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The Role of Artificial Intelligence in Naval Operations

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Securing the Maritime Commons: **The Role of Artificial Intelligence in Naval Operations**

ABSTRACT

Artificial Intelligence (AI) and its limitless application in naval operations has grabbed the imagination of strategic planners worldwide. The applicability of AI to naval operations surpasses its usage in any other military domain due to the hostility, unpredictability and sheer size of the ocean environment. While these systems and vehicles can never be equivalent replacements for human naval commanders and traditional naval vessels, evidence suggests that wherever these intelligent systems have been deployed, they have made existing manned operations more effective. Future innovation in such technologies might lead to completely autonomous systems with lethal capabilities, provoking debates on ethical issues. This paper undertakes an examination of the use of AI in naval operability and its role in transforming maritime security missions.

INTRODUCTION

Artificial Intelligence (AI) is starting to revolutionise every aspect of human life. From assisting healthcare to navigating commercial delivery drones, science and engineering have made unprecedented progress in delivering 'intelligent machines' that can bring immense benefits to people. The impact of artificial intelligence is so extensive that any field bereft of its accompanying technological jump is sure to miss out on the scientific evolutions of the future. For this reason, various countries have placed considerable importance on developing military uses of AI to maintain battle-space superiority. AI-based technologies can be employed in the military domain to execute complex and exacting missions, especially in environments that are hostile and unpredictable; the maritime battle-space perfectly fits this frame. Oceanic environments are often unmapped and difficult to navigate, and the use of AI-based systems to track, calculate, detect, chart and execute the best actions for a vessel augments existing nautical capabilities. In operating locales that need constant intelligence, surveillance and reconnaissance of the ocean environment, AI-supported systems can negate the hostilities of marine physics, i.e., hydrostatic pressure, ocean turbulence, thermal gradient, and ocean salinity, among others.[1] Additionally, navies can employ these technologies to target, map, and even engage enemy vessels. All these factors make unmanned intelligent systems an indispensable asset in naval force structures. Moreover, the relatively 'uncluttered' marine environment might be the first battle-space that witnesses the deployment of fully autonomous weapons.[2]

However, even as these technologies are being developed, legal and ethical issues on the use of autonomously capable lethal systems are beginning to gain greater salience. Questions remain as to where these systems stand with respect to international law, especially Article 36 (Additional Protocol I) of the Geneva Convention, which specifies that states need to undertake a legal review of new weapons to ensure their compliance with international law.[3] Therefore, even as the new generation of AI-based combat technology looms on the horizon, endowing such systems with targeting autonomy will have to be subject to strict provisions of international law. In the specific context of AI-based naval operations, AI-supported systems with targeting abilities will need to be able to continuously distinguish between military assets and civilian vessels.

This paper charts the development of AI in naval systems, their integration in naval combat management, and the resulting consequences for the existing operational environment. It seeks to ascertain whether AI-based systems are an answer to maintaining security in the maritime commons. The three issues that dominate the overall discussion are – human-machine collaboration (also known as man-machine teaming), the different degrees of machine autonomy, and the various missions in which AI can affect naval operations. The paper examines how principles on the use of such systems are being developed concurrently with the progress in such technologies, and what human, conceptual and organisational challenges may result from an AI-centric battle environment. It gives an overview of India's approach to unmanned naval systems, and the operational landscape for the Indian Navy as the country pursues a national AI strategy. The final section recommends measures to ensure a smooth transformation to AI-supported naval operations.

