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Victory at Sea: Unmanned Surface Vessels and the Distribution of Future RCN Capabilities

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By Lieutenant-Commander J.C. Hunt

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LIST OF ACRONYMS

AAW	Anti-Air Warfare
AIP	Air Independent Propulsion
AOPS	Arctic Offshore Patrol Ship
ASuW	Anti-Surface Warfare
ASW	Anti-Submarine Warfare
A2/AD	Area Access / Area Denial
CAD	Computer Aided Design
CAMM	Common Anti-Air Modular Missile
CAF	Canadian Armed Forces
CEC	Cooperative Engagement Capability
CMS	Combat Management System
COLREG	International Regulations for Preventing Collisions at Sea
COTS	Commercial-Off-The-Shelf
CPF	Canadian Patrol Frigate
CSC	Canadian Surface Combatant
C2	Command and Control
C3	Command, Control and Communicate
DFO	Department of Fisheries and Oceans
DMO	Distributed Maritime Operations
EMW	Electronic Maneuver Warfare
EEZ	Economic Exclusion Zone
EW	Electronic Warfare
GoC	Government of Canada
HF	High Frequency
IMO	International Maritime Organization
IP	Intellectual Property
IRB	Industrial Regional Benefits

ISSC	In-Service Support Contract
ISR	Intelligence, Surveillance, Reconnaissance
ISTAR	Intelligence, Surveillance, Target, Acquisition and Reconnaissance
JSS	Joint Support Ship
LCS	Littoral Combat Ship
LUSV	Large Unmanned Surface Vessel
MCM	Mine Counter-Measures
MUSV	Medium Unmanned Surface Vessel
NATO	North Atlantic Treaty Organization
NAVSEA	Naval Sea Systems
NSS	National Shipbuilding Strategy
PEO USC	Program Executive Office Unmanned and Small Combatants
RAN	Royal Australian Navy
RCN	Royal Canadian Navy
RHIB	Rigid Hull Inflatable Boat
RN	Royal Navy
SAR	Search And Rescue
SM3	Standard Missile 3
SSC	Small Surface Combatant
SSE	Strong, Secure, Engage
UN	United Nations
UNCLOS	United Nations Convention on the Law Of the Sea
USV	Unmanned Surface Vessel
UUV	Unmanned Underwater Vehicle
UWW	Under-Water Warfare
VLS	Vertical Launch System

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ABSTRACT

Future maritime warfare demands operating in a persistent state of detection, where destruction or significant loss of fleet capabilities through a myriad of anti-ship weapon systems are virtually certain. Western navies have deduced that distribution of capabilities is the best approach to surviving future maritime conflicts. However, the exorbitant cost of the RCN's highly sophisticated and versatile CSC precludes further distribution of capabilities through simply building more vessels. To remain relevant through its intended service life, CSC will necessitate a mid-production redesign to incorporate new technology. Such unaccounted for and unknown cost will do nothing to address the issue of capability distribution. Rather, it will concentrate more capability into a smaller and smaller fleet of ships, increasing the overall risk to the RCN. Instead of chasing good money after a bad redesigned CSC, the RCN would be better positioned to invest in a built-in-Canada program, within NSS, which introduces a fleet of 35 large and medium sized Unmanned Surface Vessels (USV's). USVs distribute and increase the overall number of weapons and sensors available in the battlespace, thereby providing freedom of maneuver, superiority in future naval engagements, and future interoperability with NATO and US allies. USVs are a more cost effective platform to undertake traditional RCN functions such as sovereignty patrols, support to law enforcement, and other whole of government efforts. Finally, global USV sales are a rapidly growing industry, estimated be worth $65 billion / US annual by 2040. USV technology present a unique commercial - military business opportunity upon which NSS could rapidly advance its primary objectives of building a stable, self sufficient maritime industry in Canada and while generating the capabilities needed by the RCN at an affordable cost.

ABOUT THE AUTHOR

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VICTORY AT SEA: UNMANNED SURFACE VESSELS AND THE DISTRIBUTION OF FUTURE RCN CAPABILITIES

> *It follows then as certain as that night succeeds the day, that without a decisive naval force we can do nothing definitive, and with it, everything honorable and glorious.* – (George Washington)

INTRODUCTION

The ability to anticipate what tools, techniques, and innovations are necessary to achieve victory in future military conflicts has been a perplexing question as old as the very nature of conflict itself. In the maritime domain, anticipating what future threats will emerge is not only a question of foresight but arguably an endless quest to iteratively reinvent oneself and one's navy.

The pace of technological advancements is often attributed as a driving factor for change in the Air and now emerging Cyber and Space domains. So too is technology now radically changing the historically slow evolutionary pace of naval doctrine. The increasing need for navies to employ platforms capable of operating seamlessly across all domains of warfare – Sea, Land, Air, Cyber and Space - most certainly now dispels that oldest of naval axiom "*the Navy one hundred years of tradition, unimpeded by progress"*

Proliferation of information across the modern naval battlespace is compressing the size of oceans. The ability to hide a fleet from the adversary is becoming increasingly impossible. Adaptation of unmanned reconnaissance technologies, increased capabilities of spaced-based assets, and progressively more capable modern radar and electronic warfare systems have led to predictions that by 2030, it shall be impossible to conceal a surface ship's presence on the ocean and that efforts are required by navies wishing to exercise a global presence to address this fact.

Equally disturbing is the exponential growth in relatively cheap anti-ship missiles which are alarmingly lethal and increasingly deployed by potential adversaries. Future navies will need to hide as well as confront a confounding number of hypersonic and conventional precision guided munitions, in salvo sizes, aimed at overpowering defences of the fleet and individual ships. This new maritime domain inspires tacticians and strategic planners to revisit existing fleet compositions. Increasing the current distribution of naval capacity across a larger number of hulls is one potential consequence. Larger numbers of contacts complicates an opponent's defences and increases overall survivability of future fleets by positioning more weapons and sensors into a maritime battlespace.

The Royal Canadian Navy (RCN) and its intended fleet of vessels must necessarily confront this complex future. Under the National Shipbuilding Strategy (NSS), the RCN intends to build fifteen new Canadian Surface Combatant's (CSC) to replace existing patrol frigates and recently decommissioned destroyers. CSC is meant to be the backbone of the future RCN fleet incorporating cutting edge weaponry and sensors, making it a highly versatile tool capable of defeating near term challenges and threats. Yet, paradoxically by incorporating the vanguard of technology and versatility into a single design, the RCN has driven up production cost thereby limiting overall number of vessels, resulting in potentially catastrophic loss of capabilities when a small number of ships are sunk or damaged irreparably in combat. Uncertainty now exists as to whether or not CSC platforms to face down future maritime threats are sufficient and survivability of these warships in naval combat is now an open question. Simply put, given the dual threat of a shrunken ocean and increased probability of destruction from anti-ship weapons, the RCN has concentrated too much on one platform.

The planned structure of the RCN's new fleet of CSCs lacks sufficient distribution of naval capabilities to achieve victory in future engagements, is prohibitively costly to employ in support of the RCN's other traditional constabulary and diplomatic naval functions, and is estimated to require an expensive redesign during its initial construction to facilitate necessary capability upgrades to remain relevant over its intended service life. Instead of chasing good money after bad redesigning CSC mid-build, the RCN would be better positioned to invest in a built-in-Canada program, within the framework of NSS, which introduces a fleet of 35 large and medium sized Unmanned Surface Vessels (USV's), akin to those envisioned as part of the US Navy's Future Surface Combatant Force. USVs would distribute and increase the overall number of weapons and sensors available in the battlespace, providing the RCN freedom of maneuver and ability to secure superiority in future naval engagements. USVs would equally allow the RCN to employ a more cost effective platform to undertake a number of traditional functions such as sovereignty patrols, support to law enforcement and other government agencies, including international aid to humanitarian / disaster relief efforts. Additionally, procurement and construction of a made-in-Canada USV fleet presents opportunities to generate economic growth and technological advantages in the highly lucrative emerging military and commercial markets. They ensure that the RCN maintains a high degree of interoperability with NATO allies and the US Navy, Canada's primary partner in continental defence.

The RCN's future fleet vision, the intended capabilities and requirements it perceives as necessary, as well as, the CSC design and its intended capabilities have created a program that is exorbitantly expensive and precludes the ability to simply buy more CSC's to achieve the required level of capability distribution. Three key cost drivers in modern warship procurement limit the RCN's ability to procure more CSC platforms and adequately distribute naval capabilities. Those key cost drivers include NSS and the nature of warship procurement in Canada, the increasing service lives of warships and the associated need to *future proof* designs to maintain their relevance, and; the continuing presence of humans onboard warships.

The US Navy's current strategy strives to maintain dominance in the future maritime domain, namely the concept of Distributed Maritime Operations (DMO). The US Navy concluded that USVs represent the most cost effective technology to distribute appropriately naval capacity and subsequently defeat emerging future naval threats. The inherent advantages that USVs provide navies in comparison to manned vessels, as well as the US Navy's intended operational employment of Large and Medium USV (LUSV and MUSV), will vastly increase the survivability of manned vessels while equally improving overall fleet operational availability. Parallel plans for USV development in other allied navies such as the Royal Navy (RN), Royal Australian Navy (RAN) and NATO demonstrate a growing dependency on USV programs to carry out dangerous roles previously conducted by manned machines. If the RCN wishes to maintain interoperability within the international community to achieve future security objectives, then it must be capable of operating and controlling USV assets.

From the Government of Canada's perspective, the relative novelty of USV technology present a unique commercial - military business opportunity upon which NSS could rapidly advance its primary objectives of building a stable, self sufficient maritime industry in Canada. While equally leveraging research and development efforts to produce lucrative export possibilities. Pushing forward in developing made-in-Canada USV solutions ensures that the RCN and its allies maintain technological superiority over its adversaries in future naval engagements.

For all their good, employment of USVs within the RCN presents many novel challenges, but thankfully with equally attainable solutions. General legal, regulatory and ethical issues surrounding employment of USVs face all navies. Potential force employment and force generation issues involve personnel, training, maintenance and interoperability as well. Doctrinal issues pertaining to how, where and when the RCN might employ USVs are non-existent and need to be developed quickly. Finally, political and economic issues surrounding how much they cost, as well as where and when USVs shall be procured and manufactured requires close coordination between the RCN and the Government of Canada (GoC).

CHAPTER 1 – DEFINING THE PROBLEM SPACE

The future maritime threat environment and the RCN's vision for its future fleet starting in 2035 and beyond will increasingly challenge the capabilities currently envisioned in CSC. The modern maritime domain will be a highly contested battlespace, where ships are susceptible to continuous detection and tracking from a multitude of subsurface, surface, airborne, and space-based sensors. This environment where weapon systems ranges and speeds have been designed to inundate modern layer defenses will challenge existing fleet compositions, characterised by limited numbers of highly capable warships. Surviving future naval conflict relies on greater distribution of naval capabilities at sea. While CSC may prove sufficient to address near term threats, limited numbers are a drawback and current capabilities will need to evolve to confront the future maritime threat and achieve the RCN's vision. Despite this knowledge, due to their cost, growing the fleet by simply adding increased numbers of CSC will not be an option.

Driving the exorbitant costs of CSC is the need to replace the capabilities of the RCN's current multipurpose HALIFAX Class frigates, as well as, the decommissioned area air defence IROQUOIS Class Destroyers in a single platform. This decision has limited the RCN to building at most 15 vessels. Key cost drivers to ship construction in Canada, first the establishment of NSS; second the need for a highly modular and flexible design capable of adapting to new threats over a protracted lifecycle, and; third, the presences of human onboard the vessel, have all conspired to further limit overall ship numbers. Consequently the RCN is not only building a new class of ships capable of evolving and remaining relevant over the next 40 -50 years, but equally rebuilding and sustaining Canada's national maritime industry at the same time.

NSS was established to eliminate the cyclical nature that has historically plagued naval shipbuilding in Canada, necessitating the rebirth of the maritime industry to support new RCN acquisitions. Designed to provide benefits to Canada's economy, regional employment and security interest, it has driven up CSC production costs in comparison to our allies. Estimating what requirements a warship may need to defeat all future threats is an impossible task, as such designers look to integrate modularity and flexibility in modern warship design. The more of each a design contains the greater production costs. Compounding this issue is the notion of protracted design and construction timelines, such as those being proposed for CSC, which can lead to a warship becoming obsolete before it's even finished. Avoiding this issue requires expensive redesign efforts in the middle of production, using a process of flights and batches.

The presence of humans onboard presents its own unique design challenges and increasingly is becoming a major cost not only for designing a warship, but equally impacting the year over year operation and maintenance costs. The RCN's ability to adequately support a growing list of constabulary and diplomatic missions, while simultaneously maintaining a credible military force with only 15 ships is highly suspect. Concentrating all RCN capabilities into a limited number of vessels runs the risk of jeopardizing force structure with the loss of even a single vessel.

Future maritime domain

The world's oceans are vast, covering 70% of the earth's surface. They create a battlespace that historically has afforded navies the ability to manoeuver freely; to concentrate forces in secret; and, to arrive on mass to confront the enemy. Naval tactics, doctrine, and ship design, from Nelson and the age of sail to the tactics employed during the Cold War have relied on the ability to conceal navies at sea. Unlike armies on land, there is no concept of reserve. The ability to destroy an enemy revolved around, whoever hits first and hits hardest, was likely to carry the day.

In the new century, dawn of information age advances in telecommunications, space-based sensors, unmanned aerial drones, surface radars and integrated tactical networks compress the vastness of open oceans.[1] The ability for navies to covertly transit and assemble in force is rapidly diminishing, if command of the sea is contested. This is particularly true in operational areas including the littorals and relatively confined bodies of water within reach of land such as the Mediterranean, South China Sea, or, Baltic Sea. It is projected that as early as 2030, navies will need to be capable of carrying out operations in a virtually persistent observed environment.[2] Surviving future surface naval engagements demands that navies revisit how they protect and employ forces.

In addition to difficulties faced by navies trying to obscure their movements is the rapidly evolving set of kinetic threats facing modern warships, from highly agile hypersonic missiles, to directed energy weapons, or proliferation of cheap anti-ship missiles capable of being fired from all 3 dimensions (subsurface, surface and air) simultaneously.[3] The emergence of highly lethal and increasingly stealthier modern submarines and torpedoes serve to further threaten surface fleets. Recent developments in cheap, reliable Air Independent Propulsion (AIP) systems allow adversaries to patrol

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[1] Andrew Kerpinevich, *Maritime Competition in a Mature Precision-Strike Regime* (Washington, D.C.: Center for Strategic and Budgetary Assessments, 2014), 63-76.
[2] Ben Lombardi, *The Future Maritime Operating Environment and the Role of Naval Power (O*ttawa, Canada: Defence Research and Development Canada (DRDC),[2016], 80.
[3] Alex Zelinksy, "The Future Navy Powered by Science and Technology" Sea Power Centre - Australia, 2015).

submerged and deadly quiet for disproportionally longer periods. Capabilities previously reserved for nations outfitted with nuclear powered submarines are now available to potential adversaries at a fraction of the cost.

