmanned Surface and Undersea Vehicles: Background and Issues for Congress'. Congressional Research Service, 20 December 2023, P12-23. **https://sgp.fas.org/crs/weapons/R45757.pdf**

DARPA is also working on a No Manning Required Ship (NOMARS) project to explore new technologies and designs for uncrewed ships and develop vessels that are capable of operating missions for months at a time with no human support outside annual maintenance cycles. Designs will not need to address crew safety or comfort, resulting in a number of perceived advantages in size, payload, and power factors.[23]

As well as surface vessels, the US Navy is also seeking to develop underwater drones and has set up an equivalent unit to SURFDEVRON to experiment with undersea systems. Unmanned Undersea Vehicle Squadron One (UUVRON 1) was established in September 2017 to test underwater drones and develop their operational concepts. As of September 2021 the squadron was operating with two Large Training Vehicle (LTV) test units, an extra-large unmanned underwater vehicle (XLUUV) prototype and two *Razorback* medium sized drones.[24]
The Navy has also developed the *Snakehead* Large Displacement Unmanned Undersea Vehicle (LDUUV), which can be launched and recovered underwater from submarines for reconnaissance, monitoring, and intelligence-gathering tasks. Large underwater drones such as this could potentially carry weapons or electronic warfare payloads, or possibly be employed on autonomous resupply tasks.[25] However, the *Snakehead* programme is currently unfunded, and the US Navy is instead looking to identify commercially available LDUUVs that could be rapidly fielded and deployed at scale – possibly as early as 2024.[26]

The US Navy is planning to reduce submarine numbers during the 2020s and plans to employ uncrewed systems to undertake some of the work formerly done by crewed submarines. In the long term the Navy's 30-year shipbuilding plan envisages a fleet with 18 to 51 XLUUVs, intended to have the capability to deliver multiple payloads at extended ranges. The Navy recently began testing its first Boeing *Orca* XLUUV with the intention that the drone will commence operations in 2026.[27]

The NATO military alliance is also showing an interest in naval drones. During the July 2018 NATO summit in Brussels 13 member states, led by the US, agreed to co-operate on the introduction of uncrewed maritime systems in roles such as mine and submarine hunting to "increase both our situational awareness and our control of the seas."[28] In February 2023, NATO set up an Underwater Infrastructure Coordination Cell based in Brussels as a dedicated task force working in this field.[29]

23 Richard Scott: 'Ghost Fleet', op cit.

24 GlobalData Thematic Intelligence: 'Unmanned underwater vehicles: defence and technology trends'. Naval, Technology, 9 September 2021. **https://www.naval-technology.com/comment/unmanned-underwater-vehicles-defence-and-technology-trends/?cf-view**

25 Brett Tingley: 'This Is Our First Look At The Navy's Snakehead Unmanned Submarine'. The Drive, 17 February 2022. **https://www.thedrive.com/the-war-zone/44339/this-is-our-first-look-at-the-navys-snakehead-unmanned-submarine**
Bill Rivers and Matt DiRisio: 'For survivable resupply, look to autonomous submarines'. C4ISRNet, 8 November 2023. **https://www.c4isrnet.com/opinion/2023/11/08/for-survivable-resupply-look-to-autonomous-submarines/**

26 Megan Eckstein: 'US Navy aims to field manned-unmanned fleet within 10 years'. Defense news, 12 April 2023. **https://www.defensenews.com/naval/2023/04/12/us-navy-aims-to-field-manned-unmanned-fleet-within-10-years/**

27 Megan Eckstein: 'US Navy aims to field manned-unmanned fleet within 10 years', op cit.

28 'Thirteen Allies to cooperate on the introduction of Maritime Unmanned Systems'. NATO, 4 October 2018. **https://www.nato.int/cps/en/natohq/news_158672.htm**

29 Elisabeth Gosselin-Malo: 'How AUVs are helping safeguard Europe's underwater infrastructure'. C4ISRNet, 17 April 2023. **https://www.c4isrnet.com/unmanned/2023/04/17/how-auvs-are-helping-safeguard-europes-underwater-infrastructure/**

People's Republic of China

Less information is available from publicly available English language sources about China's maritime drone programme compared to that of the US. While there are reports of a variety of experimental systems, little has been written about operational capabilities. English language reports about Chinese capabilities must be treated with caution as Chinese media have been known to report on experimental platforms which have not materialised as operational capabilities, and secondary English language sources are prone to exaggerate capabilities and threats from China.

China's People's Liberation Army (PLA) recognises the military importance of using the latest technologies and has begun research and investment into next-generation weaponry and technologies such as AI, drones, and autonomous systems. China is also keen to expand its naval capabilities to defend its coastline and dominate the seas to the East of China through an 'anti access and area denial' approach.[30] In 2019 China's HSU-001 large UUV was on display at China's National Day military parade marking the 70th anniversary of the founding of the People's Republic of China.[31] The South China Morning Post newspaper has reported that academics from China's Northwestern Polytechnic University, which is directed by China's Industry and Information Ministry, have stated that drones, uncrewed surface ships and underwater gliders are necessary to patrol contested waters if China is to protect its maritime interests and claims in the South and East China Seas (see case study 3 below).[32]

China is known to be operating underwater drones, and has deployed fleets of *Haiyi* (Sea Wing) glider craft in the South China Sea, Indian Ocean, and Arctic Ocean to collect oceanographic data. The *Haiyi* is reportedly very similar to the US Navy's Littoral Battlespace Sensing Glider.[33] According to Chinese government sources twelve Haiyi drones were launched in the Indian Ocean in December 2019 by the specialist survey ship *Xiangyanghong 06* and recovered in February 2020 after making more than 3,400 observations. The drones were undertaking survey work for a Joint Ocean and Ecology Research Project run by China's Ministry of Natural Resources and were reportedly measuring seawater temperature, salinity, turbidity, chlorophyll and oxygen levels and transmitting data back to the survey ship. Such information is dual use in nature, and can play a role in both environmental monitoring and submarine warfare.[34]

A 2021 report in the South China Morning Post has suggested that China has tested a torpedo-armed underwater drone able to detect, track, and attack enemy submarines. The drone was said to have been developed by the Harbin Engineering University and able to use AI methods to "recognize, follow and attack an enemy submarine without human instruction." During the test, which is said to have taken place in 2010, possibly in the Taiwan Strait, an unarmed torpedo was reportedly fired towards a simulated submarine. This would

30 Kartik Bommakanti and Aditya Gowdara Shivamurthy: 'China's Military Modernisation: Recent Trends'. Observer Research Foundation, 13 May 2021. https://www.orfonline.org/research/chinas-military-modernisation-recent-trends-2/

31 Mingmei: 'China exhibits advanced drones, unmanned underwater vehicles in military parade'. Xinhuanet, 1 October 2019. http://www.xinhuanet.com/english/2019-10/01/c_138439078_3.htm.

32 Kristin Huang: 'China should use drones to patrol and defend contested seas, academics say'. South China Morning Post, 30 January 2021. https://www.scmp.com/news/china/military/article/3119570/china-should-use-drones-patrol-and-defend-contested-seas

33 H.I. Sutton: 'Chinese-Sea-Wing-Submarine-Drone'. Covert Shores, 12 January 2021. http://www.hisutton.com/Chinese-Sea-Wing-Submarine-Drone.html

34 H I Sutton: 'China Deployed 12 Underwater Drones In Indian Ocean'. Forbes, 22 March 2020. https://www.forbes.com/sites/hisutton/2020/03/22/china-deployed-underwater-drones-in-indian-ocean/

suggest that the drone is relatively large in size in order to accommodate a conventionally sized torpedo. It should be emphasised that the account of the test has been contested by other authors.[35] Chinese engineers have reportedly also developed a drone that can operate both underwater and in the air.[36]

In May 2021 the People's Liberation Army Navy (PLAN) launched a catamaran drone 'mother ship' as part of an experimental naval training force. The ship can carry and launch aerial drones and has a large open rear deck which could be used for launching and recovering other kinds of drones. It has been described by Chinese state media as a "Navy Experimental Training Base" and is apparently intended to simulate drone swarms, anti-ship missile strikes, and electronic warfare attacks during naval training exercises and support research and evaluation of countermeasures against drone attacks. Video footage of the ship broadcast on the Chinese state television channel CCTV-7 shows it carrying tandem rotor helicopter drones, possibly a variant of the ZC Aviation ZC300 which has been evaluated for the transport of small cargo loads.[37]

Another drone mother ship, the *Zhu Hai Yun*, was launched in May 2022 and is itself able to operate autonomously. The ship can be controlled remotely in busy waters when leaving port and then navigate autonomously in the open sea. Much of the length of the 88.5 meter long ship is an open deck for launching and recovering aerial drones and it is also equipped with launch and recovery equipment for aquatic drones. The ship is reportedly able to carry 50 flying, surface and submersible drones that it can launch and recover autonomously and which can operate together as a network. The *Zhu Hai Yun* is owned and operated by the Southern Marine Science and Engineering Guangdong Laboratory, which describes it as "a platform for marine disaster prevention and mitigation, seabed precision mapping, marine environment monitoring, and maritime search and rescue".[38]

The Zhu Hai Yun, China's autonomous drone 'mother ship'
Credit: South China Morning Post

35 Thomas Newdick: 'China Tested An AI-Controlled Submarine-Hunting Underwater Drone A Decade Ago: Report'. The Drive, 9 July 2021. **https://www.thedrive.com/the-war-zone/41478/china-tested-an-ai-controlled-submarine-hunting-underwater-drone-a-decade-ago-report**

36 Loro Horta: 'PacNet #7 – China's growing confidence in drone warfare'. Pacific Forum, 4 February 2022. **https://pacforum.org/publication/pacnet-7-chinas-growing-confidence-in-drone-warfare**

37 Joseph Trevithick: 'China's Naval mother ship For Aerial Drones Looks To Be Operational'. The Drive, 22 December 2022. **https://www.thedrive.com/the-war-zone/chinas-drone-carrier-mother ship-looks-to-be-in-service**

38 Gabriel Honrada: 'China floats first-ever AI-powered drone mother ship'. Asia Times, 1 June 2022. **https://asiatimes.com/2022/06/china-floats-first-ever-ai-powered-drone-mother ship/**

Yunzhou Tech, China's first and most successful autonomous vessel company, is reportedly also working on a drone ship carrying six smaller drone boats which can work in co-ordination to surround and attack enemy surface ships. There has been speculation that the design philosophy underpinning these drone mother ships could be scaled up in future to develop ships able to launch drone swarm attacks on targets ashore or at sea.[39]

Russian Federation

Since the mid-2000s the Russian Federation has been investing significantly in modernising the technology available to its armed forces. Moscow considers that military AI and robotics systems can provide a cheap but capable force which will render the expensive high-tech weapon systems of its adversaries unsustainable. It has therefore been working on the development of robotic systems and drones and has tested a number of such systems in the war in Syria.[40]

Although Russia aims to develop uncrewed and robotic systems as a priority, achieving this vision would require a major shift in its technological sophistication. With the first Russian armed drone only entering into service in late 2020, Russia lags behind the US, China, and other potential adversaries in its capabilities in AI and military autonomous technologies, and has to date been largely reliant on hardware from abroad. The country's long term ability to develop next generation AI platforms will require it to build innovation networks which will be hindered by the international sanctions that were imposed following the invasion of Ukraine in 2022. In terms of maritime systems, the Russian Navy's recent priority has been to update and modernise its crewed fleet, rather than develop new uncrewed systems. However, a Chatham House study into Russia's advanced military technology capabilities identifies Russia's ability to manufacture and test deep-diving uncrewed underwater vehicles such as the *Poseidon* nuclear-armed uncrewed underwater vehicle as a significant potential future challenge to NATO forces.[41]

First unveiled in 2015, *Poseidon* has been developed as a hedge against the US' developing anti-ballistic missile defences and is intended to be able to detonate a nuclear weapon deep below the surface of the ocean to generate a tsunami that can destroy coastal cities, as well as aircraft carrier strike groups. Powered by a miniature nuclear reactor and reportedly travelling at a speed of 70 knots at a depth of up to 1 kilometre, *Poseidon* is intended to be able to travel too fast and too deep to be reliably intercepted and to have an unlimited range. Up to six of the drones will be carried by Russia's new K-329 Belgorod submarine. *Poseidon* may also serve as a test bed for nuclear-powered underwater drone technologies, enabling Russia to develop systems faster than crewed submarines which are able to stay at sea for months at a time.[42]

