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ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING WITHIN THE MARITIME OPERATING ENVIRONMENT

AIM

1. In the years following the 2017 release of *Strong, Secure, and Engaged: Canada's Defence Policy* (SSE), the global battlespace has irreparably changed. The COVID-19 pandemic has reached every corner of the earth, inciting challenges to the global economy and the stability of the present world order. The principal mission of the Canadian Armed Forces (CAF) is to Detect, Deter, and Defend against threats to first Canada and then North America.[1] Unfortunately, fulfilling these missions within the context of Future Maritime Operating Environment (FMOE) requires tools that are not yet universally applied within the Royal Canadian Navy (RCN) inventory. This service paper will examine the future roles of Artificial Intelligence (AI) and Machine Learning (ML) within the maritime environment and how the Command and Control relationship of the Human-Machine interface may be best used as a battlespace management tool from peacetime cruising to full-spectrum conflict.

INTRODUCTION

2. Akin to moments in military history like that of when bows and arrows were adopted for use in land combat and when fighter aircraft took control of the skies, the maritime environment is on the precipice of its next evolution. The rise of quantum computing technology has empowered cyber capabilities to reach within all elements of the Pan-Domain, manipulating the pace of data for Commanders to consider within their decision-making sphere of influence. Furthermore, this computational skillset has empowered the development of hypersonic weapons and space threats that are tactically impossible for the unassisted human brain to defeat. Pairing this with the advances in autonomous systems capabilities, and the geopolitical motivations to employ them, the already challenging maritime environment can now be described as near chaos. Unique in comparison to the land domain, the seas are relatively uncluttered, allowing for this battlespace to be a prime testing ground for the employment of fully autonomous platforms including those that can carry and discharge weapons. [2]

3. The FMOE eludes to a time in which Anti-Access/Area Denial (A2/AD) challenges pollute the modern battlespaces of both the littoral and blue water zones, where not only are the risk of close-quarters combat situations elevated, but technological advances are reducing reaction times to fractions of a second.[3] In short order, smaller more agile weaponry is set to take

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[1] National Defence, 'Strong, Secure, Engaged: Canada's Defence Policy', navigation page - audience page, 31 May 2019, 14, https://www.canada.ca/en/department-national-defence/corporate/reports-publications/canada-defence-policy.html.

[2] United Nations Institute for Disarmament Research, 'The Weaponization of Increasingly Autonomous Technologies in the Maritime Environment: Testing the Waters' (United Nations Institute for Disarmament Research, 2015), 1, https://unidir.org/files/publications/pdfs/testing-the-waters-en-634.pdf.

[3] Ben Lombardi, 'The Future Maritime Operating Environment and the Role of Naval Power', Scientific (Defence Research and Development Canada – CORA 101 Colonel By Drive Ottawa, Ontario K1A 0K2: Defence Research and Development Canada, May 2016), 80–82.

the place of what was considered the minimum standard fit in western navies. The harpoon anti-ship missile is currently being investigated by the US Navy to be replaced by Low-Cost UAV Swarming Technology (LOCUST) which reaps a 50% reduction in cost while maintaining or even improving effectiveness. LOCUST utilizes a single human operator who remotely controls a solo drone that autonomously pilots a swarm of 29 potentially weaponized UAVs against a threat.[4] Swarm tactics are not new however, Fast In-shore Attack Craft have been practicing these manoeuvers for decades. Using the same technology that has replaced some major fireworks displays around the world, this is the first time UAV swarm tactics have been militarized.[5] It is the prevalence of these new threats that became the impetus for the US Navy to also radically change doctrine away from traditional Task Group (TG) operations to that of distributed lethality, allowing for both disintegrated force protection, as well as, being a forcing function to employ action capabilities amongst all dispersed assets.[6] Based on its TG concept, the same strategic vulnerability lies within the RCN which its offensive and defensive abilities are based upon an automated practice of utilizing prescript threat libraries as the basis for fighting its ships. To that end, this paper will inform the reader as to the fundamentals of AI and ML. Important for situational awareness and employable within all spirals of the targeting process, the differences between automated and autonomous systems and processes, while similar in engineering, may derive intrinsically different tactical outcomes. Based on this, the future Command and Control (C2) framework can be inferred to require an increased human-machine interface.