Existence of such weapons means that warships' defensive systems, operating either independently or in smaller formations, shall be quickly inundated or overrun. Equally perplexing are increasing ranges of weapon systems. Current Area Access /Area Denial (A2/AD) weapons such as Chinese ballistic land-based anti-ship missiles are capable of striking assets further and further from the shoreline, in excess of 900 nm.[4] Navies will need to operate increasingly further away from land when operating in contested waters.

Technologies which navies leveraged in the past, namely large monostatic radar such as the US Spy 6 radar, which are well suited to detect and track targets at longer ranges are becoming increasingly susceptible to counter detection by passive enemy RF sensors, capable of classifying and geolocating the friendly forces emitter. These environments are creating a growing need to embrace Electromagnetic Maneuver Warfare (EMW). In EMW, the battlespace is filled with passive sensors that allow greater awareness while still achieving a creditable defensive posture, without the continuous employment of powerful emitters such as the Spy 6.[5]

These realities have led to increased reliance on automation to digest the cornucopia of information retrieved by modern naval sensors, as well as evaluate targets

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[4] Bryan Clark and Timothy Walton, *Taking Back the Seas: Transforming the U.S. Surface Fleet for Decision-Centric Warfare* (Washington, D.C.: Center for Strategic and Budgetary Assessments,[2019]), 28-33.
[5] Clark and Walton, 41-42.

and present the human operator with a course of action to neutralize threats. Modern warfare has reached the point where the limiting factor in successfully winning naval engagements may be the finite capacity of humans to process recommendations and make a timely decision.

In this evolving future maritime threat environment, it is no longer about who can find and engage the enemy first (though still relevant), but increasingly naval warfare is about who has successfully distributed their naval capacity to complicate the enemy's targeting equation, increase their threat detection range thus creating greater reaction times for humans operators, and ultimately reduce the consequences of losing a single vessel to enemy fire.

In essence, the future of maritime warfare forces navies to address the conundrum of quantity versus quality. Is it better to invest in vessels that are extremely flexible, versatile, adaptive, survivable and subsequently costly; or, distribute capabilities of their navy over numerous platforms to avoid the issue of too much concentration? Increasingly, navies are shifting away from limited numbers of expensive multi-purpose surface combatants, in favour of a more balanced distribution of capabilities. Achieving a properly distributed fleet composition, however, poses a significant challenge predicated on each navy's unique constraints on resources (people, industry, skillsets or materials), technology, budgets, political will, or time.

Practically, distributing naval capacity is about returning to manoeuver warfare and making use of sea space. Despite the rise of China and Russia and renewed great power competition, technology has made attrition style warfare anticipated and planned for during the Cold War era unlikely. The latest iteration of manoeuver warfare focuses on deploying assets into contested areas in order to disrupt and counter enemy aggression, with aim of deterring an attack. A highly distributed navy will be able to degrade, delay, or defeat enemy attacks. [6] The RCN will operate in this threat environment and may have insufficient CSC vessels to do so effectively.

The RCN's future vision

To meet the challenges of the future maritime domain, the CAF has embodied its vision for the RCN in three key documents; Strong, Secure, and Engage (SSE) which articulates the current strategic level RCN requirements, the RCN's own Strategic Vision 2017-2022, which lays out detailed intent on implementing SSE in the near term; and, LEADMARK 2050 which provides of some likely end state capabilities the RCN aspires to have following forecasted recapitalization to meet objectives laid out in SSE.

At the strategic level, the CAF envisions the future RCN as a globally deployable navy capable of simultaneously executing all sorts of domestic and international operations, independently as well as in coalitions with allies. Domestically, the RCN must continue to defend Canada's sovereignty, patrol vast coastlines, and protect extensive natural resources within its Economic Exclusion Zones (EEZ). As a G8 nation, Canada's economy is heavily reliant on trade and therefore needs an RCN capable of contributing to collective efforts maintaining existence of safe, navigable oceans and waterways to facilitate continued national economic prosperity. While Canada's largest trading partner remains the United States, over 90% of all global goods transit via oceans at some point in their manufacturing lifecycles. Therefore, Canada's navy must be

[6] Bryan Clark and Timothy Walton, *Taking Back the Seas: Transforming the U.S. Surface Fleet for Decision-Centric Warfare* (Washington, D.C.: Center for Strategic and Budgetary Assessments,[2019]), 11-18.

capable of securing those lines of transit, in keeping with international laws and the rules-based order. As a result, the RCN needs vessels well-suited to constabulary and crisis management functions, while equally capable of seamlessly transitioning to a combat role at any time.

Internationally, Canada is committed to principles of multilateralism. A founding member of NATO and the UN, Canada is obligated to support its defence alliances and uphold international institutions espousing western ideals. To fulfil these responsibilities, the RCN must be capable of simultaneously deploying and sustaining two naval task groups consisting of up to four surface combatants and a joint support ship.[7] The ability to sail two independent task groups affords the GoC a level of contingency, whereby it can creditably support military alliances while equally reserving capacity to address any domestic or other international crises should they arise. These RCN's ships must demonstrate flexibility, presence, and self-sustainment while conducting either independent Canadian operations or meeting international commitments.

To achieve these strategic aims, the future navy needs to be agile and adaptive in approach. Key capabilities include advancing interoperability and maintaining strategic partnerships with the US and NATO, achieving a high level of comprehensive integration with other government departments to support the *whole of government approach*, and, building and sustaining a national maritime industrial base to foster technological agility and innovation in order to defeat future threats.[8] Consequently, future RCN ships will

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[7] Department of National Defence, Canada, *Strong, Secure, Engage* (Ottawa: Government of Canada, 2017), 113.
[8] Royal Canadian Navy, *Canada in a New Maritime World: LEADMARK 2050* (Kingston, Ontario: Government of Canada, 2016), 33-35.

need to be designed and constructed in Canada to ensure these key capabilities are achieved.

Expanding on the intents for the RCN's domestic role at an operational level, the CAF intends on using defence procurement to incentivize Canadian research and development in important emerging technology areas. Nowhere is this approach more apparent than the existence of the National Shipbuilding Strategy.[9] The CAF is prioritizing advancements in joint ISR capabilities, to provide a clearer picture of Canada's maritime and air approaches to identify threats to security and sovereignty, particularly in the north, while supporting allied partners through five eyes and NATO.[10] To fulfil this objective, future RCN ships need to be highly adaptable sensor platforms, capable of collecting and transmitting information over a wide operating area.

Looking deeper into the RCN's expectations internationally at an operational level, future navies need to be capable of projecting meaningful joint action at sea as well in support of operations ashore. This requirement needs to be accomplished throughout the full spectrum of warfare, from high intensity conflict through to influence activities to isolate and dissuade enemies resolve and capacity to re-engage.[11] A return to major power competition (read China and Russia), non-state actors and terrorism, littoral conflict, the freedom of navigation and domestic/ humanitarian operations will be the RCN's focus.[12] The next generation of RCN ships can be expected to undertake

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[9] Department of National Defence, Canada, *Strong, Secure, Engage* (Ottawa: Government of Canada, 2017), 75.
[10] DND, *Strong, Secure, Engage*, 64-66.
[11] Royal Canadian Navy, *Canada in a New Maritime World: LEADMARK 2050* (Kingston, Ontario: Government of Canada, 2016),30-32.
[12] Department of National Defence, Canada, *Royal Canadian Navy Strategic Plan 2017- 2022* (Ottawa, Canada: Government of Canada, 2016), 8-9.

increasingly diverse missions that necessitate a highly survivable design, capable of operating in contested environments near land, and supports a multipurpose mandate.

Proliferation of information technology forces navies to balance use of human judgment and automation in the ever increasing nature of data rich and fast pace modern warfare. The key is a faster cycle of innovation.[13] As a result, the RCN needs a fleet of ships that are easily upgradable and can keep pace with rapidly evolving computer and software developments.

The CAF is committed to being an international leader in discussions on employment and use of automated and remotely piloted systems. The CAF is equally committed (at this time) to maintaining an appropriate level of human involvement in use of military capabilities that project lethal force. The RCN is expected to be bold with its application of innovative technologies, not only in its current fleet, but also through activities designed to advance understanding and implementation of existing core functions.[14] As such, any new RCN ships will be expected to embark, deploy, or control remotely operated sensors and weapon systems.

A clear innovation objective of the RCN is to conduct research and development of remotely piloted sea capabilities, in partnership with industry and academics.[15] By 2035, the results of industry and academic partnerships in these areas is expected to produce unmanned capabilities to offset MCM coastal patrol and route survey

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[13] Department of National Defence, Canada, *Royal Canadian Navy Strategic Plan 2017- 2022* (Ottawa, Canada: Government of Canada, 2016), 9-10.

[14] DND, *RCN Strategic Plan 2017- 2022*,10.

[15] Department of National Defence, Canada, *Strong, Secure, Engage* (Ottawa: Government of Canada, 2017), 73.

capabilities lost with divestment of the KINGSTON class general purpose minesweepers. Unmanned vehicles to conduct ISR and strike missions, referred to as the 3Ds - Dirty, Dull and Dangerous will fill part of the gap. While not envisioned to replace entirely manned vehicles, which are viewed as essential to manage effectively the complex decentralized command structure inherent to naval operations, it is expected these capabilities will reduce human workload and improve sailors current work / life balance.[16] For the RCN's vision to become reality, a future fleet must address the complexities of rapidly evolving threats in the maritime domain

The current RCN solution - CSC

Based on its vision for 2035 and beyond, the CAF and the RCN expect much from the future fleet of CSC ships. As envisioned, CSC replaces the current fleet of modernized HALIFAX class Canadian Patrol Frigates (CPF's) as well as recently decommissioned IROQUOIS class destroyers. CSC subsumes the current multi-purpose role undertaken by CPF's. In addition, it re-establishes the Command and Control (C2) and task group defence capabilities lost with retirement of the IROQUOIS class, see Figure 1.

Enhanced offensive Anti-Air Warfare (AAW) and Above Surface Warfare (ASuW) capabilities, far greater than previously resident in the RCN fleet, will enable CSC to reclaim task group defensive capabilities in addition to projecting joint action both at sea, as well as, on land. This includes 32 dedicated VLS cells capable of carrying either air / surface or land attack missiles, as well as additional surface/land strike

[16] Royal Canadian Navy, *Canada in a New Maritime World: LEADMARK 2050* (Kingston, Ontario: Government of Canada, 2016), 44-57.

capability either via its 8 Naval Strike Missiles, the 127mm main gun or additional 24 point defense missiles.[17] This combination of weapons systems provides a creditable defensive capability against current anti-ship missile systems and a modest layer defence capability against anticipated salvo.

CSC boasts an increased interoperability and shared tactical picture with US and NATO allies through the integration of ISTAR capabilities such as AEGIS Fire Control System, Spy 7 Radar, and Cooperative Engagement Capabilities (CEC). These systems are augmented by an advanced suite of Electronic Warfare sensors and effectors, as well as dedicated unmanned vehicle control capabilities. These systems vastly improve the threat detection range and reaction time for future CSC operators, relative to existing capabilities. Moreover, the inherent design flexibility and modularity provided by a mission bay capable of housing multiple sea containers, up to three additional 10 m RHIBs, or, any assortment of modular mission fit systems necessary to achieve RCN objectives allows for a seamless transition between non-combat and combat missions.[18] These enhanced technologies improve the survivability and offensive capabilities required in an increasingly hostile operating environment.

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[17] Royal Canadian Navy, "Canadian Surface Combatant," http://www.navy-marine.forces.gc.ca/en/fleet-units/csc-home.page (accessed 9 January, 2021).
[18] Royal Canadian Navy, *The Canadian Surface Combatant – More than just a Ship* (Kingston, Ontario: Government of Canada, 2020c), 2.

Figure 1: Canadian Surface Combatant - Quick Facts[19]

Finally, CSC possesses a silent electric propulsion system that works in tandem with vastly improved UWW sensors suite which includes the latest hull mounted SONAR, as well as variable depth and static towed array SONAR. These organic ship capabilities working in combination with the highly advanced SONAR capability fitted to the embarked CH 148 helicopter provides CSC the ability to conduct bi- and multi-static operations.[20] Accordingly, the RCN is well positioned to continue its role amongst allies and peers as a world leader in ASW operations.

[19] Royal Canadian Navy, "Canadian Surface Combatant - Fact Sheet," http://www.navy-marine.forces.gc.ca/assets/NAVY_Internet/docs/en/fleet/rcn_csc_factsheet-8x11_web.pdf (accessed 9 January, 2021).

[20] Royal Canadian Navy, "Canadian Surface Combatant," http://www.navy-marine.forces.gc.ca/en/fleet-units/csc-home.page (accessed 9 January, 2021).

With all these capabilities, the overall cost of the CSC program has proven prohibitively expensive. At a current cost of $ 60 billion in today's dollars (CAD) it is the single largest procurement in Canadian history. Beyond the price tag associated with the weapons technology and capabilities, the overall cost of this project is primarily a function of three elements: NSS; future proofing the design to keep it relevant for 40 years; and the need to have a human crew onboard.

Domestic shipbuilding in Canada

NSS facilitates two primary strategic objectives for the GoC. The first objective is to provide a means of recapitalizing the Royal Canadian Navy and Canadian Coast Guard fleets which are due for replacement.

Recapitalization of these fleets is a major undertaking which in the past has necessitated not only the development and design of the intended new vessels, but equally an extensive investment rebuilding Canadian maritime industries. Historically, Canadian maritime industries has been characterized as cyclical, a so called *Boom and Bust* cycle where industry was allowed to decline under market forces, following the completion of each new capital acquisition program announced by the GoC.[21] This cycle has been further exacerbated by limited levels of public and private investment in shipbuilding that generates insufficient investment to sustain a continuous industry. As a result, the cost of Canadian warship procurement projects has historically been higher than allies, which have invested in maritime industries on a continuous basis. They have bigger fleets or greater interest from the private sector and accordingly can afford to

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[21] Government of Canada, "About the National Shipbuilding Strategy," https://www.tpsgc-pwgsc.gc.ca/app-acq/amd-dp/mer-sea/sncn-nss/apropos-about-eng.html (accessed 7 January, 2021).

maintain industries through scale. Canada has been unsuccessful at exporting warship designs in the past. Production runs are subsequently small which further drives up the price of each vessel, as typically the cost per vessel drops drastically after delivery of the first 3-4 ships in any new design.[22]

The second objective of NSS is to break out of the boom and bust cycle by investing in long-term projects and sustainment activities which allows industry to modernize and maintain expertise. In turn, a sustainable industry with far reaching economic benefits, not just for the RCN, but equally for local regions as well as nationally shall be created.[23] To achieve these objectives, NSS requires ship designers and suppliers re-contribute 100% of any foreign investment back into the regional economy, so called Industrial Regional Benefits (IRBs). As a result, IRBs get apportioned into the initial procurement cost, thus driving up price in an effort to stimulate Canadian business development.

NSS also aspires to provide initiatives to drive opportunities for Canadian suppliers. That fosters innovation through Canadian research and development, and offers Canadians opportunities to expand skills and develop new export opportunities. To date, this strategy has resulted in the average shipyard salary being 30% higher than the national manufacturing average salary.[24] Yet, this statistic is misleading as the limited pool of skilled labour across Canada must be competed for between other major

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[22] Ian Mack, "Making Waves," *Canadian Naval Review* 16, no. NO.2 (2020), 27-29. https://www.navalreview.ca/.