DEFINING 'ARTIFICIAL INTELLIGENCE' IN NAVAL OPERATIONS

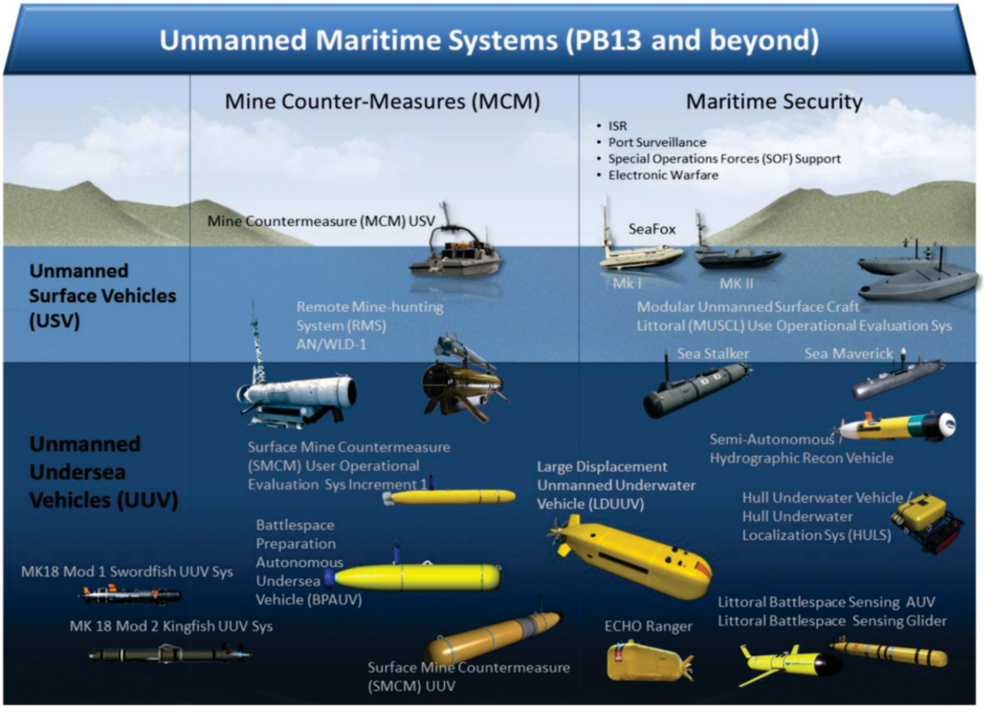
At the outset, it is necessary to distinguish between AI-based naval combat systems and AI-based naval vehicles. While not mutually exclusive, AI-based naval combat systems that are being developed and adopted to augment general nautical operations require comprehensive human-machine collaboration, compared to AI-based naval vehicles, which may not always have a human supervisor. The two broadly distinguishable ways by which AI can influence and augment naval operations are the following:

Naval Combat Systems – The application of AI in naval combat systems can enhance general naval operability through a combination of software processes for smarter command and control. These technologies can also be used in combat management systems for better targeting and mapping of enemy assets. Integrating such systems into existing sensors of a naval vessel will augment the decision-making process of the officers on board, "by intelligently processing multiple sources of information, whilst cueing systems to assess and confirm potential threats."[4] The objective of the navies developing these systems is to improve, "operational capability in its fighting units," and, "enable rapid decision-making in complex, fast-moving warfighting scenarios."[5]

Unmanned Naval Vehicles – The application of AI in unmanned naval vehicles can extend from general navigational support to complete functioning autonomy. These vessels or vehicles (used interchangeably), have become a key part of naval operations and are commonly deployed in non-lethal roles alongside conventional vessels. Broadly classified as Unmanned Underwater Vehicles (UUVs) and Unmanned Surface Vehicles (USVs), most of these vessels are under direct human control and lack mission autonomy. These vessels can be remotely operated (referred to as ROV) through 'tele-piloting', which allows a remote operator to command and supervise unmanned vessels using satellite links.[6]

A sub-group of unmanned naval vehicles that enjoy a certain degree of autonomy are commonly classified as Autonomous Underwater Vehicles (AUVs) and Autonomous Surface Vehicles (ASVs). The SIPRI report on 'Mapping the Development of Autonomy in Weapon Systems' defines autonomy as, "the ability of a machine to execute a task, or tasks, without human input, using interactions of computer programming with the environment."[7] These systems perform most analytical functions without human intervention, and thus reduce the need for human crews that have conventionally performed them. With vessels where operators are in complete control, humans are considered "in the loop"; for vessels which have a certain degree of autonomy, but are under human supervision, humans are considered "on the loop"; while for untethered vessels that function with complete mission autonomy, humans are considered, "off the loop".[8] These different degrees of autonomy are especially important in discussions on the type of mission these unmanned assets are programmed to execute. Figure 1 and Table 1 demonstrate the various classifications of unmanned naval vehicles.

Figure 1: Classifications of Unmanned Maritime Systems



Source: Photo: U.S. Department of Defense[9]

Table 1: Detailed Classification of Unmanned Maritime Systems displayed in Figure 1 (U.S. Navy, 2013)