DISCUSSION

Artificial Intelligence & Machine Learning

4. AI has infiltrated every aspect of our everyday lives. Websites, Apps and Bots are capable of analyzing your online needs. When AI compares them to your personal data and habits, it can derive a custom-tailored solution to you, wherein some places can be placed on your doorstep by ‘intelligent machines’ like commercial delivery drones.[7] From a military context, AI platforms like ROKE’s STARTLE ® and CGI’s SYCOIEA are presenting similar functionality as a decision tool that enables human action via autonomous function. Specifically, these aids support the recurring capability functions of mobility; targeting; intelligence; interoperability; and health management. [8] Ultimately within the FMOE, the primary objective of

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[4] Irving Lachow, ‘The Upside and Downside of Swarming Drones’, *Bulletin of the Atomic Scientists* 73, no. 2 (4 March 2017): 97, https://doi.org/10.1080/00963402.2017.1290879.
[5] Tuneer Mukherjee, ‘Securing the Maritime Commons’:, ORF Occasional Paper (New Delhi, India: Observer Research Foundation, July 2018), 12, https://www.orfonline.org/wp-content/uploads/2018/07/ORF_Occasional_Paper_159_AI-Naval.pdf.
[6] Loren Thompson, ‘“Distributed Lethality” Is The Surface Navy’s Strategy For The Trump Era’, Forbes, accessed 23 January 2022, https://www.forbes.com/sites/lorenthompson/2017/01/10/distributed-lethality-becomes-the-surface-navys-strategy-for-the-trump-era/.
[7] Mukherjee, ‘Securing the Maritime Commons’, 1.
[8] Vincent Boulanin and Maaike Verbruggem, ‘Mapping the Development of Autonomy in Weapon Systems’ (Solna, Sweden: Stockholm International Peace Research Institute, November 2017), 20,

AI is to augment the decision-making process of the Commander. [9] AI systems themselves will analyze the vast pools of data it receives from onboard and remote systems of individual naval vessels regardless of their class. [10] This does however come with risks. Utilizing both live and historical information, AI can enhance detection ranges and predict adversarial actions based on, pattern recognition, and signals analysis, potentially now preemptively influencing Commander's decisions leading to a technically optimal, yet negative outcome. The worst-case scenario example of this would be AI enabling the enactment of a preemptive strike decision based on data, leading to the outbreak of war.

5. Given the influential quotient towards Command decision outcomes, it behooves the end-user to understand the preceding requirement for systemic deep learning. Working hand in hand with AI, deep learning is a form of ML in which a computer is now able to learn how to learn. [11] The processes of ML itself originated post-WWII, growing to be known as cybernetics in the 1960s, Connectionism in the 1990s; however, has only recently made extensive capability gains due to major advancements in computing power. [12] Critical in terms of the maritime operating environment and much like a sailor, AI now can systematically build its own reference set of conclusions based upon the resultant outcomes of singular or multiple small events and correlate them to larger problem sets. This not only supports decision augmentation but also reduces front-end manual coding requirements in which a human operator would direct the computer in all aspects of its knowledge.[13] Comparatively, this human program approach is not much different than that applied to the base threat programming for the combat management system (CMS 330) in the modernized HALIFAX-Class frigates. The system itself is very capable, however, its limitations come in the form of that its knowledge is limited to what the RCN has provided it. The ships of tomorrow will develop their own experiences and compare them with others in their class as well as shore-based establishments like operational support and information centres, land-based test facilities and training infrastructure with the end state being improved end-user Maritime Domain Awareness.[14]

Autonomous or Automated

6. With three coastlines to patrol in addition to expeditionary deployments, the Canadian Maritime tasks far outnumber the supply of available assets. The FMOE discusses how the

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https://www.sipri.org/sites/default/files/2017-11/siprireport_mapping_the_development_of_autonomy_in_weapon_systems_1117_1.pdf.