39 Gabriel Honrada: 'China floats first-ever AI-powered drone mother ship', op cit.

40 Krystyna Marcinek, Eugeniu Han: 'Russia's Asymmetric Response to 21st Century Strategic Competition: Robotization of the Armed Forces'. RAND, 2023. **https://www.rand.org/pubs/research_reports/RRA1233-5.html**
Anna Nadibaidze: 'Great power identity in Russia's position on autonomous weapons systems' Contemporary Security Policy, Vol 43(3), 19 May 2022. **https://www.tandfonline.com/doi/full/10.1080/13523260.2022.2075665**

41 Samuel Bendett, Mathieu Boulègue, Richard Connolly, Margarita Konaev, Pavel Podvig, & Katarzyna Zysk: 'Advanced military technology in Russia: Capabilities and implications'. Chatham House, September 2021. P61. **https://www.chathamhouse.org/sites/default/files/2021-09/2021-09-23-advanced-military-technology-in-russia-bendett-et-al.pdf**

42 Samuel Bendett et al: 'Advanced military technology in Russia: Capabilities and implications', op cit. P25-6.

Russia's current maritime uncrewed and autonomous technology is focused on obtaining data and conducting intelligence, surveillance, and reconnaissance (ISR) operations in the undersea environment to inform operations such as anti-submarine and counter-mine warfare operations and the protection of assets such as ports. The Russian Navy eventually plans to equip all its warships with surface, subsurface, and aerial robotic complements, and also equip crewed ships themselves with a high degree of automation and robotic systems. Russia therefore has a number of experimental and developmental UUV programmes underway. Many of these are led by the Advanced Research Foundation (ARF), an innovation centre intended to develop technology for the Russian military, which works in partnership with the Rubin Design Bureau for Marine Engineering, Russia's largest submarine design institute.[43]

The *Vityaz* deep-water autonomous underwater vehicle, developed by Rubin and the ARF, is able to collect data and conduct tasks autonomously underwater. In 2020 the *Vityaz* drone reached the bottom of the Mariana Trench – the deepest point in the world's oceans. Another AI-enabled UUV, the *Galtel* underwater vehicle, was tested in Syria in 2017-18 and used to chart the Tartus port area – at the time of writing the only Russian maritime drone system to have been used in a combat environment.

Underwater drones currently in development include the anti-submarine *Cephalopod* UUV, which is possibly intended for escort and guard duties; the *Surrogat* UUV, which can reproduce an acoustic and electromagnetic signature that mimics a submarine to draw enemy submarines out or hide Russian vessels from detection; and the *Klavesin*-2R-PM deep-water drone, designed to reach a depth of 6,000 metres.

The potential to exploit Arctic energy reserves as global warming reduces ice coverage is also fuelling the development of autonomous maritime systems. Rubin and ARF recently published information about their *Iceberg* project to build crewed and uncrewed vehicles for seismic prospecting, drilling, energy and oil and pas production in the Arctic. Although a civilian project, the drones could also provide military ISR capabilities. ARF has also developed the *Sarma* UUV to cover long distances without surfacing and without external communication in order to conduct ISR operations in the region, and Russia's defence ministry is designing an underwater microbot swarm that can work in Arctic conditions.[44]

Apparently in response to the use of drones against Russian targets in the Black Sea by Ukraine, Russia has developed the *Vizir* uncrewed surface vehicle platform (see case study 1 below). The Russian Navy has tested USVs with varying degrees of autonomy for minesweeping, such as the *Iskatel*, *Skanda*, and Buk-600 craft. Russia has also launched a small ship equipped with uncrewed navigation capabilities: the *Pioneer-M* catamaran is a 114 ton test platform for uncrewed navigation technologies and will be used to develop experience in this field.[45]

43 Samuel Bendett et al: 'Advanced military technology in Russia: Capabilities and implications', op cit. P58-60.

44 Samuel Bendett et al: 'Advanced military technology in Russia: Capabilities and implications', op cit. P60.

45 'Russia Launches Research Ship with Unmanned Navigation Capabilities'. The Maritime Executive, 7 October 2021. **https://maritime-executive.com/article/russia-launches-research-ship-with-unmanned-navigation-capabilities**

4 The UK's uncrewed maritime aspirations and programmes

Like the larger powers, the UK is keen to exploit the potential of artificial intelligence, uncrewed systems, and autonomous technology for military purposes. The UK government's 2021 Integrated Review document described artificial intelligence as a "battle-winning technology",[46] and the 2023 Integrated Refresh reaffirmed the government's commitment to AI as "an area that is critical for our future prosperity and security."[47] The MoD has announced that it will be publishing an Uncrewed Systems Strategy to "help accelerate UK Armed Forces' access to uncrewed systems and rapidly equipping them with innovative technology."[48]

Writing in the foreword to the MoD's 'Defence Artificial Intelligence Strategy' in June 2022 the then Secretary of State for Defence, Ben Wallace, described artificial intelligence as "one of the technologies essential to Defence modernisation," stating that "we must be ambitious in our pursuit of strategic and operational advantage through AI."[49] Speaking specifically about the maritime domain, First Sea Lord Admiral Sir Ben Key said during an interview in June 2023 that AI can be "tremendously beneficial" at detecting hostile or illegal activity at sea and is "tremendously good at spotting inconsistencies in the patterns or spotting other patterns that we haven't necessarily identified."[50] The Navy sees maritime autonomous systems as a "major component of the future fleet", operating on and under the sea and in the air on both front line logistics and support tasks.[51]

46 'Global Britain in a competitive age: The Integrated Review of Security, Defence, Development and Foreign Policy'. CP403. HM Government, 16 March 2021. P101. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/975077/Global_Britain_in_a_Competitive_Age-_the_Integrated_Review_of_Security__Defence__Development_and_Foreign_Policy.pdf

47 'Integrated Review Refresh 2023: Responding to a more contested and volatile world'. CP811. HM Government, 13 March 2023. P4. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1145586/11857435_NS_IR_Refresh_2023_Supply_AllPages_Revision_7_WEB_PDF.pdf

48 'Defence Minister James Cartlidge DSEI 2023 Keynote Speech'. Ministry of Defence and James Cartlidge MP. 12 September 2023. https://www.gov.uk/government/speeches/defence-minister-james-cartlidge-dsei-2023-keynote-speech

49 'Defence Artificial Intelligence Strategy'. Ministry of Defence, 15 June 2022. P1. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1082416/Defence_Artificial_Intelligence_Strategy.pdf

50 Sophie Church: '"We are effectively in a war for talent in this country": The First Sea Lord interview'. The House, 20 June 2023. https://www.politicshome.com/thehouse/article/we-are-effectively-in-a-war-for-talent-in-this-country-the-first-sea-lord-interview-86344

51 'Dstl and DASA research underpins Royal Navy maritime autonomy'. Defence Science and Technology Laboratory, 26 January 2023. https://www.gov.uk/government/news/dstl-and-dasa-research-underpins-royal-navy-maritime-autonomy

Whilst the UK has to date used uncrewed technologies to undertake routine tasks such as survey work and dangerous operations such as minesweeping, in the longer term it has the familiar aims of automating and roboticising many of the roles of its capital ships and equipping them with uncrewed aerial, surface, and undersea vehicles to contribute to a low cost weaponised sensor network.[52] However, despite generating considerable publicity for future initiatives, the systems currently deployed by the UK are still mainly small scale and / or experimental systems, while the sums of money involved have been relatively modest to date.

The Royal Navy has been trialling and experimenting with maritime drones for several years. In 2016 the Navy organised the 'Unmanned Warrior' exercise off the west coast of Scotland as part of the Joint Warrior NATO naval training exercise which is hosted by the Royal Navy every autumn. The exercise involved some of the UK's military allies and teams from industry in testing and evaluating over fifty different uncrewed and autonomous systems. The exercise was intended to "demonstrate the maturity and utility of unmanned autonomous systems to both the wider Royal Navy and the public at large, as well as dispelling some of the negative connotations surrounding the use of 'drones'." Highlights included the largest co-ordinated unmanned anti-submarine warfare event held in UK, direct comparative mine hunting trials between crewed and uncrewed platforms, and the survey of over 5,000 square kilometres of ocean using uncrewed systems.[53]

The Royal Navy has set up an 'Autonomy and Lethality Accelerator' unit, branded NavyX, as part of its Develop Directorate to develop, test and trial new naval technology and rapidly bring it into operation.[54] With a base at the Defence BattleLab innovation centre in Dorset, NavyX operates the Navy's new maritime experimental platform, *XV Patrick Blackett*, bought to support trials of autonomous systems and other new technology.[55] The ship is highly automated, with the possibility of further upgrades with autonomous systems, and has already conducted trials of new navigation radar equipment and software and a quantum accelerometer to enable navigation in a satellite denied environment.[56] The manufacturers have provided the Navy with a 'digital twin' – a computer model of the ship which can be used to explore and test systems virtually prior to onboard testing.[57]

52 'First Sea Lord's keynote address to his annual Sea Power Conference in London'. Royal Navy, 17 May 2023. https://www.royalnavy.mod.uk/news-and-latest-activity/news/2023/may/17/20230517-first-sea-lords-key-note-speech

53 'Unmanned Warrior'. Royal Navy. https://www.royalnavy.mod.uk/news-and-latest-activity/operations/united-kingdom/unmanned-warrior

54 'NavyX'. Royal Navy. https://www.royalnavy.mod.uk/navyx

55 'New testbed ship to enhance experimentation in Royal Navy'. Royal Navy. 29 July 2022. https://www.royalnavy.mod.uk/news-and-latest-activity/news/2022/july/29/20220729-new-testbed-ship-to-enhance-experimentation-in-royal-navy

56 'Experimentation ship tests new navigation radar ahead of fleet installation'. Royal Navy, 20 June 2023. https://www.royalnavy.mod.uk/news-and-latest-activity/news/2023/june/20/230620-patrick-blackett-tests-radars
'First Sea Lord's keynote address to his annual Sea Power Conference in London'. Royal Navy, 17 May 2023. https://www.royalnavy.mod.uk/news-and-latest-activity/news/2023/may/17/20230517-first-sea-lords-key-note-speech

57 'Cutting-edge solutions for Damen and Royal Navy'. Seawork Press, 31 August 2023. https://seawork.com/newfront/news/cutting-edge-solutions-for-damen-and-royal-navy

The Royal Navy's experimental trials platform, XV Patrick Blackett
Credit: Royal Navy

Among the programmes which NavyX has fronted is the Maritime Demonstrator For Operational Experimentation (*MADFOX*) autonomous surface vehicle. *MADFOX* was originally developed by L3Harris for the Defence Science and Technology Laboratory (DSTL) under the Maritime Autonomy Surface Testbed (MAST) programme and is a small high-speed drone boat that can be operated partially or fully autonomously. The boat is equipped with unspecified sensor systems and can also be fitted with weapons. It is now undergoing test and evaluation trials with NavyX and has participated in Unmanned Warrior 2016 and subsequent large-scale exercises. *MADFOX* is potentially able to undertake a variety of duties, including surveillance and reconnaissance to collect intelligence and identify threats, fleet protection tasks; and an attack role. A government press release reported that it has also been trialled by the UK Border Force to support operations relating to refugee crossings of the Channel.[58] In 2020 *MADFOX* took part in experiments with the assault ship *HMS Albion* to transit in and out of the ship's dock,[59] and 2021 it participated in the Robotic Experimentation and Prototyping Augmented by Maritime Unmanned Systems (REPMUS) exercise hosted by the Portuguese Navy. During the REPMUS exercise the boat launched a *Switchblade* 300 loitering munition as part of a trial to test the interoperability of US-UK command and control systems. The entire process was commanded, enabled and facilitated using only information provided by uncrewed systems.[60]

MADFOX is expected to be put to use in coastal security and surveillance work, and during the REPMUS exercise the boat took part in a night time surveillance operation, observing a target and transmitting live imagery from an onboard camera. The boat has also undertaken reconnaissance and surveillance operations during coastal landing exercises with Royal Marines in Dorset.[61]

58 'Uncrewed marine platform to deliver next-generation coastal security'. Defence Science and Technology Laboratory, 16 September 2021. https://www.gov.uk/government/news/uncrewed-marine-platform-to-deliver-next-generation-coastal-security

59 'New autonomous vessel delivered to Royal Navy'. Royal Navy, 26 March 2021. https://www.royalnavy.mod.uk/news-and-latest-activity/news/2021/march/26/210326-madfox-vessel

60 'Royal Navy launches missile from autonomous vessel in NATO exercise'. 14 October 2021. https://www.royalnavy.mod.uk/news-and-latest-activity/news/2021/october/14/211014-madfox-at-nato-exercise

61 'Drone swarms support Commando Forces trials in a first for the UK's armed forces'. Royal Navy, 17 July 2021. https://www.royalnavy.mod.uk/news-and-latest-activity/news/2021/july/17/210715-autonomous-advance-force-4 B

NavyX is also investigating the use of autonomous Rigid Inflatable Boats (RIBs), based on a concept developed by BAE Systems. The RIBs would be deployed from a frigate and could be used for sentry duties or coastal landings. BAE's RIB was first demonstrated at the Unmanned Warrior 2016 exercise and has also taken part in trials with *HMS Argyll*. The Navy has long operated RIBs and autonomous technology can easily be retrofitted to existing craft. The planned Type 26 and Type 31 frigates of the future will be designed to operate in association with a range of off-board drones, operating in all three domains, and will have a dedicated mission bay handling system for launching drones as well as the necessary command and control systems.[62]

Another current focus for autonomous surface vessels in the Royal Navy is minehunting. The Navy is beginning to use autonomous boats to replace traditional mine countermeasures vessels, reducing the threat to naval personnel and allowing more extensive searches of the sea, and work in this arena has been led by the Maritime Autonomous Systems Trials Team (MASTT) under 'Project Wilton'.

