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RUNNING AND HIDING ARE NO LONGER OPTIONS: WHY A DESTRUCTIVE NEUTRALIZATION CAPABILITY TO COUNTER THE TORPEDO AND UUV THREAT IS A NECESSITY FOR THE RCN SUBMARINE FORCE

AIM

1. The role of a navy is to operate across the various oceans of the world in support of national interests, as espoused in Canada's current National Defence Policy, which states "Canada requires a Navy […] to *project power* responsively and effectively *far from Canada's shore*"[1] [emphasis added]. Contingent to this is the ability to operate in the presence of adversarial maritime capabilities, many of which rely on some form of torpedo weapon system as a destructive effector. Equally, the accelerating introduction of autonomous/uninhabited[2] underwater vehicles (A/UUVs) with navies worldwide – many of which share characteristics and capabilities with submarines and torpedoes (and equally, the latter of which will almost certainly draw upon developments of the former) will pose new challenges to RCN vessels.

2. As maritime domain awareness capabilities continue to increase, it is anticipated that the submarine will become increasingly important to maritime operations – at least until the emergence of a commensurate ability to detect and track them at significantly greater ranges. Until then, the ability of a submarine to remain undetected is expected to play a significant role in maritime operations. However, acknowledging that the strategic influence potential of an undetected submarine and the commensurate efforts expected to be allocated to locate and neutralize them, it should be expected that RCN submarines may be subject to kinetic engagement. This service paper will address the increasing imperative for RCN submarines to be fitted with a destructive neutralization capability for these types of threats in an informative manner by: exploring the evolving nature of the threats, discussing the challenges posed in countering them, review some current and proposed solutions, and finally, providing recommendations.

INTRODUCTION

3. Despite the introduction and evolution of anti-ship missiles, the modern heavyweight torpedo (HWT) remains a principle anti-surface and anti-sub-surface (commonly referred to as anti-submarine) effector of choice for many navies. Equally, the lightweight torpedo (LWT) continues to prevail as the anti-submarine effector of choice for surface and airborne platforms. Commensurately, many platforms continue to operate with this weapon system, and future platform development programs continue to incorporate it as well. From the broad-range of platforms, ranging from aircraft (soon to

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

[2] Previously, the term "unmanned" was used, but is gradually being supplanted by "uninhabited" and "uncrewed" under gender inclusivity efforts.

include UAS, such as the BAE Systems T-650 UAS, unveiled with a *Stingray* LWT at DSEI in 2021)[3] to surface combatants and submarines,[4] the latter is relatively unique (barring select, predominantly Soviet-era, surface combatants and aircraft)[5] in its ability to operate a torpedo weapon system (TWS) employing the HWT.

4. The continued evolution of modern torpedoes (especially the large-diameter "heavyweight"-class common to most naval submarine platforms) increases the threat posed to RCN surface and subsurface vessels. As increasingly robust and capable digital elements and propulsion systems are incorporated, the effectiveness of traditional torpedo countermeasures is commensurately reduced. Exacerbating the issue further is the anticipated proliferation of a wide-range of autonomous uninhabited underwater vehicles – many of which share characteristics with current torpedo weapon systems (both LWT and HWT) such as size, speed, and payload; for which the allocation of an HWT may be disproportionate and/or less effective.

DISCUSSION

Evolving Nature of the Threat

5. While the origins of the modern-day torpedo can be traced back to the Napoleonic era, the general contemporary concept is that of an elongated body that is capable of travelling through the water in pursuit of a target, containing a form of propulsion, a mechanism to detect and track a target (sensor), the ability to orient itself towards a target (control surfaces/mechanism), and a means of coupling effects to the target (typically, a blast or shaped-charge warhead). The desirability for a weapon of this type arose as a means of reducing the adversary's ability to detect and respond to the threat. [6] Later, it would be discovered that greater destructive effects could be achieved using a large blast *near* the target vessel's hull (vice directly impacting it), creating conditions for the keel of a surface vessel to be broken by the vessel's own mass and structure, and in the case of submarines, the creation of a "water-hammer" effect to amplify the directionality and concentration of kinetic shock force generated by the blast inwards into the target's hull.[7]

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[3] George Allison, 'BAE Unveil Torpedo Carrying Heavy-Lift T-650 Drone', *Ukdefencejournal.Org*, 14 September 2021, https://ukdefencejournal.org.uk/bae-unveil-torpedo-carrying-heavy-lift-t-650-drone/.