Name	Classification	Manufacturer	Primary Application*
Mine Countermeasures Unmanned Surface Vehicle (MCM USV)[10]	USV	Textron Systems	Mine Sweeping
Remote Mine Hunting System (RMS)[11] AN/WLD-1	USV	Lockheed Martin	Mine Detection
Surface Mine Countermeasure (SMCM) User Operational Evaluation Sys Increment 1[12]	USV	Not Available	MCM
Battlespace Preparation Autonomous Undersea Vehicle (BPAUV)[13]	AUV	Bluefin Robotics	MCM
Surface Mine Countermeasure (SMCM) UUV[14]	UUV	General Dynamics Mission Systems	Mine Sweeping
MK18 Mod 1 Swordfish UUV Sys[15]	UUV	Hydriod Inc.	ISR and MCM
MK18 Mod 2 Kingfish UUV Sys[16]	UUV	Hydriod Inc.	ISR and MCM
SeaFox (MK 1)[17]	UUV	Atlas Elektronik	Mine Sweeping
Modular Unmanned Surface Craft Littoral (MUSCL) Use Operational Sys[18]	USV	Program Executive Office, Littoral Combat Ships	ISR
Sea Stalker[19]	UUV	Pennsylvania State University Applied Research Laboratory	ISR
Sea Maverick[20]	UUV	Pennsylvania State University Applied Research Laboratory	ISR
Semi-Autonomous Hydrographic Recon Vehicle (SAHRV)[21]	AUV	General Atomics	ISR
Large Displacement Unmanned Underwater Vehicle (LDUUV)[22]	UUV	Office of Naval Research, U.S.	IPOE and ISR
Hull Underwater Vehicle / Hull Underwater Localization Sys (HULS)[23]	UUV	Bluefin Robotics	Explosive Ordnance Disposal
Echo Ranger[24]	AUV	Boeing Defense, Space & Security	Hydrographic Survey
Littoral Battlespace Sensing AUV[25]	AUV	Hydroid Inc.	ISR
Littoral Battlespace Sensing Glider[26]	UUV	Teledyne Brown Engineering	ISR

**ISR – Intelligence, Surveillance and Reconnaissance, MCM – Mine Counter-Measures, IPOE – Intelligence Preparation of the Operational Environment*

ARTIFICIAL INTELLIGENCE IN NAVAL COMBAT SYSTEMS

The purpose behind the application of AI to naval operations through information management systems is to influence and augment the decision-making process of the naval commander. The practice of using digital assistants for enhanced navigability is not a new concept in naval vessels, but the groundbreaking aspect of the next step in naval combat systems is their ability to revolutionise command and control of an entire vessel, or even an entire fleet. The AI software gives command teams the ability to monitor real-time combat situations and suitably utilise the naval assets at their disposal. These systems combine hardware and software (processes) to completely transform naval manoeuvres. System developers have attempted to mimic the processes of the human brain and generate machine learning processes that analyse vast amounts of incoming data from sensor suites such as satellite imagery and active sonars.[27] The combination of neural networks and deep learning algorithms are then able to present a seamless operating picture to the command team and assist them in taking decisions, enhancing their human capacity. These systems can even enhance fleet operability, given assets are connected to each other. The Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) oriented system can be connected to individual naval vessels, irrespective of their class. Submarines, frigates, aircraft carriers, battleships, unmanned vehicles, can all be equipped individually with such systems to augment their specific functions. Unmanned assets connected to the system with the ability to relay back intelligent video analytics will be able to provide over-the-horizon (OTH) mapping and targeting, extending the line-of-sight of the fleet in all directions.

As shown in Figure 2, Britain's Royal Navy plans to induct AI systems on board its ships to better detect threats and assess combat scenarios.[28] Roke Manor Research's (Roke) 'STARTLE' machine situational awareness software, will augment a vessel's existing detection systems and make informed decisions based on the data it receives from those sensors.[29] The AI-based intelligent systems will cue other systems and confirm potential threats, which they will then relay back to the officer in charge. These systems recognise behaviour patterns, run multi-agent-based simulations with deep learning techniques, and enable end-users to improve their Maritime Domain Awareness for rapid tasking, detecting, and tracking of non-cooperative vessels.

Figure 2: Roke's 'STARTLE' Threat Monitoring System

Source: Photo: Roke.co.uk[35]

China is also planning to provide its nuclear submarines with an AI-based decision-support system, one that would lessen the burden of its submarine commanders.[30] The deep learning algorithms of such support systems can correlate with other sensors and help commanding officers, "estimate the risks and benefits of certain combat maneuvers, even suggesting moves not considered by the vessel's captain."[31] Sub-surface naval commanders are often engaged in dull operations that require patience, skill and navigational expertise, and above all, the ability to react to sudden changes in situations. These systems can reduce their fatigue and greatly boost their operational proficiency.

Among private operators, aerospace manufacturer Rolls Royce has signalled its intent to develop completely autonomous ships, free of human crew.[32] The manufacturer has "incorporated the latest in navigation technology, combining an array of sensors with an AI-powered computer."[33] The company has teamed up with Google Cloud and will use Google's Cloud Learning Engine to train its AI-based object classification system.[34] This software will primarily be used for detection, tracking and identification.

