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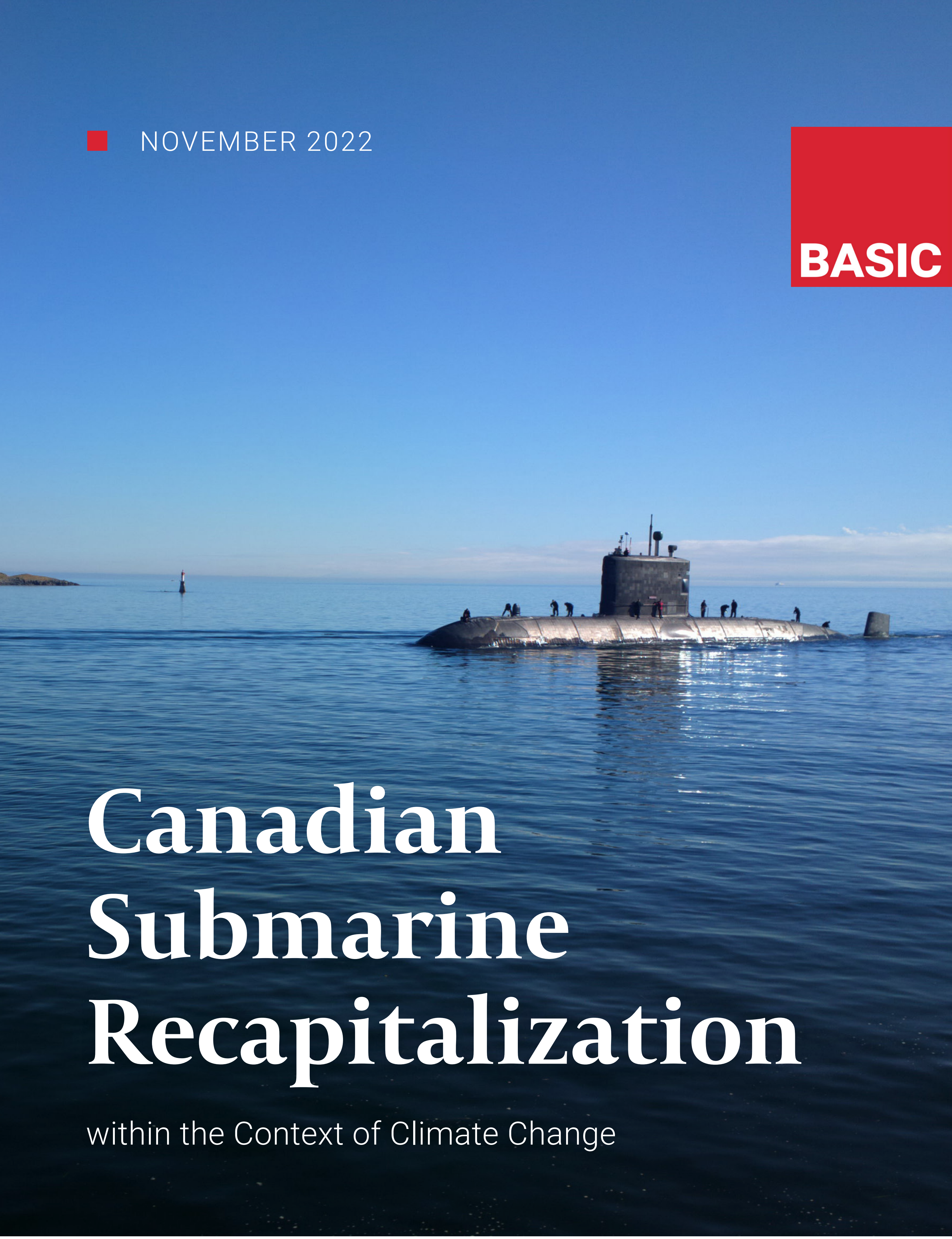

Canadian Submarine Recapitalization

within the Context of Climate Change

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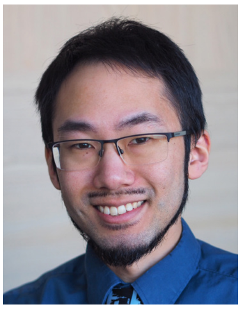
Défense nationale National Defence



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PART I

Introduction

> As Canada goes through the recapitalization of the four-ship Victoria class diesel-electric submarine fleet, the Royal Canadian Navy (RCN) once again faces the opportunity to reconsider the importance and feasibility of acquiring an Arctic under-ice capability.

This is especially poignant in the face of climate change's rapid reduction of the region's sea ice, which is happening most severely on the Russia side of the Arctic Ocean. With Russia's dependence on the Arctic sea ice as cover for their underwater nuclear deterrent, it is reasonable to expect Russian underwater activity to thus move closer to the North American side of the Arctic as they pursue the retreating ice cover. This poses a new concern for Canada's future role in the Arctic. While the current Victoria Class Modernization (VCM) program endeavours to improve many of the existing capabilities of the subs' late Cold War design, they will not suffice to significantly enhance their ability to operate in the Arctic. Although the VCM aims to ensure the Victorias' operability out to their 2030s retirement date, analysis of other new-build options must be considered as soon as possible due to the long procurement and build times of submarines. While such analysis is currently ongoing in the Department of National Defence under the Canadian Patrol Submarine Project[1], this report contributes both a parallel "outsider" perspective of options while proposing greater attention to operations under the central Arctic sea ice given climate change impacts.

Historically, the Arctic ice-cap has provided a reliable physical barrier to substantive military activity, even during summer months. But as the sea ice retreats, this barrier gets smaller and with the first total Arctic sea ice melt possible by the summer of 2035, a new transient but strategically critical ocean may be navigable that leaves nothing but open water between North America and Russia, however briefly.[2] This presents Arctic states with a new problem of and requirement for patrolling their northern aspects with more ships and with greater frequency. This change in maritime activity may require additional assets or a seasonal reshuffling of naval power: something that may not be possible for navies with traditional Arctic presence given potentially more pressing concerns elsewhere in the world such as China's rapid naval growth.

While the Royal Canadian Navy has recognized the need to improve its underwater domain awareness within its Arctic archipelago as demonstrated in Operation Nanook 2022, there is a tendency to minimize discussions on the potential need to extend this awareness north of Ellesmere Island and into the central Arctic Ocean. To some extent, this is justified by the presence of allied American and British nuclear-powered attack submarines (SSNs), which can help monitor the region under the sea ice for Russian submarines.

1 Lee Berthiaume, "Navy kicks off long-anticipated push to replace Canada's beleaguered submarine fleet," CBC News, July 14, 2021, https://www.cbc.ca/news/canada/nova-scotia/navy-submarine-new-fleet-1.6102598.

2 Alejandro Borunda, "Arctic summer sea ice could be gone as early as 2035", National Geographic, August 13, 2020

However, with China overtaking the United States as the world's largest navy and exhibiting no signs of slowing down, the American navy may not be in a position to perform that traditional role towards the future. With the need to deploy more SSNs in the Western Pacific, the United States may not have SSNs to spare for Arctic surveillance and tracking. Thus, consideration must be given to Canada developing its own Arctic under-ice capability, whether that is restricted to merely tracking other countries' submarines or including the more ambitious goal of interception and neutralization.

This report thus analyzes options for replacing the Victoria class submarine with a focus on Arctic under-ice capabilities. Recognizing the shipbuilding challenges faced by Canada's traditional Arctic underwater allies (i.e. the United States and United Kingdom) as they struggle to keep pace with China's growing fleet, this report highlights the potential need for Canada to take up that traditional task of tracking Russian submarine activity under the Arctic ice. The report begins by discussing the extent to which Russia historically and currently employs Arctic sea ice for their SSBNs. It then explores the likely trends in Arctic Sea Ice Extent over the coming decades to help determine where the sea ice will most likely retreat and remain. The past and present tasks of the Canadian submarine fleet is then outlined to examine how future Canadian submarine tasks may evolve or echo past experience. Finally, an analysis of the technological challenges of Arctic submarines will be used to help inform three main options for the Victoria class replacement.

This report analyzes options for replacing the Victoria class submarine with a focus on Arctic under-ice capabilities.

PART II

Russian SSBNs and the Bastion Strategy: Past and Current Practices

> Since approximately 1973, Russian nuclear-powered ballistic missile submarines (SSBNs) have been deployed in "bastions" close to their home bases, though Western navies did not recognize this until nearly a decade later.[3]

For the Northern Fleet in Murmansk, this has meant SSBNs operating in the Barents Sea and under the Arctic sea ice. The bastion strategy forces enemy anti-submarine warfare (ASW) forces to operate closer to the Russian mainland, where sea, air, and land forces can help protect the SSBNs more easily than if the latter were deployed farther overseas. The relative benefits of the bastion approach is made more evident by the maritime chokepoints that Russian SSBNs would otherwise have to go through to reach the "World Ocean". For Northern Fleet submarines seeking the relative safety of the Atlantic, they have to run the gauntlet of NATO ASW forces along the Greenland-Iceland-Norway (GIN) and Greenland-Iceland-United Kingdom (GIUK) gaps. This drastically reduced the survivability of those submarines, rendering them an unreliable arm of Russia/the Soviet Union's nuclear triad. Another benefit of the bastion strategy is the reduced transit times to patrol areas, effectively increasing Russia's ability to have deployed ships at sea without actually increasing the number of hulls and crews.[4]

Competing explanations have been offered for why the Soviets adopted the bastion strategy. Some scholars have suggested it was the result of the Soviet Navy wishing to remain relevant in the face of their inability to prosecute American and allied SSBNs, and thus resorted to selling their purpose as defenders of Soviet SSBNs – a mission only the Soviet conventional navy could perform.[5] US officials have speculated that the Soviet navy was unable to maintain the reliability, maintenance scheduling, and training levels required for constant overseas patrols.[6] Meanwhile, the Soviets never explicitly admitted to a bastion strategy or offered their own rationale, though Western analysts have recently interpreted a series of public articles by Admiral Gorshkov, commander of the Soviet Navy in the 1970s, as being essentially such an admission while

3 Dismukes, "The Return of Great-Power Competition: Cold War Lessons about Strategic Antisubmarine Warfare and Defense of Sea Lines of Communication," *Naval War College Review* 73, no. 3 (2020): 37.

4 Jan Breemer, "The Soviet Navy's SSBN Bastions: Why Explanations Matter," *The RUSI Journal* (Winter 1989), 34-35.

5 Breemer, "The Soviet Navy's SSBN Bastions," 36-37; Dismukes, "The Return of Great-Power Competition," 38.

6 Breemer, "The Soviet Navy's Bastions," 34.

contemporary civilian analysts also argued for the Bastion Strategy's existence by taking such statements at face value.[7] Regardless of why, the turn towards a bastion strategy was enabled by the introduction of the SS-N-8/R29 *Sawfly* family of submarine-launched ballistic missiles (SLBMs), which provided the necessary range to attack the continental United States from the Barents Sea and North Pacific. To carry these new larger missiles, new submarines had to be designed for them, namely the *Delta* class SSBNs.[8] These were supplemented by the infamous *Typhoon* class towards the end of the 1980s designed specifically to maximize their ability to surface through ice, while a decreasing number of the old *Yankee* class with their much shorter ranged missiles continued to occupy American and Canadian ASW forces in the western side of the North Atlantic.

In response to the bastion strategy, the United States adopted the "Maritime Strategy" of the early 1980s. This was promulgated in NATO as well, resulting in a new NATO naval strategy that aimed to attack Soviet SSBNs in their bastions at the outset of war. This meant deploying NATO naval forces close to and within Norwegian waters, from where American aircraft carriers could strike Soviet submarines on the Murmansk peninsula. For Canada, this meant sending its ASW frigates and destroyers as escorts to protect the carriers from Soviet "tactical" submarines. However, Canada's surface fleet was not designed to operate within range of Soviet air forces and lacked the air defense capabilities to reliably operate in Norwegian coastal waters. Their replacements, the *Halifax* class, was designed to help fill vital gaps in this combat capability and entered service after the Cold War, and they continue to serve today.

With the collapse of the Soviet Union, much of the USSR's military fell into disarray and disrepair. The navy and its dozens of submarines were no exception. Of the sixty-two SSBNs that were in service at the end of the Cold War, only twenty-three remained by 2001, and this fell further to a mere five in 2011 due to a lack of regular maintenance or mid-life refits.[9] Nonetheless, Russia has been able to bring its submarine construction programs back on track in the last decade. The new generation of SSBNs, the *Borei* class, now number five completed with another five scheduled for the next several years as of December 2021. This brings the combined SSBN fleet to ten boats as of 2022, comprised equally of five previous generation SSBNs and five *Borei* class.[10] The Borei class submarines are comprised of two different "flights". They are easily distinguished by the shapes of their sails, where the first two boats have an unusual forward-angled leading edge as one proceeds from the hull to the top of the sail, while the newer "Borei-A" boats take on a more conventional shape with a slight curve where the hull and leading edge meet, similar to the American Virginia class attack submarines. After much growing pains, these new Borei class subs carry the latest SLBMs of the Bulava series, while the remaining Delta IV class SSBNs carry the Sineva SLBMs.