[4] It should be acknowledged that the term "submarine" is very generic and applies to a range of vessels that may not be suitable for, nor regularly involved in military operations. The use of this term within this service paper should be interpreted as "combat(-capable) submarines employed by military forces for military purposes", espoused by modern analogues such as the US VIRGINIA-class, UK ASTUTE-class and CHI SHANG II-class SSNs; and the RFN SEVERODVINSK I/II-class SSGN.

[5] 'Post-World War II Torpedoes of Russia/USSR - NavWeaps', accessed 1 February 2023, http://www.navweaps.com/Weapons/WTRussian_post-WWII.php.

[6] 'Torpedo -- Britannica Academic', accessed 7 February 2023, https://academic.eb.com/levels/collegiate/article/torpedo/72952.

[7] Craig Payne, *Principles of Naval Weapons Systems*, 1st ed. (Annapolis, Md: Naval Institute Press, 2006), 358–59.

6. Typically, the propulsion system will take the form of a shaft-mounted propeller or ducted rocket exhaust. A compromise is required between speed and detectability by passive acoustic means, and many modern torpedoes are capable of adjusting their speed (in a limited fashion[8]), favouring a lower speed during the search and acquisition phase before shifting to a higher speed for prosecution. With the emergence of digital electric propulsion constructs, predominantly centred on the direct-current brushless motor,[9] higher-speeds are possible due to enhanced efficiencies, and (arguably more importantly) the ability to adjust the speed of the weapon across a wider range of increments. The employment of digital versions of these motors offers even greater efficiencies as well as range and precision in speeds available – providing for enhanced flexibility in managing the weapon's endurance and speed.[10] Continuing efforts in battery technology further increase the capability of future electrically-propelled underwater vehicles.[11]

7. One of the other areas of increasing concern is that of the sensory mechanism employed by torpedoes for target acquisition and tracking. Advances in both hardware and software have a compounding effect upon one-another, increasing the range at which targets can be detected and tracked, and improving the weapon's resilience to countermeasures.[12] While the employment of wake-homing sensors remains focused on applications against surface vessels, it is plausible that the concept could be extended to application against submarines. Equally, while not sufficiently functional to be employed in this role, there exist several other underwater sensing technologies that may eventually

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[8] A review of multiple sources indicate that most current in-service torpedoes typically have 2 speed settings available to them, though some with electric propulsion constructs are being employed to explore more, such as the German DM2A4-series.

[9] Jianqi Qiu et al., 'Counter-Rotating Permanent Magnet Brushless DC Motor for Underwater Propulsion', in *2006 CES/IEEE 5th International Power Electronics and Motion Control Conference*, vol. 2, 2006, 1–5, https://doi.org/10.1109/IPEMC.2006.4778119.

[10] Jianqi Qiu et al., 'Counter-Rotating Permanent Magnet Brushless DC Motor for Underwater Propulsion', in *2006 CES/IEEE 5th International Power Electronics and Motion Control Conference*, vol. 2, 2006, 1–5, https://doi.org/10.1109/IPEMC.2006.4778119; Andrew P. Frits, 'Formulation of an Integrated Robust Design and Tactics Optimization Process for Undersea Weapon Systems' (Ph.D., United States -- Georgia, Georgia Institute of Technology), accessed 7 February 2023, https://www.proquest.com/docview/304999806/abstract/58A2EB7478AE482DPQ/1, pg 21 – 24.

[11] Jinmao Chen et al., 'Progress and Applications of Seawater-Activated Batteries', *Sustainability* 15, no. 2 (January 2023): 1635, https://doi.org/10.3390/su15021635; Ariel Chiche et al., 'A Strategy for Sizing and Optimizing the Energy System on Long-Range AUVs', *IEEE Journal of Oceanic Engineering* 46, no. 4 (October 2021): 1132–43, https://doi.org/10.1109/JOE.2021.3062047; Clemens Deutsch et al., 'Energy Management Strategies for Fuel Cell-Battery Hybrid AUVs', in *2020 IEEE/OES Autonomous Underwater Vehicles Symposium (AUV)*, 2020, 1–6, https://doi.org/10.1109/AUV50043.2020.9267932.