The Consolidated Afloat Networks and Enterprise Services (CANES) network of systems adopted by the US Navy for its Littoral Combat Ships (LCS) is an example of an existing naval combat system being expanded and cyber hardened by means of AI.[36] An upgraded version of the CANES will seamlessly connect ships, submarines, shore locations and other tactical nodes, and augment naval operability and shorten action cycles against cyber-attacks, protecting existing combat systems.[37] Modern naval vessels are fitted with an astonishing number of sensor suites, and by analysing the plethora of information received from various nodes, an upgraded version of the CANES network can rationalise the information, remove the anomalies and assist the human command team, while also protecting the system from cyber intrusions. According to Kris Osborn, an upgraded CANES network, based on AI, "is being specifically configured to increase automation - and perform more and more analytical functions without needing human intervention."[38] He adds that, "LCS, in particular, draws upon interconnected surface and multiple mission packages engineered to use a host of ship systems in coordination with one another – the kinds of things potentially enhanced by AI analysis."[39] The US Navy plans to expand the upgraded AI-supported CANES network to all its combat assets in the future, including its nuclear submarines and its flagship Ford class of aircraft carriers.[40]

The common factor of all these naval combat systems is their ability to learn constantly from the feedback received from the environment. Deep learning algorithms embedded in their systems enable them to keep learning from various situations, especially by evaluating human input over time.[41] Software developers have realised that relying solely on human inputs is not enough. Therefore, to expedite the learning process and go beyond human competences, these systems increasingly rely on 'machine learning'. As a report mentions, "Machine learning is an approach to software development through which systems learn tasks and improve their performance through experience."[42] This development suggests that there might be a future where ships will operate with complete autonomy, without human oversight. At a rudimentary level of assistance, some of which already exists, these systems can provide information on bathymetry, water temperatures and salinity levels for sonar accuracy, and assist in course-plotting through waypoint navigation and collision avoidance technology, augmenting the navigability of the vessel.[43] However, in a more war-fighting role, "strides in machine learning, has created opportunities for the development of autonomy in weapon systems."[44] Such levels of autonomy warrant the question of whether navies around the world would be willing to concede so much control to such combat management systems.

A.I. IN UNMANNED NAVAL VEHICLES

While the application of AI to naval combat systems is at a nascent phase, it is more established in unmanned naval vehicles. Unmanned naval vehicles have become a common feature of modern-day naval structures, and as they are deployed for more sophisticated naval missions, the degree of human control over them is progressively decreasing. Consequentially, when such vessels are operating in untethered environments devoid of any satellite uplinks, they are being granted complete mission autonomy. Sean Welsh, ethics and security automata expert, argues that these vessels are primarily being employed as force multipliers in naval security missions to provide seamless maritime domain awareness (MDA).[45] Figure 1 and Table 1 demonstrate that the primary missions of these unmanned naval vehicles involve non-lethal assignments, such as Intelligence, Surveillance and Reconnaissance (ISR), Intelligence Preparation of the Operational Environment (IPOE), and Mine Countermeasures (MCM).

Collective advances in technology have allowed these vehicles to execute more complex missions, with increased autonomy and their own support packages. Welsh describes, "submarine launched USVs attached to their "mother" subs by tethers, providing video communications of the surface without the sub having to come to periscope depth. Such USVs then launch small Unmanned Aerial Vehicles (UAVs) to enable the submarine to engage in reconnaissance from the air."[46] Raytheon SOTHOC (Submarine over the Horizon Organic Capabilities) is an example of such a system – "it launches a one-shot UAV from an unmanned launch platform ejected from the submarine's waste disposal lock."[47] For surface level operations, the US Navy's Sea Hunter is an example of how ASVs can be deployed for large area surveillance operations to track submarines and relay the information back to a nearby vessel or pre-determined command station.[48] Developed by the Defense Advanced Research Projects Agency (DARPA), the Sea-Hunter, also known as the Anti-Submarine Warfare Continuous Trail Unmanned Vessel (ACTUV), can be equipped with a parasailing sensor array, allowing it to increase its sensory capabilities by more than a thousand feet, augmenting its omni-directional radio connectivity.[49] The Sea Hunter can loiter for months at sea, searching and tracking submarines.