But aside from the technical development and modernization of its SSBN force structure in the post-Cold War period, has Russian maintained its late-Cold War bastion strategy? The secret nature of submarine deployments, and especially SSBN deployments, make this difficult to ascertain for the entire period. Still, after a nearly decade-long pause, Russia began regular test-launches of SLBMs from ice-covered waters in September 2006, albeit only while surfaced.[11] More recently, Russia has publicized its ability to not only

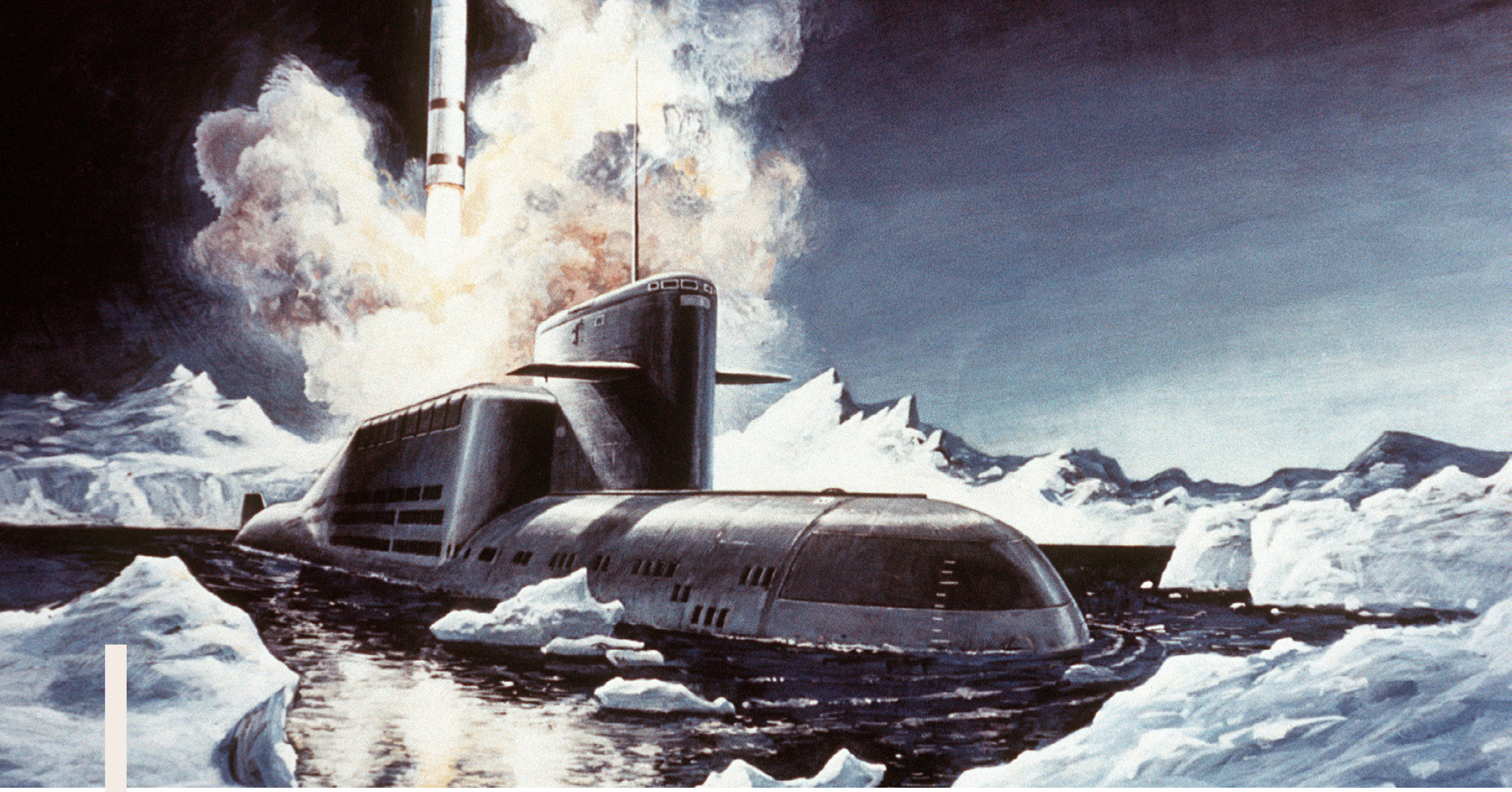
7 Dismukes, "The Return of Great-Power Competition," 37, 39.

8 Dismukes, "The Return of Great-Power Competition," 37.

9 Ina Holst-Pedersen Kvam, "'Strategic Deterrence' in the North: Implications of Russian Maritime Defence Planning and Seapower to Norwegian Maritime Strategy," (Master's thesis, University of Bergen, 2018), 71; Victor Mizin and Michael Jasinski, "The future of the Russian sea-based deterrent," *The Journal of Slavic Military Studies* 16, no. 1 (2003): 75-76.

10 Thomas Nilsen, "Sevmash hands over two nuclear subs to the navy," *The Barents Observer*, December 21, 2021; Thomas Nilsen, "Russia launches new Borei-A class ballistic missile sub," *The Barents Observer*, December 25, 2021.

11 James Martin Center for Nonproliferation Studies, *Russia Nuclear Chronology* (Monterey: Nuclear Threat Initiative, 2011), available at https://www.nti.org/wp-content/uploads/2021/09/russia_nuclear.pdf; Pavel Podvig, "Arctic launch of a R-29RM Sineva missile," *Russian strategic nuclear forces*, October 28, 2006, https://russianforces.org/blog/2006/09/arctic_launch_of_a_r29rm_sinev.shtml; response from Norwegian academic survey participant.



The turn towards a bastion strategy was enabled by the introduction of the SS-N-8/R29 Sawfly family of submarine-launched ballistic missiles (SLBMs), which provided the necessary range to attack the continental United States from the Barents Sea and North Pacific. To carry these new larger missiles, new submarines had to be designed for them, namely the Delta class SSBNs.

deploy SSBNs under and in the Arctic ice, but to do so with multiple ships simultaneously. Between March 20 and 27, 2021, the Russian Navy carried out the "Umka-21" Arctic military exercise. As part of this, three SSBNs simultaneously surfaced next to each other within a 300-meter radius through approximately 1-1.5m-thick sea ice south of Alexandra Island of the Franz Joseph archipelago.[12] The submarines involved have been identified as the Knyaz Vladimir (Borei-A class), a Delta IV, and the Podmoskovye, a Delta-IV that has had its missile tubes removed for "special mission" clandestine equipment. This simultaneous surfacing was apparently unprecedented, and demonstrates Russia's ability to get multiple SSBNs underway as well as coordinate their underwater activities with precision and skillful shiphandling.[13] A satellite image taken by the company Maxar on March 27 further showed a large hole in the sea ice with one of the Delta IVs surfaced adjacent to it. While the Russian Ministry of Defence did note efforts to create an opening in the ice, it did not specify the method nor intent. Other exercises before and since provide some hints as to the relationship between Russian SSBNs and surfacing through the ice. A January 2020 article by the Russian newspaper Izvestia discussed recent developments in the Russian navy to develop unguided high-explosive "icebreaker

12 Ministry of Defense of Russia, "Комплексная арктическая экспедиция ВМФ России и РГО «Умка-21»," *YouTube*, March 26, 2021; H I Sutton, "Russian-Navy-Submarines-Surface-In-Artic [sic]," *Covert Shores,* March 27, 2021; TASS News Agency, "Arctic Exercise Umka-2021 Shows Russian SSBN Can Deliver Massive Strike," *Naval News*, April 10, 2021; Thomas Nilsen, "Three nuclear ballistic missile subs surfaced simultaneously through the ice in complex Russian Arctic exercise," *The Barents Observer*, March 26, 2021; Maxar Technologies, "#Satellite imagery from March 27, 2021, reveals a Russian #naval exercise, known as Umka-2021, in progress," *Twitter*, March 29, 2021.

13 Sutton, "Russian-Navy-Submarines-Surface-In-Artic [sic]."

rockets" designed specifically to create openings in thick Arctic sea ice.[14] The intention of these is to allow the Borei class SSBNs and the Yasen class SSGNs to fire their missiles or release emergency escape capsules without having to find thin ice or leave the ice cover entirely. Previously, the Russian navy had employed torpedoes for the role of making holes in the ice, but they were apparently not as effective as hoped. That being said, it appears the torpedo method remains an option that is practiced, most recently in December 2021 according to a Northern Fleet press release.[15] The same press release emphasized that 2022 would see even greater attention to under-ice operations by Russia's SSBNs, building on the previous year's exercises in that regard.

Clearly, Russia is making it known that not only does it employ the Arctic sea ice as protective cover for its SSBNs, it is also developing new technologies to help increase its ability to exploit that cover, namely aerial access for its missiles. After a long period of hiatus, it is resuming a practice that had begun during the Cold War. The only missing element to truly consolidate Russia's intent and capability to launch SLBMs from under the Arctic sea ice would be an actual test launch of a missile from a hole blasted through it. Recent tests have not provided much proof of such an end-to-end capability: an exercise in August 2019 was perhaps the closest thing, when two separate test firings were carried out in "the polar region of the Arctic Ocean" in addition to one from the Barents Sea.[16] Video footage attached to the announcement did not indicate the presence of any sea ice, however, which suggests the tests took place in open waters closer to the Russian coast.[17] Still, the traditional method of firing while surfaced in ice should be considered a remaining option. Regardless, it may well be prudent to take one's adversary at their word. As Dismukes noted, believing opponents' public statements on their military capabilities and intent may well be more accurate than trying to impose alternative explanations and interpretations by an outsider.[18] This was the case with previous debates on whether the "bastion" strategy was indeed a real practice, which saw some Western scholars, like Jan Breemer, expressing their doubts during the 1980s, unconvinced by the contemporary circumstantial evidence. Post-Cold War, the presence of the "bastion" strategy was not only confirmed, but confirmed to have been implemented much earlier than Western navies had thought. Dismukes noted that the commander of the Soviet Navy in the 1970s, Admiral Sergei Gorschkov, essentially indicated as much in his public writings during the early 1970s.

How climate change's effects on the Arctic sea ice may affect such bastion operations will depend on the extent of those effects. However, it is likely that so long as some degree of ice cover remains, Russian SSBNs will continue to exploit its cover even if it means having to travel through a greater amount of "ice free" waters to get there. As one Norwegian defence researcher noted in the course of this report, even loose ice provides sufficient "pollution" to make ASW efforts difficult, and Russia will likely be willing to expend the necessary efforts to protect their SSBNs during their more vulnerable voyage stages. This greater expenditure on protecting nuclear assets will be even more likely in the aftermath of Russia's conventional military failures in Ukraine, pending the overall state of the economy given sanctions.

14 Алексей Рамм and Богдан Степовой, "В потолок ледяной: подлодки пробьют полынью для всплытия ракетой," *Izvestia,* January 24, 2020; an English article discussing this piece can be found here: Michael Peck, "Russia's Icebreaker Rocket Can Punch a Hole Through the North Pole," *Forbes,* August 16, 2021.

15 Press Service of the Northern Fleet, "Submariners of the Northern Fleet will improve the practice of ice navigation in the Arctic," *Ministry of Defence of the Russian Federation*, January 8, 2022.

16 Polina Devitt, "Russia test fires missiles from submarines in the Barents Sea," *Reuters*, August 24, 2019.

17 Reuters, "Russia Test-Fires Ballistic Missiles from Submarines," *RadioFreeEurope/RadioLiberty*, August 24, 2019.

18 Dismukes, "The Return of Great Power Competition," 48.

This graphic shows the external differences between the original Borei class design (top) and the current Borei-A design (bottom). Note the different sail shapes, with the Borei-A's likely to be more efficient for ice operations.

Credit: Mike1979 Russia, Wikimedia Commons, CC BY-SA 3.0"]

Finally, the design characteristics of the new Borei class also support the notion that they are meant for operations under the ice. Unlike their Delta class predecessors but similar to the larger Typhoon class and American ice-capable attack submarines, the Borei class have no diving planes on their sails. Instead, they are located on the forward hull where they can be retracted. This helps protect them when surfacing through thick ice, whereas the Deltas have to turn their sail-mounted planes to the vertical, which limits the thickness of ice they can surface through and may reduce the time they can remain on the surface before the ice reforms under the planes, trapping the submarine on the surface.[19] By the same logic, the Borei-A variant with its more conventional sail likely makes it more suitable for ice operations than the original variant where the forward-angling of the sail's leading edge may complicate diving through ice. Indeed, it is worth noting that it was a newly-commissioned Borei-A that broke through the ice during the aforementioned Umka-21 exercise, rather than an original Borei variant with a more experienced crew.