[9] Mukherjee, 'Securing the Maritime Commons', 6.

[10] 'Situational Awareness in the Information Age - Roke', accessed 23 January 2022, https://www.roke.co.uk/insights/situational-awareness-in-the-information-age; Mukherjee, 'Securing the Maritime Commons', 7.

[11] Bengio, Yoshua, Ian Goodfellow, and Aaron Courville. *Deep Learning*. Cambridge, MA: MIT Press, 2015. https://www.deeplearningbook.org/.

[12] Boulanin and Verbruggem, 'Mapping the Development of Autonomy in Weapon Systems', 17.

[13] Bengio, Goodfellow, and Courville, *Deep Learning*, 13.

[14] Mukherjee, 'Securing the Maritime Commons', 8.

integrated Intelligence, Search, Reconnaissance (ISR) task list can be alleviated using un-crewed systems across the spectrum of aerial, surface and underwater domains.[15] Up to this point, the RCN has specifically focused upon remotely piloted/automated systems; however, there is a decision required as to the way ahead in terms of AI employment. Utilizing a complex adaptive system of systems approach to the use of AI, one can begin to see the benefits of fully autonomous systems in support of the core mission sets of SSE.[16] Applying the varied subsurface topography and environmental challenges of the Canadian coastline as a baseline, the greatest challenge to overcome is continuous communication with deployed assets. Therefore, the ability for a system to both function independently from a control source or, with or without other paired autonomous systems becomes a significant capability enabler.

7. In terms of advancing present un-crewed systems to an autonomous state, the primary objective must be to advance the critical capability of self-directed navigation. [17] In practical terms and on a much larger scale, this could constitute an AI-based Officer of the Watch in ships for peacetime cruising. In this instance the AI need only process the Command intent as a feature and the system will navigate the ship from Point A to Point B. The AI will continuously monitor and analyze all sensors and inputs such as "connected assets, human analytics, remote presence and asset management, and big data analytics" to develop follow-on deep learning algorithm points, while simultaneously applying them in accordance with international collision regulations.[18] Graduating from the basics of autonomous navigation in the military sense, the next steps include the addition of the full C4ISR suite and the application of the targeting process comprising of identification, tracking, prioritization and selection of targets, up to and including engagement. [19] While the present-day CMS 330 could be employed in this fashion, the scope of its abilities does not extend beyond that of placing the system into an automatic mode. Automatic Target Recognition (ATR) in this instance is based on a series of checklist parameters being met such as electromagnetic or acoustic signature, speed, flight profile or depth, and closest point of approach. Short of IFF signal identifiers, the system cannot distinguish the difference between a civilian or military object without human injects. While in time ML practices could enable ATR algorithms to distinguish the difference, the challenge remaining would be developing predictability of AI action against the rationales of hostile intent and capability of an asymmetric aggressor. [20] However, as systems move forward towards AI-driven autonomous systems, it is not unfathomable to conceive that a future ship will not only have the capability to employ weapons to defend itself but paired with the ML lessons of peacetime navigation could also manoeuver on its own or in consort with others for the most optimal outcome while preserving both the mission objectives and human life.

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[15] Ben Lombardi, 'Maritime Operating Environment', 83.

[16] Fernando Escobar et al., 'Littoral Operations Paper - DA4500' (US Naval Postgraduate School, 27 April 2017), 6, https://www.nps.edu/documents/105575500/107753748/Littoral+Operations+Paper+for+DA4500.pdf.