The team has developed a number of remote-controlled motor boats that can search for and destroy mines and act as a host craft for *Remus* robotic submersibles and other underwater survey drones, and specialised submersibles carrying an explosive charge which are able to destroy any suspicious object. Geospatial and data company Envitia and BAE Systems have together developed an AI system for tasking submersibles to hunt underwater mines autonomously, allowing them to scan an object, identify the threat, and make decisions about what to do with it more quickly, and use machine learning techniques to analyse mission conditions and improve reliability over time.[63]

The minehunting boats are capable of working under direct human control, remotely or autonomously to detect and classify mines and maritime ordnance, and can communicate with each other. They are equipped with sense and avoid systems to prevent collision with other vessels, a launch and recovery system, and towed side-scan sonar.[64] The 15 metre craft are portable by aircraft and can be rapidly deployed around the world. In the short term the Navy intends to deploy them from a *Hunt* class mine countermeasures ship, but in the long term it is hoped that they could be operated from any warship or a land-based control centre.[65]

The new Royal Fleet Auxiliary ship *Stirling Castle* has been developed as a mother ship for autonomous minehunting systems and is able to launch and recover the minehunters, pilot them remotely, and analyse data gathered as they search for mines and underwater explosive devices. The ship underwent trials at Portland in Dorset in July 2023 with three autonomous minehunting motorboats.[66]

62 'Seaboats without sailors – Royal Navy autonomous RIB development'. Navy Lookout, 2 December 2021. https://www.navylookout.com/seaboats-without-sailors-royal-navy-autonomous-rib-development/

63 'Royal Navy tasks team to add AI to UUVs'. Shepherd News, 1 July 2019. https://www.shephardmedia.com/news/uv-online/royal-navy-tasks-team-add-ai-uuvs/

64 'Atlas Elektronik to deliver further autonomous minehunter to RN'. Shephard News, 31 January 2022. https://www.shephardmedia.com/news/naval-warfare/atlas-elektronik-to-deliver-further-autonomous-min/

65 'Royal Navy tests remote-controlled minehunter'. Ministry of Defence and Defence Equipment and Support, 16 April 2014. https://www.gov.uk/government/news/royal-navy-tests-remote-controlled-minehunter
'Final autonomous minehunting boat delivered to Clyde'. Royal Navy, 21 June 2021. https://www.royalnavy.mod.uk/news-and-latest-activity/news/2021/june/21/210621-final-autonomous-minehunter-delivered

66 'Autonomous vessels join minehunting mother ship for trials debut'. Royal Navy, 4 July 2023. https://www.royalnavy.mod.uk/news-and-latest-activity/news/2023/july/04/230704-stirling-castle-autonomous-trials

The Ministry of Defence is also collaborating with France and the Organisation for Joint Armament Cooperation (OCCAR), a European intergovernmental programme for purchasing weapons, on the joint Maritime Mine Countermeasures programme. Working with arms contractor Thales, the programme has developed surface and underwater drones, a towed synthetic aperture sonar array and 'multi aspect' sonar system, and a portable operation centre. The system will be able to detect, identify and neutralize mines up to 300 meters deep. Prototype systems have been delivered to the French and British navies and production systems are scheduled to be delivered in 2024 and 2025.[67]

The Royal Navy's autonomous minehunting boat *Harrier* preparing for trials at the Clyde naval base in 2020 **Credit:** Royal Navy.

The Royal Navy's 'Project Hecla' is part of the MoD's Future Military Data Gathering Programme and was established to enable the Navy to collect and use hydrographic and oceanographic information using autonomous and uncrewed surface and underwater systems. Such information plays an important role in submarine warfare, as factors such as water temperature, pressure, and salinity affect the way sound travels through water, influencing the function of sonar and sensor systems. Experiments have been conducted with a number of systems as part of the project.

The Royal Navy first acquired *Remus* underwater drones in 2002 and has used them for mine countermeasures and survey work to provide data to produce navigation charts. In 2022 the Navy acquired three more of the vehicles to add to its small underwater autonomous drone fleet.[68]

Under the terms of Project Hecla a *Slocum* underwater glider capable of sensing and transmitting real time information on temperature, depth, salinity, current movements, oxygen levels, turbulence, and other factors has been tested during a five month trial off the west coast of Scotland. Eventually the Navy hopes to deploy gliders in high risk areas to maintain a constant picture of the underwater environment. The Navy is also trialling profiling floats (a cylinder equipped with sensors) that can operate at a set depth where they have a neutral buoyancy for many months, occasionally surfacing to send measurements to shore.[69]

67 'World-class mine-hunting technology delivered to Royal Navy'. Ministry of Defence, 8 December 2021. **https://www.gov.uk/government/news/world-class-mine-hunting-technology-delivered-to-royal-navy** Vivienne Machi: 'French-British underwater drone proves de-mining ability, says Thales'. Defense News, 13 September 2023. **https://www.defensenews.com/industry/techwatch/2023/09/13/french-british-underwater-drone-proves-de-mining-ability-says-thales/**

68 'Royal Navy grows Remus 100 fleet with latest arrivals'. Shephard News, 21 September 2022. **https://www.shephardmedia.com/news/naval-warfare/royal-navy-grows-remus-100-fleet-with-latest-arrivals/**

69 'Royal Navy trials underwater gliders that can aid submarine hunters'. Royal Navy, 30 April 2020.

Project Hecla is also reviewing the use of an *Otter Pro* robot boat for bathymetric surveys and data gathering in sheltered inshore waters. In tests at Horsea Lake, Portsmouth, the system has been used to collect sonar imagery of a number of wrecks and was able to gather and process survey information rapidly. Subsequent trials were intended to take place in a more complex environment and examine data processing and different echo-sounder and sonar systems. Like the Project Wilton minehunting boats, the vessels are intended to be portable and easily deployed.[70]

In other roles, the MoD is investigating the use of uncrewed surface / subsurface drones to support commando operations. In September 2021 MoD advertised for the potential acquisition of a clandestine multi-payload, low-signature, long-endurance uncrewed surface and subsurface vessel able to deliver covert capability both on and below the surface of the sea in support of operations by Royal Marines. The drone should be able to operate autonomously and capable of deploying sensors and weapons while surfaced and submerged, and could be used for reconnaissance of landing and operations areas for Royal Marine forces. It would need to be capable of long-endurance missions, loitering and deploying at high speeds over extended ranges, and able to be launched from the Navy's current and future ships.[71]

MoD has also commenced a programme to investigate how autonomous and robotic systems could be used to detect submarines. Under 'Project Charybdis' the Submarine Delivery Agency has commissioned a Defence and Security Accelerator programme to work with industry and academia to develop a wide range of technologies and systems to deliver an improvement to uncrewed anti-submarine warfare capability. The intention is to develop technologies which allow a wider scale and quality of surveillance, reduced reliance on high value crewed assets, and a reduced requirement for crew at sea, but it is acknowledged that this "is likely to necessitate significant innovation and development".[72]

In addition to acquiring uncrewed vehicles for use in the maritime domain, MoD is also developing the software and architecture necessary to control and co-ordinate their operation. DSTL's Maritime Autonomy Framework has funded the development of software for operating uncrewed underwater, surface, and air vehicles co-operatively within squads. The framework, produced by QinetiQ for DSTL, was tested during the Unmanned Warrior 2016 exercise, where it was used to operate a variety of uncrewed systems autonomously. Working with vehicles and software provided by SeeByte, ASV Global, and Bluebear Systems Research, the system controlled autonomous mine countermeasures missions undertaken in collaboration with research teams and systems from the US and Canada, directing seven underwater vehicles, two surface drones and one aerial drone. Such systems are intended to allow the development of mine countermeasures and hydrography capabilities and enable the operation of drones from warships such as the Type 26 frigate.[73]

70 'Royal Navy tests robot survey boat for future operations'. Royal Navy, 11 August 2021. https://www.royalnavy.mod.uk/news-and-latest-activity/news/2021/august/11/210811-otter-pro-robot-survey-vessel

71 Richard Scott : 'UK reveals USSV requirement for covert surface and sub-surface delivery'. Jane's, 10 September 2021. https://www.janes.com/defence-news/news-detail/uk-reveals-ussv-requirement-for-covert-surface-and-sub-surface-delivery
Harry Lye: 'UK hunts for uncrewed surface and subsurface vessel to support future commando operations'. Shephard Media, 4 October 2022. https://www.shephardmedia.com/news/naval-warfare/uk-hunts-for-uncrewed-surface-and-subsurface-vessel-to-support-future-commando-operations/

72 'Market Exploration Document: Project CHARYBDIS'. Defence and Security Accelerator, 18 January 2023. https://www.gov.uk/government/publications/market-exploration-project-charybdis/market-exploration-document-project-charybdis

73 'QinetiQ to integrate unmanned air, sea and subsea vehicles under Dstl contract'. SUAS News, 17 August 2016. https://www.suasnews.com/2016/08/qinetiq-integrate-unmanned-air-sea-subsea-vehicles-dstl-contract/
'Collaborative Autonomy. Product: Neptune'. SeeByte. https://www.seebyte.com/expertise/collaborative-autonomy/

The Royal Navy's aerial drones

The Navy has operated ship-launched aerial drones for a number of intelligence, surveillance and reconnaissance tasks. This work has been led by 700X Naval Air Squadron (NAS), an experimental unit formed to oversee the development and innovation of remote-piloted flight systems within the Navy which is based at Royal Naval Air Station Culdrose in Cornwall, with test facilities at nearby Predannack Airfield. 700X NAS operates in-service uncrewed systems for the Royal Navy and Royal Marines, provides training in operating drones, and conducts experiments and trials with new systems.[74]

The Royal Navy began experimenting with Insitu *ScanEagle* drones in around 2010 and in 2013 announced that it had entered into a contract with Insitu parent company Boeing Defence UK to lease, maintain, and fly the drones from Type 23 frigates and the auxiliary ship *RFA Cardigan Bay* operating in the Arabian Gulf region. *ScanEagle* conducted surveillance for maritime security and counter-drug operations and was credited with success on a number of occasions in spotting and tracking smugglers operating off the coast of Africa. The drone was launched from ships by a pneumatic catapult and operated by contractors under the direction of 700X NAS personnel, and then at the end of the flight recovered back to the ship using a trap-wire arrangement.