19 Adam Lajeunesse and Timothy Choi, "Here there be dragons? Chinese submarine options in the Arctic," *Journal of Strategic Studies*, DOI: 10.1080/01402390.2021.1940147.

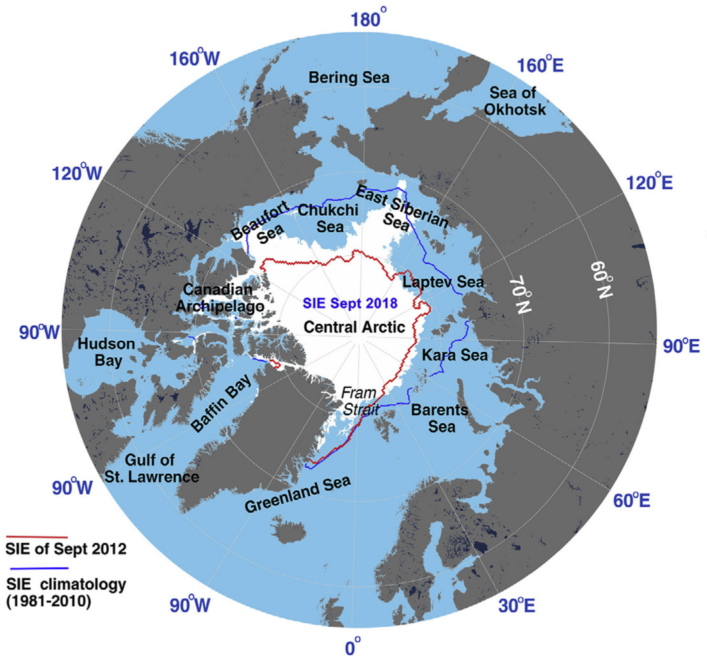
PART III

Climate Change and Arctic Sea Ice Coverage

The role of submarines in the Arctic will be directly influenced by the thickness and extent of the Arctic Sea Ice (referred to henceforth as Sea Ice Extent, or SIE). Reduced SIE will not only limit cover for nuclear-powered submarines employing the Arctic Ocean as a bastion, it will also provide greater northward operational range for diesel-powered variants. Therefore, as SIE is likely a decision making variable for submarine commanders across all Arctic and NATO states that use them, the level of sea ice reduction in the 2030s and beyond will impose certain design requirements on naval architects today.

SIE, thickness, volume and multi-year ice coverage in the Arctic ocean have declined rapidly in the past four decades. As the Arctic Ocean absorbs more solar energy when it is no longer shielded by the ice cap itself, there is a positive feedback loop forcing a much more rapid change in land-ocean temperatures. Whereas global land-ocean temperatures have risen approximately 0.78C in the past 40 years, the Arctic land-ocean temperature has increased by 3.1C in that same period - four times the global temperature rise. There are additional mechanisms by which the Arctic ocean environment is changing that compounds this issue: strong southerly winds are drawing warmer air up from temperate regions to the Arctic cells, and sea ice is being transported out of the Arctic by strong winds.

Figure 1a: Sea Ice Extent in 2012, and the average for the period 1979–2010



From the paper *Global warming leading to alarming recession of the Arctic sea-ice cover: Insights from remote sensing observations and model reanalysis* by Kumal et al, 2020.

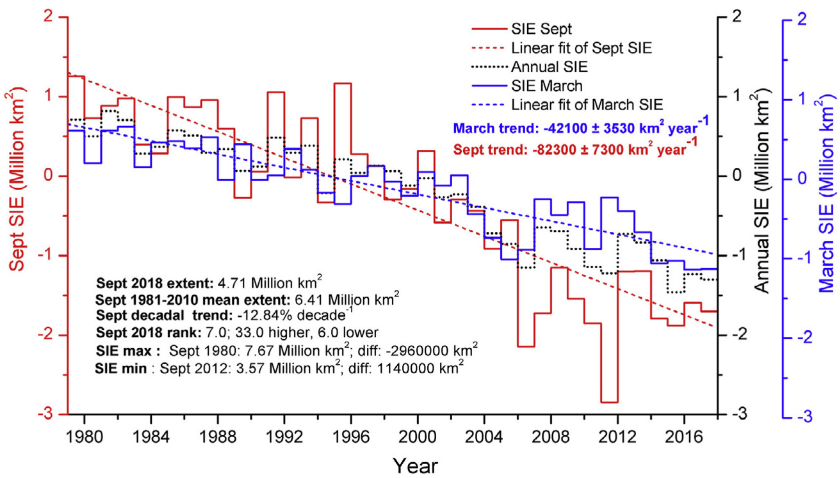
The data in Figure 1b below shows this rapid decline of summer Sea Ice Extent (red trace) compared to the sea-ice extent maxima in March - which is still showing a rapid decline. Whilst this trend is averaged across the entire Arctic Ocean, there are some regions seeing greater decline than others. The northern Laptev, East Siberian, Chukchi, and Beaufort Seas have seen the bulk of the reduction. While this will have enormous global impacts, Figure 1a shows that this is of particular and direct significance for Russian, Alaskan, and Canadian waters, their governance and the behavior and activities of actors in those waters. One of the most worrying trends is the decline in sea ice that persists over multiple years - this ice acts as a buffer against total Arctic Sea melt, and could herald the imminence of the first recorded Blue Ocean Event (BOE).[20] Every aspect of this research must be contextualized in sea-ice coverage - where, when, and how much. The extent of summer sea-ice is not uniform, as shown in Figure 1a, and therefore the impacts will also be distributed.

Two Arctic Ocean currents, the Beaufort Gyre, and the Transpolar Drift, work in tandem to push loosened chunks of ice into Canada's archipelago, which in turn make transit through it one of the last Arctic Ocean regions to be easily accessible. This has strategic and commercial implications, not least, given that the sea ice chunks that survive the longest to interfere with transiting ships are the harder, tougher, multi-year ice - as opposed to first year ice, which is easier to break through.

Historical sea-ice extent can be seen in Figure 2, which clearly shows both the accelerating summer sea-ice decline compared to the winter maxima, as well as the general trend towards a reduced Arctic sea-ice coverage year round. Recent analysis has shown, through improved modelling approaches, that the first BOE could be reasonably expected to occur by 2035.[21]

The significance of an ice-free summer in the Arctic cannot be overstated. Not only as a symbolic watershed moment, but a direct Transpolar Sea Route (TSR, yellow trace, Figure 3) in the boreal summer could be extremely attractive for commercial shipping – especially if it becomes commonplace, predictable and reliable. However, more immediately, the Northeastern Passage (pink trace, Figure 3) and Northwestern Passage (green trace, Figure 3) are likely to see greater ice-extent declines and therefore may open space for more regular, if highly specialized, shipping routes.

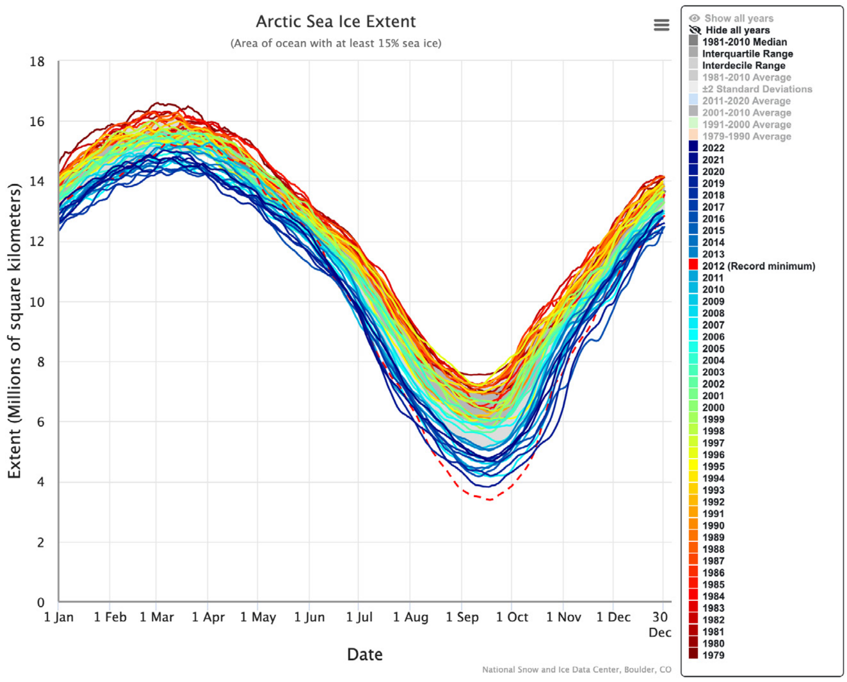
Figure 1b: SIE anomaly (1979–2018) for March and September with a linear least-squares fit and annual SIE



From the paper *Global warming leading to alarming recession of the Arctic sea-ice cover: Insights from remote sensing observations and model reanalysis* by Kumal et al, 2020.

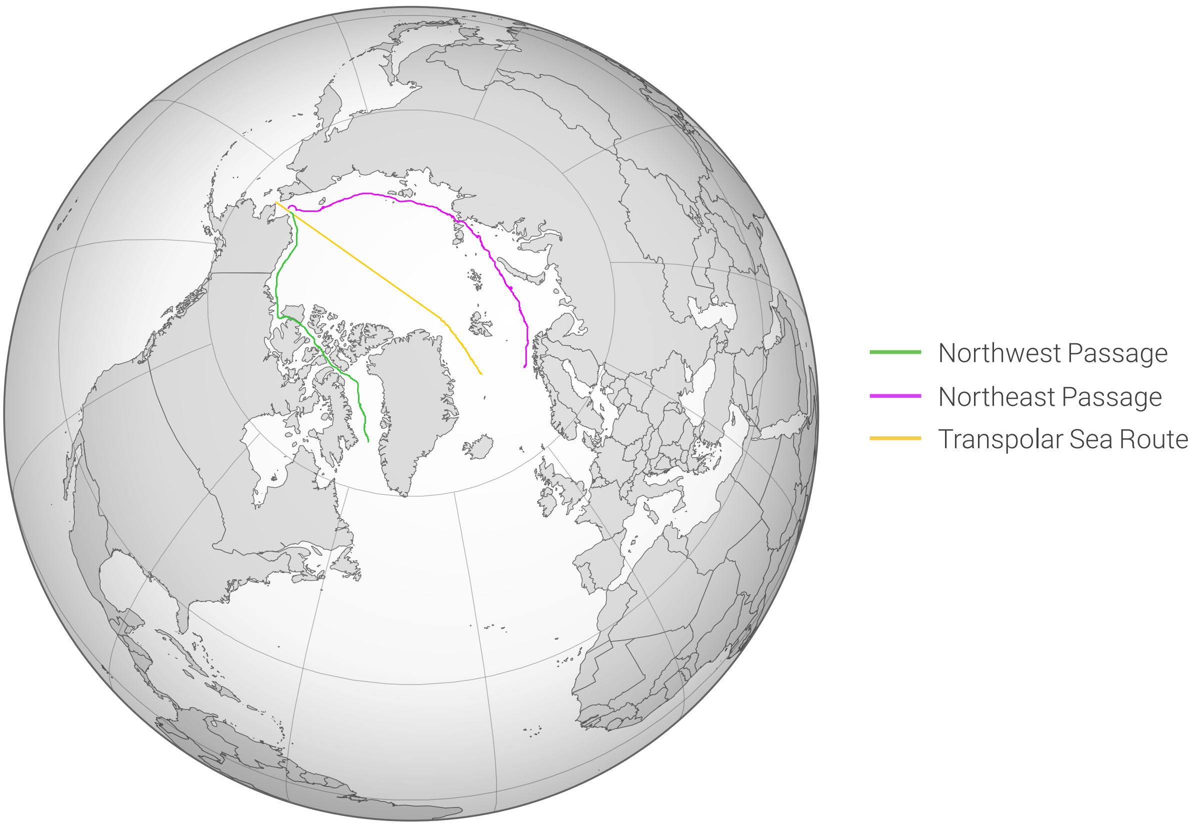
20 Global warming leading to alarming recession of the Arctic sea-ice cover: Insights from remote sensing observations and model reanalysis
21 Sea-ice-free Arctic during the Last Interglacial supports fast future loss

Figure 2: Sea Ice Extent each year since 1979



Data visualised from National Snow and Ice Data Center's Charctic Interactive Sea Ice Graph.