[23] Government of Canada, "About the National Shipbuilding Strategy," https://www.tpsgc-pwgsc.gc.ca/app-acq/amd-dp/mer-sea/sncn-nss/apropos-about-eng.html (accessed 7 January, 2021).

[24] Government of Canada, "The Year in Review: Canada's National Shipbuilding Strategy—2019 Annual Report," https://www.tpsgc-pwgsc.gc.ca/app-acq/amd-dp/mer-sea/sncn-nss/rapport-report-2019-2-eng.html (accessed 7 January, 2021).

industries such as oil and gas. As a result, shipyards offer wage incentives to secure talent and relies on shipyard-related unions to provide workers. Ultimately, these wages are rolled up in to the overall production cost associated with warships.

Future proofing warships

Warships are a complicated system of systems, whose design and construction have historically been lengthy endeavors, necessitating an iterative approach that progressively balances and trades off capabilities in an effort to optimize the design and meet intended requirements.

Despite advances in Computer Aided Design (CAD) tools and systems engineering processes that have helped to expedite modern warship design, it still requires on average 7-10 years of requirements development and design work to arrive at the final production product. This is subsequently followed by a lengthy first of class build period, often plagued by the need to develop novel production process and system integration issues. As a result, a country wishing to recapitalize its fleet with modern warships is looking at a 10-20 year process, from the initial identification of operational capabilities to receipt of its first new vessel.[25] This often leads to systems or whole warships becoming obsolete before they are finished construction.

A compounding issue is the increasing trend of maintaining vessels in service for disproportionately longer periods of time. The IROQUOIS class destroyers, designed for a 30 year lifespan, were maintained in-service with at least one deployable platform for well over 40 years. In their final phase of life, the vessels rapidly degraded in capability

[25] The range 10-20 years was calculated by the author follow a review of open source information pertaining to multiple western navy warship design and builds programs, undertaken in the last 2 decades.

and operational availability. While the specific divestment dates of the HALIFAX class vessels are unknown, they were also designed to achieve a 30 year service life. Based on historical trends demonstrated by the IROQUOIS class and projected delivery dates for the CSC vessels, the HALIFAX class shall reach 40 years of age around the 2030 timeframe at the same time initial delivery of CSC takes place. Divestment of these platforms will in all likelihood commence in and around that time, certainly not much before then. Therefore, the RCN needs to design a ship that can both operate reliably for 40 years while also maintain its military relevance.

A design process so lengthy for a ship intended to operate that long is inherently full of risk for naval and defence planners, trying to divine and to understand what future threats and mission requirements will be necessary to fulfill national security objectives 50-60 years away. This becomes particularly challenging when considering the current pace of technological development in both weapons and sensor systems, the rapidly changing political landscape, the diversification of warfare domains from Land, Sea & Air to now including Space and Cyber, as well as the changing nature of warfare from state on state conventional hostilities which dominated the Cold War, to the advances in Grey Zone or Hybrid Warfare that permeates conflicts today. Getting the fundamental requirements right from the outset is essential to ensure any new warship has potential to meet and overcome challenges and threats it will face tomorrow. The task is functionally impossible to get perfect. So, warship designers have developed means to *Future Proof* and de risk potential designs. Buying away future risk with these measures always costs money.

Current practices for future proofing a warship design center around two key concepts: modularity and flexibility. Modularity can be viewed as establishing fixed boundaries, interfaces, and services within the ship, which allow for bespoke systems to be selectively, designed, and developed independent of the core ship design. A practical example would be a containerized system, housed in a standardized sea container. By ensuring that both the core ship design and containerized systems have compatible interfaces, in theory capabilities can be perpetually upgraded throughout the life of the ship by simply updating the containerized system.[26] Consequently, if the warship design requires rapidly interchangeable capabilities, then increased modularity is the way to go.

Alternatively, designers can strive to build flexibility directly into the core design. This is typically achieved by extending the design requirements for key system enablers such as power (electrical and propulsion), weight, space, cooling and more recently bandwidth (both internal within ship ie. fiber optic cabling and external communications).[27] If the final warship design is anticipated to need extensive increased permanent capabilities, then flexibility is the best choice.

With either of these approaches, additional system capacity not required at the onset of the ship's service life is accounted for. Therefore, initial acquisition cost will be substantially greater. Both approaches have drawbacks. Modularity functionally limits the systems and equipment that naturally lend themselves to being containerized. Additionally, should the system inside the container exceed one of the ship's key system

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[26] John F. Schank et al., *Designing Adaptable Ships: Modularity and Flexibility in Future Ship Designs* (Santa Monica, CA: RAND Corporation, 2016), 11-17.
[27] John F. Schank et al., *Designing Adaptable Ships*, 33-50.

enablers (i.e. requires too much power, weighs too much, requires too much bandwidth or cooling) then it becomes prohibitively expensive to employ.

Similarly, restricting design to simply making due with flexibility through enhanced design margins equally restricts implementation of new capabilities. If those capabilities are only required temporarily, installation of systems will require extensive labour internal to the ship to install.

Ultimately, the best choice is a blend of modular and flexibility, which is what is present in the RCN's CSC design and the Royal Australian Navy's (RAN) HUNTER Class and Royal Navy's (RN) parent design Type 26. A combination of carefully selected through life design margins and inclusion of a multi-purpose mission bay provide a myriad of options to pursue through life upgrades, but come with a significantly inflated initial production and design cost.[28] Consequently, the RN has already cancelled 5 of the originally planned 13 Type 26 vessels under construction, and redirected those funds into development of other platforms, such as the Type 32 and Type 31. [29] Given the RN's decisions, and continued CSC program cost increases it is conceivable that the CSC project may equally succumb to budgetary pressures resulting in cuts to its total numbers. Considering alternative options now would be a prudent measure to ensure adequate number of hulls are available to meet the RCN's needs.

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[28] David Axe, *Britain's New Type 26 Frigate is Going to be Amazing* (Online Publication: Center for the National Interest, 2019).
[29] Andrew Chuter, "Ballpark Cost Revealed for Royal Navy Frigates," https://www.defensenews.com/pentagon/2015/09/25/ballpark-cost-revealed-for-royal-navy-frigates/ (accessed 10 March, 2021).

In the event of a protracted design and build program, new capabilities and requirements will invariably necessitate fundamental redesign of the vessel. This process is often referred to as the Flight and Batch approach to designing ships. Batches represent a production run for a predefined number of vessels. Between sequential batches of ships within a single flight incremental low cost changes between systems due to obsolescence issues or minor technological improvements may occur. Development of a new flight represents a substantial redesign effort, wherein major technological advances are implemented into the ship's design (typically due to changing threat environment or user needs). New flights can result in a radically different vessel both in dimensions and operating capabilities. Take for example the US Navy DDG-51 ARLEIGH BURKE destroyer program, which commenced in the 1980s and subsequently has had multiple flight iterations. Comparatively Flight I to Flight III are fundamentally different vessels, see table 1.

Based on the development timeline between Flight I, commissioning in 1991, and then extensive redesigned Flight IIA, delivery in 1997, a dramatic change in design coincided with the end of the Cold War and a new threat environment. If this example is then superimposed on the estimated CSC program timelines, approximately 2015 to 2045, it becomes evident that a CSC batch and flight approach may be necessary, if not impossible, to avoid. As a consequence, the current CSC project needs to expend substantial additional funds, currently unaccounted for in the existing design and build contract, to redesign the vessel to incorporate whatever unknown new capabilities become necessary to defeat the evolving future threat environment.

Characteristic	Flight I	Flight II	Flight IIA	Flight III
1st Commissioned	1991	1996	1997	Est. 2023
Displacement	8,315 long tons	8,300 long tons	9,300 long tons	9,500 long tons
Crew	300	300	380	380
Helicopter(s)	Flight Deck Only	Flight Deck Only	2 x MH-60	2 x MH-60
VLS Cells	90 Cells	90 Cells	96 Cells	96 Cells
Main Radar	Spy 1 - 3D Radar	Spy 1 - 3D Radar	Spy 1 - 3D Radar	Spy 6 – AESA 3D
Total in Flight	20 Vessels	7 Vessels	Planned 45ships	Planned 14ships

Table 1 - DDG-51 ARLEIGH BUREK Flight Comparisons[30]

Again drawing parallels to the DDG-51 program, see Figure 2, the decision to execute this redesign would occur around 2030 with an estimated 4-6 CSC ships delivered or under construction. This represents a critical decision point for the RCN. Whether it is best to invest considerably more time, labour and resources into upgrading the remaining limited number of CSC still in production to meet the new threat paradigm, or choose to invest money in an effort to adequately distributing new capabilities across a fleet of more cost effective platforms.

[30] Table 1 was generated by the author from several open sources of information, all publically available through www.Janes.com

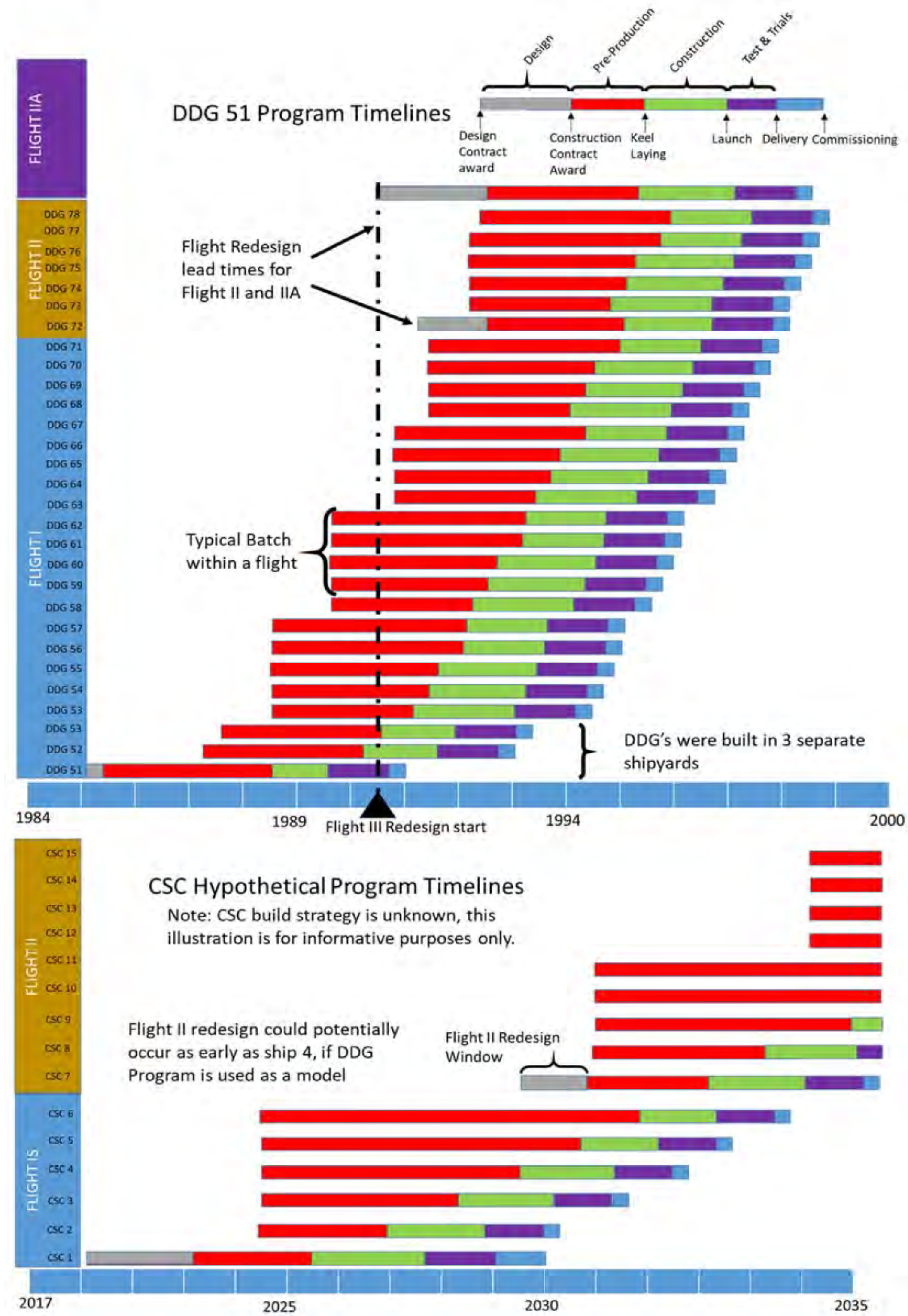

Figure 2: Illustrative comparison of DDG-51 program and hypothetical CSC program[31]

[31] Figure 2 was generated by the author from open source information pertaining to the CSC program, and historical DDG-51 program information, contained in *Design adaptable ships* (Schank et al.)

Having humans onboard makes it difficult

Besides the complexities and cost associated with future proofing warships, supporting the human element of warships has equally become a challenging and progressively costlier endeavour.

Take for example the myriad of systems which exist solely to support human life onboard a ship. Life saving equipment from medical facilities and first aid equipment, to survival equipment in the event the ship is lost to sea are prime examples. The various hospitality services from galley and food storage, to wash places and wastewater treatment. Extensive bunking requirements, habitability spaces, and fresh water production are also added. Necessity to maintain a fresh air supply in what is otherwise an enclosed space and HVAC requirements to ensure adequate living conditions from the Arctic to the Equator all consume substantial amounts of volume, power and weight which further drive up costs. Finally, the indispensable and extensive need to populate the ship with internal communications and human machine interface devices from simple personal computers and phones to complex control positions located on the bridge, operations room or machinery control room represent just some requirements.

Now consider that all these systems necessitate some redundancy, resilience, or other means of graceful degradation and it becomes quickly apparent that having humans onboard a warship dramatically increases complexity and size. Paradoxically, as procurement costs rise due to presence of human related systems, there is less room in the design budget to inject modularity and flexibility, as these design elements cost money and equally consume the very elements necessary to future proof a vessel, namely space, weight, volume, power, cooling, and bandwidth.

As a consequence, designers have increasingly looked to automation to reduce the overall crew size onboard ships. Yet, despite these efforts, crew sizes for major surface combatants such as frigates or destroyers has remained relatively stable at approximately 200 personnel over the past 30 years.[32] That is, mainly due to the overarching requirement on personnel to simultaneously conduct warfare operations (i.e. *fight* the ship), as well as conduct damage repair and recover lost capabilities (i.e. sustain the *float* and *move* functions of the ship).

Compounding presence of humans onboard ships today is the mounting regulatory and statutory requirements related to quality of life at sea, which have become increasingly more stringent and further drive up procurement cost of a warship in an effort to improve amounts of personal space the average sailor can enjoy. These regulations affect elements such as size and types of amenities within personal accommodations, including everything from the size of one's personal bunk to the number of personnel who share a mess deck / cabin; the number of heads and wash places onboard, or; the comforts of home such as WIFI and internet connectivity. These changes are driven by the evolving nature of societal expectations and the need for employers to attract a modern, young workforce. Fundamentally, enticing someone to work at sea is made infinitely easier if their at sea environment more accurately reflects what they are accustomed to at home.