ScanEagle was withdrawn from service in 2017,[75] and some of its roles are being taken up by the lightweight AeroVironment *Puma* RQ-20 drone. Smaller than the *ScanEagle*, the *Puma* has a shorter range and endurance but is nevertheless said to be able to monitor a sea area of up to 270 square miles and is simpler to launch and recover. The drone is small enough to launch from a landing craft and can provide high-resolution video images, track small fast-moving inshore craft, and provide overwatch for Royal Marines during landing operations. It has been flown from *HMS Albion* supporting Royal Marines during international Baltops (Baltic Operations) exercises in the North and Baltic Seas, and has also been flown from offshore patrol vessels *HMS Tamar* and *HMS Mersey*, with operator training provided by 700X NAS.[76]

The Future Maritime Aviation Force (FMAF) vision for 2030 sets out the future shape of the Navy's air capabilities, and envisages that a number of roles will be eventually undertaken by uncrewed platforms. The Navy is taking an incremental, step-by-step approach to developing future uncrewed aircraft capabilities and a number of trials and projects are currently underway to help meet this goal. 'Project Vampire', led by Royal Navy's Develop Directorate, is looking at lightweight, fixed-wing drones and autonomous systems which can fly from aircraft carriers for intelligence, surveillance and reconnaissance missions, electromagnetic operations, and threat simulation exercises. In 2021 the Navy undertook trials with three QinetiQ *Banshee* Jet 80+ aerial target drones on the aircraft carrier *HMS Prince of Wales*. The *Banshee* is launched from the ship by a pneumatic launcher and recovered after a parachute landing, and the trials looked at how the drone, the launcher, and other support equipment could

74 '700X Naval Air Squadron'. Royal Navy. https://www.royalnavy.mod.uk/our-organisation/the-fighting-arms/fleet-air-arm/support-and-training/700x-naval-air-squadron

75 'Royal Navy's new 'eye in the sky''. Ministry of Defence and Philip Dunne MP. 20 June 2013. https://www.gov.uk/government/news/royal-navys-new-eye-in-the-sky

76 'Royal Navy's Puma drone gets its claws into maiden deployment'. Royal Navy, 9 October 2020. https://www.royalnavy.mod.uk/news-and-latest-activity/news/2020/october/09/20201009-drone-trials-on-albion

be be integrated onto the ship and flight deck.[77] Following the trials the Navy took delivery of four *Banshee* drones from QinetiQ in March 2023 together with a launcher, an operating station, and technical support and training, and a new flight was set up at 700X NAS to maintain and operate the drones. Further tests were scheduled to be held at Predannack Airfield in Cornwall during summer 2023.[78] Towards the end of 2023 the Royal Navy also conducted trials with General Atomics' *Mojave* medium altitude long endurance drone from *HMS Prince of Wales* off the east coast of the USA.[79]

A Royal Navy sailor launches a Puma drone from the flight deck of HMS Albion **Credit:** Royal Navy

Another FMAF project, 'Project Proteus', aims to develop a medium-sized rotary wing drone for submarine hunting and surface searches. The drone is intended to be equipped with a large *Crowsnest* style radar system and able to deploy sonobuoys and 'dipping sonar' sensors. The Royal Navy sponsored a demonstration of a Schiebel *Camcopter* S-100 helicopter drone during the REPMUS 2022 exercise in Portugal. The drone was used in an anti-submarine role to relay data transmissions from a string of deployed sonobuoys to a command centre, and also to deliver cargo.[80] In February 2023, under an Urgent Capability Requirement, the Navy entered into a £20 million contract with Schiebel and Thales to provide a *Camcopter* S-100 equipped with radar, high definition camera, and AIS provided by Thales UK. The system, named *Peregrine* by the Navy, will be used for ISR tasks and tracking surface vessels by frigates deployed in the Gulf and will be able to feed real-time images and radar data back to the ship. *Peregrine* will be deployed from mid-2024 for two years with an option to

77 'Drones launched from HMS Prince of Wales during landmark demonstration'. Royal Navy, 29 September 2021. **https://www.royalnavy.mod.uk/news-and-latest-activity/news/2021/september/29/210929-prince-of-wales-drones**

78 'New drone welcomed into Royal Navy'. Royal Navy, 16 March 2023. **https://www.royalnavy.mod.uk/news-and-latest-activity/news/2023/march/16/230316-banshee-drone**

79 Craig Hoyle: 'Unmanned Mojave makes trials debut aboard UK's HMS Prince of Wales'. FlightGlobal, 17 November 2023. **https://www.flightglobal.com/defence/unmanned-mojave-makes-trials-debut-aboard-uks-hms-prince-of-wales/155910.article**

80 'Royal Navy successfully operates Schiebel Camcopter S-100 UAS during NATO exercise'. Navy Recognition, 24 October 2022. **https://www.navyrecognition.com/index.php/naval-news/naval-news-archive/2022/october/12391-royal-navy-successfully-operates-schiebel-camcopter-s-100-uas-during-nato-exercise.html**

extend the contract beyond this and the potential for wider use across the fleet.[81] Deployment of the drone is intended to allow the Navy to develop operating experience, and eventually the Navy hopes to field a Flexible Tactical Uncrewed Air System (FTUAS) capable of undertaking a range of functions, such as anti-submarine warfare, ISR, and cargo delivery.

The Royal Marines have also experimented with light drones in number of roles, anticipating that they will play an important future role for Littoral Strike Groups and become a standard part of Marine operations, reducing the need to use helicopters. During the Autonomous Advance Force 4.0 exercises in Dorset and at RAF Spadeadam in July 2021 a swarm of six Malloy TRV150 drones were operated autonomously to resupply a commando assault group with food, ammunition, and medical supplies and was also able to conduct reconnaissance missions to provide intelligence for commando raids ashore and at sea. Other systems tested during the exercise included the Anduril *Ghost* rotary wing drone, used to provide a live feed of what lay ahead, the Blue Bear *Cobra* portable fixed wing drone which was used to identify and track targets, and the Tactical Precision Strike system, a one-way attack drone.[82]

Malloy drones have also been tested during ship-to-shore logistics flights in exercises in Cyprus, Norway and the USA., As part of a 'Heavy Lift Challenge' MoD has issued small contracts to Malloy Aeronautics and W Autonomous Systems to lead to the development of a drone designed for autonomously transporting light cargo in the maritime domain, with tests undertaken by 700X NAS.[83] During trials an autonomous twin-engined HCMC drone built by W Autonomous Systems flew from Predannack Airfield to the aircraft carrier *HMS Prince of Wales* to trial the transfer of stores and supplies between ships. The drone landed on the ship, delivered a small payload, and then took off again and returned to the airfield – a first for the Royal Navy.[84]

XLUUVs

Like the US Navy, the Royal Navy is experimenting with XLUUVs. During 2023 trials were underway off the South Coast of England with a 9 metre long S201 submarine manufactured by Marlin Submarines Ltd (MSubs) which has been retrofitted with a modified hull and an autonomous control system to allow uncrewed operation. It is fuel-cell powered and can operate for about a week without charging. The XLUUV is able to deploy a lightweight towed array sonar and is intended to be able to carry, deliver and recover test payloads of sensors and communications equipment.[85] The vehicle's movements and tasks can reportedly be directed entirely by AI and among the trials which have been conducted are demonstrations of underwater obstacle avoidance.

81 Ministry of Defence: 'DE&S procures Royal Navy's new 'eye in the sky''. DESider 175, March 2023, p8. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1140102/March_2023_Desider.pdf

82 'Drone swarms support Commando Forces trials in a first for the UK's armed forces'. Royal Navy, 17 July 2021. https://www.royalnavy.mod.uk/news-and-latest-activity/news/2021/july/17/210715-autonomous-advance-force-4

83 Richard Scott: 'UK awards two contracts for Heavy Lift Challenge'. Janes, 16 November 2021. https://www.janes.com/defence-news/news-detail/uk-awards-two-contracts-for-heavy-lift-challenge

84 Andrew Chuter: 'Britain tests transport drone's ability to land, take off from ship'. Defense News, 8 September 2023. https://www.defensenews.com/unmanned/2023/09/07/britain-tests-transport-drones-ability-to-land-take-off-from-ship/

85 'Manta – the Royal Navy gets its first extra-large autonomous submarine'. Navy Lookout, 31 March 2020. https://www.navylookout.com/manta-the-royal-navy-gets-its-first-extra-large-autonomous-submarine/ 'Towed array sonar integrated with Royal Navy experimental autonomous submarine'. Navy Lookout, 23 May 2023. https://www.navylookout.com/towed-array-sonar-integrated-with-royal-navy-experimental-autonomous-submarine/

As no human operators would need to be accommodated, XLUUVs would be smaller and less detectable than crewed platforms and more focused on the payload. They would be dramatically cheaper and quicker to build than crewed submarines, and the Navy is considering using them for ISR and anti-submarine tasks. ISR work could be undertaken in littoral waters to monitor undersea infrastructure or deployed from Type 26 frigates to reconnoitre waters ahead of a group of warships. The vessel might eventually support anti-submarine operations, either independently or alongside crewed submarines, for example by helping to create a 'barrier' to prevent intruding submarines from reaching sensitive areas such as the approaches to a port, or as part of a large anti-submarine deployment in the North Atlantic. However, as explained in the introduction to this report, difficulties in communicating underwater present challenges for command and control, particularly with weaponised systems, and so it is likely that it will be a decade or two until XLUUVs become part of the Navy's forces, and that they will be used principally in ISR roles.

Work on XLUUVs is now being taken forward through the Navy's 'Project Cetus', with MSubs contracted to deliver a new purpose-built 17 tonne vehicle by the end of 2024. MoD claims this will be "the largest and most complex crewless submersible operated by a European navy" and it will also be able to dive deeper than any other Royal Navy submarine. The vehicle will have a modular payload bay that can be extended by inserting another section, or alternatively additional batteries can be incorporated to allow an increase in range. As with the Navy's previous XLUUV, the vehicle will be used as an experimental and trials platform with the aim of reducing risks associated with the future acquisition of underwater autonomous vehicles. Tender documents state that the Project Cetus XLUUV will be used to demonstrate and develop a concept of operations and build trust in autonomy by safely demonstrating beyond visual range autonomy and long-duration surface operation.[86] In a separate programme, BAE Systems is collaborating with Cellula Robotics to develop its own XLUUV technology demonstrator, known as *Herne*. Like the Royal Navy's XLUUVs, the aim is to build a platform able to conduct anti-submarine warfare and ISR operations. Trials are scheduled to take place off the south coast of England in 2024.[87]

MSubs S201 XLUUV is being trialled by the Royal Navy
Credit: Royal Navy

86 'Royal Navy orders first crewless submarine to dominate underwater battleground'. Royal Navy, 1 December 2022. **https://www.royalnavy.mod.uk/news-and-latest-activity/news/2022/december/01/20221201-royal-navy-orders-first-crewless-submarine-to-dominate-underwater-battleground**
'Innovations to be tested on pioneering autonomous submarine'. Defence and Security Accelerator and Defence Science and Technology Laboratory, 16 February 2021. **https://www.gov.uk/government/news/innovations-to-be-tested-on-pioneering-autonomous-submarine**

87 'BAE Systems and Cellula Robotic to launch Herne XLAUV'. ADS Advance, 12 September 2023. **https://www.adsadvance.co.uk/bae-systems-and-cellula-robotic-to-launch-herne-xlauv.html**

5 | Case studies

The final part of this report examines the use of maritime drones in three different parts of the world to identify how their military applications are evolving. We consider the Black Sea, Arabian Gulf, and South and East China Seas as case studies of situations where maritime drones have been used to advance the security interests of the players involved. These are not the only places where maritime drones are in use – drones are involved in intensive maritime surveillance operations in the Bering Sea[88] and East Mediterranean[89], for example – but between them, the three case studies demonstrate the use of a wide range of operating concepts for maritime drones, including intelligence, surveillance, and reconnaissance tasks; offensive operations, and the deployment of persistent autonomous networks of drones.

It should be remembered that military activities involving maritime drones in the case study regions are inevitably part of a broader conflict in which propaganda and information manipulation also play an important role. Operations involving drone operations may not be always acknowledged by those undertaking them and are often beset by claims and counter-claims, meaning that the reality of a situation may not always be easily verified.

Case Study 1: The Black Sea

The Black Sea lies between Europe and Asia, to the east of the Balkans and to the north of Turkey. There are six countries on its coast: NATO members Bulgaria, Romania, and Turkey; Georgia and Ukraine; and Russia. The sea is an important maritime trade route and strategic corridor linking Asia and Eastern Europe to the world's oceans. It is also rich in reserves of oil and natural gas and a transit hub in the flow of oil and gas exports to Europe, the Mediterranean and beyond.

The Russian Navy's Black Sea Fleet has its primary base at Sevastopol on the Crimean Peninsula, and the Black Sea plays an important role in its ability to project power across the region and gain access to the Mediterranean Sea,

88 Tabby Kinder: 'How Silicon Valley is helping the Pentagon in the AI arms race'. Financial Times, 31 July 2023. https://www.ft.com/content/2ed278cc-6c3f-4569-b73c-64ad378f3ea8

89 'Assistance for the refugee and migrant crisis in the Aegean Sea'. NATO, 17 January 2023. https://www.nato.int/cps/en/natohq/topics_128746.htm

the Middle East, and North Africa. NATO also considers the sea to be a region of strategic importance, and has increased its military presence in the area in response to Russia's annexation of Crimea in 2014 and invasion of Ukraine in 2022.[90] The Black Sea has been a significant factor in the current war between Russia and Ukraine, with the Russian Navy using the area as a platform for attacks on Ukrainian targets and military activities impacting on the transport of goods and supplies, particularly Ukrainian grain exports, from Black Sea ports. The use of various types of maritime drones has been a significant factor in the war.