Figure 3: Potential future sea routes in the Arctic



Source: https://commons.wikimedia.org/wiki/File:Transpolar_shipping_routes.svg#metadata

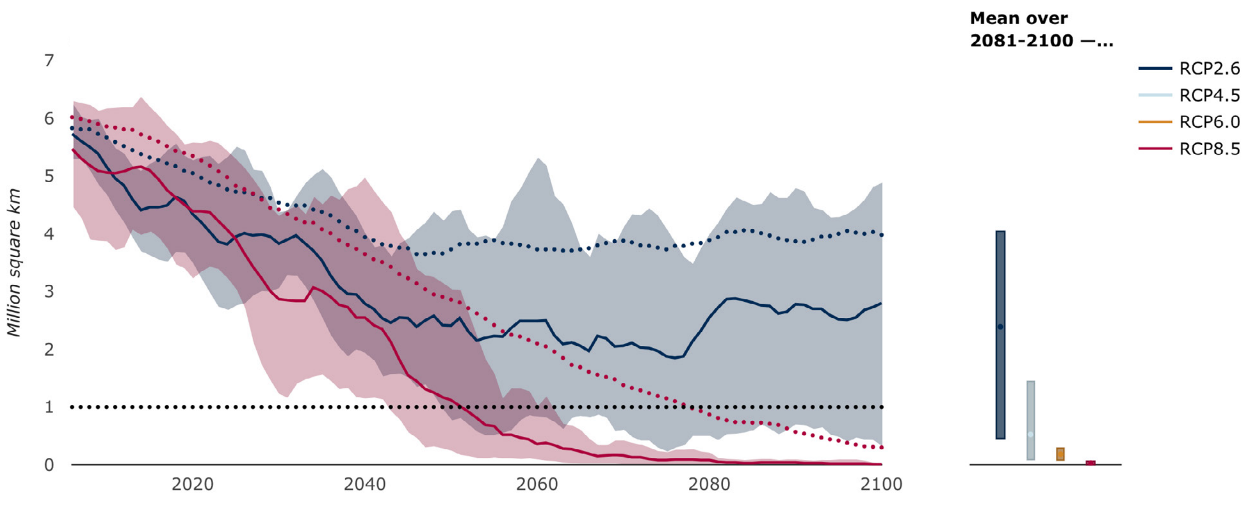
Predicting Sea Ice Extent in the coming decades

Being able to predict where sea ice will be present, thickest, and most likely to disappear in the coming decades is vital to understanding the strategic implications of sea ice retreat. For example, a faster ice retreat in waters proximal to Russia's Northern Fleet operational area may drive Russian Federation SSBNs to travel further seeking cover from the Arctic Ice Cap. There will also be other strategic impacts that are at present unpredictable and will only become clear once they are about to occur, or have already occurred – the 'unknown unknowns'.

Predicting sea ice distribution accurately using physical dynamical models is possible, up to a few weeks ahead of present.[22] After that point however the models begin to break down as assumptions, rounding errors, and other uncertainties accumulate. Other, probabilistic, models have claimed reasonable success in predicting sea ice distribution up to six months ahead of the present, but this is still unsuitable for understanding the long term impacts of a non-uniform sea ice retreat on strategic stability in the Arctic. No model will be able to predict accurately and precisely, to the level of a physical dynamical model, sea ice concentration and distribution a decade from now, but we may be able to estimate which strategically important regions retain much ice, or become ice-free as a general rule.

Data from the European Environment Agency in Figure 4, shows how the climate model, CMIP, predicts Sea Ice Extent out to 2100 under a range of emission scenarios (RCPX.Y in the legend to the right, a standard set of emissions scenarios used in climate modeling). The RCP2.6 and RCP8.5 scenarios are plotted, with the shaded area representing the uncertainty attached to these predictions.[23] Again, however, these models do not provide data on *where* the Sea Ice Extent is concentrated.

Figure 4: Projected changes in Sea Ice Extent in the northern hemisphere in September



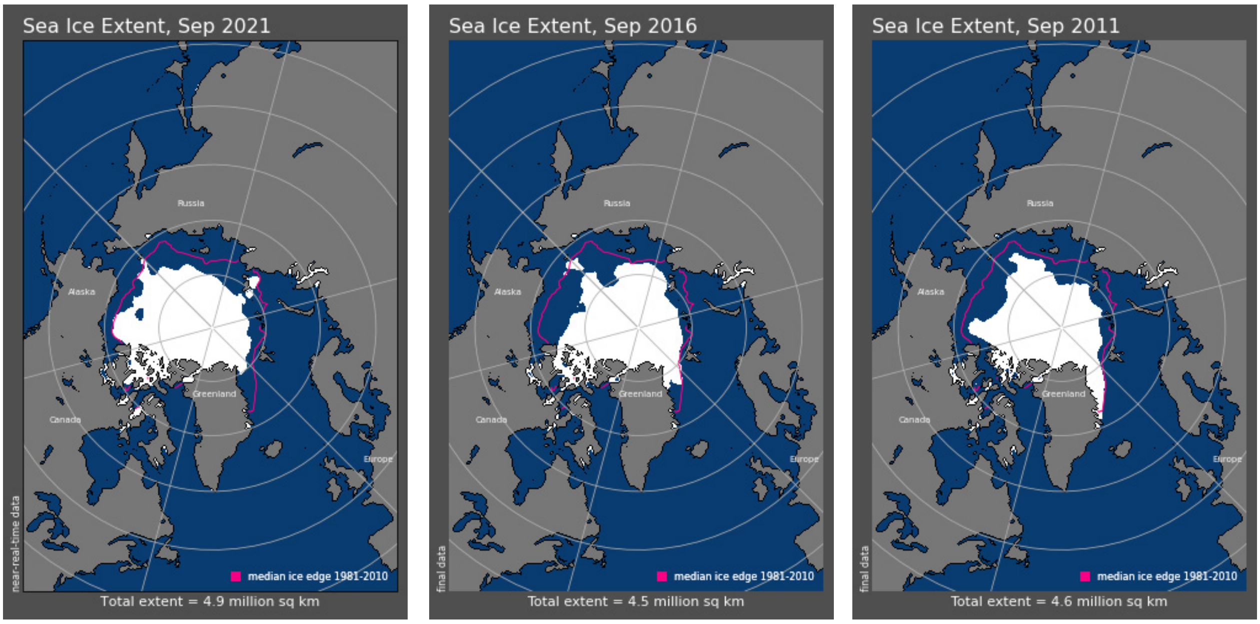
Source: https://www.eea.europa.eu/data-and-maps/daviz/projected-changes-in-northern-hemisphere#tab-dashboard-01

22 Seasonal Arctic sea ice forecasting with probabilistic deep learning, Andersson et al, 2021
23 Data visualisation from the European Environment Agency, accessed in 2022

One way we can begin to intuit a sense of the distribution of sea ice in the Arctic is to look historically at where sea ice has retreated over the past 20 years. Clearly, taking individual data from Septembers at five-year intervals as examples has methodological drawbacks, but we can still gather important insights – namely, where sea ice has remained relatively stable and where it has receded most rapidly.

Using a data visualization tool from the National Snow & Ice Data Center,[24] in Figure 5 we can see that sea ice concentration remains high in the Canadian Archipelago across the past fifteen years, and retreats most (compared to the 1981-2010 ice-edge median) in areas of open sea from Alaska through the majority of the eastern half of the Russian Federation.

Figure 5: Arctic sea ice concentration in 2021, 2016 and 2011



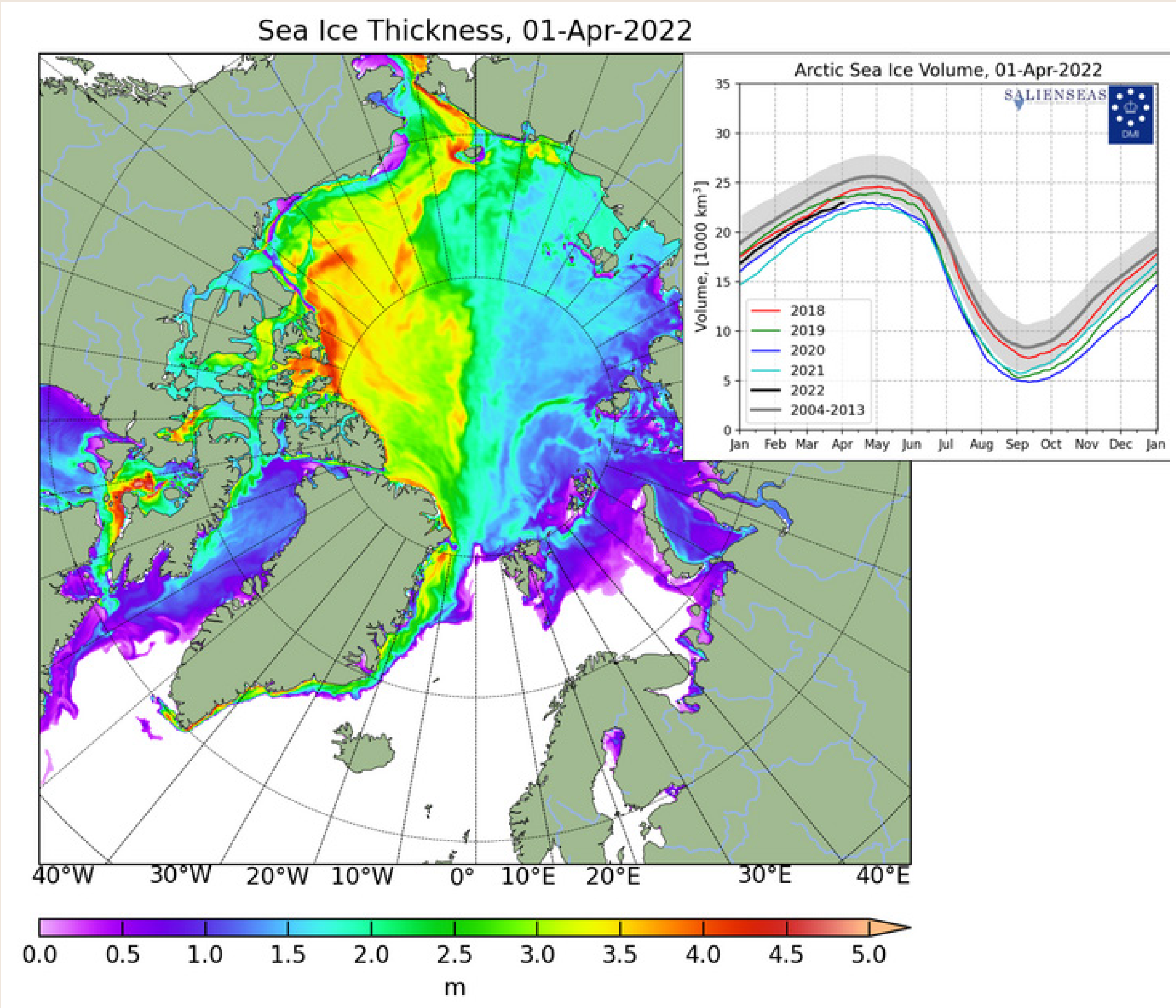
Source: https://nsidc.org/data/seaice_index/compare-animate

24 Data visualisation from NOAA, NSIDC, accessed in 2022

Sea Ice Thickness

In addition to the extent of sea ice, another key characteristic that must be considered for submarine operations is the thickness of that ice. As can be seen in Figure 6, the thickness of Arctic sea ice peaks in the lead-up to May, with the thickest portions on the Canadian side of the Arctic Ocean. Over the past two decades, it is clear that the ice has not only reduced in extent as noted above, but also in thickness. There is now rarely sea ice thicker than 3.5m, and the trend would suggest a further reduction towards the commissioning of the Victoria class replacement. As will be detailed further below, this has direct implications for the suitability of current submarine designs as they relate to the ability to safely surface in Arctic ice.

Figure 6: Sea ice thickness across the Arctic region in the beginning of April between 2004 and 2022.[25]



25 http://polarportal.dk/en/sea-ice-and-icebergs/sea-ice-thickness-and-volume/. For corroboration, see also http://psc.apl.uw.edu/research/projects/arctic-sea-ice-volume-anomaly/.

PART IV

Canadian Submarine Tasks to Date

Submarines in Canadian Service and Victoria Class Modernization

Table 1

Mission	Past	Present (2010s-2022)	Future
	Periods and specific examples where available	*Balance of likelihood that mission continues today*	*Balance of likelihood of a future mission*
Training targets for NATO ASW	1960s, 1970s, 2000s (e.g. HMCS Windsor 2005-2006, US Carrier Strike Group workups)	Yes, e.g. 2016 Dynamic Mongoose, 2018 Dynamic Manta	Yes
SSN/SSBN tracking	Late 1970s-1990	SSN only, e.g. HMCS Windsor 2014, North Atlantic	Yes
Intelligence collection and maritime domain awareness	1980s, 1990s (e.g. Op Ambuscade), 2000s (e.g. Op Nanook)	Yes; 2017 HMCS Chicoutimi (Op Projection/Neon, NW Pacific); 2018 HMCS Windsor (Op Sea Guardian, Mediterranean)	Yes
Sovereignty patrol	2000s (e.g. HMCS Corner Brook, Op Nanook 2007 and 2009)	Limited (no known Arctic deployments)	Yes
Water space management	Since at least the 1970s	Yes	Yes

In the 2010s, the Victoria class were employed overseas for intelligence gathering in the constabulary role.