[17] Boulanin and Verbruggem, 'Mapping the Development of Autonomy in Weapon Systems', 22.

[18] Jukka Savolainen et al., *Working Paper: Handbook on Maritime Hybrid Threats – 10 Scenarios and Legal Scans*, 2019, 13.

[19] Boulanin and Verbruggem, 'Mapping the Development of Autonomy in Weapon Systems', 24.

[20] Boulanin and Verbruggem, 24.

The Human-Machine Interface

8. For any sailor, the greatest attribute to obtain at sea is the trust of the Captain. This is the benchmark standard for any Naval Warfare Officer looking to initially earn their watch-keeping certification. It is not likely to be any different for autonomous systems where human force developers evolve away from hardware-focused procurement systems, to one in which procured software cannot only dictate the criteria for autonomy but also create it. [21] This means commanders will need to trust that the software has not only factored all of the fluid variables in its recommendations but also learned from any possible iterations of failure in history. AI in this respect needs to develop to a point of what can be described as being human. To that end, at least in the short and medium-term, it is unlikely that these systems will ever be an equivalent replacement for human commanders. [22] Even with a perfect world of AI and infallible ML, the debate of the ethics of Lethal Autonomous Weapons Systems (LAWS) can be argued at length. Presently there is no legal framework that completely regulates autonomous weapon system use, including caveats within international humanitarian law; however, would still be subject to the principles of humanity.[23] The present intent, therefore, is to provide the human commander with the best tools and advice to enhance C2 and alleviate the challenges and stressors of routine administration.

9. It cannot be stressed enough that for the AI and the human commander to collaborate effectively, each must fully understand the other's decision-making process. [24] To effect this outcome a safe and mutual learning environment within the future training establishment is needed, in which the AI utilizing ML techniques, can learn alongside its human counterpart. Essentially this process will mimic the training of any human crew member, with the dual purpose of indoctrinating human operators, as future commanders, with their digitalized shipmate. Their combined efforts should produce a twofold effect of both improved efficiency and combat effectiveness while normalizing the presence, use and trust in AI in warships.

CONCLUSION

10. Given the prevalence of AI within everyday society there is no alternative reality within the FMOE that does not include aspects of AI and ML within the military construct. Embracing the transition from hardware-driven goals to software solution sets will be challenging given that an inherent humanlike trust between operator and machine must be established. Like AI, the human quotient must adapt and learn the intricacies of algorithms and decision-making processes that will better support command decisions in a time where fractions of a second are the difference between life and mission failure. The common misconceptions between the differences in autonomous and automated systems present a strategic risk to the RCN which could lead to the CAF being unable to meet the first two of its mandated core missions. Overcoming the hesitations in employing true autonomous systems vice that of automated ones will be the doctrinal turning point in RCN operations. While some aspects of this can be

[21] 'Lethal Autonomy in Autonomous Unmanned Vehicles | Center for International Maritime Security', accessed 23 January 2022, https://cimsec.org/lethal-autonomy-autonomous-unmanned-vehicles/.
[22] Mukherjee, 'Securing the Maritime Commons', 1.
[23] United Nations and Office for Disarmament Affairs, *Perspectives on Lethal Autonomous Weapon Systems*, 2017, 7.
[24] Mukherjee, 19.

achieved in the form of immediately employing small self-navigating ISR assets or utilizing app-based AI to support routine personnel administration, the true test will come when ML-enabled AI resides within RCN training establishments, Land-Based test facilities, and ultimately ships. This future is not decades away anymore. This future is starting now.

RECOMMENDATION

11. While the use of computer aids in naval warfare from navigation to combat is not a new practice, the implementation of AI-driven autonomous systems has yet to be adopted into doctrine. Given the small fleet size of the RCN and its adoption of a single surface combatant force, empowering this platform and its commanders with as many tools as possible makes sense within the construct of the FMOE. Autonomy can come in many forms, however, and initial focus upon both autonomous ISR systems and situational awareness tools that aid human commanders in their decision-making abilities is paramount. It is recommended that the RCN consider immediately applying an ML empowered AI to its training enterprise with the initial goal of having it self-assess a training needs analysis for the employment of AI as a decision-making tool within the FMOE.