The Black Sea and surrounding nations

Following the annexation of Crimea, NATO has been conducting intelligence-gathering flights in the Black Sea region using both crewed aircraft and drones. Among the drone operations known to have taken place are flights by both NATO and US RQ-4 *Global Hawk* drones and US *Reaper* drones from Sigonella Air Base on Sicily.[91] These drones are equipped with high resolution air-to-ground and synthetic aperture radar systems, able to create three-dimensional images and track moving objects, and are also be able to collect signals and electronic intelligence. While it is not known whether intelligence gathered during these flights is passed on to Ukrainian military forces, the flights are seen as provocative by the Russian government and matters came to a head in March 2023 when a Russian Sukhoi SU-27 warplane buzzed a US *Reaper* drone in international airspace over the Black Sea and dumped fuel, causing the drone to lose power and crash into the sea. In the aftermath of the incident it appears that NATO drone flights were routed further south over the Black Sea in order to "deconflict" them with Russian air activity.[92]

90 Phil McCausland: 'Why the Black Sea is such a flashpoint between the U.S. and Russia'. NBC News, 17 March 2023. **https://www.nbcnews.com/news/world/black-sea-us-russia-flashpoint-drone-ukraine-war-rcna75269**

91 Thomas Newdick: 'Ukraine Situation Report: RQ-4 Global Hawk Flies Off Sochi'. The Drive, 9 May 2023. **https://www.thedrive.com/the-war-zone/ukraine-situation-report-rq-4-global-hawk-flies-off-sochi**
'NATO surveillance drone conducts first mission over Finland'. NATO, 13 September 2023. **https://www.nato.int/cps/en/natohq/news_218113.htm**

92 Oren Liebermann, Natasha Bertrand and Jim Sciutto: 'US military releases footage of Russian fighter jet forcing down American drone over Black Sea'. CNN, 16 March 2023. **https://edition.cnn.com/2023/03/16/politics/us-military-video-drone-russian-jet/index.html**
Oren Liebermann and Jim Sciutto: 'US flying surveillance drones farther south over Black Sea after collision with Russian fighter jet, officials say'. CNN, 21 March 2023. **https://edition.cnn.com/2023/03/21/politics/us-drones-black-sea-south/index.html**

The use of uncrewed maritime surface vehicles by Ukraine has also been a dramatic feature of the war against Russia. According to the BBC, Ukraine had conducted at least 13 attacks on Russian forces using sea drones as of September 2023, targeting military ships, the naval port at Sevastopol, and Novorossiysk harbour – an important civil port (see Box 1).[93] Ukrainian security forces have claimed that these attacks were undertaken using *Sea Baby* suicide drone boats, specially developed by the Ukrainian military in the aftermath of the invasion.[94] In addition to using drone boats, Ukrainian forces also reportedly attacked Russian assault craft with Bayraktar TB2 aerial drones during fighting at Snake Island in May 2022 and used the drones to locate enemy ships in the Black Sea.[95]

Ukraine's 'mosquito fleet' of drone boats has attracted considerable comment for engaging with Russian naval forces in the Black Sea, and has been acclaimed as heralding a new era in naval warfare. A high profile attack on Sevastopol naval base in October 2022 was hailed as "the first event in which unmanned surface vessels were used in multiple simultaneous attacks against manned surface vessels."[96] Since then, in August 2023, President Vladimir Zelenskiy has announced the formation of a new naval unit, the 385th Separate Brigade, exclusively to operate uncrewed systems.[97]

Ukraine's USVs are apparently based on simple, low-cost commercially available technology and are equipped with a camera; communications equipment relying on commercial satellite networks; sensors, and a payload of several hundred kilograms of explosives. The system also includes a land-based control station, a transportation and storage system, and a data centre. The drone boats appear to be video controlled and able to travel considerable distances – at least 150 miles, and possibly much further – if they are able to attack targets in Russian-occupied territory from areas controlled by Ukraine. Ukraine appears to have developed and fielded at least six different types of such craft over the course of the war with Russia.[98] The Ukrainian government, which has reportedly appealed for crowdfunding to build the USVs, has stated that the price of each boat is approximately 10 million Ukrainian Hryvnia (£222,000).[99] In addition to Ukraine's own drone boats, it has been reported that the US has supplied some USVs to Ukraine, possibly short range MARTAC *Mantas* T-12s, and Germany has also said it will provide Ukraine with fifty new USVs.[100]

93 Joshua Cheetham: 'Sea drones: What are they and how much do they cost?'. BBC News, 13 September 2023. **https://www.bbc.co.uk/news/world-europe-66373052**

94 Nick Paton Walsh, Victoria Butenko and Florence Davey-Attlee: 'The moment Ukraine used an experimental drone to attack a Russian bridge'. CNN, 15 August 2023. **https://edition.cnn.com/2023/08/15/europe/ukraine-crimea-bridge-drone-strike-video-intl/index.html**

95 Joe Barnes, Nataliya Vasilyeva, and Dominic Nicholls: 'Watch: Drone destroys Russian Raptor boats off Snake Island'. Telegraph, 2 May 2022. **https://www.telegraph.co.uk/world-news/2022/05/02/watch-drone-destroys-russian-patrol-boats-snake-island/**
Joost Oliemans and Stijn Mitzer: 'Neptune's Wrath: The Flagship Moskva's Demise'. Oryx, 16 April 2022. **https://www.oryxspioenkop.com/2022/04/neptunes-wrath-flagship-moskvas-demise.html**

96 Kieron Monks: 'Ukraine's mysterious marine drones threaten Russian control of Black Sea coast'. iNews, 1 November 2022. **https://inews.co.uk/news/world/ukraines-mysterious-marine-drones-threaten-russian-control-of-black-sea-coast-1945274**

97 David Hambling: 'Ukraine Promised Drone Boat Fleet By Germany. It May Be Weapons Not Yet Seen'. Forbes, 21 September 2023. **https://www.forbes.com/sites/davidhambling/2023/09/21/germany-to-supply-ukraine-with-drone-boats--but-where-will-it-get-them/**

98 H.I. Sutton: 'Evolution of Ukraine's Maritime Drone'. Covert Shores, 28 July 2023. **http://www.hisutton.com/Ukraine-Maritime-Drones-Evolution.html**
'New version of the marine drone developed in Ukraine'. Militarnyi, 22 March 2023. **https://mil.in.ua/en/news/new-version-of-the-marine-drone-developed-in-ukraine/**
Kieron Monks: 'Ukraine's mysterious marine drones threaten Russian control of Black Sea coast', op cit.

99 Roland Oliphant: 'How Ukraine's drone navy is outsmarting Russia's superior Black Sea forces'. Telegraph, 4 August 2023. **https://www.telegraph.co.uk/world-news/2022/11/26/how-ukraines-drone-navy-menacing-russias-superior-black-sea/**

100 David Hambling: 'Ukraine Promised Drone Boat Fleet By Germany. It May Be Weapons Not Yet Seen', op cit.

Box 1: Reported Ukrainian USV attacks on Russian forces*

29 October 2022 Russia's Ministry of Defence said nine air and seven sea drones had caused "minor damage" to a minesweeper, *Ivan Golubets*, in an attack on Sevastopol naval port. Ukrainian sources also claimed that the frigate *Admiral Makarov* was damaged.[101]

17 November 2022 Unverified Russian sources reported that a Ukrainian naval drone struck the Sheskharis oil terminal in Novorossiysk.[102]

22 March 2023 Unverified Ukrainian reports claimed that three drone boats were destroyed by Russia in an attack on the Sevastopol naval base.[103]

24 April 2023 The Russian Ministry of Defence claimed that three uncrewed high-speed boats were destroyed during an attack on Sevastopol naval base.[104]

24 May 2023 The signals intelligence-gathering ship *Ivan Khurs* was attacked by three uncrewed speedboats in the Southeast Black Sea. The Russian Ministry of Defence said that the speedboats failed to hit the ship. The Ukrainian Ministry of Defence released video film of the attack showing a small boat approaching a larger ship at high speed, which cuts out as the boat approaches the ship.[105]

11 June 2023? Unverified Russian reports claimed that the signals intelligence gathering ship *Priazovye* was attacked by six drone boats, which were all destroyed, in the Southeast Black Sea.[106]

17 July 2023 Sea drones used to attack and damage the Kerch Bridge which connects Russia to Crimea. Ukrainian forces claimed responsibility for the attack.[107]

4 August 2023 Maritime traffic was halted and the Russian navy's *Olenegorsky Gornyak* assault ship was damaged during a sea drone attack conducted by Ukrainian forces near the Russian port of Novorossiysk. Ukrainian intelligence sources claimed that the ship "received a serious breach and currently cannot conduct its combat missions". The Russian defence ministry confirmed the attack and claimed that the drones had been destroyed by Russian warships.[108]

7 August 2023 Russian chemical tanker *Sig* was attacked by Ukrainian drones in the Kerch Strait. Russia's Federal Agency for Marine and River Transport confirmed the attack and said that the tanker had received a hole in the engine room near the waterline and that there were no casualties.[109]

1-2 September 2023 In messages posted to Telegram the Russian Ministry of Defence said three semi-submersible uncrewed boats had been destroyed during an attack on the Kerch bridge.[110]

13 September 2023 Russia's Ministry of Defence said Ukraine had used three sea drones to attack Russian ships in the Black Sea and ten cruise missiles in an attack on the Sevastopol shipyard, injuring 24 people.[111]

24 October 2023 Following unverified reports of explosions in Sevastopol, the Russian Ministry of Defence said that three uncrewed vessels belonging to the Ukrainian navy had been detected in the Northern part of the Black Sea.[112]

*February 2022 – October 2023. Other unreported attacks may also have taken place over this period.

101 Luke Harding and Isobel Koshiw: 'Russia's Black Sea flagship damaged in Crimea drone attack, video suggests'. Guardian, 30 October 2022. https://www.theguardian.com/world/2022/oct/30/russias-black-sea-flagship-damaged-in-crimea-drone-attack-video-suggests

102 H.I. Sutton: 'Ukraine's Maritime Drone Strikes Again: Reports Indicate Attack On Novorossiysk'. Naval News, 18 November 2022. https://www.navalnews.com/naval-news/2022/11/ukraine-maritime-drone-strikes-again-reports-indicate-attack-on-novorossiysk/

103 Tayfun Ozberk: 'Russia repels Ukraine's drone attack on Sevastopol'. Naval News, 23 March 2023. https://www.navalnews.com/naval-news/2023/03/russia-repels-ukraines-drone-attack-on-sevastopol/

104 Lydia Kelly: 'Russia says it repels naval drone attack on Sevastopol'. Reuters, 24 April 2023. https://www.reuters.com/world/europe/black-sea-fleet-repels-drone-attack-sevastopol-russian-backed-governor-2023-04-24/

105 Tara Subramaniam, Christian Edwards, Ed Upright, Aditi Sangal, Leinz Vales and Tori B. Powell: 'May 25, 2023 Russia-Ukraine news'. CNN, 25 May 2023. https://edition.cnn.com/europe/live-news/russia-ukraine-war-news-05-25-23/h_895cee888bce092ff0a8291b6d1a7b1f

106 H.I. Sutton: 'Spy Ship Attacked: Russia Implies Ukrainian/NATO Threat To TurkStream Gas Pipeline'. Covert Shores, 11 June 2023. http://www.hisutton.com/Implied-Threat-To-TurkStream-Gas-Pipeline.html

107 Nick Paton Walsh, Victoria Butenko and Florence Davey-Attlee: 'The moment Ukraine used an experimental drone to attack a Russian bridge'. Op cit.