Missions undertaken by Canadian Submarines, Past and Present

Clockwork Mice/Training targets

Canadian submarines have played the role of surrogate enemy submarine targets for Canadian and allied antisubmarine forces since the end of the First World War. This was the dominant mission for the Canadian Cold War submarine fleet so long as Soviet submarine technology was still roughly comparable in performance to the RCN's diesel-electric submarines. This "clockwork mice" role was most prevalent in HMCS *Grilse* and *Rainbow*, second-hand US Navy submarines operating in the 1960s, but was also a primary mission for the three British-built Oberon class SSKs that entered service in the early 1970s. However, this training mission did not last very long as improvements to Soviet submarines rendered the Oberons obsolete as realistic surrogates. Ironically, this would free up the Oberons to carry out several of the operational missions outlined below against adversaries that take advantage of their stealthy nature.[26] In more recent years, the Victoria class SSKs that replaced the Oberons have reprised the ASW training role in numerous NATO exercises such as the 2016 iteration of Exercise Dynamic Mongoose and 2018's Exercise Dynamic Manta.[27] They have also helped American carrier strike groups to train for deployment.[28]

26 Julie H. Ferguson, *Through a Canadian Periscope: The Story of the Canadian Submarine Service* (Toronto: Dundurn, 2014), 282-283, 308-309, 330.

27 Alex Calder, "HMCS Windsor returns from Exercise DYNAMIC MONGOOSE 2016," *Trident News*, August 22, 2016, https://tridentnewspaper.com/issues/Volume-50/2016-08-22-17.pdf; Ryan Melanson, "East Coast submariners receive SSM-Expedition medals," *Lookout Navy News*, May 27, 2020, https://www.lookoutnewspaper.com/east-coast-submariners-receive-osm-expedition-medals/.

28 Royal Canadian Navy, "His Majesty's Canadian Submarine Windsor (SSK 877)," *Government of Canada*, October 13, 2022, https://www.canada.ca/en/navy/corporate/fleet-units/submarines/victoria-class/windsor.html.

SSN/SSBN tracking

One of the main operational missions undertaken by the previous generation Oberon class submarines was to track and locate the Soviet Union's Yankee and Delta class ballistic missile submarines as they took up stations off the United States and Canadian eastern coasts. While the Oberons were not fast enough to keep up with the nuclear-powered Soviet SSBNs to tail them constantly, a combination of different intelligence sources enabled them to be pre-positioned along likely transit routes.[29]

In more recent years, the current Victoria class has demonstrated a similar role. In 2015, HMCS *Windsor* was tasked with tracking an unusual "surge" of five Russian attack submarines (four nuclear, one diesel-electric) entering the North Atlantic.[30] While the recent nature of this event prevents us from knowing the degree of success experienced by *Windsor*, it demonstrates the continued relevance of a mobile underwater asset in tracking nuclear-powered submarines in areas of Canadian and NATO interests. Of especial note was that *Windsor's* tasking appeared to have been requested by NATO rather than stemming from solely Canadian authorities, highlighting the utility of Canadian submarines even when a situation does not directly concern Canadian interests.

Recent years have also seen a greater concern by NATO towards ASW and naval operations in the European Arctic region. Although the accession of Sweden and Finland to NATO may increase NATO's maritime focus to the Baltic Sea, NATO Secretary General Soltenberg's visit to Canada's Arctic in August 2022 demonstrates a commitment to northern security issues. Thus, at the same time that NATO naval assets are being pulled towards the "south", the high Arctic remains a space of great importance to alliance interests. In this context, Canada may be expected to pull more weight in the coming years to help keep track of Russian underwater assets in the Arctic while other alliance assets are drawn elsewhere.

Intelligence Collection and Maritime Domain Awareness

The stealthy nature of submarines lends well to their use as intelligence collection platforms. While previous Canadian submarines have not had an extensive history of use in such a capacity, the Oberon class did surveil Soviet surface ships operating off Canada's Atlantic coast and for limited amounts of time off the UK coast during training.[31] During 1993 and 1994, Oberons collected intelligence as part of fisheries enforcement operations off George's Bank, a scallop-rich area between the Canadian and American maritime boundary off their east coasts. While a submarine could not threaten the use of force against illegal fishers (threatening to use a torpedo against a trawler would hardly have been credible), their clandestine all-weather presence allowed them to capture close-range evidence of illegal fishing gear and practices that aircraft and surface patrol ships could not. Once such operations were made public, instances of boundary violations decreased drastically in the following years.[32]

In the 2010s, the Victoria class were employed overseas for intelligence gathering in the constabulary role. HMCS Chicoutimi forward deployed to Japan for several months in 2017 as part of Op Projection-Asia Pacific, during which observers suspect it participated in Operation NEON, the Canadian Armed Forces'

29 Michael Whitby, "Boomers, Draggers and Black Boxes: The Operational Legacy of Canada's Oberon Class Submarines, 1983-1998," *The Northern Marine*r 23, no. 4 (2013): 370-373, 383.

30 Bruce Campion-Smith, "Canadian sub in underwater hunt for Russian vessel," *Toronto Star,* May 28, 2016, https://www.thestar.com/news/canada/2016/05/28/canadian-sub-in-underwater-hunt-for-russian-vessel.html; Brett Ruskin, "Incident in North Atlantic last fall shows why Canada needs submarines, navy says," *CBC News,* May 26, 2016, https://www.cbc.ca/news/canada/nova-scotia/hmcs-windsor-submarine-canada-navy-greenwood-subs-halifax-1.3601633.

31 Whitby, "Boomers, Draggers and Black Boxes," 369-370.

32 Whiby, "Boomers, Draggers and Black Boxes," 383-397; Sean M. Maloney, "Canadian Subs Protect Fisheries," *USNI Proceedings* 124, no. 3 (1998): 1141.

Although the official purpose of Chicoutimi in the region has only been revealed to be building relations with regional partners and allies, various news reports and analysts have indicated that the clandestine observations of North Korean-related shipping and at-sea oil transfers was part of the boat's operational activities.

contribution to monitoring and enforcing sanctions on North Korea. Although the official purpose of Chicoutimi in the region has only been revealed to be building relations with regional partners and allies, various news reports and analysts have indicated that the clandestine observations of North Korean-related shipping and at-sea oil transfers was part of the boat's operational activities. Certainly, the RCN's surface fleet as well as the Royal Canadian Air Force have engaged in Op NEON in a very public way, and having the clandestine capabilities of a submarine engaged in such a mission would not be unusual. More concretely, the RCN has made it public that the Victorias have also deployed to Operation Caribbe, the CAF's counter-narcotics mission in the Caribbean and eastern Pacific. These took place in 2008 (HMCS Corner Brook), 2011 (HMCS Corner Brook), and 2013 (HMCS Victoria) but have since ceased.[33]

Both at home and abroad, Canadian submarines have supported Maritime Domain Awareness (MDA), which builds a recognized picture of typical actors and activities in a given area of maritime space. While the secretive nature of submarine operations again prevents us from knowing where such "picture building" have taken place, there is at least one clear instance where it was the primary mission: HMCS *Windsor's* participation in NATO's Operation Sea Guardian during its deployment to the Mediterranean in 2018.[34] Operation Sea Guardian primarily "aims to reinforce maritime situational awareness, counter-terrorism efforts…and capacity-building in the Mediterranean Sea. These tasks focus on gathering relevant information about current maritime activities in the Mediterranean region to help identify possible security concerns."[35]

33 Royal Canadian Navy, "His Majesty's Canadian Submarine Victoria (SSK 876)," *Government of Canada*, October 13, 2022, https://www.canada.ca/en/navy/corporate/fleet-units/submarines/victoria-class/victoria.html; Royal Canadian Navy, "His Majesty's Canadian Submarine Corner Brook (SSK 878)," *Government of Canada,* October 13, 2022, https://www.canada.ca/en/navy/corporate/fleet-units/submarines/victoria-class/corner-brook.html.

34 Royal Canadian Navy, "His Majesty's Canadian Submarine Windsor (SSK 877)."

35 NATO, "Operation Sea Guardian," *NATO*, May 17, 2021, https://www.nato.int/cps/en/natohq/topics_136233.htm.

Sovereignty patrol

With a long history of foreign submarines operating in its Arctic waters (albeit mostly American with Canadian consent), Canada has seen a need for asserting its sovereignty over those waters both on and below the surface.[36] To this end, the Victoria class have been deployed sparingly to the country's Arctic region as part of Operation NANOOK.[37] This has included the use of the submarines as platforms for deploying and retrieving special operations forces, which is especially vital given the sparse degree of infrastructure in the Canadian Arctic. However, despite the fact that much of the Canadian discourse surrounding past, present, and future submarines involve their relative ability to operate under sea ice and thus enhance the military's Arctic presence, actual Arctic deployments by Canadian submarines have been minimal. Instead, expeditionary operations abroad in support of constabulary and military objectives have tended to be more common since the entry into service of the Victorias.

Water Space Management

One of the arguments to maintain a Canadian submarine capability is to be part of NATO's water space management regime. This informs all submarine-operating countries within NATO as to the rough area where an ally's submarines may be operating in order to reduce the chances of collision or mis-identification. This reduces the requirement for Canada to independently detect, track, and identify all underwater contacts in its areas of interest. This relates to the sovereignty mission at home: without either a large submarine force or extensive underwater sensors, maintaining an uninterrupted awareness of what is occurring beneath Canadian ocean surfaces would be impossible. Having that information provided "free" by virtue of maintaining even a small submarine force is therefore a cost-effective way of maintaining awareness of the underwater domain in so far as allied forces are concerned.[38]

The importance of such deconfliction measures was sharply illustrated in February 2009 when the French submarine *Le Triomphant* and the British Royal Navy's HMS *Vanguard* collided in the Atlantic Ocean.[39] Of particular significance was that both vessels were nuclear-powered ballistic missile submarines carrying out their deterrence patrols. The fact that two of the most powerful and deadly weapons in the world could simply hit each other within the wide expanse of the oceans shows how difficult it is to detect modern submarines and therefore the relatively high worth of being part of a water space management regime. At the time of the collision, France had left NATO's military command and was potentially not privy to the full extent of water space management protocols. A month after the incident, France returned to being under NATO military command.[40] Whether this decision was due specifically to the collision and a recognition of the importance of deconfliction of submarine operations is uncertain, but the timing is highly suggestive that such was the case given the lack of other discussions at the time on France resuming being under NATO command.

36 See Adam Lajeuensse, *Lock, Stock, and Icebergs: A History of Canada's Maritime Sovereignty* (Vancouver: University of British Columbia Press, 2016).

37 Royal Canadian Navy, "His Majesty's Canadian Submarine Corner Brook (SSK 878)."

38 Phil Webster, "Arctic Sovereignty, Submarine Operations and Water Space Management," *Canadian Naval Review* 3, no. 3 (2007): 14-16.

39 Caroline Gammell and Thomas Harding, "British and French nuclear submarine collision 'as serious as sinking of Kursk'," *The Telegraph,* February 16, 2009, https://www.telegraph.co.uk/news/uknews/defence/4640673/British-and-French-nuclear-submarine-collision-as-serious-as-sinking-of-Kursk.html.

40 Steven Erlanger, "France Will Take Full NATO Membership Again, With Greater Military Role," *The New York Times*, March 11, 2009, https://www.nytimes.com/2009/03/12/world/europe/12france.html.

Summation of Current Victoria Class Missions

The scope of missions carried out by the current submarine fleet can be divided in geographic terms. Firstly, its Arctic operations have been limited in frequency and duration. Although formally in place for sovereignty assertion, they have appeared to be used as a way to test the limitations and abilities of operating the class in ice-infested waters and to support limited numbers of special operations forces on the ground. Secondly, they have been used in southern Canadian waters, though it remains uncertain how much of this was for training versus operational patrol, surveillance, or support for other government departments as had previously been the case for the Oberon class. Thirdly, the Victorias have been deployed abroad. Ranging from counternarcotics in the Caribbean and tracking Russian submarines in the North Atlantic to providing support for sanctions enforcement against North Korea, it is clear that the most regular operational use of the Victorias is far from home. This has been despite the general acknowledgement that diesel-electric submarines are ill-suited for such expeditionary operations, and that the Victoria class had originally been designed for patrolling waters around the United Kingdom close to their original home bases.