Another development in unmanned operations that is changing the nature of naval missions is called 'swarming'. Swarming essentially involves a group of drones (vehicles) that act autonomously within themselves, but as a whole are remotely operated. They are tailored to execute an overall objective, but each unit has individual autonomy in relation to one another. Software development allows these individual drones to execute mini-tasks within a larger mission by themselves, while being seamlessly connected. The US Navy has invested in a research programme to develop such capabilities. The programme titled, "Low Cost Unmanned aerial vehicle Swarming Technology" (LOCUST), will allow its operators to control the behaviour of the swarm, while preserving individual drone autonomy.[50] The US Office of Naval Research (ONR) even held a robot swarm demonstration, where four drone boats patrolled an area while maintaining their formation automatically, with human control only over the swarm's larger movements.[51] A Chinese technology company – Yunzhou Intelligence Technology (Yunzhou Tech) performed a similar demonstration in the Wanshan Archipelago with 56 autonomous USVs by equipping them with specially developed 'autonomy modules'.[52] Such missions can be termed "on the loop", relating back to the idea of machines having autonomy to execute functions under human supervision, but without continuous remote control. Technological developments associated with swarming have the ability to transform naval operations, which have been traditionally centred on strategic assets like aircraft carriers. Swarming will allow navies to disperse their smaller tactical assets and perform the same security missions as a large conventional vessel, as long as these assets perform their assigned task in unison.

The same concepts of deep learning algorithms that apply to naval combat systems are also applicable to autonomous naval vehicles. These unmanned vessels, without human supervision, are constantly learning from their environment and improving their capability to execute missions with increased perspicacity. Targeting autonomy in such unmanned vessels may serve the necessities of future warfare and let an ASV like the Sea Hunter conduct full-range anti-submarine warfare operations with the mission autonomy to engage targets. Similarly, AUVs may well be the future replacements of attack submarines if lethal autonomy is granted. Autonomy to carry out lethal missions would allow such unmanned vessels to provide active protection to harbours, large ships, commercial convoys, sea lines of communication and even nuclear submarines. Plausibly, the future of the maritime battle-space could be balanced in favour of autonomous systems. The question then arises as to when Lethal Autonomous Weapon Systems (LAWS) will be deployed.

LETHAL AUTONOMOUS WEAPON SYSTEMS (LAWS)

Ocean environments are considered the most suitable area for the initial deployment of LAWS as identification of assets is easier, and there is relatively smaller presence of civilians.[53] An armed AUV would increase the bandwidth at which any naval task force operates, as vessels will have the ability to function and engage enemy targets without human intervention or any input from the command team. The future in this automation revolution may well take us to a system that will be at the helm of command and control of navies, with authorisation to deploy lethal unmanned assets when it deems it necessary, completely replacing human command teams. The use of LAWS brings an undeniable advantage in protecting marine zones, where there is high exposure to submarine threats. Deploying LAWS will make additional sense for sub-surface missions, as targeting through ROVs is problematic, with existing communications in submarines being restricted to VLF (Very Low Frequency) and ELF

(Extremely Low Frequency) radio waves because of the properties of radio waves in salt water.[54]

Conversely, the conformity of AI-based LAWS with international humanitarian law is a debate that has assumed global significance over the last few years. For the purposes of this paper, it is appropriate to use the definition favoured by the International Committee of the Red Cross. The Red Cross uses “'autonomous weapons” as an umbrella term encompassing any type of weapon with 'autonomy' in its “critical functions”, meaning a weapon that can select (i.e. search for or detect, identify, track) and attack (i.e. intercept, use force against, neutralise, damage or destroy) targets without human intervention.”[55] The United Nations Convention on Certain Conventional Weapons (CCW) in Geneva, which has been the platform for the discussions surrounding the legality of LAWS, has held multiple rounds of consultations on the topic, but has failed to arrive at a consensus on how these evolving weapon systems should be regulated.[56] While the international debate goes on, governments and militaries around the world keep developing weapon systems with varying levels of autonomy. It is quite plausible, that before any international convention on the regulation of lethally autonomous weapon systems is agreed upon, there will already be in existence weapon systems with 'autonomy in their critical functions'. International regulators can only control what states want to reveal, and any covert programme undertaken by nations for development of LAWS will remain outside the ambit of the CCW. To avoid such a scenario, a coalition of non-governmental organisations initiated the International Campaign to Stop Killer Robots. Led by Human Rights Watch, the campaign has consistently demanded a pre-emptive blanket ban on the deployment and development of LAWS.[57] As many of these technologies are well in their advanced stages, the concerns about LAWS in the international community are not hypothetical. The SIPRI report suggests that the CCW should explore the concept of 'meaningful human control' over autonomous systems to regulate LAWS.[58]