The consideration for human operational costs associated with major warships are another growing cost driver for navies. As military pay rates incrementally increase to

[32] The average crew size of 200 personnel was calculated based on open source information from www.janes.com relating to the crew sizes of frigates and destroyers built by Canada, USA, UK, France, Germany, Spain, Australia, Norway and the Netherlands over the past 30 years.

better align with comparable civilian alternatives, the salary cost of operating ships becomes increasingly problematic. Take for example the current Halifax Class Frigates with a crew complement of 230 sailors, officers and NCO's. A conservative estimate based on current pay rates puts the annual combined salary for a single frigate's crew at approximately $12 million (CAD). That does not account for any costs associated with embarking an aircrew or other specialized teams such as Naval Tactical Operations Groups (NTOG). Nor does it account for any additional pay allowances such as sea pay, or associated training cost necessary to maintain combat readiness of the unit. Consequently, running a warship is an expensive proposition for any nation. For the RCN, presence of humans onboard is only aggravating already tight budgetary constraints.

The calculous of employing modern warships

With reduced fleet sizes, more naval power concentrates into a singular element. As a result, militaries and governments are less likely to send a capital asset into future threat environments because the risk is just too great.

Currently, the RCN has 12 frigates. With introduction of CSC, that number could rise to 15 ships. Due to operational cycles for scheduled docking work periods and the capacity to absorb unexpected equipment/material failures, the total loss of 1 to 2 ships due to enemy action could cripple the RCN's ability to form its basic naval element the task group.

Despite the RCN's smaller fleet size, the GoC increasingly demands more of its warships. The limited number of platforms available means increasingly warships are called upon to undertake missions which are less about high intensity combat and involve diplomatic or constabulary roles. The use of a warship, as complex as CSC, is often in excess to requirements in certain scenarios when the RCN is tasked to support other government departments in operations such as patrols of Economic Exclusion Zones (EEZ) for illegal fishing in support of DFO, or support to law enforcement actions such as the counter narcotics activities during OP CARRIBE; SAR, or; Human Disaster Relief and even to a certain extent missions in support of NATO requirements such as the humanitarian crisis response in the Mediterranean arising from the Syrian war.

If CSC equipment is routinely exhausted in the pursuit of these non-military roles, it will further drive up operating and maintenance cost through the lives of vessels as well as reducing the overall operational availability of the fleet.

The RCN vision for 2035 and beyond necessitates a fleet capable of enforcing Canadian sovereignty while equally projecting influence globally. Whether domestic or international operations, the RCN expects to be capable of generating its own task groups when required and work in an interoperable fashion with allies by leveraging the latest advances in technology to achieve a whole of government approach to future conflicts. To achieve these objectives, the future fleet of CSCs have been designed as highly modular and flexible platforms, outfitted with the latest in weapons and sensor technology. The detriment of the CSC design is its overall cost, driven up by issues associated with the nature of shipbuilding in Canada; the need to future proof its design and the potential future unknown cost of a new flight redesign; as well as, inherent costs associated with having a crew onboard

The procurement and through life costs of CSC are a limiting factor in the overall number of ships being constructed. The planned 15 CSC will be extremely hard pressed to fulfil all constabulary and diplomatic functions expected by the GoC, while simultaneously fulfilling core military functions. Operating in a future maritime environment, where the battlespace is shrinking and the threat of highly lethal precision guided munitions is growing exponentially, demands a highly distributed set of capabilities across a large number of platforms. Due to cost considerations, the RCN cannot simply buy more CSCs to fulfill this need. This therefore calls into question the overall distribution of capabilities of the future RCN fleet.

CHAPTER 2 – THE PROMISE OF USVs

The US Navy's approach to the future maritime threat environment is embodied in its Distributed Maritime Operations (DMO) policy. Key to the implementation of DMO is the development of an Unmanned Surface Vessel (USV) program, with particular focus on the benefits and characteristics of Large and Medium sized USVs intended to form the core of the US Navy's new fleet composition. The Future Surface Combatant Force has exhibited significant reductions in operating and procurement cost, compared to a fleet of manned vessels. They provide for increased operational availability, are deployable into contested waters where risk to life is greater, and have reduced force generation / force employment requirements. Combined, these characteristics allow the Navy to vastly increase the number of *hulls in the water*, achieving a more distributed fleet composition

A Future Surface Combatant Forces fleet composition, comprising more than two-thirds USV allows for increased availability and diversity of sensor and weapons, to combat the future threats of increased salvo size and lethality, achieve increased complexity of force composition, as well as achieve a higher degree of offensive capacity.

Similar efforts undertaken by allied countries and NATO have indicated that employment of USV does not merely benefit major naval powers, but is proving to be a highly influential force multiplier for all navies. The use of USVs is fundamentally reshaping how navies approach development of future fleet compositions, from development of unmanned motherships to deployment in all aspects of naval warfare.

Globally, the USV industry is rich with emerging technology and business opportunities for both commercial and military sales. The extensive use of COTS equipment, and the opportunity to diversify USV developments into other major industries means a build-in-Canada USV program, that would not only increases the RCN capabilities but equally provides a means to achieve a primary objective of NSS, to generate a self-sustaining maritime industry in Canada.

The US Navy's problem space

In the mid 2000's, the US Navy re-examined the composition of its future naval force structure. The then aging fleets of TICONDEROGA class guided missile cruisers, as well as Flight I and II ARLEIGH BURKE class destroyers were reaching the end of life expectancy. The evolving threat of massive salvo sizes being launched towards aircraft carrier task groups and the ballooning cost of the replacement ZUMWALT destroyer project necessitated that the US Navy extend the service lives of older ships until suitable replacements were commissioned. The prospect of operating and maintaining the aging fleet in addition to recapitalizing them with *like for like* replacements was costly.[33] Equally concerning, this fleet composition of expensive multipurpose cruisers and destroyers was proving increasingly incapable of defeating perceived future threats, which at the time included increased operations in the littorals. In the mid 2000's, concerns began to include the return to great power competition with the rise of China and resurgence of Russian naval power.

[33] Congressional Research Service, *Navy DDG-51 and DDG-1000 Destroyer Programs: Background and Issues for Congress. CRS Report* (Washington, D.C.: Congressional Research Services,[2020b]).

As a result, the US Navy needed to develop less expensive vessels to increase their overall fleet size in a cost effective manner. They started to explore the notion of disposable manned vessels, what Vice Admiral Art Cebrowski referred to as the "streetfighter" concept, consisting of a heavily armed light ship (1000 tones) to be employed to deliver effects in the littorals but incapable of sustaining any significant damage thus reducing overall cost.[34]

In 2003, the notion of employing *disposable manned vessels* was abandoned, but out of this came the concept for the Littoral Combat Ship (LCS). LCS was envisioned as a minimal crew, modular, multi-mission platform whose cost would be reduced by limiting its survivability characteristics. In 2013 as the US Navy's demands on the LCS platform grew beyond operations in the littorals, to take on more roles traditionally conducted by expensive destroyers, so too did its overall cost. A victim of scope creep, LCS costs ballooned. Yet, despite the increasing cost, the overall capabilities of the vessel coupled with its lower survivability characteristics rendered it utterly ineffective against virtually all threats, save small fast attack craft and missile boats.[35]

In an effort to rectify this blunder, the next year, the US Navy launched its future Small Surface Combatant (SSC) project, acknowledging limitations of the LCS and continued need to build a capacity of affordable, capable, and particularly more survivable ships to conduct a C2 and multi-role mission (in essence a frigate program). With announcement of SSC, the US Navy again found itself in the same conundrum it started with. The procurement cost of a fleet of highly modular and flexible SSC frigates,

[34] David Axe, *How the Navy's Warship of the Future Ran Aground* (Boone, IA: WIRED, 2011).
[35] Congressional Research Service, *Navy Littoral Combat Ship (LCS) Program: Background and Issues for Congress. CRS Report* (Washington, D.C.: Congressional Research Services,[2019]).

thought cheaper than a fleet of destroyers, would not provide the US Navy the ability to expand sufficiently overall size to achieve distribution of capabilities anticipated in the future threat environment.[36]

Distributed Maritime Operations (DMO)

The continuing dilemma of expanding the overall fleet size to defeat future threats with the limitations of a fixed budget triggered an investigation into an affordable fleet mix model subsequently presented to the heads of the US Navy. What was to become known as Distributed Maritime Operations included three key objectives.[37]

First, increase the complexity of the surface force composition, by rapidly increasing the overall size of their surface fleet between 25 to 50 percent. The increased number of assets would work to complicate the enemies targeting calculations, by increasing the overall number of "effect chains" the enemy would have to overcome in an effort to neutralize friendly C2 and retaliatory capabilities.[38]

Second, significantly increase the required salvo size necessary for an adversary to achieve a decisive victory, through both distribution of capabilities as well as increased capacity of friendly forces to identify, detect and neutralize threats using a more comprehensive use of passive sensors.

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[36] Congressional Research Service, *Navy Constellation (FFG-62) Class Frigate (Previously FFG[X]) Program: Background and Issues for Congress. CRS Report* (Washington, D.C.: Congressional Research Services,[2021]). https://crsreports.congress.gov/product/pdf/R/R44972.
[37] Clark and Walton, *Taking Back the Seas: Transforming the U.S. Surface Fleet for Decision-Centric Warfare* (Washington, D.C.: Center for Strategic and Budgetary Assessments,[2019]), 24-25.
[38] ***Effect Chains*** – (aka Kill Chains) can be defined as the overall structure of an attack. While various definitions exist the generally accepted practice involves the sequence of: Finding, Fixing, Targeting and ultimately Engaging the enemy. This is followed by Assess phase of the preceding engagement phase. Breaking any element in this sequence is a means of defending oneself against their adversaries; conversely increasing one's own redundant capabilities to execute any one of these activities, equally confounds an adversaries efforts.

Third, increase overall offensive capacity of surface forces, thus allowing for a reserve offensive / retaliatory capability when confronted with great power peers, such as China or Russia.

To best achieve these objectives, the US Navy established the Program Executive Office for Unmanned and Small Combatants (PEO USC), its mandate was to investigate potential technologies and future distributed fleet composition for the US. In response, PEO USC stood up PMS 406 Unmanned Maritime Systems, to conceptually test and trial the abilities to operate increasingly bigger and more complicated autonomous and semi-autonomous vessels.

USV Program

Over the course of the next several years, PMS 406, in concert with the US Naval Sea Systems (NAVSEA) command, began to develop a vision for what the USV fleet would look like.

It identified 4 classes of USV for potential development based on operational capabilities and size, see Figure 3. PMS 406 commenced procuring numerous commercially available class 1 and 2 demonstration vehicles, to support early development of communications and autonomous operations technologies. Several of these initial demonstration vehicles quickly made their way into service supporting force protection and MCM operations. Additionally, they illustrated the need to explore USV operations in other potential areas such as EW, ISR and ASW.[39]

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[39] Ru-jian Yan et al., "Development and Missions of Unmanned Surface Vehicle," *Journal of Marine Science and Application* 9, no. 4 (2010), 451-457. doi:10.1007/s11804-010-1033-2. https://doi.org/10.1007/s11804-010-1033-2.

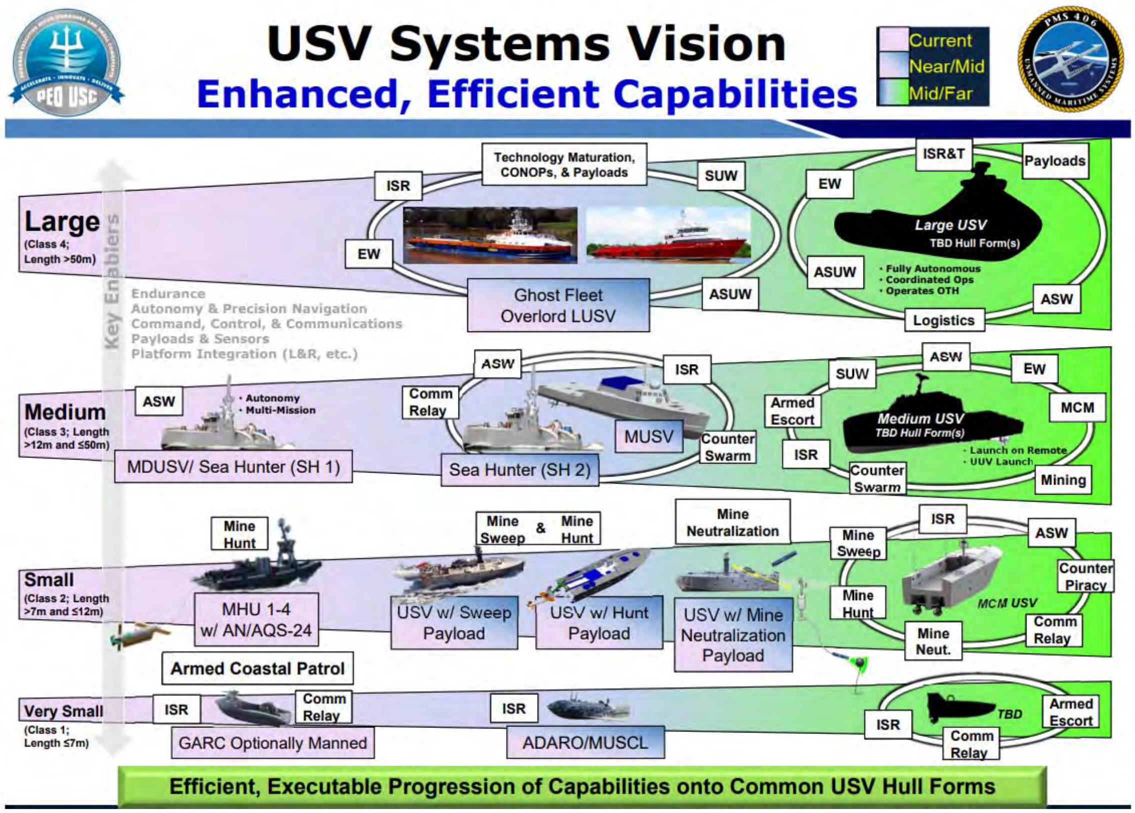

Figure 3: PEO USC - Current Classes of Unmanned Vessels and Development Paths[40]

In 2016, the program commenced proof of concept trials employing a class of medium displacement USV demonstration vehicle called SEA HUNTER, with the intent of furthering research and development of multi-mission, autonomous surface vessels operations. Initial success of SEA HUNTER demonstrated the rapidly growing capability of USVs to be employed throughout the full spectrum of high intensity warfare. Based on the SEA HUNTER trials, the US Navy estimated that operating cost for medium sized USV, conducting multi-role operations including tasks such as combined ASW, EW and ISR would cost between 15,000 -20,000 dollar US per day; vice an ARLEIGH BURKE

[40] CAPT Pete Small, *Presentation - Unmanned Maritime Systems Update - 33rd National Symposium of Surface Navy Association (On*line Publication: Program Executive Office - Unmanned and Small Combatants, 2019).

destroyer at 700,000 dollar US per day. [41] This major disparity between unmanned and manned vessel succinctly illustrates USVs' cost effectiveness and capacity to rapidly grow fleet sizes within existing naval operating budgets. Practically speaking, SEA HUNTERs operating costs equate to employment of 35 to 45 USVs for the price of a single manned destroyer.