PART V

General Capabilities of the Victoria Class and their Modernization

> At approximately 2400 tons when new, the Victoria class were among the world's largest diesel-electric submarines in service.[41]

While the latest generation of submarines being built or recently built in East Asia, such as South Korea's SSK-III or Japan's Taigei classes, are notably larger, many European SSKs remain under the 2000 ton mark.[42] This reflects the original purpose of the Victoria class design: to operate for long periods of time in blue water throughout the GIUK gap. This long endurance capability has now been repurposed, under Canadian command, for Canada's domestic and overseas naval missions. This has included the annual summer Operation Nanook in Canada's Arctic and, more recently, deployments to East Asia via the use of Japan as a forward base and northern Europe. Such overseas missions have spanned months in duration, though made use of forward bases like Yokosuka in Japan and various locations throughout northern Europe.

The large size of the Victorias have also allowed them to be equipped with sensors similar to those of their nuclear-powered brethren. These include three flank array sonars on each side of the boat, a towed array, a large bow passive array, hull-mounted intercept array, and hull-mounted fire-control sonars.[43] All of these allow the vessels to maintain a greater degree of underwater situation awareness than their smaller coastal counterparts.

In terms of weaponry, the Victorias have been converted to employ the American-made Mk. 48 heavyweight torpedoes in place of the original British Tigerfish in order to make use of the RCN's pre-existing Mk. 48 supply chain that was used on their Oberon class predecessors. However, they have not retained the Harpoon anti-ship missile capability that was implemented briefly on the Oberons.[44] Nonetheless, the

41 Ferguson, *Through a Canadian Periscope*, 341.

42 See section below for the SSK-III and Taigei. An example of a European SSK is the Type 214, which displaces 1690 tons submerged, while the Swedish Gotland class displaced 1380 tons when new: Sam Lagrone, "Singapore Buys New Class of German Attack Submarines," *USNI News*, December 4, 2013, https://news.usni.org/2013/12/04/singapore-buys-new-class-german-attack-submarines; Xavier Vavasseur, "Saab Delivers 2nd Upgraded Gotland-Class Submarine To Sweden," Naval News, December 16, 2020, https://www.navalnews.com/naval-news/2020/12/saab-delivers-2nd-upgraded-gotland-class-submarine-to-sweden/.

43 Julie H. Ferguson, *Deeply Canadian: New Submarines for a New Millennium* (Port Moody: Beacon Publishing, 2000), 198; Jerry Proc, "Victoria Class Submarines," *RADIO COMMUNICATIONS AND SIGNALS INTELLIGENCE IN THE ROYAL CANADIAN NAVY*, 2022, http://jproc.ca/rrp/victoria.html.

44 Ferguson, *Deeply Canadian*, 200.

Victorias' large size compared to other SSKs of its time provides them with more ammunition should the need arise.[45]

Finally, the above-water intelligence, surveillance, and reconnaissance capabilities of SSKs like electronic intelligence (ELINT) and imagery intelligence (IMINT) cannot be ignored. However, asides from the usual periscopes, the highly secretive character of such equipment make it difficult to provide an assessment of their suitability and adequacy for current or future requirements. It suffices to mention, however, that the Victorias' current operational missions of sanctions enforcement and counternarcotics would make heavy use of such capabilities and that they would continue to be a vital requirement in the future should Canada continue to require an overseas submarine presence.

In sum, the Victorias have played a fairly conventional role in the RCN. More than many other SSKs, they provide an unparalleled ability to monitor the undersea and surface domain without being detected. Their ability to attack potential targets using Mk. 48 heavyweight torpedoes is amplified by the relatively deep magazine depth compared to traditional coastal submarines. Still, the Victorias lack long-range anti-ship and land attack capabilities, which constrain their utility in terms of Canada's expeditionary naval posture.

Recent Upgrades

In recent years, the Victorias have or are undergoing a series of modernization efforts. Perhaps the most notable amongst these is the addition of the same sonar processing suite (the BQQ-10) as the latest American Virginia class nuclear-powered attack submarines (SSNs). This has been completed on some of the boats and are being installed on the rest as they enter their refit periods.[46] These new sonar processors should greatly enhance a Victoria's ability to make sense of what it hears from its sonars. The actual hydrophone arrays, specifically each boat's six flank arrays, have also been approved for renewal/upgrades under the Victoria Class Modernization (VCM) program with industry engagement plans approved in March 2021.[47] It remains to be seen when this major element of the modernization will be completed.

As part of the VCM program, the class is also receiving new periscopes, potentially similar to the latest American SSNs.[48] Digital pericopes would allow the images from the scope to be projected on monitors throughout the boat, rather than be restricted to only those who are peering through the periscope itself. The digital nature also allows for low-light enhancements and integration with other systems. In the meantime and preceding the VCM, the class is also receiving the Universal Modular Mast, which "allows high-speed, highly-secure, jam-resistant satellite communications with shore." They are also being upgraded to enable firing the Mk. 48 Mod 7AT torpedo, a fourteen-year upgrade of the previous Mk. 48 Mod 4M.[49] The Mod 7AT, which is an upgrade kit for the old Mod 4 torpedo bodies that incorporates the United States Navy's Mod 7 CBASS (Common Broadband Advanced Sonar System) guidance and control elements, allows for

45 Compare the Victorias' 18 total weapons with, for example, the Norwegian Ula class's 14 and German Type 212A's 13.

46 Lee Willett, "Sense, Send and Strike," Armada International, May 28, 2020, https://www.armadainternational.com/2020/05/sense-send-and-strike/.

47 Department of National Defence, "Victoria-class submarines," *Government of Canada*, December 22, 2021, https://www.canada.ca/en/department-national-defence/services/procurement/victoria-class-submarines.html.

48 Marcello Sukhdeo, "Upgrading the Victoria-class Submarines Against Current and Evolving Threats," *Vanguard Canada,* December 6, 2021, https://vanguardcanada.com/upgrading-the-victoria-class-submarines-against-current-and-evolving-threats/.

49 Department of National Defence, "Heavyweight Torpedo Upgrade," *Government of Canada*, January 9, 2020, http://dgpaapp.forces.gc.ca/en/defence-capabilities-blueprint/project-details.asp?id=1771; Department of National Defence, "Canada's most modern submarine returns to the water," *Government of Canada,* June 16, 2021, https://www.canada.ca/en/department-national-defence/maple-leaf/rcn/2021/06/canadas-most-modern-submarine-returns-to-the-water.html; Ben Goodlad, Luca Peruzzi, and Richard Scott, "Big hitters: heavyweight torpedoes follow an incremental course," *IHS Jane's*, 2015, https://kipdf.com/big-hitters-heavyweight-torpedoes-follow-an-incremental-course_5b380c76097c47ef698b4588.html.

easier modular upgrades in the future and improved shallow water sonar performance while being more resistant to countermeasures.

Beyond these combat systems upgrades, the VCM will focus on habitability and galley improvements, which ensure the vessels are able to operate until the 2030s while optimizing them for the RCN's current and projected demographic composition.

Capability gaps

In the current VCM plans, there remains a number of capabilities that are absent but could be deemed an important part of Canada's current and near-future submarine capabilities.

Firstly, the Victorias do not possess the ability to safely operate under sea ice. Although modernized with high-frequency active sonar to help detect sea ice above and enable their ability to operate on the edges of sea ice, the limited underwater endurance of a conventional diesel-electric submarine combined with its limited buoyancy prevents the class from being able to either sail long enough underwater to find ice-free waters or punching up through sea ice to engage its diesel engines and recharge its batteries.[50] While there are certainly some circumstances where and when a regular SSK's battery capacity suffices to transit through limited amounts of sea ice, the unpredictability of Canada's Arctic sea ice makes this a tricky prospect. The Beaufort Gyre and the Transpolar Drift help to push Arctic sea ice into Canadian waters, clogging the myriad straits that make up the Canadian Arctic archipelago. Combined with icebergs formed from calving glaciers on land, a submarine that relies upon regular surfacing to recharge its batteries cannot safely and reliably operate throughout the Canadian Arctic unless it limits its voyage profile to the ice edge and permanent polynyas.

Secondly, the Victorias lack any ability to strike land targets. Unlike American and British SSNs with their Tomahawk long-range land-attack cruise missiles, the Victorias are only equipped with anti-ship torpedoes. While this is the norm for European SSKs, newer SSKs built elsewhere such as Japan and South Korea are adding such capabilities. This is especially important under current considerations for how NORAD should respond to increased Russian aggression and conventional strike capabilities. Given the challenges of modern hypersonic and highly-maneuverable weaponry, there are some hints amongst Canadian officials that a greater emphasis towards a strategy of conventional "deterrence by punishment" rather than relying solely on "deterrence by denial" will be necessary.[51] Although government and military officials have openly called for the need to improve the continent's ability to intercept inbound new missiles as part of deterrence by denial, such efforts may require approaches that impose an unfavourable cost-ratio for the defender.[52] In essence, this means that Canada and the United States should have the ability to retaliate in a credible non-nuclear manner against Russian (or any other aggressor's) assets, rather than simply making it harder for an aggressor to attack North American targets. For a submarine, this means being able to launch land-attack cruise missiles at high-value targets in the attacking country's territory. Quite aside from the lack of

50 Marcello Sukhdeo, "Upgrading the Victoria-class Submarines."

51 Amanda Connolly, "Canada will spend $40B over 20 years to upgrade NORAD defences amid 'new threats'," *Global News*, June 20, 2022, https://globalnews.ca/news/8933288/canada-upgrading-norad-amid-new-threats/; discussions with lead author held under Chatham House rules.

52 Andrea Charron and James Fergusson, "North America's Imperative: Strengthening Deterrence by Denial," *Strategic Studies Quarterly* (Winter 2021), https://www.airuniversity.af.edu/Portals/10/SSQ/documents/Volume-15_Issue-4/D-Charron.pdf, 44; Department of National Defence, "Joint Statement of NORAD Modernization," Government of Canada, August 14, 2021, https://www.canada.ca/en/department-national-defence/news/2021/08/joint-statement-on-norad-modernization.html; Minister of National Defence, "Minister of National Defence Announces Canada's NORAD Modernization Plan," *Government of Canada,* June 20, 2022, https://www.canada.ca/en/department-national-defence/news/2022/06/minister-of-national-defence-announces-canadas-norad-modernization-plan.html.

suitable weapons control systems, the Victorias' lack of adequate ammunition storage renders the addition of strike weapons a challenging prospect at best. Indeed, a desire to be able to launch retaliatory land-attack weapons has been one of the rationales behind Australia's shift from SSKs to SSNs for its future submarine program.

Finally, the Victorias have no known ability to operate underwater uncrewed vehicles (UUVs).[53] Such vehicles can potentially extend the sensory range of the submarine by sailing ahead and around the launching vessel. In the Canadian Arctic, this is especially valuable given the safety challenges of SSK under-ice operations. A UUV could, for instance, sail under the ice without concern for crew safety in the event it cannot return home in time. However, it would require a relatively large UUV with its associated large power supply to take maximize the advantage of its under ice capability given the vast extent of sea ice in the Canadian Arctic. A small UUV with limited endurance would not appreciably extend a crewed submarine's sensor range, for instance, though it may prove useful in "peering around corners" in the myriad fjords and passages of the Canadian Arctic. Given the limited size of the Victoria class and the standard Mk. 48 torpedo-size tubes, large UUVs would not be easily integrated into (or onto) the current submarine fleet.

53 Marcello Sukhdeo, "Upgrading the Victoria-class Submarines."

PART VI

Replacement Program and Options

Program Office, Arctic Priority, and Technical Challenges

On July 14, 2021, the Canadian Press revealed that Canada has stood up the initial stages of a program to replace the current Victoria class submarines. Dubbed only as the "Canadian Patrol Submarine Project", its scope is limited to analyzing future needs and options for replacing the current underwater fleet.[54] It does not aim to propose a single path forward nor does it commit the government to any actual path. Thus, a range of options exists to date. Little is known publicly about the priorities and of the office in terms of submarine objectives, cost ceilings, and technological risk acceptance. However, the lead writer of this report has previously been in discussions with members of the office under Chatham House rules. During such discussions, there was a clear emphasis on Arctic under-ice capabilities – any future Victoria class replacement option would have to increase Canada's current ability to operate under the Arctic sea ice. This need for the CPSP to "include the Arctic" has also been articulated in an interview with the Commander of the Canadian Submarine Force.[55]

With such a priority, there are only a limited number of options that would be feasible. These options would have to emphasize at least one of the following: power density, autonomy, and/or size.