108 Tom Balmforth: 'Ukrainian drone disables Russian warship near Russia's Novorossiysk port'. Reuters, 4 August 2023. https://www.reuters.com/world/europe/blasts-gunfire-reported-near-russian-black-sea-port-novorossiysk-2023-08-04/

109 'Russian chemical tanker hit by Ukraine drones in Kerch Strait'. Guardian, 5 August 2023. https://www.theguardian.com/world/2023/aug/05/russian-chemical-tanker-reportedly-hit-by-ukraine-drones-in-kerch-strait

110 'Russia Claims Naval Drones Targeting Crimean Bridge Destroyed'. Voice of America, 1 September 2023. https://www.voanews.com/a/russian-missile-strike-hits-central-ukraine-region/7250350.html

111 Dasha Litvinova and Illia Novikov: 'Ukrainian attack damages 2 ships, injures 24 people and sets port on fire in Russia-annexed Crimea'. AP, 13 September 2023. https://apnews.com/article/russia-ukraine-war-sevastopol-925cf5d35b53ea061d1dc73dd0cf329f

112 Yohannes Lowe, Charlie Moloney , Rachel Hall and Warren Murray: 'Russia-Ukraine war live: Zelenskiy says he will keep up military pressure on Russian-occupied Crimea – as it happened'. Guardian, 24 October 2023. https://www.theguardian.com/world/live/2023/oct/24/russia-ukraine-war-live-sabotage-attack-launched-on-sevastopol-says-occupation-governor?filterKeyEvents=false&page=with:block-65378b138f082cf83f9c2f7e

A drone boat, believed to be a Ukrainian USV which washed ashore in Crimea in September 2022 **Uncredited**

Such drones are not without disadvantages. Their on-board video cameras give a restricted field of vision, easily obscured by spray and poor weather, making it necessary to use geolocation data. The restricted vision also makes it hard to track moving targets and spot camouflaged ships. In addition. commercial satellite streams are easily blocked or jammed, and any interference with the control link will thwart their use. Despite this, the drone boats have appear to have played a substantial role in constraining Russian naval operations in the Black Sea and damaging supporting infrastructure. In response Russia has employed signal jamming techniques and bolstered physical defences around key naval bases and the Kerch Bridge, with satellite images showing nets, booms, and pontoons deployed as barriers at the entrance to the Sevastopol port to prevent sea drones from entering.[113] A drop-off in reports of Ukrainian drone boat activity towards the end of 2023 may signify that such countermeasures have had some degree of success.

As well as uncrewed surface vehicles, Ukraine is also developing underwater uncrewed vehicles. In 2023 a prototype of a UUV called the *Toloka* was exhibited at arms fairs. A loitering torpedo able to carry explosives, the *Toloka* is intended to be built in three different versions with different ranges and explosive payloads. At the time of writing it is not known whether the drone has been used operationally.[114] The Ukrainian arms industry is also developing a new large autonomous underwater vehicle, the *Marichka*. Said to be in the prototype phase during the summer of 2023, the *Marichka* has been advertised as being for anti-ship and bridge attack, intelligence gathering, and transport.[115]

Russia has reportedly also used USVs to attack the Zatoka bridge near Odesa in February 2023.[116] Apparently in response to Ukraine's use of drone boats, the Russian military contractor KMZ (Kingisepp Machine Building Plant) has

113 Mariano Zafra and Jon McClure: 'Sea drones and the counteroffensive in Crimea'. Reuters, 17 July 2023. **https://www.reuters.com/graphics/UKRAINE-CRISIS/CRIMEA/gdvzwrmrlpw/**

114 H.I. Sutton: 'Russia Faces New Threat: Ukraine's 'Toloka' Underwater Maritime Drone'. Covert Shores, 26 April 2023. **http://www.hisutton.com/New-Ukraine-Underwater-Maritime-Drone.html** 'Unmanned underwater vehicles are being developed in Ukraine'. Militarnyi, 27 April 2023. **https://mil.in.ua/en/news/unmanned-underwater-vehicles-are-being-developed-in-ukraine/**

115 H.I. Sutton: 'Ukraine's Marichka Underwater Drone (AUV)'. Covert Shores, 23 August 2023. **http://www.hisutton.com/Ukraine-Marichka-AUV.html**

116 Howard Altman: 'Ukraine Situation Report: This May Be Russia's First Kamikaze Drone Boat Attack'. The Drive, 10 February 2023. **https://www.thedrive.com/the-war-zone/ukraine-situation-report-this-may-be-russias-first-kamikaze-drone-boat-attack**

developed the multifunctional '*Vizir*' uncrewed surface vessel platform. Exhibited at Russia's 'Army 23' arms fair and described by the manufacturers as a "disposable boat", the *Vizir* is intended operate as either a suicide drone or a reusable uncrewed craft with an automated return-to-base function. A number of potential roles are envisaged for the boat: detection of and protection against aerial, surface, and underwater drones; protection of coastal bases; electronic and anti-submarine warfare; transport of troops or cargo; coastal and underwater mapping; and a platform for the launch of an aerial drone. The *Vizir* USV is a shallow-draught small boat with a minimum height above the surface of the water for low visibility. KMZ claim that it can reach speeds of 80 km/h and has a range of 200 kilometres and that a swarm of six boats can be controlled from a single control station. The boat can reportedly carry a payload of around 600 kg, which can be either high explosive, cargo or troops, weaponry such as machine guns or light missiles, reconnaissance equipment, or an aerial drone able to launch from the boat. Russia's Ministry of Defence had reportedly agreed on delivery of ten of the boats by the end of 2023, for testing in the war with Ukraine.[117]

117 'Army 2023: KMZ from Russia unveils new Unmanned Surface Vehicle'. Navy Recognition, 17 August 2023. https://www.navyrecognition.com/index.php/naval-news/naval-news-archive/2023/august/13467-army-2023-kmz-from-russia-unveils-new-unmanned-surface-vehicle.html

Case study 2: The Arabian Gulf and Beyond

The Arabian Gulf and its coastal margin are the world's largest single source of oil, and the Gulf nations of Bahrain, Iran, Iraq, Kuwait, Qatar, Saudi Arabia, and the United Arab Emirates are believed to hold around two-thirds of the world's crude oil reserves and a similar proportion of the world's natural gas reserves. Oil-related industries dominate the region, which includes some of the world's most important shipping routes. These routes pass through a number of critical choke points: the Strait of Hormuz in the Gulf itself, the Suez Canal and the Strait of Bab-al-Mandeb at the southern tip of Yemen. Oil passing through the Strait of Hormuz comprises roughly 40% of all the oil traded in the world. Seaways in the region have also been prone to smuggling, piracy, and illegal fishing.[118]

The geopolitics of the Gulf region are dominated by the long standing rivalry between United States and the Islamic Republic of Iran. The US and its allies view the activities of Iran as a growing threat, while Iran sees the US's heavy military involvement in the region as intended to isolate and coerce it and eventually replace its leadership. Iran's strategy of resistance is based on asymmetric military capabilities and support for regional allies, including armed non-state proxies.[119]

Navigation rights and the limits of Iran's territorial waters in the Gulf are contested, and in 2019 the International Maritime Security Construct (IMSC) was established under the leadership of the United States to ensure freedom of navigation for merchant vessels in international waters in the region. IMSC currently consists of eleven members, including the United Kingdom. Coalition Task Force (CTF) Sentinel, the operational arm of IMSC, seeks to "deter state-sponsored malign activity in the region" and undertakes security patrols in the waters of the Arabian Gulf, Gulf of Oman, Gulf of Aden, and the Southern Red Sea.[120] At the same time a broader naval coalition, the Combined Maritime Forces (CMF) , which consists of 38 nations and is again led by the US, is aimed at countering illicit non-state actors at sea in the region, focusing on counter-narcotics, counter-smuggling, and suppressing piracy. CMF works through four Combined Task Forces (CTF), CTF 150, 151, 152, and 153, which undertake maritime security operations in the region.[121] This includes the use of surveillance operations using conventional ships and aircraft and UAVs and USVs. In November 2023 a US MQ-9 *Reaper* drone was shot down off the coast of Yemen by Iranian-backed Houthi forces, and US Navy ships operating in the region have also shot down Houthi drones on a number of occasions.[122]

118 Anthony H. Cordesman: 'Iran, Oil, and the Strait of Hormuz'. Center for Strategic and International Studies, 26 March 2007. https://web.archive.org/web/20120319230056/http://csis.org/files/media/csis/pubs/070326_iranoil_hormuz.pdf

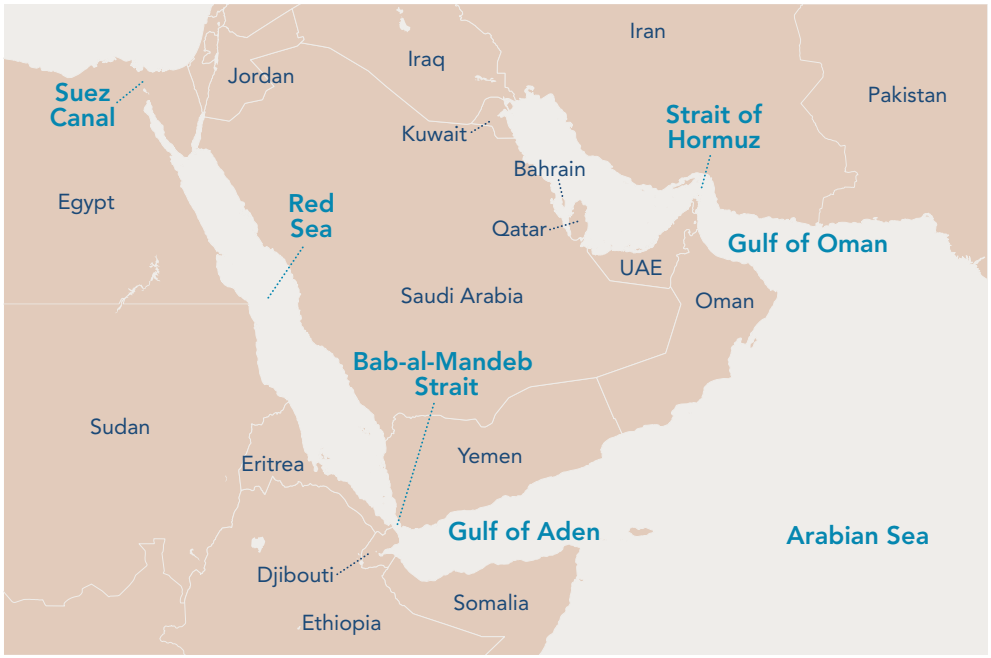
119 Robert Malley: 'Gulf Tensions Could Trigger a Conflict Nobody Wants'. International Crisis Group, 20 October 2020. https://www.crisisgroup.org/middle-east-north-africa/gulf-and-arabian-peninsula/united-arab-emirates-saudi-arabia-qatar-oman-3

120 International Maritime Security Construct: https://www.imscsentinel.com/

121 Combined Maritime Forces (CMF): https://combinedmaritimeforces.com/

122 Jake Epstein: 'Crashed, harassed, and shot down: It's been a rough year for the MQ-9 Reaper, America's workhorse combat drone'. Business Insider, 10 November 2023. https://www.businessinsider.in/international/news/crashed-harassed-and-shot-down-its-been-a-rough-year-for-the-mq-9-reaper-americas-workhorse-combat-drone/articleshow/105104316.cms

The Arabian Gulf and the Red Sea



As part of these initiatives, the US 5th Fleet, responsible for naval forces in this region, established Task Force 59 – the first US Navy task force of its kind – in September 2021 to integrate uncrewed robotic systems and AI within maritime activity in the fleet's area of operations. Task Force 59 focuses on experimentation and development and has the goal of using uncrewed systems of all types – UAS, USV, and UUV – that have not been deployed before to combine their capabilities with conventional crewed platforms. It brings together loitering systems for surveillance, high-speed systems and crewed ships able to respond to incidents, and AI and machine learning systems to analyse the large quantities of data generated by the dozens of uncrewed platforms deployed. Building on the work of Task Force 59 in the Middle East, the US Navy now plans to expand its work with uncrewed systems and AI into its 4th Fleet, operating in Central and South America.[123]

Task Force 59 has focused on deploying inexpensive commercial off-the-shelf systems, and in doing so has worked closely with partner navies which are also deploying uncrewed systems in the area. The unit aimed to establish a fleet of 100 uncrewed surface vessels operated by the US Navy and its allies during 2023, to act as a surveillance network monitoring seaways in the region.[124] The distributed monitoring network of connected sensors and unmanned systems is controlled from operational hubs in Jordan and Bahrain, analysing data gathered to flag anomalies and predict events so that crewed platforms can be deployed as necessary. The aim is to generate a 'digital ocean', with "every partner and every sensor collecting new data, adding it to an intelligent synthesis of around-the-clock inputs, encompassing thousands of images from seabed to space, from ships, unmanned systems, subsea sensors, satellites, buoys, and other persistent technologies" according to 5th Fleet Commander Vice Admiral Brad Cooper.[125]

123 Megan Eckstein: 'Navy creating unmanned, AI operations hub within US Southern Command', op cit.

124 Megan Eckstein: 'Navy creating unmanned, AI operations hub within US Southern Command'. Defense News, 4 April 2023. https://www.defensenews.com/newsletters/2023/04/04/navy-creating-unmanned-ai-operations-hub-within-us-southern-command/

125 Brandi Vincent: 'Navy's Task Force 59 reaches full operational capability as it works to build a 'digital ocean' of connected assets'. DefenseScoop, 10 January 2023. https://defensescoop.com/2023/01/10/navys-task-force-59-reaches-full-operational-capability-as-it-works-to-build-a-digital-ocean-of-connected-assets/