In 2017, project Ghost Fleet Overlord was initiated, to further mature Large USV autonomous technologies, develop CONOPS, and, explore the potential to employ weapons and advanced radar systems payload options. The demonstration vessels were commercial offshore supply vessels, procured and retro fitted such that they could be operated autonomously.[42] Between 2019 and 2021, the Ghost Fleet vessels successfully completed several Trans-Atlantic crossings, as well as operations within the littorals, demonstrating their ability to safely navigate autonomously and avoid collisions in adherence to International Regulations for Preventing Collision at Sea (COLREGs). [43] The success of SEA HUNTER and Ghost Fleet Overlord initiatives to demonstrate the viability of USV technologies in naval warfare solidified the US Navy's resolve to pursue Large and Medium USVs as a means of distributing overall capabilities.

Advantages of USV's

The use of USV's as means of achieving increased distribution of naval capabilities is appealing for a number of reasons: lack of human occupants; the associated

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[41] Christopher Cavas, *Unmanned Sub-Hunter to Begin Test Program* (Online Publication: Sightline Media Group, 2016).
[42] James Goldrick, *Optionally Manned Systems and the Future Naval Force* (Fort Lauderdale, Florida: Online Publication, 2020).
[43] Todd Lopez, "DOD's Autonomous Vessel Sails through Transit Test, Participates in Exercise Dawn Blitz," https://www.defense.gov/Explore/News/Article/Article/2471165/dods-autonomous-vessel-sails-through-transit-test-participates-in-exercise-dawn/ (accessed 15 January, 2021).

reduced costs to operate and sustain; as well as, the potential for economic benefits within the domestic maritime industry are significant.

Absence of humans onboard uniquely positions USVs to undertake missions that are historically characterized as Dull, Dangerous and Dirty - the 3Ds. Lack of an embarked human operator naturally lends navies to employ the vessel in threat environments that present increased risk to life. The ability to remove all elements necessary to support human life onboard, as well as, leveraging Commercial-Off-The-Shelf (COTS) technology in lieu of more costly militarized equipment, results in USV production costs drastically less than a comparable surface vessels equally equipped with weapons or sensor packages.

Lack of human support systems in USVs equally affords design teams the luxury of additional space and weight, making incorporation of high degrees of modularity and flexibility easy and cheap. USV's can be designed to a common standard across class sizes, permitting employment of rapidly interchangeable containerized systems – what the US navy is referring to as "mission modules".[44] This substantially decreases the USV's through life costs. In essence, it maximizes future proofing and avoids issues associated with batches / flights. For the RCN, a fleet of USVs would alleviate some pressures on the limited CSC fleet by preserving operational availability. Operational availability for short notice tasks equally benefit from a fleet of USVs thanks to an ability to be rapidly outfitted with appropriate mission modules. Equally, more cost effective

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[44] Wayne Prender, "The Case for Unmanned Surface Vehicles in Future Maritime Operations," *Ocean News & Technology* (2019), 49. http://cimsec.org/the-case-for-unmanned-surface-vehicles-in-future-maritime-operations/40325.

USV platforms could increasingly undertake more basic maritime functions, such as fisheries or sovereignty patrols, again reducing wear and tear on CSC.

From an operational and sustainment perspective, absence of humans in combination with use of commercial standards and COTS equipment in USV designs, translates into a dramatic reduction in the need for redundant and safety critical systems. As a result, overall maintenance costs are significantly reduced. Factor in the inherent higher risk tolerance to deploy USV units, in particular with known defects, and the overall operational availability will be increased relative to manned vessels. This does not mean that all maintenance constraints will no longer be necessary. Critical systems such as those associated with navigational safety and communications are still likely to preclude operational availability, but the overall requirement and complexity of maintenance plans for a USV relative to a manned vessel will be infinitely less. Currently the RCN spends approximately $8.4 million (CAD) annually to maintain a single CPF, following limited routine operations (i.e. 100 days at sea).[45] Given the CAF foresees employing CSC increasingly in support of a greater whole of government mandate, overall operational time at sea and maintenance cost for CSC will be significantly higher. Comparatively, existing UAV systems such as the MQ-9 REAPER or MQ-1B PREDATOR exhibit maintenance costs that are 10 to 17 times less than their manned F-22 RAPTOR or F-15 EAGLE counterparts, while logging 4 to 8 times more flight

[45] Zakia Bouayed et al., *Estimating Maintenance Costs for Royal Canadian Navy Ships A Parametric Cost Model (Ottawa*, Canada: DRDC – Centre for Operational Research and Analysis,[2017]).

time.[46,47] Consequently, the RCN could maintain and operate a fleet of USVs on the anticipated through life maintenance budget for a single CSC.

If current legislative and doctrinal policies continue to require humans *in, or on the loop* to employ weapons, then current estimates envision employment of Medium and Large USV requiring 1-2 dedicated personnel.[48] This force structure would be similar to the training and employment of the US military's existing UAV assets such as the MQ-9 REAPER, where there is one operator to pilot the vehicle and another responsible to control weapons and sensors with a supervisor to oversee decisions and targeting.[49] Unlike the MQ-9 REAPER or other UAVs, for the USV, the requirement for personnel may be intermittent as autonomous functions associated with transit, navigation, loitering and sensor / weapons cueing functions are currently already available. In practical terms, the current estimated 100 sailors required to manoeuver and fight a single CSC platform, would be sufficient to pilot and operate a fleet of 30 USVs.

From the perspective of developing the national maritime industrial base, USV manufacturing and procurement is a rapidly growing market in both military and commercial sales. The potential economic and industrial benefit to nations looking to invest and develop their high tech and maritime sectors is significant, in particular when it comes to LUSV and MUSV.

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[46] Mark Thompson, "Costly Flight Hours," *Time Magazine,* 02 April, 2013, .
[47] Sgt. Daryl Knee, "MQ-1B, MQ-9 Flight Hours Hit 4 Million," https://www.af.mil/News/Article-Display/Article/1781271/mq-1b-mq-9-flight-hours-hit-4-million/ (accessed 17 April, 2021).
[48] Congressional Research Service, *Defense Primer: U.S. Policy on Lethal Autonomous Weapon Systems, CRS in Focus. CRS Report* (Washington, D.C.: Congressional Research Services,[2020a]).
[49] John Tirpak, "Rise of the Reaper," *Air Force Magazine,* 1 February, 2008, .

For instance, LUSV and MUSV designs lend themselves to construction in smaller shipyards. Diversifying the potential contractor network, reducing potential manufacturing bottlenecks, and expanding existing maritime industries are pluses that smaller shipyards would bring to NSS and its efforts to rebuild the maritime industry in Canada.[50] The commercial shipping industry is investing heavily in autonomous vessels to help drive up a ship's efficiency, reduce operating cost and most importantly improve safety, as 57.8% of all accidents at sea are related to human error.[51] Some estimates predict that by 2040 over 50% of all commercial shipping will be fully autonomous, making the USV market at that time worth roughly $65 billion (US) / year.[52] This represents a significant avenue to expand NSS, providing a commercial export market which could then be leveraged to increase overall regional benefits as well as capacity to build militarized USV for the RCN and its allies.

Currently, several key areas where USV commercial opportunities exist for investors to advance existing industrial capacity or exploit areas of research and development. These key areas represent emerging sectors in the maritime industry which could equally be exploited by NSS in development of a USV program.[53]

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[50] Daniel Tiznado, "Enhance Shipbuilding by Funding Unmanned Vessels," *National Defense (Washington)* 105, no. 802 (2020), 18. https://www.nationaldefensemagazine.org/articles/2020/8/31/enhance-shipbuilding-by-funding-unmanned-vessels.

[51] Koji Wariishi, *Maritime Autonomous Surface Ships: Development Trends and Prospects - how Digitalization Drives Changes in Maritime Industry* - (Tokyo, Japan: Mitsui & Co. Global Strategic Studies Institute,[2019]).

[52] $65 billion (US)/year, was calculated based on current global market projections for international ship building in 2040 and historical trends over the last 20 years.

[53] CAPT Pete Small, *Presentation - Unmanned Maritime Systems Update - 33rd National Symposium of Surface Navy Association (On*line Publication: Program Executive Office - Unmanned and Small Combatants, 2019).

For USVs to be fully unmanned, existing machinery endurance will need to be addressed. Critical machinery associated with power generation, propulsion, and auxiliary systems, such as chillers and sea water systems, currently require some element of human intervention to address routine maintenance needs (i.e. changing oil, or filters). Enhancing traditional mechanical equipment to improve its existing endurance in order to facilitate weeks to months of continuous operations without human interaction will be necessary to facilitate USV operations. While commercial technologies already exist to address some of these critical systems, more development is needed. Research in these areas would have tremendous commercial and military manned vessel applications, improving vessels operational availability as well as reducing operating and maintenance costs.

The SEA HUNTER demonstration vehicle has exhibited a high degree of autonomy and capacity to conduct precision navigation. Yet, for USVs to safely transit to and from operations, independently pilot busy maritime traffic lanes and deploy into high density littoral waters will require further improvements to existing levels of decision making, accuracy and reliability of autonomous systems. This will equally necessitate advances in Artificial Intelligence (AI) and machine learning capabilities. Considerable efforts to progress these technologies are already happening within the commercial shipping industry. Military USV designers working in collaboration with industry could accelerate these timelines, with the added benefit of establishing standardized protocols and system interfaces to reduce costs. For Canada, being involved in this ground breaking research would open up a highly lucrative commercial and military export markets for

Canadian businesses, as well as provide the ability to transition these technologies into other military domains such as Air or Land.

Command, Control, and Communications (C3) functions related to USV deployment equally need continued investment and research. Existing technologies used to control UAVs have been leveraged to an extent. However, the difficulty of controlling USVs in adverse weather or heavy seas provides unique challenges. While several adapted commercial products exist, they lack any formal standardization of C3 functions, which creates a significant problem if the navy intends on operating a diverse range of USV classes simultaneously in a shared operating environment. Standardization of C3 would facilitate a common operating system and console. Thereby, reducing training and maintenance cost and equally reducing production cost across the greater fleet of USVs. For the CAF, becoming a key global developer of these technologies is in line with stated objectives in SSE to be a leading voice within the international community on development and employment of remotely piloted vehicles.

Increasing capacity and capability within the existing footprint of modularized payloads (i.e. a standardize sea containers) to carry increasingly more powerful sensors and heavier payloads is also an existing challenge. Solving this issue not only improves military capabilities but presents a potential commercial avenue for sales. For military applications, USVs need to address this area to facilitate interchangeable "mission modules" to conduct ISR, EW, MCM or ASW operations. From a maritime industry perspective, solutions to this problem space lend themselves to a number of commercial industries. Specifically, increased capacity and capabilities within modular payloads would be directly transferable to maritime industries such as oil and gas, mineral and resource extraction even commercial fishing industry creating economic opportunities for Canadian businesses. Expensive manned commercial assets used seasonally or infrequently could be rerolled to operate in other industries relatively quickly and cheaply by simply swapping out modular payloads, increasing profit margins for vessel owners.

Lastly, USV platform integration and increased capabilities of manned vessels to launch and recover USVs requires continued attention. There currently exists a limited number of commercial products to facilitate launch and recovery operations, particularly with Medium or Small USVs. From a military application, these technologies will be needed to facilitate development of "mothership" vessels, capable of employing unmanned vehicles either surface or subsurface in nature. Again, advances in these technologies would be immediately transferable to commercial and scientific communities.

Large and Medium USV – Capabilities & Operations

The US Navy's primary mission profile for the LUSVs is intended to be in support of combat operations in future air, surface, and subsurface engagements. Categorized as a vessel between 60 to 100 meters in length and displacing between 1,000 to 2,000 tones, initial cost estimates range between $50-100 million (US) per vessel. LUSVs will be equipped with standardized MK41 Vertical Launch System (VLS) enabling them to fire a host of weapons ranging from the Standard Missile 3 (SM3) anti ballistic defence missile, to a variety of anti-air defence and surface attack missile, including the ASROC lightweight rocket launched torpedo. Supported by its own Air-Surface radar, LUSV are in essence a *floating magazine*, to augment the limited number of missiles available to manned vessels. The LUSV's associated tactical communications and networking capabilities to share information between other USV in the battlespace, will allow operation either independently, in concert with other USV's ,or in support of a manned vessel(s). While any decision to release weapons still resides with a human operator, presently US Navy CONOPS is unclear if those operators will be embarked onboard a nearby vessel, or operating the LUSV from a centralized location ashore. LUSV secondary mission profiles are likely to include ISTAR and EW. LUSV's are expected to navigate to and from an area of operations autonomously, while obeying all established international collision avoidance regulations. Operating in up to sea state 5, independent of physical human interaction to conduct maintenance / repairs of machinery or equipment, for up to 90 days is the aspiration.[54] This operating profile ensures that LUSV are employable in comparable conditions, for which, manned vessels currently undertake.

Similarly, MUSVs are envisioned to support naval operations by conducting EW, ISTAR, ASW, and MCM roles. Characterized as vessels ranging between 12 to 50 meters in length and weighing up to 500 tones, initial cost estimates come in at $35 million (US) per vessel. MUSVs are equally intended to be employed independently, in an unmanned vessel task group, or working in concert with manned vessels. A critical function for the MUSVs will be to extend the fleet's coverage of passive sensor and detection systems as well as act as a communication node between USVs and warships. While not envisioned to carry weapons systems as a primary role, the ability to embark self contained modular

[54] David Larter, "A Classified Pentagon Maritime Drone Program is about to Get its Moment in the Sun," *Defense News* Online Article, no. Online Article (14 March, 2019). https://www.defensenews.com/naval/2019/03/14/a-classified-pentagon-maritime-drone-program-is-about-to-get-its-moment-in-the-sun/.

point defence systems on to MUSV, such as the UK's Common Anti-Air Modular Missile (CAMM) containerized defence system embarked on their replenishment ships, are potential mission modules the US Navy is considering. MUSV would equally be expected to operate in sea state 5, for a period of 90 days to facilitate coordinated deployments with USV or other manned warships.

LUSVs and MUSVs capabilities and operational performance will also reshape traditional understanding of what constitutes a task group. Conventionally manned vessels in a task group, such as CSC, provide offensive capabilities to achieve mission objectives and defensive abilities to protect supporting High Value Units (HVUs) such as supply ships or aircraft carriers. With introduction of USVs, a task group could be formed through a combination of HVUs, such as the RCNs future AOPS or JSS platforms, and a fleet of LUSVs and MUSVs to fill the traditional role of CSC. This provides the RCN with an incredible amount of flexibility when designing future mission and task group operations.

In addition to primary and secondary roles, USVs are equally force multipliers when dealing with humanitarian and disaster relief operations, or as a means of augment existing sea lift capabilities. Given their inherent capacity to swap out capabilities in containerized roles, employment as cargo carrying vessels to embark critical stores in support of military or humanitarian operations will in all likelihood become an increasingly important capability in the future. For the RCN, the ability to support humanitarian and disaster relief or provide general sea lift capability would significantly advantage whole of government response to demands for international aid.