In terms of power density, the challenges of diesel-electric propulsion have already been mentioned earlier. In summary, the need to regularly surface to recharge the batteries via running the diesel engines dramatically limits how long and where in the Arctic the submarine can operate. While large polynyas like the Pikialasorsuaq (North Water Polynya) between Greenland and Ellesmere Island offer year-round thin ice or ice-free areas that are relatively predictable, such areas are limited in numbers and would drastically constrain where and when a submarine can operate to ensure it can reach a polynya for recharging, communications, or emergencies. This would put the SSK at a significant disadvantage should it be expected to monitor all areas where a potential nuclear-powered submarine intruder may be operating. SSNs, with no need to surface for regular operations, can roam relatively freely in the Canadian Arctic depending on the purposes of their mission. For a Canadian submarine replacement to freely operate under the ice, it would require a means of propulsion that does not depend upon regular access to the air. Whether this is nuclear power, advanced air-independent propulsion (AIP) systems, or very high capacity batteries like lithium ion is something the program office will have to detail.

Each of these propulsion systems have their advantages and disadvantages: nuclear is incredibly expensive to acquire and maintain with accordingly high political, personnel, and temporal costs. AIP systems vary in their exact means of converting secondary fuel sources into usable power, but they all suffer from the need to carry that secondary fuel, which occupies space that may be better used for more energy-dense fuels like

54 Berthiaume, "Navy kicks off long-anticipated push to replace Canada's beleaguered submarine fleet."
55 Marcello Sukhdeo, "Upgrading the Victoria-class Submarines."

diesel or other systems. AIP's ability to extend a submarine's underwater endurance is also dramatically affected by the rate at which the fuel is exhausted, which is dependent upon the speeds and power consumption demanded at the time of use. Such limitations are rarely discussed or specified by AIP manufacturers when they claim certain endurance periods. Finally, high capacity batteries like lithium ion remain relatively untested. Only a small number of submarines have been built to date with them, mainly in Japan. There remain concerns over the relative ease with which they can catch on fire in comparison to traditional lead-acid batteries, though this is certainly something that submarine battery manufacturers are actively working on controlling. Insofar as "the more endurance the better" is concerned, there is also the option to combine these technologies. An AIP system that recharges lithium-ion batteries might, for example, match the functional endurance that an SSN can achieve (though not the latter's speed and power) given the need for even SSNs to replenish consumables like food. For instance, today's AIP systems recharging traditional lead-acid batteries are publicized as capable of underwater durations on the order of three weeks.[56] Lithium Ion batteries have the potential to increase power storage by up to four times that of lead-acid counterparts.[57] If sufficient AIP fuel is available, then theoretically an AIP lithium-ion boat could have sufficient underwater endurance to last twelve weeks. Alternatively, replacing the space currently used by AIP equipment with more lithium ion batteries recharged through snorkelling may result in similar endurance.

But if the cost of building new submarines with highly-expensive propulsion systems that would be sufficient for under-ice operations proves prohibitive, one alternative is to leverage uncrewed underwater vehicles (UUVs) that can be deployed either from land or from cheaper conventional SSKs. Although their smaller sizes would almost certainly result in inferior sensors and weapons compared to a crewed submarine, the lack of personnel allows them to be used in more risky situations than their crewed counterparts. While this benefit is obvious in a general sense against military threats, this becomes even more desirable when environmental threat of heavy sea ice is thrown into the equation. Without the need to ensure the crew's survival by carrying sufficient power to reach predictable surfacing areas, a UUV can be used with greater risk thresholds and in the event of power loss, may be retrievable at later dates. This can allow them to be sent ahead of a carrier submarine into and under heavy sea ice for long periods. Although these UUVs will be smaller than their crewed counterparts, the lack of crew spaces allow them to have a much greater share of their internal volume be dedicated to batteries or fuels, and the associated reduction in cross section allows for stiffer, lighter hullforms.

Indeed, existing independently-deployed Extra Large UUVs like the US Navy's Orca can already operate without replenishment for months on end. Whether Canadian geography and infrastructure could support the deployment of such large UUVs for Arctic operations is uncertain. For instance, the distance from Canada's Atlantic naval base in Halifax to the refueling station of Nanisivik on the eastern entrance of the Northwest Passages is the same as crossing the Atlantic to Great Britain. An XLUUV would almost certainly need to refuel/recharge in the Canadian Arctic before proceeding under ice for patrols throughout the NWP or the central Arctic Ocean. However, it is doubtful that any independent UUV, even an XL variant, would be able to breach the ice-covered surface during Arctic winters – which is when an under-ice capability is most necessary. More will be discussed regarding the requirements for surfacing in ice later.

56 Kate Tringham, "First Spanish S-80 Plus submarine starts sea trials," *Janes*, May 31, 2022, https://www.janes.com/defence-news/news-detail/first-spanish-s-80-plus-submarine-starts-sea-trials;

57 José Cañadas Méndez, "Power Estimates for an Arctic AIP Submarine for Canada," *Canadian Naval Review* 16, no. 2: 24-26.

One major challenge regarding UUVs of all sizes is their ability to communicate with shore-based, submarine-based, or ship-based personnel. While this challenge is notable in ice-free waters, at least such oceans allow an UUV to surface or deploy communication buoys whenever and wherever required. In ice-covered waters, this is not an option. Sea ice prevents UUVs from surfacing, while communications buoys can be torn off due to icebergs (and cannot themselves surface through ice). This means Arctic UUVs must rely on either communication techniques that are effective underwater or employ very high levels of autonomy. Currently, underwater communications experience extreme trade-offs between distance, bandwidth, and antenna size. The density of water makes it difficult for high-bandwidth radio signals to penetrate a long distance, while acoustic means of long-distance communications tend to have low bandwidth. Very large antennas can overcome these problems to some extent, but they are so large that they need land-based facilities and cannot be fitted onto ocean-going platforms. Newer technologies like lasers can deliver video-quality bandwidth, but are limited to only around 100 meters in distance.[58]

There are ways to get around this problem within Canadian waters, though they each come with their own challenges. Foremost amongst these are underwater stations that the UUV can dock at to download their data and update their instructions. These stations, in turn, can be connected by cable to land based antennas that enable direct higher bandwidth satellite or radio communications. However, such an approach has to deal with at least two additional problems: firstly, the stations need to have their own power source and secondly, underwater stations can be damaged by sea ice and icebergs scraping along the seafloor. The first of these problems can be resolved without too much trouble, as the Canadian Coast Guard already conducts annual refueling operations for uncrewed aids to navigation in the Canadian Arctic.[59] The second issue is more problematic given the effects of climate change on decreased predictability of sea ice behavior in the Canadian Arctic. Collapsing glaciers would, for instance, result in large, deep icebergs with enough draft and erratic shapes to drag along both the seafloor and slopes where one may place underwater stations. This would require frequent and expensive replacements or repairs when the stations and their cables are damaged.

58 Naval Sea Systems Command, "Compact, Efficient 2-Band Underwater Optical Communications System," *NAVSEA - Naval Sea Systems Command*, January 14, 2021, https://www.navysbir.com/n21_A/N21A-T006.htm.

59 CCG, "Canadian Coast Guard Begins 2021 Arctic Season," *Government of Canada,* June 22, 2021, https://www.canada.ca/en/canadian-coast-guard/news/2021/06/canadian-coast-guard-begins-2021-arctic-season.html.

Submarines surface through ice not by sailing quickly and ramming it, but by gently resting against the underside of the ice and blowing its ballast.

The other solution, which also applies to ice-free oceans, is to increase the autonomy of UUVs. Such autonomy would be designed to reduce the need to send data back to human operators who would decide on updated instructions. In the event the UUVs were to employ more advanced or complicated propulsion technologies, the autonomy would also have to take into account controlling those complex systems without human intervention. Above all, however, is the need to decide on whether these UUVs are to have a lethal capability, which results in a level of autonomy that puts the decision of life and death into its robotic hands. Ultimately, a decision to develop an uncrewed under-ice capability for the RCN that emulates the entire range of capabilities possessed by crewed submarines would have to involve a very high level political decision on whether uncrewed vehicles can decide for themselves on whether to take human lives.

Finally, there is the issue of size. While size dictates range, endurance, weapons capacity, sensor capabilities, and crew comfort in ice-free waters, it has an additional impact in ice-covered waters: the ability to "punch" up and through sea ice. Contrary to some popular notions that nuclear power is required to generate sufficient force to push up and through the ice, the main determinant of a submarine's ability to surface through ice is its mass and reserve buoyancy. The larger a submarine and the more buoyant it can be, the more upward force it can generate when rising up against sea ice. Submarines surface through ice not by sailing quickly and ramming it, but by gently resting against the underside of the ice and blowing its ballast.[60] Thus, the method of propulsion plays little to no role in a submarine's ability to surface through ice. Rather it is whether the submarine has sufficient mass and buoyancy to split the ice above it as it rises. All of this means that if an Arctic underwater vehicle, whether crewed or uncrewed, wishes to have access to the air, it would have to be fairly large. In the 1980s, this size was assessed to be in the upper 3000 tons range for a crewed submarine.

Whether a Canadian submersible vehicle in the Arctic requires access to the air depends on its expected missions. Intelligence collection, whether through optical or electronic means, would certainly require some ability to raise sensors and masts above the surface. The launching of cruise missiles or aerial drones would be another mission that requires through-ice surface capability. While the Victorias do not currently have a cruise missile capability, if Canada adopts a "deterrence by punishment" posture as part of NORAD modernization, that would certainly justify an RCN submarine cruise missile capability to hold at risk other Arctic actors' surface or land assets. These two missions potentially apply regardless of whether the submarine is crewed or uncrewed. If it is crewed, however, then there is the additional need to ensure the submarine has the ability to surface through ice in order to evacuate injured crew members or abandon the boat in the case of extreme emergency. All of this is in addition to any potential need to surface in order to recharge the boat's batteries should the vessel be built with such a propulsion arrangement.

60 See Lajeunesse and Choi, "Here There be Dragons?"

Overall Options

Acknowledging the above need to emphasize at least power, autonomy, or size, the following high-level paths are available for the RCN in its efforts to replace the Victoria class.

The SSN Option

Firstly, the RCN could attempt to procure a nuclear-powered crewed submarine (SSN). A "Holy Grail" of sorts for the Canadian navy since the first attempt in the 1960s, Canadian naval officials and some politicians have long identified SSNs as being the optimal choice for operating around Canada's long coastline and especially under the Arctic sea ice. Their underwater endurance and (generally) large sizes make them the best option for sailing under sea ice as well as surfacing through them for various operational and emergency requirements. With the Canadian side of the Arctic Ocean likely to be home to the longest-lasting amounts of sea ice, Russian SSBNs and their SSN escorts will likely patrol close to or within the Canadian Arctic EEZ well into the mid-century. Although legal under international law, such operations will likely increase demand for NATO underwater presence, and the RCN would almost certainly be pressured from both NATO allies and by its own populace to provide some means of monitoring and intercepting such submarine activities. A fleet of RCN SSNs would certainly be the most obvious method for carrying out this mission, and SSNs' ability to sail at high speeds without concern for recharging allows them to have superior positioning and combat options over SSKs when faced with opposing SSNs.

With the RCN's turn towards global operations in the past two decades, the unlimited underwater range of SSNs has only been more attractive from a performance and operational perspective, while their large sizes generally allow more room for weapons and sensors that increase their relevance across a wide range of global scenarios. However, the nuclear option comes with both dramatically higher financial and political costs that few Canadian politicians in power have seen fit to truly advocate for. Most recently, Prime Minister Justin Trudeau has indicated that SSNs are out of the question for Canada in response to questions as to whether Canada has any interest in the AUKUS partnership between Australia, the United Kingdom, and the United States.[61] With the current Liberal government rejecting a nuclear submarine option and a potential Conservative government likely to prioritize limited government spending, a Canadian SSN program is not likely to come to fruition.

The SSK Option

Secondly, the RCN could pursue a conventionally-powered crewed submarine (SSK). This has generally been viewed as the more realistic option even though it remains quite challenging from a procurement perspective. Canada has only succeeded once in taking a SSK procurement from conception to new construction and delivery, with the ordering of the Oberon class during the 1960s. Previous and subsequent acquisition efforts have relied on second-hand submarines from the United States and United Kingdom, which meant Canada had to make the best out of vessels that were not designed or built to meet Canadian requirements. Although Canada currently has a build-in-Canada policy in place for its federal fleet due to the National Shipbuilding Strategy, submarines are not yet included in that policy. Thus, while Canadian politicians and shipyards will likely press for a domestic submarine construction approach, there remains the possibility that a foreign shipyard may end up being the builder. This is particularly likely given the full

61 Amanda Connolly, "Was Canada invited to join AUKUS? Officials mum but stress no interest in subs," *Global News*, September 16, 2021, https://globalnews.ca/news/8196164/aukus-defence-deal-canada-china-relations/.

schedules of the three main Canadian shipyards during the 2030s timeframe in which the submarines will have to be built, as they are already occupied with existing and agreed-upon future work.