[12] Bryan Clark, 'The Emerging Era in Undersea Warfare', Centre for Strategic and Budgetary Assessments, 22 January 2015, https://csbaonline.org/research/publications/undersea-warfare/publication/1; Sebastien Roblin, 'New Carrier, Old Threat: The Navy Is Struggling to Counter Torpedos', Text, The National Interest (The Center for the National Interest, 27 June 2021), https://nationalinterest.org/blog/reboot/new-carrier-old-threat-navy-struggling-counter-torpedos-188696.

reach the point where they are. Examples include LiDAR,[13] where a light source (including laser) is emitted and the reflections may indicate targets (akin to active sonar) with wavelengths in the blue-green portion of the spectrum identified as the most promising; and gravimetrics,[14] where distortions in the local gravitational field may arise from the presence of volumes of dense matter – such as a submarine (especially nuclear-powered, given the density of the nuclear fuel and reactor vessel), which could be leveraged for detection and tracking by sufficiently sensitive and directional sensory apparatuses.

8. Finally, there is significant interest in increasing both the autonomy of individual uninhabited vessels, and of the ability to communicate with one another in pursuit of increased effectiveness and responsiveness in dynamic environments, with a reduced reliance on human operators.[15]

9. When considered in isolation, any one of the aforementioned developments increases the threat posed to RCN submarines. Consideration of multiple elements in various combinations exacerbates the issue even further – especially those that reduce or outright eliminate the effectiveness of current countermeasures. So, if the *existing* defensive capabilities available to the submarine are sufficiently reduced in effectiveness (or outright *negated*) by these developments, enhancements or alternative solutions should be sought, and it under this pretense that a destructive neutralization capability against these threats should be pursued for the RCN submarine fleet.

Countering the Threat

10. The two scenarios to consider are: when the target is unaware and when it is aware of the inbound threat torpedo. In the case of the former, most reactive countermeasures (those that are deployed or executed in response to detection of an

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[13] Dennis C. Estrada et al., ‘Underwater LiDAR Image Enhancement Using a GAN Based Machine Learning Technique’, *IEEE Sensors Journal* 22, no. 5 (March 2022): 4438–51, https://doi.org/10.1109/JSEN.2022.3146133; V. Mitra, Chia-Jiu Wang, and S. Banerjee, ‘Lidar Detection of Underwater Objects Using a Neuro-SVM-Based Architecture’, *IEEE Transactions on Neural Networks* 17, no. 3 (May 2006): 717–31, https://doi.org/10.1109/TNN.2006.873279.

[14] L.V. Kiselev and V.B. Kostousov, ‘On Interrelation and Similarity in Solution of Navigation and Gravimetric Tasks in Underwater Robotics’, in *2019 26th Saint Petersburg International Conference on Integrated Navigation Systems (ICINS)*, 2019, 1–3, https://doi.org/10.23919/ICINS.2019.8769448; Jérôme Verdun et al., ‘Development of a Lightweight Inertial Gravimeter for Use on Board an Autonomous Underwater Vehicle: Measurement Principle, System Design and Sea Trial Mission’, *Remote Sensing* 14, no. 11 (January 2022): 2513, https://doi.org/10.3390/rs14112513.

[15] Yue Yang, Yang Xiao, and Tieshan Li, ‘A Survey of Autonomous Underwater Vehicle Formation: Performance, Formation Control, and Communication Capability’, *IEEE Communications Surveys & Tutorials* 23, no. 2 (2021): 815–41, https://doi.org/10.1109/COMST.2021.3059998; Shijie Zhu et al., ‘Recent Progress in and Perspectives of Underwater Wireless Optical Communication’, *Progress in Quantum Electronics* 73 (1 September 2020): 100274, https://doi.org/10.1016/j.pquantelec.2020.100274; Johannes Peters, ‘Below the Surface: Undersea Warfare Challenges in the 21st Century’ (From the North Atlantic to the South China Sea, Nomos Verlagsgesellschaft mbH & Co. KG, 2021), 93–110, https://doi.org/10.5771/9783748921011-93.

inbound threat) are rendered ineffective by virtue of not being introduced into the engagement. This can be mitigated through the employment of a detection and monitoring system (whether leveraging existing underwater sensors – if capable, or employing a dedicated system). For the purposes of this service paper, the focus will be on the latter case, given the existing capability to detect the presence of threat torpedoes in the form of the sonar system common to modern naval submarines.[16]