There is scope for finding a middle ground, where LAWS can be programmed to conform to norms of international law. In the scenario that these AI-based vehicles and systems are lethally enabled and have the freedom to engage targets, their mission autonomy can be limited to pre-programmed manoeuvres coded into their systems. Additional control can be exercised by the software developers on how their targeting autonomy functions. At the most rudimentary step, developing a lethal UUV or giving network systems lethal capabilities would be a matter of developing a simple vessel identification system that can react to distinctive acoustic signatures. Further control can be imposed on these systems by instituting ethical control based on the principles suggested by American roboticist and roboethicist, Ronald Arkin.[59] Arkin has argued for inducting a 'Responsibility Adviser' while designing autonomous systems.[60] His paper titled, 'Governing Lethal Behaviour: Embedding Ethics in a Hybrid Deliberative/Reactive Robot Architecture', details the "basis for the development of autonomous systems architectures capable of supporting ethical behaviour regarding the application of lethality in war."[61] These mechanisms will ensure that the design of intelligent behaviours only provides responses within rigorously defined ethical boundaries. The software that would code the learning algorithms for machine learning should have superior target discrimination capabilities and allow for the creation of techniques to permit adaptation of an ethical constraint set and underlying behavioural control parameters that evolve with its learning.[62] This is especially important for the autonomous system when distinguishing between friendly forces and adversarial targets, and between civilians and combatants.

OPERATIONAL LANDSCAPE FOR A.I. - BASED NAVAL SYSTEMS AND UNMANNED VEHICLES

The US and China are at the forefront of the development of AI-based naval systems that will enhance their nautical capabilities. Both have devoted considerable resources to developing an action plan for the implementation of AI-based systems in their navies and have accompanied such plans with innovative operational procedures that would support this shift to unmanned manoeuvres.[63] The seizure of a US UUV by the Chinese navy in 2016 demonstrated the emerging competition between the US Navy and the People's Liberation Army Navy (PLAN) in this new generation of naval warfare involving intelligent systems.[64] The Third Offset Strategy developed by the Department of Defense of the United States placed considerable importance on developing military uses of artificial intelligence, with the purpose of maintaining battle-space superiority.[65] The strategy devised during the Obama administration focused on developing cutting-edge defence technology to maintain American superiority over adversaries like Russia and China in the calculus of battlefield technology.[66] Even though, after the change in administration in Washington D.C., investments in conventional forces have been given more priority, offices such as the Strategic Capabilities Office (SCO) and Defense Innovation Unit Experimental (DIUx), associated with the Third Offset Strategy continue to receive, "increasing investments."[67] China has prioritised technological innovation in this arena and claims to be on an equal footing with its US counterparts.[68] Led by Xi Jingping, all military units of the Chinese state have placed considerable emphasis on developing strategies and technologies suited to an AI-conducive battle environment.[69]

Simultaneously, military planners in Beijing and Washington are coming up with innovative operational concepts apposite for this new stage of unmanned manoeuvres.[70] China anticipates that swarm intelligence and swarming tactics could serve as an asymmetric method to target high-value US weapons platforms.[71] Swarm technology is attractive to Beijing, as it would allow China to project force with a lower probability of military confrontation.[72] At the other end, the US strategy of distributed lethality aims to shed years of naval strategy around high-value targets and distribute action capabilities among dispersed assets.[73] Both strategies make targeting difficult and overwhelm the capabilities of the adversary.

By and large, unmanned platforms have the most potential in sub-surface missions, especially in Anti-Access/Area-Denial (A2/AD) strategies.[74] Conversely, they can also be used for countering A2/AD strategies, as ORF analyst, Abhijit Singh remarks, "their defining attribute is the ability to extend combat operations into the adversary's anti-access/area-denial zone without risking the integrity of onboard systems or putting own forces in harm's way."[75] Unmanned vehicles can perform a variety of non-lethal actions: active surveys of shallow water littoral regions, detection and monitoring of mines, jamming enemy communications, providing acoustic intelligence, conducting oceanographic and hydrographic surveys, providing submerged communications to undersea platforms, and carrying out active counter-measures against naval mines.[76] AI -based information systems can further amalgamate and synthesise data, and transform the ISR capabilities of a navy. Unmanned platforms can also improve intelligence preparation in the battle-space, providing fleets protected passage, by conducting clearance, sweeping and protection missions.[77] Essentially, unmanned platforms promise to improve productivity, allowing manned systems to pursue more specialised/important tasks, increasing the effectiveness of operational procedures.[78]