BIBLIOGRAPHY

Ben Lombardi. 'The Future Maritime Operating Environment and the Role of Naval Power'. Scientific. Defence Research and Development Canada – CORA 101 Colonel By Drive Ottawa, Ontario K1A 0K2: Defence Research and Development Canada, May 2016. https://cradpdf.drdc-rddc.gc.ca/PDFS/unc229/p803867_A1b.pdf

Bengio, Yoshua, Ian Goodfellow, and Aaron Courville. *Deep Learning*. Cambridge, MA: MIT Press, 2015. https://www.deeplearningbook.org/.

Boulanin, Vincent, and Maaike Verbruggem. 'Mapping the Development of Autonomy in Weapon Systems'. Solna, Sweden: Stockholm International Peace Research Institute, November 2017. https://www.sipri.org/sites/default/files/2017-11/siprireport_mapping_the_development_of_autonomy_in_weapon_systems_1117_1.pdf.

Defence, National. 'Strong, Secure, Engaged: Canada's Defence Policy'. Navigation page - audience page, 31 May 2019. https://www.canada.ca/en/department-national-defence/corporate/reports-publications/canada-defence-policy.html.

Escobar, Fernando, John Hoffner, Bonnie Johnson, and Tim Teti. 'Littoral Operations Paper - DA4500'. US Naval Postgraduate School, 27 April 2017. https://www.nps.edu/documents/105575500/107753748/Littoral+Operations+Paper+for+DA4500.pdf.

Lachow, Irving. 'The Upside and Downside of Swarming Drones'. *Bulletin of the Atomic Scientists* 73, no. 2 (4 March 2017): 96–101. https://www.tandfonline.com/doi/full/10.1080/00963402.2017.1290879.

'Lethal Autonomy in Autonomous Unmanned Vehicles | Center for International Maritime Security'. Accessed 23 January 2022. https://cimsec.org/lethal-autonomy-autonomous-unmanned-vehicles/.

Mukherjee, Tuneer. 'Securing the Maritime Commons': ORF Occasional Paper. New Delhi, India: Observer Research Foundation, July 2018. https://www.orfonline.org/wp-content/uploads/2018/07/ORF_Occasional_Paper_159_AI-Naval.pdf.

Savolainen, Jukka, Terry Gill, Valentin Schatz, Lauri Ojala, Tadas Jakstas, and Pirjo Kleemola-Juntunen. *Working Paper: Handbook on Maritime Hybrid Threats – 10 Scenarios and Legal Scans*, 2019. https://www.hybridcoe.fi/wp-content/uploads/2020/07/NEW_Handbook-on-maritime-threats_RGB.pdf

'Situational Awareness in the Information Age - Roke'. Accessed 23 January 2022. https://www.roke.co.uk/insights/situational-awareness-in-the-information-age.

Thompson, Loren. '"Distributed Lethality" Is The Surface Navy's Strategy For The Trump Era'. Forbes. Accessed 23 January 2022. https://www.forbes.com/sites/lorenthompson/2017/01/10/distributed-lethality-becomes-the-surface-navys-strategy-for-the-trump-era/.

United Nations Institute for Disarmament Research. 'The Weaponization of Increasingly Autonomous Technologies in the Maritime Environment: Testing the Waters'. United

Nations Institute for Disarmament Research, 2015. https://unidir.org/files/publications/pdfs/testing-the-waters-en-634.pdf.

United Nations and Office for Disarmament Affairs. *Perspectives on Lethal Autonomous Weapon Systems*, 2017. https://reliefweb.int/report/world/perspectives-lethal-autonomous-weapon-systems