LUSV and MUSV Next Steps

The US Navy announced in 2019 that its new proposed distributed fleet structure would consist of 20 SSC for every 10 LCS with an associated 30 LUSV and 40 MUSVs. Another way of looking at it would be that for every 100 surface ships the navy would have 30 manned ships and 70 USVs. This force structure is now being referred to by the US Navy as its "Future Surface Combatant Force".[55] This is a considerable investment in the future of the unmanned fleet and will fundamentally alter the way in which the US Navy operates, both as an independent naval force as well as in coalitions with allied nations. Extrapolating this force structure into an RCN context results in the development of 35 USVs to support the intended 15 CSCs. Broken down further into 15 LUSVs and 20 MUSVs, this would represent an initial investment of $ 1.5 to 2.0 billion dollars (CAD) and require approximately 150 RCN personnel to operate (accounting for contingencies, such as medical issues and training needs).

The US Navy is wasting no time in securing its Future Surface Combatant Force. As illustrated in Figure 4, the simplicity of USVs designs that leverage COTS equipment and make extensive use of interchangeable mission modules means they can be built far faster than a conventional warship. The initial delivery timelines for the first operational MUSV is expected as early as FY2023 with follow-on delivery of the first operational LUSV estimated to be FY2025. The latest US Navy budget submitted to Congress identified certain procurement activities pertaining to MUSV and LUSVs.

[55] Ronald O'Rourke, *Navy Large Unmanned Surface and Undersea Vehicles: Background and Issues for Congress. CRS Report* (Washington, D.C.: Congressional Research Services,[2020]), 5.

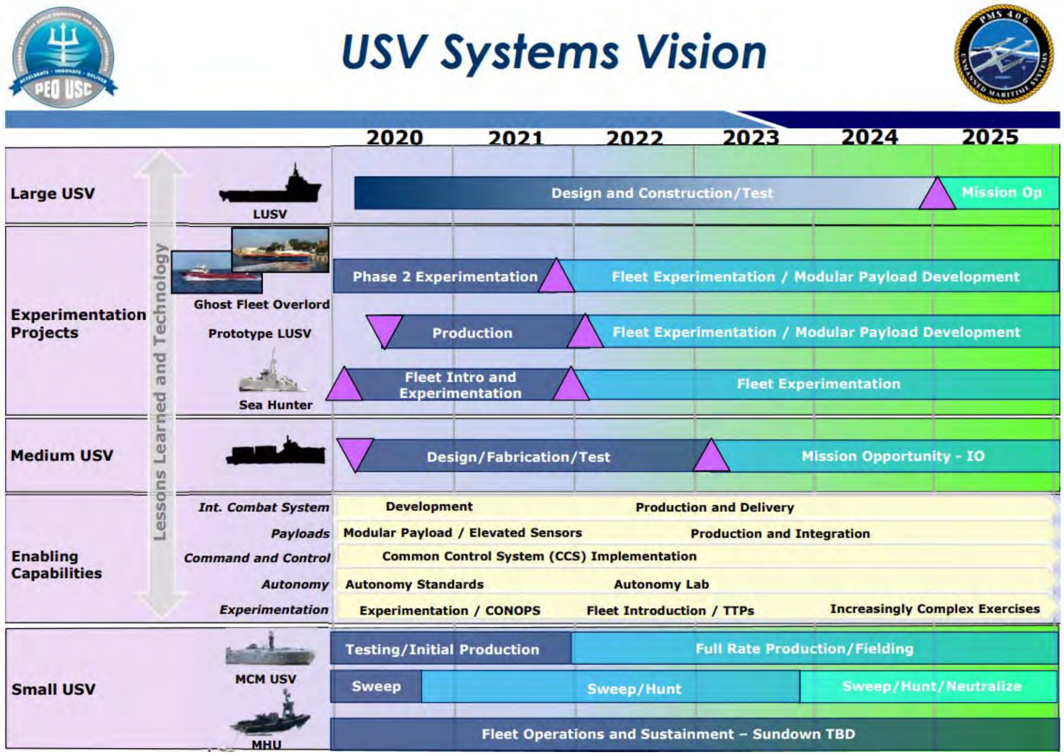

Figure 4: US Navy's LSUV and MUSV Program Timelines[56]

A $579 million investment in research and development of USVs and Underwater Unmanned Vehicles (UUV) is the signature feature.[57] In July 2020, the US Navy announced a $35 million US contract with L3 Harris, to develop the first MUSV operational vessel, anticipated to enter service in FY2023, with the option to buy up to 8 more.[58] Finally, in September 2020, the Navy announced a $60 million contract to 6 companies for LUSV studies, to help the navy refine requirements for future LUSV procurement to ensure that designs are affordable, reliable, and achievable before

[56] CAPT Pete Small, *Presentation -Unmanned Maritime Systems Update - 34th National Symposium of Surface Navy Association* (Online Publication: Program Executive Office - Unmanned and Small Combatants, 2020).
[57] Ronald O'Rourke, *Navy Large Unmanned Surface and Undersea Vehicles: Background and Issues for Congress. CRS Report* (Washington, D.C.: Congressional Research Services,[2020]).
[58] Press Release, *L3 Harris Technologies Awarded Medium Unmanned Surface Vessel Program from US Navy* (Lafayette, LA.: L3 Harris Technologies, 2020).

entering into design and build contracts.[59] The US Navy expects these initial procurement and investments in requirements analysis will facilitate rapid expansion in the US maritime industrial complex, to facilitate their overall objectives of restructuring their force towards a highly USV dependent fleet.

If the GoC wishes to leverage NSS as an investment tool to capitalise on this emerging market, then the US Navy's aggressive development timelines should as fair warning, indicate that the USV market is about to get very busy and lucrative very soon.

Allied and NATO USV Programs

While the US Navy is certainly leading the way with respect to development of LUSV and MUSV platforms, others are close behind. As USV technology is still relatively in the infancy phase of development, a substantial amount of technological cross-over continues to exist between commercial and military vehicle development. A 2013 survey of the global USV development and production market in Figure 5 demonstrates a robust and diverse global market for USV technologies, where rapid technological breakthroughs are being driven by dual military and expanding commercial desire to exploit unmanned capabilities. Prevalence of COTS equipment on USVs means a significant amount of research and development efforts by military designers can be commercialized quickly and cheaply for sale to industry or general public. This reality makes for a highly lucrative business model that could be easily exploited by the Canadian maritime industry.

[59] Mallory Shelbourne, *6 Companies Awarded Contracts to Start Work on Large Unmanned Surface Vehicle* (Annapolis, MD: US Naval Institute, 2020).

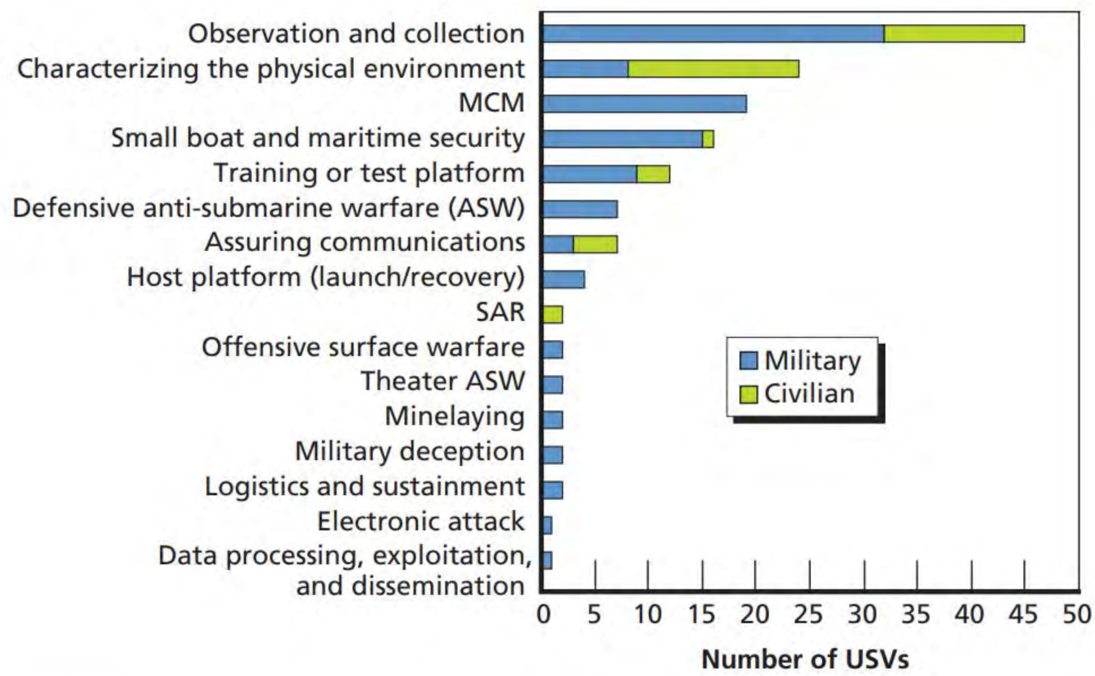

Figure 5: Distribution of USV platforms and mission profiles[60]

Presently, efforts in most western countries' are centered on development of MUSV and small USV platforms. The RN is procuring USV to support MCM, ISR and force protection functions, under a recently announced Maritime Autonomous Surface Testbed 13.[61] A 13 million GBP contract to Atlas Elektronik UK to procure the ARCIMS a versatile MUSV capable of executing MCM, ASW, ISR and diver support has also been recently announced.[62] Furthermore, the RN announced in November 2020 that the upcoming Type 32 Class frigate will be designated as a "Unmanned Mothership" to deploy all manner of vehicles, predominately USV, such as the ARCIMS (or its

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[60] Scott Savitz, Rand Corporation and National Defense Research Institute, (U. S.), *U.S. Navy Employment Options for Unmanned Surface Vehicles (USVs)* (Santa Monica, Calif: Rand Corporation,[2013]).

[61] Administrator, "Maritime Autonomy Surface Testbed (MAST) 13," https://militaryleak.com/2019/12/18/maritime-autonomy-surface-testbed-mast-13/ (accessed 7 January, 2021).

[62] Harry Lye, "Royal Navy to Begin Unmanned Mine Hunting Operations," *Naval Technology* Online Article, no. Online Article (14 January, 2020). https://www.naval-technology.com/news/royal-navy-to-begin-unmanned-minehunting-operations/.

successors).[63] Much like the US Navy, the RN has deduced the value of incorporating USVs into their fleet composition going so far as to dedicate an entire class of future surface combatants to launch and recover USV. This approach avoids the requirement to enhance USV machinery endurance to last 90 days, as well as avoids issues with the legal definition of the USV (to be discussed in the next section). In trade, the RN approach introduces limitations on number of USVs capable of being deployed and equally requires a fully manned vessel, with its associated operating, design and procurement costs to employ those USVs.

The RAN is investigating procurement of both MCM and MUSV capabilities as well as the Extra Large Unmanned Underwater Vehicle (EXUUV) project.[64] The future RAN fleet is equally split between a new surface fleet, including procurement of multiple classes of vessels most notably the new HUNTER class, the sister ship to CSC, and a fleet of 12 AIP submarines to provide enhanced offensive and ISR capabilities. The current RAN recapitalization plan is heavily dependent on its new submarine force of SHORTFIN BARRACUDA – large patrol boats to dominate the sea approaches to Australia and address the complications of future surface warfare.[65] To balance RAN needs for increased subsurface distribution of naval capabilities, they are pursuing an EXUUV fleet to support their future submarines. EXUUV design is a joint project between the US Navy and Boeing. While early small sized UUVs show considerable

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[63] Xavier Vavasseur, "Royal Navy's New Type 32 Frigate to Serve as Unmanned Systems Mothership," *Naval News* Online Article, no. Online Article (30 November, 2020). https://www.navalnews.com/naval-news/2020/11/royal-navys-new-type-32-frigate-to-serve-as-unmanned-systems-mothership/.
[64] Lee Dr. Willett, "Unmanned Transformation," *Asian Military Review*, no. No. 7 (2019). https://asianmilitaryreview.com/2020/04/unmanned-tranformation/.
[65] Australian Defence Force, *2020 Defence Strategic Update* (Sydney, Australia: Government of Australia, 2020).

promise, significant technological hurdles remain. In particular, the inability to communicate continuously underwater limits the EXUUVs usefulness as a real-time information gathering asset and equally calls into question their use in support of offensive actions. UUVs like the EXUUV that are designed to carry payloads and weapon systems will require considerably more autonomous operations testing and trials, beyond that already demonstrated by USVs, before they are ready to enter service.

The Turkish Navy is one of the first nations to develop an armed MUSV, the ULAQ class, fitted with long range optically controlled and laser guided anti tank missiles. The primary role of ULAQ will be in support of coastal defence operations, capable of employing a multitude of rapidly interchangeable mission modules, including ISR and EW capabilities.[66] Turkey's ULAQ is a clear indication that proliferation of weaponized USVs is no longer an abstract technology for debate but a functional reality.

In 2018, NATO stood up the annual Recognised Environmental Picture augmented by the Maritime Unmanned Systems (REPMUS) exercise. It is intended to pool and share the alliances' military and commercial resources, knowledge, and expertise to advance collective understanding and employment of unmanned systems.[67] In recent years, NATO has expanded this initiative to seek future USV interoperability between alliance members. Currently, NATO is focused on several key areas, such as information sharing; standardization; policy; doctrine development; R&D; logistics, support and training; acquisition and industry engagement, with the aim of establishing

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[66] Cem Devrim Yaylaii, "Turkish Armed USV Development Breaks Cover," https://www.janes.com/defence-news/news-detail/turkish-armed-usv-development-breaks-cover (accessed 7 January, 2021).
[67] North Atlantic Treaty Organization, *Thirteen Allies to Cooperate on the Introduction of Maritime Unmanned Systems*North Atlantic Treaty Organization (NATO), 2018).

common baseline agreements in these areas with all NATO members by 2021-2022.[68] For Canada, NATO is a key entry point into the USV field, yet the CAF is conspicuously absent in these discussions. If it truly intends to be a leading voice in how autonomous weapon systems are developed and employed in future conflicts, then it needs to get involved in ongoing USV discussion with its allies. Moreover, not having its own USVs diminishes influence in these discussions.

The evolving nature of future threats in the maritime domain has forced the US Navy, Canada's closest partner and ally, to revisit fleet composition in an effort to vastly increase distribution of its capabilities through the employment of USVs. For the RCN, employment of LUSVs and MUSVs provides tremendous advantages over manned surface combatants, primarily due to lack of human occupants. From LUSV supporting offensive operations across Air, Surface, and Underwater warfare to MUSV supporting ISR, MCM and EW operations, the RCN can operate a fleet of USVs and increase its overall size by 70% for the operating and maintenance cost of a single CSC. With anticipated austere spending practices post-COVID, recapitalization of the RCN will face significant challenges. If CSC becomes too costly to re-design mid production (i.e. new Flight), or simply too expensive to deliver the anticipated 15 ships than USVs provide a creditable, cost effective alternative. USV will ensure the RCN not only increases its distribution of capabilities, but can do so in a fiscally responsible manner.

USVs will alter the nature of how the RCN operates by radically increasing operational availability of its vessels to respond to ever increasing demands from the

[68] North Atlantic Treaty Organization, *Maritime Unmanned Systems (MUS) -Factsheet*North Atlantic Treaty Organization (NATO), 2020).