11. While the specifics of any particular response are often nation and platform-specific – and thus classified, the response to detection of an inbound threat torpedo can be generalized into two inter-related elements: kinematic evasion by the platform and interference with the threat weapon's ability to detect and track the target, or prematurely actuate the fuzing mechanism.[17] As the capabilities of threat torpedoes increased and expanded, evasion became increasingly difficult as the speed and endurance of the threat weapons increased and eventually the ability to re-attack the target if missed, which led to a focus on interfering with the weapon's ability to prosecute its target, in the form of expendable decoys intended to seduce or distract the threat weapon by interacting with the sensory elements, signal processing and/or homing logic, or attempt to actuate the fuzing mechanism before it reaches the target. But now, even these decoys – as advanced as they may be, are being rendered increasingly ineffective. This creates a situation of perceived *inevitability*, where once a threat torpedo has been deployed against an RCN submarine,[18] with the current capabilities available (evasion and non-destructive effectors), it is almost certain that the weapon will reach the target and neutralize it.[19]

Destructive Neutralization

12. The desire for a destructive neutralization capability to counter the torpedo threat has increased in recent years, reflecting the increased lethality of the threat weapon and reduced effectiveness of current countermeasures. The first (publicly declared) dedicated system was the *TorBuster* by Rafael Electronics in 2007, which is an evolution of an existing (stationary) acoustic decoy – now incorporating an explosive charge and proximity sensor intended to incapacitate the threat torpedo.[20] The functionality of this system is predicated on the torpedo opting to pursue the decoy and *not* the submarine, an outcome that is increasingly unlikely. Alternatively, the submarine could try to create the

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[16] Acknowledging that such systems may not be optimized for this task, and do not guarantee detection.

[17] Payne, *Principles of Naval Weapons Systems*; Luca Peruzzi, 'Guarding Ships Against the Modern Torpedo Threat', issuu, accessed 1 February 2023, https://issuu.com/edrmag/docs/edr_65_-_web/s/17015006.; While Peruzzi addresses surface vessels, the same principles are applicable to submarines.

[18] Presuming sufficient understanding of the weapon by those deploying it, and an appropriate level of competence in its employment such that operator error (ie. Launching at the fringe or beyond maximum *effective* range) is not a factor, and that the weapon itself is sound (ie. not subject to electrical or mechanical defects).

[19] Depending on the size of the weapon's warhead, fuzing mechanism and terminal geometry (closest point of approach/point of impact) the scope and magnitude of damage will vary.

[20] 'Rafael Introduces Torbuster - 4th Generation Hard-Kill Torpedo Countermeasure', *Defense Update:* (blog), 2 October 2007, https://defense-update.com/20071002_torbuster.html.

appropriate geometry that would force the threat torpedo to pass near enough to the deployed countermeasure. Nevertheless, the concept of deploying a proximity-fuzed mine with an explosive payload has merits, discussed further in a recent article submitted to the US Naval Institute.[21]

13. Acknowledging that relying on the success of decoys was insufficient, the USN opted to pursue an interceptor-styled solution and revealed that they had installed such a developmental destructive neutralization capability aboard one of their aircraft carriers in 2013 (eventually expanding to five, and a palletized variant for installation aboard other vessels), comprising the "Torpedo Warning System (TWS)" to detect, classify and localize threat torpedoes, and the "Compact Anti-Torpedo (CAT)", a small torpedo-based interceptor, under the Surface Ship Torpedo Defence program.[22] However, following over five years of testing, the decision was made to discontinue the testing due to issues with performance and reliability.[23] Despite the failure of this program, the concept remains of great interest, and the Atlas Electronik *SeaSpider* appears to have overcome many of the difficulties experienced by the US.[24] A video depicting this concept in action is provided on the company's website.[25]

14. These examples highlight the manner in which the challenge can be approached – the first attempting to bring the threat to the effector, and the second endeavouring to deliver the effector to the threat. Both are viable options, but also involve compromises. In the case of the former, it is likely a lower footprint (*TorBuster* is designed to be employed with existing submarine decoy launchers) but demands more of the submarine in terms of managing the engagement geometry to ensure the threat weapon will enter the destructive radius of the defensive effector,[26] and may be more demanding in terms of number of rounds required per engagement. Conversely, the latter places increased demands on the platform, requiring greater fidelity on the range, bearing and depth of the inbound threat weapon, as well as either specific launchers and/or modifications to

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[21] Matthew Conners, 'A Hard-Kill Solution to Threat Torpedoes', U.S. Naval Institute, 1 November 2021, https://www.usni.org/magazines/proceedings/2021/november/hard-kill-solution-threat-torpedoes.