CONSEQUENCES OF A.I. IN THE MARITIME DOMAIN

The hype surrounding AI is certain to increase in the coming years, and as more of these systems get deployed, it is likely that the world may soon enter a stage of warfare in which AI-supported navies will be common in the maritime battle-space. However, there are multiple consequences to broad-based initiation of AI-based systems in naval operations. Foremost among them is institutional resistance from conventional naval personnel who will oppose any move that seeks to replace them.[79] The tasks that are to be performed by AI-supported naval combat systems are currently carried out by personnel on board naval vessels or from stations at shore. Therefore, replacing human analysts in the decision cycle of naval combat will transform multiple sections of the naval force. As naval operations get transformed, navies will need the help of these conventional analysts as operational procedures go through transition and are calibrated for man-machine teaming. There will be a need to develop a new training curriculum to produce technologically literate and AI-calibrated personnel, and an equally proficient testing and validation regime to test these new technologies.[80] The Navy Center for Applied Research in Artificial Intelligence of the US Navy is a good example of how a specialised agency has been tasked with examining these topics.[81] In an era that precedes man-machine teaming in lethal engagements, navies need to indoctrinate their operations, corps and systems with every possibility, no matter how remote they may seem. Most notably, operational paradigms and tactics need to be revamped to suit multi-vehicle control.

At present, the majority of the applications of AI to naval operations are dependent on a human operator, making human-machine calibration extremely important. Naval combat systems only perform analytical functions in a combat scenario, whereas the final decision of engagement rests with the human naval commander. Therefore, navies employing AI in their operations will need to ensure that both the human commander and the AI-supported machine understand each other's decision-making loop. John Hawkley, an American engineering psychologist, writes in *Patriot Wars* that, "Newly automated systems rarely live up to their initial billing. First-time users of automated systems must anticipate a debugging and calibration period during which the system's actual capabilities and limitations are determined."[82] Hawkley further refers to the 'brittleness' of automated systems, where he discusses the "machine's inability to handle unusual or ambiguous tactical situations reliably."[83] This also makes vigilance over the automated system difficult for human supervisors, as they are required to perform 'critical functions', and yet are out of the decision loop in the other autonomous functions.[84] Automation complacency amongst technologically trained commanders alongside misgivings about automation among veteran commanders can cause disparity within the forces.[85] Automation in these systems should not be taken at face value, as one report mentions, "Belief in the system's infallibility (i.e., it's always right) can lull operators into a false sense of security, with the result that they will not make checks that would otherwise be advisable."[86] Further, in some autonomous systems with deep learning neural networks, the input-output process is not yet completely transparent, and this can cause barriers to man-machine teaming, as human commanders will fail to understand how a system processes information and arrives at a decision. Thus, in the present context, it is highly unlikely that 'off the loop' autonomous weapon systems will be endowed with lethal capabilities, all the more due to the ethical questions surrounding them.[87]

Another barrier to the development and deployment of such systems are their vulnerabilities from countermeasures, some of which have already been created. Many of these AI-supported vehicles are still in the design phase and it should be expected that in parallel with their development, adversaries will also invest in developing countermeasures. Acoustic stealth and acoustic quieting technologies are already being inducted into submarines, and the future improvement of these technologies can send the acoustic identification system of an AI-based vessel for a complete toss.[88] Acoustic stealth technologies involve designing ships with reduced noise signature and radar cross-section – the new generation of diesel electric submarines is a good example of this.[89] The acoustic signatures of unmanned vessels are also unfavourable to their deployment, as adversaries will easily recognise their presence, and this can open them up to easy engagement. Additionally, the functioning of unmanned vehicles in GPS-denied environments, either due to constraints of bathymetry, or GPS jamming by enemy forces, raises serious concerns about how such systems would work uninterrupted. Non-GPS based guiding systems and anti-jamming protection software will need to be included in the research and development process. Many countries are developing capabilities that will allow them to adopt soft kill measures against unmanned systems, specifically using hacking and jamming software.[90] The possibility of a naval task force's UUV or USV being hacked and used against it is one that will haunt every naval commander. Hack-proofing unmanned systems should be a priority for developers. Developers and end-users need to consider all of the above factors while these systems are still under development.