This makes exploring the possibility of a foreign-built SSK of vital importance. The paths for this are unclear, however, given Canada's relatively unique requirement combining non-nuclear propulsion with long-endurance, which results in a submarine that is larger than most current SSKs. Although most Western submarine builders have offered larger long-range versions of their current in-production submarines, such as Saab's A-26 derivatives and France's Shortfin Barracuda, these are not yet proven and have not been designed to operate in Arctic ice-covered waters. An "off the shelf" option therefore does not exist, and significant modifications such as ice-strengthening would have to be made with attendant design and engineering costs. Still, leveraging in-service large-displacement SSKs would at least minimize risk, and such options are so far available in the forms of the South Korean KSS-III (3600 tons), Japanese Taigei/29SS (3000 tons), and the Spanish S-80 Plus (3000-3400 tons).[62] Each of these are notable for different things: the KSS-III is one of the few operational SSKs designed to carry submarine-launched ballistic missiles (SLBMs), the Taigei incorporates lithium-ion batteries in place of traditional lead-acid batteries, and the S-80 Plus is the largest European SSK.[63] While a SLBM capability may seem incredulous to most Canadians, it is one logical answer to NORAD's potential changing continental defence strategy towards "deterrence by punishment" instead of "deterrence by denial". At the very least, the SLBM tubes could be removed and their weight and space margins reutilized for other features like ice strengthening, uncrewed underwater vehicles, and improved habitability. Meanwhile, Japan's pioneering work on incorporating lithium-ion batteries on submarines will provide much-needed real-world test results regarding their continued viability, ensuring Canada will have sufficient data to assess whether the technology is mature enough for use.

62 Gabriel Dominguez & Dae Young Kim, "DSME contracted to build South Korean navy's second KSS-III 'Batch II' submarine," Janes September 10, 2021, https://www.janes.com/defence-news/news-detail/dsme-contracted-to-build-south-korean-navys-second-kss-iii-batch-ii-submarine; 高橋浩祐, "海自の最新型潜水艦「たいげい」就役――潜水艦22隻体制が完成," *Yahoo Japan*, March 9, 2022, https://news.yahoo.co.jp/byline/takahashikosuke/20220309-00285588; José Cañadas Méndez, "Power Estimates for an Arctic AIP Submarine for Canada," Canadian Naval Review 16, no. 2: 24.

63 H I Sutton, "The First S-80-Plus Class Submarine Will Launch New Era For Spanish Navy," *Naval News*, April 22, 2021, https://www.navalnews.com/naval-news/2021/04/the-first-s-80-plus-class-submarine-new-capabilities-for-spain/.

Whether any of these submarines are large enough to meet the buoyancy requirements for surfacing through Canada's Arctic sea ice is uncertain, though history provides a hint. Putting aside for the moment the highly variable thicknesses and hardnesses of sea ice from year to year and location to location, it was determined back in the 1980s that 3 metres of sea ice was a likely presence in the Canadian Arctic and that any Canadian SSN should be able to surface through that amount. As noted in the previous section on Arctic sea ice predictions, 3-3.5m sea ice thickness represents the upper limit of what is likely to occur in and around the Canadian Arctic and therefore remains a reasonable goal. Two competing designs were offered for the Canadian SSN project at the time: the 2400t French Rubis/Amethyst class SSN and the British Trafalgar class at 4730 tons. Although displacement is not a direct indicator of buoyancy, they do apparently serve as a decent proxy. Assessments at the time did not expect the French boat to have sufficient buoyancy to surface through 3 metres of ice, though the French tested scale models with an "icepick" added to the sail that could enable such surfacing. The Trafalgar was assessed to have no issues with that amount of ice. Ultimately, DND changed their ice thickness requirement to only 1 meter in order to allow the French option to remain in the running.[64] From this, we can reasonably expect that the three aforementioned large SSKs may have sufficient buoyancy to surface through at least 1 metre, and possibly 2 metres, of sea ice. Whether this is sufficient for operations in the central Arctic Ocean would depend on the time of year and the extent of climate change impacts. While strengthening will have to be made to the submarine's various appendages like planes and propeller, at the very least the fundamental size requirement would appear to be available.

An additional question regarding an SSK option for its Arctic sea ice is its submerged endurance. While the current Victorias are known to operate along the edges of the sea ice, tracking and potentially prosecuting Russian nuclear-powered submarines in the central Arctic Ocean sea ice will require submarines with much greater operational and reserve endurance. A hypothetical underwater patrol beginning in southern Baffin Bay, through the Nares Strait, loitering some 800 kilometres in the Central Arctic Ocean, down through the western EEZ of the Canadian Arctic archipelago, and eastwards through McClure Strait and Parry Channel back to Baffin Bay would be a distance of roughly 7,000 kilometres. More direct routes are possible to reduce the distance and time required underwater, though they would sacrifice surveillance coverage. At an average speed of 6 knots or 11.1 km/h, a submarine would require roughly 26 days of underwater endurance. This could be stretched during slower loitering speeds for passive sensing in the patrol area. Advertised estimates of current SSKs equipped with the latest Air-Independent Propulsion (AIP) technologies fall just short of this, with Spain's S-80 rated for 21 days at 4 knots, and South Korea's KSS-III Batch II at "more than 20 days" at unspecified speeds.[65] Clearly, even with the relatively minimalist patrol outlined above (it does not include reserves for emergencies or higher speeds necessary for intercepting enemy submarines, for example), the latest SSK power technologies are insufficient to meet Canada's Arctic underwater needs. Still, the differences are small enough that it is conceivable that improvements over the next decade may prove sufficient, especially if a larger hull is acquired to fit more batteries and/or AIP fuel. However much improved future AIP and battery technology become, an underice SSK would still be limited in its tactical posture to that similar to the Oberon class off the North Atlantic during the end of the Cold War. They were capable of only listening and tracking transiting Soviet SSBNs rather than being able to catch up and maintain interception positions. This may or may not be satisfactory to Canadian politicians and the RCN.

64 Ferguson, *Through a Canadian Periscope*, 350-352.

65 Tringham, "First Spanish S-80 Plus submarine starts sea trials"; Daehan Lee, "South Korea's KSS-III Batch 2 Submarine To Feature Both AIP And Li-Ion Batteries," *Naval News*, June 18, 2021, https://www.navalnews.com/event-news/madex-2021/2021/06/south-koreas-kss-iii-batch-2-submarine-to-feature-both-aip-and-li-ion-batteries/.

AUKUS and the SSK Option

From a procurement standpoint, Canada may not have to order new submarines on its own. With the long timelines expected of Australia's pursuit of SSNs under the AUKUS arrangement, there have been discussions that Australia may have to procure interim SSKs. South Korea, for instance, has offered Australia such new SSKs to close the gap between the decommissioning of their existing Collins class SSKs and the arrival of the SSNs.[66] Here, Canada may be able to strike a balance between its "tradition" of buying second-hand submarines and its difficulties in acquiring brand-new ones. If Australia does decide to procure an interim new SSK, Canada has the opportunity to either add their orders to the Australians' to benefit from economies of scale, or ensure that the Australian order incorporates key Canadian requirements so that Canada can easily take them over once the Australians transition to SSNs. While the latter solution will no doubt be frustrating for Canadians, it at least ensures a second-hand option will actually meet Canadian requirements. Australia's need for long-range SSKs, as embodied by their current 3400 ton Collins class and the now-cancelled 5400 ton Attack class, makes them a sensible partner to engage for Canada regardless of which specific pathway is chosen.[67] Otherwise, it is highly unlikely that there are any other sources of second-hand submarines that meet both the basic Canadian requirements for long range and have sufficient remaining hull life at the time of transfer.

The Crewed-Uncrewed Teaming Option

Finally, Canada can leverage developments in uncrewed underwater vehicle (UUVs) technology to enhance the capabilities of an SSK option. An armed UUV-only solution is unlikely to be feasible given the size and buoyancy requirements required to surface through sea ice in order to communicate with shore via satellite or radio. By the time one develops a UUV of such size, one may as well buy a crewed submarine. A fully autonomous system with authorization to employ lethal force without human intervention, obviating the need to be large enough to surface through ice for communications, is highly unlikely to be approved by the Canadian government and the public. Thus, a more feasible option is to employ smaller UUVs alongside crewed submarines, whether nuclear or conventionally powered.

UUVs would enhance the capabilities of SSKs more so than they would SSNs. This is due to the aforementioned challenges with developing an SSK that could sail reliably under vast expanses of sea ice. By leveraging UUVs, an SSK could conceivably remain at the edge of the sea ice or under polynyas while UUVs sail ahead to survey the areas around them under thicker sea ice. This reduces the risk to the crew of the SSK in the event of an emergency surfacing and extends the time the submarine can spend deployed in the Arctic by allowing it to run its diesel engines and recharge its batteries. In the event a UUV detects an enemy submarine, the SSK can theoretically follow up and have the personnel on board authorise any necessary violent responses. Such a UUV may be carried internally in the SSK, externally like swimmer delivery vehicles, or sail for the entire duration of the deployment entirely separate from the submarine hull. Each of these options allows for different sizes of UUV, with the larger ones being able to sail farther into the ice pack ahead of the SSK.

66 Colin Clark, "South Koreans offer Aussies new subs in 7 years to close Collins gap," *Breaking Defense*, July 25, 2022, https://breakingdefense.com/2022/07/south-korea-offers-aussies-new-subs-in-7-years-to-close-collins-gap/.

67 *Royal Australian Navy*, "HMAS Collins," Royal Australian Navy, https://www.navy.gov.au/hmas-collins.

However, while this concept of operations may seem an attractive solution to the problem of putting a non-nuclear presence under Arctic ice, it also comes with at least one major issue: that of communications. While deploying a UUV with an accompanying SSK obviates the need for the UUV to surface and communicate with land personnel, it does need to communicate with the SSK either continuously or occasionally. Either of these modes would restrict how far away from the SSK the UUV can operate. Continuous communications would almost certainly require a wired method due to the many fjords, straits, and variable oceanographic conditions that are prevalent in Canada's Arctic. These conditions obstruct or degrade wireless methods like acoustic and laser, the latter of which has especially short ranges on the order of around 100 metres. The length of the wire would provide a hard limit to the UUV's range, as well as be susceptible to obstruction or damage caused by "ice jungles" (ice that have been compressed downwards into the water like stalactites in a cave) or icebergs.[68] Meanwhile, intermittent communications could see the UUV ranging farther away from the SSK to collect data before returning to the SSK to deposit its information. While this allows the UUV to operate with greater freedom, it dramatically delays the response time of the SSK due to the need for the UUV to return. This is especially problematic given SSKs' slow speeds to ensure sufficient under-ice power reserves and the much higher speeds of the likely nuclear-powered quarry. The UUV could reduce the time it takes for its data to be transferred to the SSK by docking with seabed stations, but these stations would be vulnerable to deep-drafted icebergs and their cables connecting them to the shore for communications would also be susceptible to damage by sea ice.

68 Lajeunesse and Choi, "Here There be Dragons?"

Conclusion

To acquire an Arctic under-ice capability will be no easy task. This has always been the case for Canada, but it is likely to become even more vital in the coming years.

With China's growing naval prowess pulling American and British naval resources to the Indo-Pacific region, there will be a decreasing capacity for those traditional Arctic undersea powers to track and shadow Russian submarines under the ice. Canada will likely be expected to take on that task, which is enabled by both reduced sea ice thickness and the relatively closer proximity of Russian submarines to the Canadian Arctic thanks to climate change's effects on sea ice formation.

However, options that can meet Canada's unique requirements are not simple. While nuclear-powered submarines are the obvious and most technologically mature solution, their financial and political cost (whether actual or perceived) makes them a highly unlikely option. Short of a Russian or Chinese submarine surfacing in Canadian waters to invigorate political and electorate will, a Canadian SSN would be hard-pressed to find a political champion that can carry it to fruition. Uncrewed underwater vessels offer new possibilities either on their own or in conjunction with conventional crewed submarines, but the communication challenges are very real with no obvious solution in development, drastically limiting their utility for the foreseeable future.

Ultimately, it comes down to finding that unicorn: a non-nuclear-powered crewed submarine that is large enough to have the underwater endurance and buoyancy needed to surface through ice. Rough comparisons with Canada's previous attempt to acquire SSNs suggest that there are a small number of SSKs on the market today that may approach the size necessary, providing a suitable basis for "Canadianization". The technological advancements in battery and AIP options in the coming years should make a large Arctic SSK even more plausible. However, Canada's previous attempts at acquiring new SSKs also ran into challenges, and this latest iteration is unlikely to be easy either. With Canada's three current major shipyards already busy with work through to the 2040s, Canada will likely have little choice but to buy the new vessels from foreign yards. This drastically reduces the political incentive to maintain the program on the part of government, with the risk of cancellation made ever greater due to the long timelines that are likely. Still, with Russia's conventional land forces being bogged down and potentially rendered impotent in the ongoing war in Ukraine, their naval and nuclear forces will likely become more important as an intimidation tool. Monitoring such forces will continue to be key in managing relations with Russia over the coming years.

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