[22] Director Operational Test and Evaluation, 'Surface Ship Torpedo Defense (SSTD) System: Torpedo Warning System and Countermeasure Anti-Torpedo Torpedo' (United States Government, December 2017), https://www.dote.osd.mil/Portals/97/pub/reports/FY2013/navy/2013sstd.pdf?ver=2019-08-22-111216-940.; This specific program was the "Anti-Torpedo Torpedo Defensive System (ATTDS)".

[23] Director Operational Test and Evaluation, 'FY 2018 Annual Report', December 2018, https://s3.documentcloud.org/documents/5720819/2018DOTEAnnualReport.pdf; Joseph Trevithick, 'The Navy Is Ripping Out Underperforming Anti-Torpedo Torpedoes From Its Supercarriers', The Drive, 5 February 2019, https://www.thedrive.com/the-war-zone/26347/the-navy-is-ripping-out-underperforming-anti-torpedo-torpedoes-from-its-supercarriers.

[24] 'SeaSpider by ATLAS ELEKTRONIK', SeaSpider - ATLAS ELEKTRONIK, accessed 9 February 2023, https://www.seaspider.info/; Dr Lee Willett, 'Sharpened Focus: SeaSpider Homes in on the Torpedo Threat', *Jane's International Defence Review*, 18 April 2019.

[25] *Video SeaSpider(TM)*, mp4, accessed 9 February 2023, https://www.seaspider.info/downloads/SeaSpider-Atlas-Elektronik.mp4.

[26] Even if the threat torpedo is susceptible to the acoustic seductive element of the decoy, there is still an effective range to consider and a requirement to ensure the torpedo is not presented with an opportunity to shift its focus back to the target submarine.

existing launchers, likely incurring platform orientation launch criteria. As an example, smaller weapons could be deployed from existing HWT tubes – but these almost always face forward in modern naval submarines, which creates additional risk for the submarine to launch them safely and effectively (as it is likely attempting to place the threat weapon astern and reduce its closure rate).

Idealized Solution

15. Ideally, an effective solution will: reliably and effectively detect the presence of an inbound threat torpedo, generate a response plan for the vessel (to be implemented by either crew and/or system responsible) – potentially executing the plan autonomously, require as few munitions as possible to achieve as high a probability of incapacitation of the threat torpedo as possible, as far away from the defended vessel as possible, while minimizing the impact to any other operations the platform may be engaged in. Eventually, it may be desirable to develop a capability to serve in an area defense role, providing coverage from an equipped vessel to those nearby that may not be (or to provide enhanced defensive capabilities under a collaborative approach), strengthening the force's ability to protect itself, under the SHIELD function.[27]

CONCLUSION

16. In modern operations involving the maritime domain, the submarine is expected to remain a significant capability for modern and future maritime forces due to the scope and magnitude of the effects they provide to a Commander in the SENSE, ACT and SHIELD capability domains, and facilitation of the SUSTAIN capability domain where sea lines of communication are involved. Their inherent stealth and the lethality provided by the armament that they are able to employ create a dangerous capability that is respected globally. This translates into an increased emphasis in prosecuting those of the adversary. Continued operations in face of ever-increasingly capable threats necessitates ongoing efforts to assure platform survivability. Until such time that the platform can regain sufficient advantages in non-destructive countermeasures (if at all), a defensive destructive neutralization capability will be required to preserve an ability to operate in a contested environment.

RECOMMENDATIONS

17. The following recommendations are submitted for consideration. In order to improve the survivability of the RCN submarine force in the modern and future operating environment, the RCN should:

a. Pursue an interim destructive neutralization capability(ies) to counter the threat posed by both torpedoes and other small/medium adversarial

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[27] Department of National Defence, 'Canadian Military Doctrine', *Canadian Forces Joint Publication* Canadian Military Doctrine, no. CFJP 01 (September 2011): 27.

remote/autonomous underwater vehicles;

b. Investigate and pursue a fulsome destructive neutralization capability to counter current and future iterations of the aforementioned threats; and

c. Improve the weighting (favourably) of incorporating such a capability into future submarine designs at the outset (vice attempting to modify or retrofit the capability at a later date), leveraging commonalities with surface ship equivalents where the opportunity to do so is rational and available.

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