THE INDIAN NAVY'S TRYST WITH UNMANNED SYSTEMS

India has been late in recognising the potential of autonomous systems in the military sphere and is far behind countries like the US and China in developing indigenous AI-based combat systems and naval vehicles. However, the government of India has shown some urgency in this area recently, and constituted an AI taskforce to explore various arenas in which AI can enhance conventional capabilities. During the Chennai Defence exposition in April 2018, Indian Prime Minister Narendra Modi remarked: "New and emerging technologies like AI and Robotics will perhaps be the most important determinants of defensive and offensive capabilities for any defence force in the future. India, with its leadership in the information technology domain, will strive to use this technology tilt to its advantage."[91] An Indian government official supplemented this view, when interviewed by an Indian newspaper. He said, "The world is moving towards AI-driven warfare. India is also taking necessary steps to prepare our armed forces because AI has the potential to have a transformative impact on national security. The government has set up the AI taskforce to prepare the roadmap for it."[92] Over the past year, the Indian government has earmarked some funding for AI-based research, yet the areas of specific research and development of unmanned naval vessels and systems have not received any priority.[93] On a more optimistic note, some Indian universities and research agencies have developed unmanned vehicles that can be put at the Navy's disposal, and recently India's first AI-focused research institute opened in Mumbai.[94]

In 2015, a Chinese AUV, Qianlong No. 2, successfully completed its first exploration in the southwest Indian Ocean for sulfide deposits and precious metals.[95] Such submersible vessels can be used for monitoring Indian submarine movements and can even be deployed to carry out mine laying missions near Indian territorial waters. The weaponisation of such an AUV is not a bridge too far.

The Indian Navy has till now given no thought to modifications in its operational protocols in the age of autonomous systems. However, as intelligent systems become more commonplace in the maritime security domain, there is a need for naval strategists in New Delhi to rationalise operations that can counter adversarial unmanned systems. As ORF researcher, Pushan Das mentions, "enhancing the operational effectiveness and flexibility of limited anti-submarine assets requires the adoption of evolved doctrines and specific operating concepts that enable in-tandem operations involving manned and unmanned assets."[96] He adds that, "Combining manned and unmanned assets will provide Indian warships a high degree of tactical flexibility in high-threat environments, reducing risk to crews, as well as making targeting faster and more precise."[97] Essentially, the Indian Navy can deploy autonomously capable naval vehicles for a multitude of missions, from fleet protection operations to anti-submarine warfare missions, to reconnaissance of littoral waters. The applications of autonomous systems, both lethal and non-lethal, are enormous for the Indian Navy's primary mission of providing security to the Indian Ocean Region (IOR).[98]

The Indian Navy is far behind in development and induction of AUVs into its fleet and needs to focus on easy counter-measures for now. It needs to conduct its own research and development (R&D) in this sphere, independent of the Defence Research and Development Organisation (DRDO), and recruit technologically literate personnel for this purpose. The defence establishment in India needs to show some urgency in "fostering the indigenous development of sentient technologies in collaboration with private and public sectors."[99] India has taken full advantage of the benefits offered by the advent of information technology (IT) and has provided IT-trained skilled professionals to countries around the world. It needs to display the same vigour and enterprise in developing its vast human resources, orienting their skills towards achieving proficiency in AI-related applications. As with most countries developing AI-associated military technology, R&D in the private sector has automatically proliferated to the defence industry.

CONCLUSION

This paper had set out to examine the applicability of AI to naval operations and has done so with a multi-faceted study of the different dimensions of autonomous naval missions. The key question remains whether these AI-based systems can provide security to the maritime commons and protect neutral commerce at a time when the ocean environment is getting increasingly congested due to the growing number of commercial merchant vessels. Therefore, going ahead, the most important element of autonomous systems will be their ability to distinguish between multiple vessels simultaneously and maintain an acoustic signature database of commercial vessels. This will need the cooperation of commercial shipping companies, and rigorous testing of deep-learning algorithms, to validate the pattern recognition processes of these autonomous systems. While it is mentioned that autonomous vessels can undertake a variety of naval missions, their compliance with international maritime law and conventions needs to be pre-programmed into their systems to avoid their trespassing into demarcated exclusive economic zones. Most importantly, autonomous vessels engaged in loitering missions for long periods of time need to be powered by sustainable energy resources to ensure that their missions do not cause any harm to the marine environment. The dichotomy, as one report mentions, is regulating the development of these vessels in a manner where, "the control of dual-use technologies does not hinder scientific research on civilian applications of autonomy and therefore economic development."[100]

Naval operations have been transformed with every era of human development, and, as a new age of network-centric warfare begins, naval planners will accordingly need to account for all sets of possibilities. AI-based systems offer the opportunity to go beyond what is humanly possible, and gives maritime security missions a new zeal. Yet, these technologies only grant a technological edge in the battle-space when the equation is asymmetric. Naval operators, planners and strategists need to think hard as to where this road to automation will take them. While dismissing development of AI-based systems would be taking a risk that can prove costly in the long term, a step up from the current regime presents the situation of a face-off between navies that are both commanded by AI-based systems. In such a scenario of hyper-war, where the decision-action cycle collapses completely, the lines between naval missions and naval warfare can become blurred.[101]

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