GoC. USVs are highly responsive and adaptable, ready to achieve all measure of domestic or international missions. The interoperable nature of USVs with traditional manned vessels, or their capacity to sail independently, would allow the RCN to project significantly more influence and presence globally. USVs redefine the very nature of what constitutes a naval task group and opens avenues for the RCN to generate far more than simply 2 task groups. These multitudes of task groups need not include CSC, centred instead on vessels such as AOPS or JSS which requiring far fewer crew to operate, would work to significantly reduced fleet operating cost compared to a task group laden with CSCs. Should future fiscal pressure demand a more cost effective solution than currently envisioned, USVs provide the RCN a much needed option.

Developing a built-in-Canada USV solution would provide extensive new opportunities for the maritime industry within Canada. Emerging sectors in machinery endurance, AI navigation and machine learning, C3 Systems; Modular payload designs as well as USV launch and recovery systems are clear areas which Canadian business could grow and develop. The ease with which USV military and commercial technologies can be re-marketed to each other presents immense opportunity for export sales, a major founding objective of NSS.

The US Navy is not alone in assessing the need to adopt USV technologies to dominate the Maritime Domain. The RN, RAN and NATO are all equally pushing forward with great speed towards a highly integrated and USV dominated future maritime battlespace. If Canada expects to maintain a high degree of interoperability with its allies, then the RCN needs to start investing significant interest and capital into acquiring and operating USVs. Specifically, the ability to operate not only its own fleet of USVs, but by extension those of its allies will become increasingly critical in preparation for future maritime engagements.

CHAPTER 3 – THE ISSUES WITH EMPLOYING USVs

For all their advantages, USVs are not the panacea of naval warfare. The technology is novel and with it comes a number of unique problems to be overcome by the RCN. Existing international legislation regarding the military designation of USV is the source of great debate. So too is the regulatory standards for their construction, design, and operation at sea. Ethically, the debate of fully autonomous weapon systems, which has raged for many years in the air and land domains, will need to be tackled in the context of USV employment, particularly in an A2/AD environment.

A myriad of force employment issues from recruiting to training and maintenance, as well as integration with allied nations demands the attention of RCN leadership. Additionally, a number of doctrinal issues pertaining to how and where USV shall be employed, including what policies the GoC should adopt if unmanned vessels are hijacked or destroyed by enemy action, require extensive consideration and development. Concurrently, procurement of any new military equipment will affect the political landscape in this country. Where and by whom these USVs are made will be as important a question to resolve as how many and how much they cost.

While these issues may seem extensive, USVs are a nascent technology. As such there are equally a number of plausible and highly agreeable solutions to overcome these challenges.

Legal Issues

Because existence of military USV is a relatively novel idea within the international community, several key legal issues surrounding general employment require immediate attention. Key among these is addressing regulations and laws pertaining to how a USV is defined under international law, what regulations govern their employment and safe operation, as well as, adaptations to existing collision avoidance regulations to accommodate a maritime environment populated with USVs.

The United Nation Convention on the Law of the Sea (UNCLOS) was drafted in 1982 and officially ratified by Canada on 7 November 2003.[69] UNCLOS defines the rights and obligations of states, with respect to the legal order and responsibilities of using the open oceans and high seas. It lays out rules applicable to a warship and other government ships operated for non-commercial purposes. In particular article No 29 lays out the following definition of what constitutes a warship:

> For the purposes of this Convention, 'warship' means a ship belonging to the armed forces of a State bearing the external marks distinguishing such ships of its nationality, under the command of an officer duly commissioned by the government of the State and whose name appears in the appropriate service list or its equivalent, and manned by a crew which is under regular armed forces discipline.[70]

Clearly being unmanned, USVs do not strictly meet the requirement to be "manned by a crew". While experts have called for this definition to be revisited, the current legal debate on how to account for USVs under international law is fundamentally split between if a USV is a warship, or, whether it constitutes a ship at all? The notion if a USV should be classified as a "ship" presents an interesting argument for future employment in a military context. As there exists no single legal definition of what constitutes a ship amongst various international treaties and conventions, the

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[69] Government of Canada, "Law of the Sea: United Nations Convention," https://www.canada.ca/en/environment-climate-change/corporate/international-affairs/partnerships-organizations/law-sea-united-nations-convention.html (accessed 12 February, 2021).
[70] *United Nations Convention on the Law of the Sea (UNCLOS),* General Assembly sess., (10 December, 1982): . Article No.29

defining determinate if a USV is to be classified as a ship (or something other than a ship) seems to rest with each individual nation under its own laws.[71] For RCN operation of USVs within Canadian territorial waters, this choice would be under the purview of Transport Canada to regulate. Moreover, how USVs are classified within foreign territorial waters would equally be subject to those host nations caveats. Having different definitions of what a USV comprises based on the territorial waters that the RCN is expecting to operate in becomes a highly complex planning issue.

In this context, many legal experts are advocating that USVs be classified as neither a warship nor as ships at all, but rather "warship attachments" which act as extensions of the warships' core sensors and weapon systems. As such, the USV "warship" status under UNCLOS is directly inherited by its connection (either physically or via telecommunications) to the manned mothership it serves.[72] For the US military, this point of law is fairly immaterial. Being one of only a few remaining countries in the world that does not recognize UNCLOS as binding international legislation, they have already classified USVs as warships. Yet, for other signatories of UNCLOS, such as the UK this legal argument has clearly driven the RN's choices on future fleet development. As previously mentioned, their declaration of the future Type 32 frigate as a "mothership" signals the RN's intention to classify USVs as warship attachments. This seemingly leaves the GoC in the position of declaring how they perceive their USVs, and given the context of the debate above, for the immediate future it would seem simplest to

[71] Yen-Chiang Chang, Chao Zhang and Nannan Wang, "The International Legal Status of the Unmanned Maritime Vehicles," *Marine Policy* 113 (2020), 103830.
[72] Robert Veal, Michael Tsimplis and Andrew Serdy, "The Legal Status and Operation of Unmanned Maritime Vehicles," *Ocean Development and International Law* 50, no. 1 (2019), 23-48.

declare any potential RCN USVs as extensions of their existing "mothership" warships, akin to the RN approach as a default position short of classification as outright warship.

While military employment of LUSV and MUSV may precede mass proliferation of unmanned commercial vessels, the rising business case for their use is driving international regulators to quickly standardized practices on collision avoidance and mandatory equipment for safe employment of USVs. In 2018, the International Maritime Organization (IMO) responsible for overseeing COLREGs, in anticipation of this emerging trend, instituted provisional guidance and classifications to shipbuilders and owners as to the degrees of autonomous operations and associated new requirements to ensure safe passage and collision avoidance between manned and unmanned vessels. The IMO's classifications range from simple automated systems designed to support human operators, all the way to fully autonomous unmanned vessels.[73] Equally, classification societies and insurance underwriters such as Lloyd's Register have taken to developing new regulations pertaining to construction and outfitting of unmanned vessels in an effort to standardize levels of redundancies in critical systems and minimum communication requirements for safe operations of USVs, based on level of autonomy and in line with the IMO provisional guidance.[74] The RCN and Transport Canada need to remain vigilant of these developments. In instances where RCN USVs are conducting peaceful transits or operating in non-military roles (such as humanitarian relief or in a sealift capacity), they will be expected to maneuver and be outfitted sufficiently to

[73] (IMO) International Maritime Organization, *Press Release - IMO Takes First Steps to Address Autonomous Ships* (London, United Kingdom: International Maritime Organization (IMO), 2018).
[74] *LR Code for Unmanned Marine System Code,* 1 - 9, ShipRight Design and Construction - Additional Design Procedures sess., (2017), 1-35.

coordinate with other vessels in accordance with international regulations. Both institutions would be best served to actively participate in ongoing discussion to ensure future RCN USV technologies are compliant to international regulations, as well as ensure regulations governing future foreign USVs intending to operate in Canadian waters will be sufficiently safe.

Ethical Issues

Existence of autonomous weapons systems in Canada are not new, particularly in the maritime environment where the Combat Management Systems (CMS) fitted to CPF's have historically had a *fully autonomous* defence mode of operation. This allows CMS (if permitted) to detect, classify, and engage threats to the ship. Despite the ability to operate in this capacity since the early 1990s, ethical and moral issues surrounding employment of CPFs in this fully autonomous fashion has been a significant detractor and continues to be with respect to future employment of fully autonomous USVs.

At the core of the ethical debate is the notion of *Just in Bello*. In particular the ramifications associated with the principals of discrimination, responsibility, necessity, and proportionality are significant.[75] Normative elements as they pertain to modern warfare raises some considerations pertaining to the ethical employment of autonomous weapons in a maritime domain.

The nature of *discrimination*, the act of deciphering if a target is exhibiting hostile intent or is a valid military objective vice an innocent bystander, is a complicated

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[75] Canadian Army LCol Makin, "Future Warfare Or Future Folly? Autonomous Weapon Systems on the Future Battlefield: An Assessment of Ethical and Legal Implications in their Potential Use" Royal Canadian Military College), 27-35.

problem to solve. In recent history, the nature of land campaigns and their propensity for asymmetric urban warfare, such as Iraq or Afghanistan, has elevated the public perception of the discrimination problem, as troops attempt to separate friend from foe in an environment where distinguishing marks are subtle or non-existent.

In the maritime environment, the problem of discrimination can be made substantially less complicated. For instance, the battlespace is often far less cluttered at sea than in a dense urban land environment.[76] The notion of Notice to Mariners and the establishment of traffic lanes provide effective means to distinguish between military targets and civilian or commercial vessels once hostilities are declared. Additionally, technology designed for collision avoidance at sea such as the Automatic Identification System (AIS) transponders, legally mandated to be employed by all vessels while at sea, would assist USVs in filtering out potential targets.

Despite all these potential advantages to reduce the discrimination problem, distinguishing between commercial vessels and valid military targets remains a difficult technical challenge to solve, particularly in high traffic areas (straights or littorals), or; during the opening moves of an operation when forces are attempting to shape the environment, and no previous notice of hostilities has been given. Equally challenging is the nature of post conflict stability / peacekeeping operations where forces are more likely to be threatened by asymmetric threats. Consequently, the US Navy intends on involving a human operator *in the loop* / *on the loop* to make the final determination as to the validity of a target. Equally, Congress has directed the US Navy to provide more

[76] Daniel-Cornel TANASESCU, "The Impact of the Development of Maritime Autonomous Systems on the Ethics of Naval Conflicts," *Annals – Series on Military Sciences* 10, no. 2 (2018), 118-132.

evidence and detailed operating procedures regarding how weapons will be employed on USV (particularly employment of VLS) before the systems will be sanctioned by the US government for full operations.[77] For the RCN, the GoC has already made clear that use of fully autonomous USVs capable of independent weapons release will not be sanctioned.[78] Given the RCN's history with employment of automated defensive systems, future employment of weaponized USVs will (at least in the near future) necessitate an element of human intervention in the targeting process.

Issues of *necessity* and *proportionality*, notions of limiting destruction of a target to only what is absolutely required, while simultaneously ensuring that any reciprocity, or overt offensive strike seeks to terminate a conflict rather than escalate the situation, are equally significant ethical concerns for employment of USVs. Potential solutions to these issues could range from removing weapons systems from the USV, to providing the USV with an assortment of weapon systems ranging from non-lethal to lethal. Ultimately, while Artificial Intelligence (AI) systems and machine learning software advances may allow for greater USV autonomy in maneuvering and weapons cueing to limit collateral damage, the ability to make an abstract determination on what is proportional or necessary will still continue to require human input. Whether or not adversaries will develop USVs in observance of these same limitations is doubtful. Therefore, the RCN must be vigilant and safeguard sensitive USV technologies and developments, lest it be used by adversaries unethically in future conflicts.

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[77] O'Rourke, *Navy Large Unmanned Surface and Undersea Vehicles: Background and Issues for Congress. CRS Report* (Washington, D.C.: Congressional Research Services,[2020]).
[78] Rt. Hon. Justin Trudeau, P.C., M.P, *Minister of Foreign Affairs Mandate Letter* (Ottawa, Canada: Office of the Prime Minister of Canada, 2019).

As a consequence, the issues of necessity and proportionality will continue to dissuade unrestricted use of autonomous USV weapons systems by some countries and actors. For instance, employment of USVs to conduct first strike actions on targets will be highly coordinated, with prior vetting by human beings using modern targeting practices. Moreover, while employment of USVs as point defensive measures for manned vessels could conceivably be automated (such as defeating massive missile salvos), the associated retaliatory actions are likely to continue to need human intervention, particularly if the target slated for retaliation falls outside per-established target lists or applicable ROE. For the RCN, while initial deployment of weaponized USVs may be possible, it is more likely that USVs are fitted with extensive passive / active sensors to detect threats early and subsequently deploy non-lethal effects to negate those threats. These sensor-based USVs employed in a detection or decoy function constitute the bulk of the RCN's early investments in a USV programme. In this instance, non-lethal effects could include a range of capabilities from sophisticated EW systems to jam and confuse incoming threats, or "soft-kill" options such as traditional chaff and flares to direct incoming threats away from their intended targets.

Fixing of *responsibility* should an autonomous systems' actions result in a failure of any of the above criteria is equally a perplexing issue. Does the responsibility of the autonomous systems actions reside with the designer; the tactical authority that enables and dispatches the system, or; the government that directs employment of those systems? Or all of them? For the RCN, where USVs are classified as extensions of a warship, the onus of responsibility would seem to reside with the commanding officer of that vessel. In cases where USVs are involved in collisions or accidents at sea, this attribution of responsibility to the commanding officer of a manned vessel seems warranted. In the instances where fully autonomous USVs incorrectly deploy weapon systems that cause undue harm and destruction the question becomes substantially more grey. As with all the previously mentioned ethical complexities, likelihood of the RCN employing fully autonomous USVs capable of independently deploying weapons is highly unlikely. Thus the notion of responsibility further reinforces need for a human operator, not only to observe a USVs' routine autonomous transit to and from a particular mission, but make final decisions and be held responsible for release of weapons.

Force Employment Issues

Introduction of new capabilities which USVs bring to the RCN equally raises a number of force generation and employment issues. For a modest size navy such as the RCN, incorporating USVs present issues regarding increasing force size and structure, as well as establishing new training and maintenance programs. Additionally, USVs bring increased levels of interoperability with allies, that may force leadership to tackle difficult questions surrounding how, or if, foreign navies working in consort with the RCN should be able to control their USVs.

The RCN is already struggling to meet its full manning levels. The most recent statistics for overall RCN manning would indicate only 90% of its total force strength is filled. That number drops to 60% for certain technical trades, taking into consideration needs for training and medical issues.[79] While the RCN is intending to grow its current force to fulfil the anticipated needs of CSC and other new platforms, significant pressures

[79] Lee Berthiaume, *Sailor Shortage Causing Headaches for Royal Canadian Navy* (Online Publication: The Canadian Press, 2019).

exist to achieve those goals. While operation of a single USV requires only a handful of personnel, additional demands of a fleet of USVs necessitate some novel approaches to generating personnel.

Potential solutions to address the issue include designing USV control interfaces such that the RCN can cross-train its weapons and sensor operators, to seamlessly transition between manned vessels and USV systems. The RCN could equally look to employ members of the reserves as future USV system operators. The reserves already play an active role in research, development, and full time employment of UAVs for naval operations.[80] Exposure to remotely piloted operations provides the RCN another avenue to re-role existing positions onboard the fleet of 12 KINGSTON class coastal defence vessels, as they are incrementally paid off and replaced in part by only 6 Arctic Offshore Patrol Ships (AOPS).