In September 2023 aquatic and aerial drones operated by Task Force 59 tracked Iranian Navy and Islamic Revolutionary Guard Corps (IRGC) ships and small boats over several days while they carried out routine patrols in and around the Strait of Hormuz. Twelve different uncrewed platforms were reportedly operated alongside crewed ships during the exercise. Task Force 59 is also moving to develop and deploy armed uncrewed craft in the region. In October 2023 the task force conducted exercises with a MARTAC T-38 *Devil Ray* USV equipped with a Lethal Miniature Aerial Missile System in "international waters in the Middle East". Munitions were fired from the USV and destroyed a floating target under the oversight of a human operator.[126]

The Royal Navy is a participant in US-led naval operations in the Gulf and uncrewed technologies are being used to support its actions in the region. The Navy's uncrewed minesweeping craft have been deployed in the Gulf to detect and counter sea mines,[127] and in a high-profile incident in early 2023 Royal Marines from *HMS Lancaster* intercepted a smuggled cargo of arms in response to observations from a US drone operating in the area.[128] *ScanEagle* drones previously operated by the Royal Navy in the Gulf have been credited with similar successes and from 2024 onwards the Navy plans to deploy its Schiebel *Camcopter* S-100 *Peregine* UAV in the Gulf, operating alongside crewed *Wildcat* helicopters to conduct surveillance and reconnaissance activities.[129] One of the key requirements of the Navy's planned Flexible Tactical Uncrewed Air System (FTUAS) is to provide situational awareness to counter fast inshore attack craft such as those used by the IRGC and Houthi armed groups.[130]

Major US-led international naval exercises in the Gulf have showcased the use of uncrewed systems. In 2022 the 18-day International Maritime Exercise (IMX) in the Gulf region was billed as the largest uncrewed maritime exercise in the world, with more than 80 uncrewed systems from 10 nations participating and co-ordinated through a dedicated robotics operations centre.[131] IMX 2023, held the following year, featured more than 30 uncrewed and AI systems, with uncrewed systems and AI integration being a major focus area for the exercise.[132] The Royal Navy was one of the participants operating uncrewed systems during IMX 2023, with 700X Naval Air Squadron operating the *Puma* drone on reconnaissance missions and *RFA Cardigan Bay* supervising minehunting operations using remotely operated / autonomous craft.[133]

126 Kerry Breen: '"Next level": Unmanned U.S. Navy boat fires weapons in Middle East for first time'. CBS News, 3 November 2023. https://www.cbsnews.com/news/unmanned-us-navy-boat-fires-weapons-middle-east-first-time/

127 'First Sea Lord, Admiral Sir Ben Key DSEI 2023 Keynote'. Ministry of Defence, 13 September 2023. https://www.gov.uk/government/speeches/first-sea-lord-admiral-sir-ben-key-dsei-2023-keynote

128 'HMS Lancaster seizes anti-tank missiles after high-speed chase in Gulf of Oman'. Royal Navy, 2 March 2023. https://www.royalnavy.mod.uk/news-and-latest-activity/news/2023/march/02/20230302-hms-lancaster-arms-haul

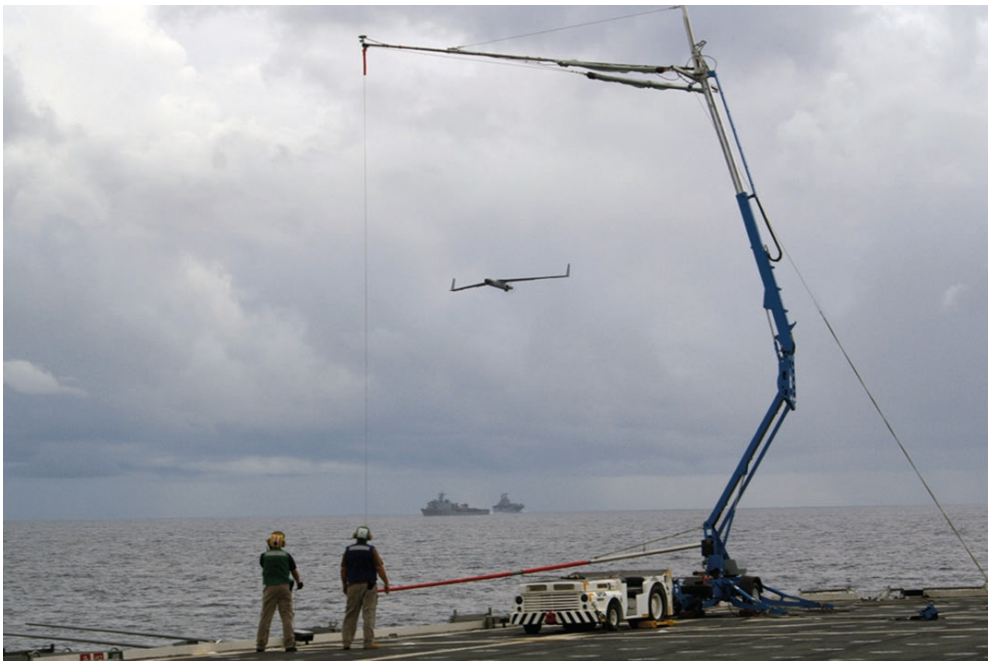
129 'DE&S procures Royal Navy's new "eye in the sky" capability to find and track threats at sea'. Ministry of Defence DE&S, 10 February 2023. https://des.mod.uk/new-uncrewed-aerial-technology-for-royal-navy/

130 Richard Scott: 'UK sets out FTUAS requirement to counter FIAC threat'. Janes, 26 May 2021. https://www.janes.com/defence-news/news-detail/uk-sets-out-ftuas-requirement-to-counter-fiac-threat

131 Xavier Vavasseur: 'IMX 2022: The Largest Unmanned Maritime Exercise in the World'. 8 February 2022. https://www.navalnews.com/naval-news/2022/02/imx-2022-the-largest-unmanned-maritime-exercise-in-the-world/

132 'U.S. Navy, 50 Partners Start International Maritime Exercise 2023'. U.S. Naval Forces Central Command, 27 February 2023. https://www.navy.mil/Press-Office/News-Stories/Article/3310707/us-navy-50-partners-start-international-maritime-exercise-2023/

133 'Royal Navy's Gulf forces complete world's second-largest maritime exercise'. Royal Navy, 20 March 2023. https://www.royalnavy.mod.uk/news-and-latest-activity/news/2023/march/20/20230320-royal-navys-gulf-forces-complete-worlds-second-largest-maritime-exercise



Operators on board a ship prepare to recover a ScanEagle drone **Credit:** Royal Navy

The use of uncrewed maritime vehicles in the Gulf has sometimes contributed to tensions in the region. Iranian forces are known to have temporarily captured Saildrone *Explorer* surveillance USVs operated by the US Navy in the region on two occasions in 2022. In August the *Shahid Baziar*, a ship operated by the IRGC, attached a line to a US Navy Saildrone *Explorer* which was undertaking remote monitoring in the Gulf. The drone was taken under tow by the ship and eventually released when the *USS Thunderbolt*, a coastal patrol boat, and a US Navy helicopter approached. The second incident took place a few days later in the Southern Red Sea and occurred when an Iranian navy frigate, *IRIS Jamaran*, removed two Saildrone *Explorers* from the water. Two US Navy destroyers and a helicopter responded to the seizure, and the drones were released the next day.[134]

Iran's operations in the Gulf region have adopted 'unconventional warfare' techniques centred around hit-and-run tactics and the use of small, fast, attack craft, often operating together as swarms. Tactics have included attacks on commercial vessels and harassment of ships operated by foreign navies with anti-ship missiles, armed speedboats, aerial drones, and remotely operated USVs.[135] Similar tactics have also been adopted by non-state actors operating in the region. For example, in 2017 Houthi forces in Yemen used a fishing skiff loaded with explosives and converted into a USV to severely damage the Saudi Arabian naval frigate *Al-Madinah* in the Red Sea,[136] and in January 2024 a USV packed with explosives was used in an attempt to attack a US ship off the coast of Yemen.[137] Other similar attacks have caused damage to a number of ships and caused the temporary shutdown of one of Saudi Arabia's busiest ports. Between January 2017 and June 2021, 24 successful or attempted maritime

134 Mallory Shelbourne: 'Iran Temporarily Captures Two U.S. Saildrones in Red Sea'. USNI News, 2 September 2022. https://news.usni.org/2022/09/02/iran-temporarily-captures-two-u-s-saildrones-in-red-sea

135 Agnes Helou: 'Iran seeks to grow naval power as it prioritizes asymmetric warfare'. Defense News, 10 January 2022. https://www.defensenews.com/naval/2022/01/10/iran-seeks-to-grow-naval-power-as-it-prioritizes-asymmetric-warfare/

136 'Defence Artificial Intelligence Strategy'. Ministry of Defence, June 2022. P12. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1082416/Defence_Artificial_Intelligence_Strategy.pdf

137 Tony Diver: 'Houthis use unmanned 'suicide boat' for first time in Red Sea attacks'. Daily Telegraph, 4 January 2024. https://www.telegraph.co.uk/world-news/2024/01/04/houthi-suicide-boat-first-red-sea-attack-navy/

drone attacks were undertaken by Houthi forces, mostly targeting commercial shipping but with four targeting civilian ports and two targeting oil production and distribution facilities.[138] Aerial drones have also been used to launch attacks on shipping in the region, most notably the drone attack on the oil tanker *Mercer Street* that took place off the coast of Oman in July 2021[139] and a string of further attacks which took place following Israel's October 2023 invasion of Gaza.[140] Drones used in these attacks are mainly Samad-2 and -3 drones, which the Houthis claim to have designed and developed themselves, although others claim them to be of Iranian origin.[141]

In response to the attacks on shipping the US has undertaken air raids on suspected Houthi bases in Yemen and has deployed warships, including the Arleigh Burke class guided missile destroyers USS Mason, USS Carney, and the USS Nitze, to the area. These ships have themselves been attacked by Houthi forces and have deployed air defence missiles and decoys in response.[142] This raises issues about the effectiveness and sustainability of countering Houthi drone attacks, since the costs of interceptors such as the SM-2 and ESSM missiles are disproportionately expensive, at around $2.4 million each, when compared to relatively cheap drones used by the Houthis. The missile launch cells also require reloading at a suitable port, removing warships from the theatre of operations. Carrier-based aircraft can be used in a defensive role, but this then requires the deployment of an aircraft carrier in the region. Other tactical options for countering drone attacks could include allowing drones to approach closer to a warship where they can be destroyed using less expensive weapons, such as close-in air defence systems and electronic warfare systems, although this poses a greater risk to the ship and its crew.[143]

The IRGC has also reportedly developed a weaponised underwater one-way attack drone, combining UUV and torpedo technology. The UUV is said to be relatively low tech and low cost and able to be produced in quantity, and suitable for covert attacks on ships at anchor. Iran is also said to be developing a naval XLUUV.[144]

In conclusion, the waters around the Arabian Gulf, like the Black Sea, are being used as a test bed for new types of maritime drone and counter-drone technology. One of the primary roles being tested is persistent monitoring over extended periods through large numbers of networked USVs and UUVs. Aerial drones also play an important role in surveillance and reconnaissance. Both aerial and sea drones have been used for attack purposes, sometimes on a clandestine basis and thus allowing perpetrators to deny involvement in attacks.

138 Håvard Haugstvedt: 'Red Sea Drones: How to Counter Houthi Maritime Tactics'. War on the Rocks, September 3, 2021. **https://warontherocks.com/2021/09/red-sea-drones-how-to-counter-houthi-maritime-tactics/**

139 Jennifer Hansler and Ellie Kaufman: 'Pentagon investigative team says Iran was behind attack on Mercer Street tanker'. CNN, 6 August 2021. **https://edition.cnn.com/2021/08/06/politics/us-navy-mercer-street-investigation/index.html**

140 Noah Berman, 'How Houthi Attacks in the Red Sea Threaten Global Shipping', Council on Foreign Relations, 5 January, 2024 **https://www.cfr.org/in-brief/how-houthi-attacks-red-sea-threaten-global-shipping**

141 Sam Cranny-Evans and Sidharth Kaushal: 'Securing the Red Sea: How Can Houthi Maritime Strikes be Countered?' RUSI Commentary, 10 January 2024. https://rusi.org/explore-our-research/publications/commentary/securing-red-sea-how-can-houthi-maritime-strikes-be-countered

142 Sam Cranny-Evans: 'Houthi maritime strike capabilities.' European Defence Review, 4 January 2024. https://www.edrmagazine.eu/edr-analysis-houthi-maritime-strike-capabilities

143 Geoff Ziezulewicz: 'What the Navy is learning from its fight in the Red Sea'. Navy Times, 18 January 2024. **https://www.navytimes.com/news/your-navy/2024/01/18/what-the-navy-is-learning-from-its-fight-in-the-red-sea**

144 H.I. Sutton: 'New Iranian Weaponized Underwater Drone'. Covert Shores, 16 March 2022'. **http://www.hisutton.com/Iran-IRGC-Weaponized-UUV.html**

Case Study 3: The South and East China Seas

The South and East China Seas and surrounding nations

The South and East China seas, including the sensitive Taiwan Strait, are another region of tension in the world's oceans. As with the Arabian Gulf, navigation and territorial rights in the region are in dispute and seas in the region are heavily militarised. In 2020 Drone Wars UK reported in detail on the points of conflict in the South and East China Seas and documented the use of aerial drones in this arena.[145] This case study provides a brief update, focusing principally on the role of sea drones.