The inherent flexibility and modularity of USVs will permit the RCN to deploy increasingly more complex suites of sensors and weapons. However, along with this plethora of new capabilities comes a substantial need to train personnel on their operation and maintenance.

While highly likely that the majority of physical equipment used on USVs will be different than those fitted to CSC, from an operator's perspective the tactical information provided by USVs can be easily standardized. Incorporating USV control into a common operating console with common operating functions identical to those used by CSC's weapon and sensor operators shall drastically reduce training costs. The question of USV

[80] Lucas Cdr. Kenward, *Ready to Lead in the 21st Century: The RCN and Unmanned and Autonomous Innovation.* (Toronto, Canada: Canadian Defence Academy, 2019), 11-13.

training for tactics and day-to-day operations will be an iterative process, no different than building the RCN's understanding of how best to employ any new capability. With establishment of some additional coursing, the majority of those costs could be absorbed into existing training programs and budgets.

Equally, maintenance of USVs needs to be accounted for either within the RCN's current fleet maintenance capacity, or under the umbrella of in-service support contracts (ISSC). Currently, the RCN is in the process of divesting a large portion of maintenance routines historically done either by ship staff or fleet maintenance facilities out to industry partners.[81] Establishing in-service contracts for maintenance of USV would be another expense in the overall quittance and estimate of how many USVs the RCN could afford. Equally, it could serve as a potential new revenue stream under NSS for regional industries.

The RCN's intended interoperability with the US Navy and 5 Eyes partners, through addition of AGEIS and CEC will dramatically increase relative to current capabilities. The addition of USVs will further complicate the dynamics of that interoperability. The RCN will need to determine the extent to which it is willing to relinquish control of its USVs to allied naval authorities during joint operations and equally how much control the RCN expects to receive from US Navy or other allied USVs.

Perplexing in the context of future engagements, particularly with the advent of tactical networks such as CEC, is the notion of weapons release, the so-called "Shooters

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[81] Justine Degez, *Royal Canadian Navy Taps THALES for in-Service Support for Up to 35 Years. - PRESS RELEASE* (Online Publication: Thales Canada, 2018).

Network".[82] Any vessel, manned or unmanned, fully enabled on the CEC network will allow the release of its weapon based on a command to fire generated from any platform on the network. In essence, all weapons are shared amongst all participants on the network. This network is designed to optimize fleet defences and response times by allowing the weapon system with the highest probability of success to engage the threat. Therefore, the scenario exists that allied forces, operating in consort with the RCN, may release weapons from an RCN USV platform without consent.[83] How, or if, this capability is fully enabled is a question requiring considerable future debate not simply for USV but equally for CSC.

Doctrinal Issues

Currently, CONOPS and doctrinal understanding of how USV shall be employed do not exist. While use is likely to mirror current employment of warships fulfilling roles in the generalized functions of crisis management, constabulary and military, several critical considerations require particular attention.[84] Given USV operations in a denied space with limited or no communications, the potential for USV employment to escalate hostilities, and how to address the theft of USV by adversaries seeking to gain tactical or sensitive information are all perplexing issues facing the future employment of USVs.

Operations in an A2/AD environment represents the most likely employment for USV units. These environments are high risk, with increased threat of anti-ship

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[82] Lucian Valeriu Scipanov and Ion-Sorin Huruiala, "Considerations regarding the Opportunity of the Cooperative Engagement Navy Capability" "Carol I" National Defence University, 2020).
[83] APL Staff, "The Cooperative Engagement Capability," *John Hopkins APL Technical Digest* 16, no. No.4 (1995), 377-396. https://www.jhuapl.edu/Content/techdigest/pdf/V16-N04/16-04-APLteam.pdf.
[84] Geoffrey Till, *Seapower: A Guide for the Twenty-First Century*, 4th; 4 ed. (Abingdon, Oxon; New York, N.Y: Routledge, Taylor & Francis Group, 2018), 61-106.

weaponry and complicated by degraded sensors and communications capabilities. Current naval communications infrastructure and shared tactical networks systems intended to coordinate USV functions cannot be relied upon. To overcome these obstacles and effectively employ USVs in these environments requires injection of new methods of communicating. This can be achieved either through development of new technologies, such as laser line of sight communications that provide encrypted and high bandwidth connections between platforms.[85] Alternatively, uses of older technologies such as wideband High Frequency (HF) networks, leveraging existing HF technology resident on all vessels to allow for the processing of data between USVs and operators could be considered.[86] Canada's existing telecommunications industry could play a critical role in developing solutions for implementation on RCN and allied USVs. Research and Development into communication solutions in an A2/AD environment could translate into significant economic benefits from international investments into a RCN USV programme.

In spite of potential technical solutions, A2/AD environments will undoubtedly render communications impossible from time to time, requiring navies to contemplate the employment of USVs in fully autonomous operations. Determining how to most effectively and ethically employ USVs autonomously is a challenge. RCN operations in A2/AD environments will incur limitations on the roles USVs play such as EW, ISR, MCM functions only. The employment and types of weapons will be limited at first,

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[85] Albrecht Müller, *The Future of Naval Communications* (Online Publication: Naval Technology, 2010).
[86] James A. Stevens et al., "Wideband High Frequency (WBHF) for Anti-Access Area-Denial (A2AD) Environments" IEEE, 2014).

while continued studies and efforts to develop effective tactics and advances in AI and C3 technologies are undertaken.

Lack of humans onboard USV may lead to scenarios of un-intended escalation in future conflicts. Employment of USVs and lack of humans onboard are frequently viewed by military planners as a safer, less assertive means of conducting operations, particularly ISR, in contested waters. Paradoxically, adversaries may take the viewpoint that USVs are prime targets of opportunity to destroy, in an effort to make a political statement. This situation raises the question of un-intended escalation of hostilities and what constitutes a proportional and measured response to overt acts of aggression towards USVs, which are in effect simply a machine. Particularly, when adversaries do not employ unmanned technologies, the ethical question of proportionality and retaliatory attacks against manned targets becomes a complicating ethical factor to consider. While every situation will necessitate its own unique response, for an RCN that defines USVs as an extension of a manned warship the government might view these acts of aggression as an attack against its personnel. The RCN and the GoC needs to establish positions on this subject prior to employing USVs in hostile waters.

Equally perplexing is how to safeguard USVs against hijackings by adversaries, when operating independently from a manned force, or at distances that limit the ability of the manned vessel to respond in a timely fashion. In 2016, while operating 100 km off of the coast of the Philippines, a US Navy research USV conducting scientific analysis of the local water conditions was seized by a Chinese naval patrol ship. The seizure took place while the USV was operating within line of sight of its handlers.[87] The US responded with a strongly worded diplomatic demarche and the commercial grade USV was eventually returned. Probability that adversaries such as the Chinese or Russians will, in the future, return highly sensitive and classified military equipment they capture is somewhat unrealistic. Historical events such as the downing of spy planes by Russia, or cyber attacks by China to secure military research and technologies from western militaries are clear evidence that the RCN's adversaries appetite to gain access to weapons specifications is incessant.

Political and Economic Issues

Politically, likelihood that the RCN would procure future naval surface vessels, even USVs, outside the bounds of NSS seems highly unlikely. Irving Shipyards on the east coast are currently running at peak production with AOPS and intentions are to transition to production of CSC without any additional capacity to take on new builds. Seaspan's Vancouver Shipyards on the west coast are well behind schedule on the delivery of vessels for the Coast Guard, which in turn have delayed the start for the RCN's two Joint Support Ships (JSS). At present, NSS is limited in the number of shipyards under contract to facilitate the construction of USV, the program would need to be expanded to grow additional production capacity. Expansion is already underway with the inclusion of Chantlier David Shipyards, who have committed to building additional icebreakers for the Coast Guard and could potentially support early USV

[87] CAMILA DOMONOSKE, *China Seizes U.S. Underwater Drone from International Waters, Pentagon Says* (Online Publication: National Public Radio (NPR), 2016).

production.[88] For the RCN to bring this capability online in a reasonable timeframe, roughly 2035, would require selection of new yards. The existing potential yards include a handful of smaller shipyards in the Maritime Provinces, the St. Lawrence Seaway and Great Lakes regions in Quebec and Ontario. Early decision on which yards would receive these projects would be key in avoiding delays due to hiring process, yard modernization efforts, political considerations, and usual delays in the contract and procurement process.

Equally, the RCN needs to decide if it would be better to procure Intellectual Property (IP) rights to construct a pre-existing design, or develop an independent novel Canadian USV design. Challenges and costs exist with either option. Procurement of IP is an expensive proposition which equally may limit the government's ability to export USV designs for foreign sale. However, this approach does de-risk the program by selecting a proven design and eliminating cost associated with R&D and integration issues. Alternatively, the choice may be to develop a purely Canadian design. Issues are vastly increased design and development timelines as well as increased initial procurement cost. Given the proposed start timeline of 2035 to develop and build, it is unrealistic to conduct a fully independent Canadian design. Therefore, program objectives should center around securing IP rights and expanding on existing designs. Building up the maritime industry, via NSS early with several quick and easy builds, helps position Canadian business to advance research and development in other lucrative

[88] Government of Canada, "Canada Announces Next Step Toward Adding Third Strategic Partner Under National Shipbuilding Strategy," https://www.canada.ca/en/public-services-procurement/news/2019/12/canada-announces-next-step-toward-adding-third-strategic-partner-under-national-shipbuilding-strategy.html (accessed 7 January, 2021).

USV technologies previously mentioned, such as C3, AI and Machine Learning navigational software, or improving machinery endurance.

Finally, the overall scope and cost associated with the project would have to be carefully considered. Pending budgetary constraints that may be necessary to recover from the current COVID-19 pandemic, convincing the public to buy into another naval procurement agenda, when a major recapitalization is already underway, with anticipated competing priorities to recapitalize the ageing Victoria Class submarines will prove politically challenging to sell to the general population. Getting into this program ahead of these other major initiatives will be critical to overall success.

Overall, while a USV program greatly improves the RCN's capabilities, a number of challenges to general employment remain unresolved. The international debate on what (if any) sort of military designation USVs can be afforded would seem to lend itself to the notion of classifying USVs as an extension of RCN warships. To this end, the resident capability to operate USVs within CSC will need to be expanded and equally integrated into other platforms such as JSS and AOPS to afford the RCN sufficient flexibility in how and where USVs are employed. For a USV program to succeed in Canada, the ground work must begin soonest, so as to avoid conflicting with other government capital acquisition programs and ensure requisite numbers of trained personnel are made available.

Employment of USVs and the ethical challenges associated with the aspects of *Just in Bello* mean that fully autonomous USVs capable of independent weapons release is not a reality for the RCN. There is no doubt that human USV operators will have a role within the RCN and that deployment of lethal effects is likely to be limited in scope.

Understanding this reality affords the RCN the ability to focus its initial efforts on development of MUSVs and employment of non-lethal effects to negate hostile actions against manned vessels, to act as a decoys, or as force enablers conducting ISR, ASW, EW and MCM operations. Employing these capabilities with the aim of becoming a leader amongst allies in EMW, akin to the role it currently plays in the field of ASW would only serve to strengthen the CAFs influence in future maritime domain. While weapon systems will likely be necessary in future iterations of USVs, leveraging experience gained from early procurement of MUSVs affords politicians and military leaders the latitude to fulsomely deliberate and resolve issues surrounding responsibility and interoperability, prior to introduction of lethal effects to the fleet.

CONCLUSION

The RCN is recapitalizing its entire fleet to generate necessary capabilities to meet the challenges of tomorrow's maritime environment. Future maritime warfare demands operating in a persistent state of detection, where destruction or significant loss of capabilities through a myriad of cheap and advanced anti-ship weapon systems is a virtual certainty. Western navies have deduced that distribution of capabilities is the best approach to surviving future maritime conflicts. However, the exorbitant cost of the RCN's highly sophisticated and versatile CSC precludes distribution of capabilities through simple acquisition of more vessels. CSCs protracted design and build program necessitates a mid-production redesign to introduce a flight, sometime around 2035, with upgraded new technology. This as yet unaccounted for and unknown cost will be significant and will do nothing to address the issue of capability distribution. Rather, it will only further concentrate more capability into a relatively small fleet of ships, and increase overall risk to the RCN's operational availability should a single ship be lost or damaged. Taking these resources and re-directing them into a built-in-Canada USV program would be a better use of those funds.

This USV program could draw parallels to the US Navy's current vision for its Future Surface Combatant Force, with 70% of the naval force structure intended to be filled by USVs. For the RCN, that would mean procuring a fleet of 15 LUSV and 20 MUSVs with an associated 150 personnel to operate them, costing between $1.5 – 2.0 billion (CAD), a comparable cost to any redesign effort for CSC.

Operated from any of the RCNs currently planned vessels, LUSV and MUSVs would radically improve distribution of capabilities intended for the RCN. In a traditional military role, they would radically increase the survivability and freedom of movement for CSC as well as those allied ships sailing in consort with the RCN. Due to ethical and legal complications with autonomous weapon systems, use of USVs within the RCN context would likely be limited in offensive capabilities. More probable is their employment as a means to conduct EMW, flooding the battlespace with a mixture of non-lethal effects, passive, and active sensors. Fulfilling roles such as ISTAR, EW, ASW, and MCM would be primary missions at first, and as experience, proficiency, and technologies advance, the RCN would look to increasingly include offensive capabilities into this mix.

USVs are inherently better options to employ into high risk environments than manned vessels, where loss of life is probable. By design, the characteristic modularity and flexibility of USVs mean they can swiftly re-role between combat and non-combat mission objectives. They represent the most cost effective means to address whole of government demands on the RCN, providing increased capacity to support humanitarian and disaster relief efforts, law enforcement activities, and sovereignty patrols to protect Canada's territorial waters and airspace in addition to underwater natural resources and economic interests. USVs are considerably cheaper to operate and maintain than current manned warships. Employing USVs to undertake a greater share of constabulary and crisis management functions traditionally fulfilled by frigates and destroyers, lowers overall RCN fleet operational and maintenance costs and reduces future wear and tear on CSC. In turn, CSC operational availability is considerably improved.

Lastly, USV technology provides a direct means of meeting the CAF's stated objectives of investing in industry to develop innovative solutions to future threats, as well as the GoC aim of building a self-sustaining maritime industry through NSS. USVs hold vast economic potential in both the commercial and military markets, estimated to generate $65 billion / year in revenue by 2040. The ability to extensively employ COTS equipment means that industry can leverage development cost and subsequently produce products that are marketable to both military and commercial USV applications. Implemented properly and swiftly, a USV program under NSS could radically increase the number of shipyards and spin-off business opportunities for Canada's economy.

The RCN is at a cross roads. In the midst of the single most expensive recapitalization in Canadian history, the government and the navy are pouring significant resources into too few ships to be truly effective in the future maritime domain. The RCN is effectively building a peacetime navy, for patrol and prestige purposes, rather than one that can reasonably fight and survive in the future maritime combat environment. The RCN needs to diversify its capabilities, and USVs serve that goal, at a far more reasonable cost. Is the RCN ready to be bold in application of innovative technology, or happy to simply sail into obscurity?

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