Over recent years a plethora of news reports have marked the recovery of sea drones from the waters of the South and East China seas. Chinese *Haiyi* drones have been found in in waters around the South China Sea on a number of occasions. In November 2016 one was found near Quang Ngai in Vietnam, followed by two more in February and March 2019 near Bangka Island and the Riau Islands in Indonesia. In January 2020, one was found near Indonesia's Masalembu Islands at the eastern end of the Java Sea, and in December 2020 a further glider was found by Indonesian fisherfolk near Selayar Island, close to strategically important seaways connecting the Pacific and Indian Oceans. The drones were apparently being used to gather hydrographic data, although such data may have dual-use functions in both environmental research and anti-submarine warfare.[146]

145 Jo Frew: 'Crowded Sky, Contested Sea'. Drone Wars UK, October 2020. **https://dronewars.net/wp-content/uploads/2020/10/DW-CrowdedSky-WEB-1.pdf**

146 H.I. Sutton: 'Underwater Drone Incidents Point to China's Expanding Intelligence Gathering'. RUSI Commentary, 15 January 2021. **https://rusi.org/explore-our-research/publications/commentary/underwater-drone-incidents-point-chinas-expanding-intelligence-gathering**

Chinese media have also reported on the discovery of "foreign spy devices" from the region's seas by fisherfolk and maritime militias. Chinese sources have merely stated that the devices, most likely glider drones, were made in other countries and has not suggested who they are owned by, although commentators have speculated that they are likely to have been deployed by US, Japanese, or possibly Taiwanese forces.[147]

Naval rivals operating in the region are using gliders and sea drones to operate surveillance networks covering wide areas of the ocean. As well as gathering oceanographic data, the drones may also play a role in mapping the sea bed, identifying underwater infrastructure, and tracking surface vessels and submarines. Many parts of the South and East China seas are unmapped, with underwater features and shallows which pose navigation hazards for both civil and military shipping, and particularly underwater operations. A 2021 collision by the submarine *USS Connecticut* submarine with an uncharted sea-mountain in the South China Sea demonstrates the risks of navigation in the region.[148]

The US Navy anticipates using uncrewed craft to engage Chinese vessels operating in China's sphere of influence in the Western Pacific. Drawing on lessons from counter-narcotics operations in the seas around South America, the US Navy's Seventh Fleet intends to monitor 'grey zone' activities aimed at advancing China's maritime claims, such as illegal fishing and harassment of fishing boats from other nations by Chinese fishing fleets, naval militias, and coast guard units. The Fleet intends to use the region as a 'benign environment' in which to learn and develop experience before scaling up to more complex operations over a wider area.[149]

As in the Arabian Gulf, the US military are operating UAVs and USVs in the waters off the coast of China for surveillance and intelligence-gathering purposes and to participate in naval exercises. US Navy's MQ-4C *Triton* aerial drones fly from Andersen Air Force Base on Guam in the Western Pacific Ocean, reportedly flying from Guam to Japan and with adequate range to reach the South and East China Seas.[150] Four of the US Navy's medium and large USVs – *Sea Hawk*, *Sea Hunter*, *Ranger*, and *Mariner* – were deployed to Japan in September 2023 to take part in the US Navy's 'Integrated Battle Problem 23.2' exercise, with the aim of using them routinely as fully operational ships in support of crewed ships, rather than experimental vessels. The USVs took part in activities in the Pacific Ocean with the *Carl Vinson* Carrier Strike Group during 'Large Scale Exercise 23', and with US Navy units stationed in Japan. According to the US Navy, the USVs played a role in "sensing on, above and below the sea; improving battle space awareness; increasing the accuracy of targeting solutions; closing kill chains faster and for longer than manned ships can; and supporting the delivery of offensive fires from longer distances, to keep manned ships away from enemy threats".[151]

147 Owen Amos: 'Why are Chinese fishermen finding so many 'submarine spies'?' BBC News, 16 January 2020. https://www.bbc.co.uk/news/world-asia-china-51130644

148 Gabriel Honrada: 'Underwater drones herald sea change in Pacific warfare'. Asia Times, 12 January 2022 https://asiatimes.com/2022/01/underwater-drones-herald-sea-change-in-pacific-warfare/

149 Patrick Tucker: 'The Navy Wants Drones to Counter China's Gray-Zone Moves'. Defense One, 4 April 2023. https://www.defenseone.com/defense-systems/2023/04/navy-wants-use-drones-counter-china-not-yet/384823/

150 Geoff Ziezulewicz: 'Navy's Triton drone squadron returns to Guam. Navy Times, 14 September 2023. https://www.navytimes.com/news/your-navy/2023/09/14/navys-triton-drone-squadron-returns-to-guam/

151 Megan Eckstein: 'Navy brings unmanned vessels to Japan to bolster fleet integration'. Defense News, 22 September 2023. https://www.defensenews.com/naval/2023/09/22/navy-brings-unmanned-vessels-to-japan-to-bolster-fleet-integration/

Some military analysts consider that the use of uncrewed craft and drones could play a central part in future strategy should war break out between the US and China over Taiwan.[152] Should China, a drone superpower, attempt to occupy Taiwan it could be expected to deploy swarms of drones to overwhelm defences. However, an invasion force would need to cross the Taiwan Strait, exposing large numbers of ships to attack. The military think-tank RAND has proposed that the US should deploy a surveillance network of large numbers of small, low-cost, expendable drones which could be used to observe shipping in the Taiwan Strait and identify targets for conventional weapons-delivery platforms to attack, or themselves undertake attacks operating together as swarms.[153] The US Department of Defence's *Replicator* drone programme – intended to develop expendable autonomous systems which can be deployed across different domains within the next two years – is intended to develop drones for just such a role, with US officials explicitly stating that the programme is intended to counter China's military capabilities.[154]

152 Steve Trimble: 'Invade Taiwan? Encounter A 'Hellscape'. Aviation Week, 26 September 2023. **https://aviationweek.com/defense-space/missile-defense-weapons/invade-taiwan-encounter-hellscape**

153 Andrew R. Hoehn and Thom Shanker: 'Can Cheap Drones Be the Answer to Tensions in the Taiwan Strait?' The RAND Blog, 29 June 2023. **https://www.rand.org/pubs/commentary/2023/06/can-cheap-drones-be-the-answer-to-tensions-in-the-taiwan.html**

154 Joe Saballa: 'US Launches 'Replicator' Drone Program to Counter China'. The Defense Post, 29 August 2023. **https://www.thedefensepost.com/2023/08/29/us-replicator-drone-program/**

6 | Key findings

Our study of trends in the development of maritime drones and the situations in which they have been used indicates that they are already widely in use for a variety of types of military operation. Situations in which maritime drones are used can be expected to increase, and the drones themselves can be expected to become increasingly weaponised and autonomous.

In the light of these findings we highlight the following as particular risks resulting from the use of drones at sea:

- In general, increasing the militarisation of areas of tension is destabilising and dangerous. If drones are deployed in a zone where there are tensions between nations there is a risk that surveillance, spying, or other missions may escalate tensions, even if not intended to do so.
- There is a perception that drone use is politically less risky than the use of piloted systems, and also that drones have greater surveillance capabilities than crewed aircraft. This may reduce inhibitions about deploying them, risking lowering the threshold for military interventions.
- With no international agreements or codes of practice in place on the acceptable use of drones, the presence of drones in a sensitive region may over time lead to further proliferation in their use and fuel regional arms races.
- Deployment of increasingly autonomous military systems – particularly at sea, where communication is difficult, raises concerns about the level of human control over their activities and whether they remain under meaningful human control.
- Activities at sea – particularly those underwater – are more difficult to observe and monitor than activities on land or in the air, leading to questions about what levels of transparency are needed over maritime drone operations. This is a particularly relevant issue given the tendency of governments to adopt drones for clandestine activities and the lack of transparency over military drone operations in general.
- Drone technology – for both aerial drones and drone boats – is relatively cheap and easily obtained. As a result drones are routinely being used by non-state actors in combat. This trend can be expected to continue, and the sophistication of drones used by non-state actors is likely to increase.

7 | Conclusion

Remote-controlled and autonomous military systems are being increasingly used at sea and there is every reason to believe that the trends of recent years will continue and accelerate over the next decade. As we have outlined in this report, major military powers are spending billions of dollars to develop systems that can cover vast swathes of territory, while smaller states and non-state groups are spending just a fraction of these sums on less sophisticated but nevertheless effective systems which are making their mark in key conflict zones.

In the aerial domain, where drones and remote controlled systems were once the preserve of a handful of elite states, we have seen that the absence of political will to control drone use has allowed drones to proliferate to the point where multiple state and non-state actors now use a wide variety of systems in numerous conflict and potential conflict zones. This trend can be expected to be replicated in the maritime domain.

The use of remotely controlled (and increasingly autonomous) drones is prized by both state and non-state actors alike as it enables surveillance and lethal strikes to be undertake with little or no risk or consequences for the user. In addition, the use of drones enables military activity to be undertaken with a degree of deniability, something also valued by those engaged in 'grey zone' warfare.

The doctrine of 'national security' endlessly drives states to push forward to develop technologies and polices which can only generate mistrust among their adversaries and exacerbate global tensions and instability. Real security lies in reducing global tension, building equality and trust between peoples, and tackling together global threats such as climate change, poverty, and disease. The increasing use of drones in any and all domains is a backwards step which must be resisted.

Acronyms

ACTUV	Anti-Submarine Warfare Continuous Trail Unmanned Vessel
AI	Artificial Intelligence
AIS	Automatic Identification System
ARF	Advanced Research Foundation
CMF	Combined Maritime Forces
CTF	Coalition Task Force / Combined Task Force
DARPA	Defense Advanced Research Projects Agency
DASA	Defence and Security Accelerator
DSTL	Defence Science and Technology Laboratory
FMAF	Future Maritime Aviation Force
FTUAS	Flexible Tactical Uncrewed Air System
GPS	Global Positioning System
HMS	Her / His Majesty's Ship
IMSC	International Maritime Security Construct
IMX	International Maritime Exercise
IRGC	Islamic Revolutionary Guard Corps
IRIS	Islamic Republic of Iran Ship
ISR	Intelligence, Surveillance, and Reconnaissance
LDUUV	Large Displacement Unmanned Undersea Vehicle
LED	Light Emitting Diode
LiFT	Lithium-ion Fault Tolerant
LTV	Large Training Vehicle
MADFOX	Maritime Demonstrator For Operational Experimentation

MARTAC	Maritime Tactical Systems
MAST	Maritime Autonomy Surface Testbed
MASTT	Maritime Autonomous Systems Trials Team
MoD	Ministry of Defence
NAS	Naval Air Squadron
NATO	North Atlantic Treaty Organisation
NOMARS	No Manning Required Ship
OCCAR	Organisation for Joint Armament Cooperation
ONR	Office of Naval Research
PLAN	People's Liberation Army – Navy
REPMUS	Robotic Experimentation and Prototyping Augmented by Maritime Unmanned Systems
RFA	Royal Fleet Auxiliary
RIB	Rigid Inflatable Boat
SPURV	Special Purpose Underwater Research Vehicle
SURFDEVRON	Surface Development Squadron
UAV	Uncrewed Aerial Vehicle
UK	United Kingdom
US	United States
USS	United States Ship
USV	Uncrewed Surface Vehicle
UUV	Uncrewed Underwater Vehicle
UUVRON	Unmanned Undersea Vehicle Squadron
XLUUV	Extra Large Uncrewed Underwater Vehicle
XV	Experimental Vessel

DRONE WARS

Shining a spotlight
on military drones