

Canadian
Forces
College

Collège
des
Forces
Canadiennes



A Submarine Replacement Project For Canada

Cdr K.H. Coffen

JCSP 38

Master of Defence Studies

Disclaimer

Opinions expressed remain those of the author and do not represent Department of National Defence or Canadian Forces policy. This paper may not be used without written permission.

© Her Majesty the Queen in Right of Canada, as represented by the Minister of National Defence, 2018.

PCEMI 38

**Maîtrise en études de la
défense**

Avertissement

Les opinions exprimées n'engagent que leurs auteurs et ne reflètent aucunement des politiques du Ministère de la Défense nationale ou des Forces canadiennes. Ce papier ne peut être reproduit sans autorisation écrite.

© Sa Majesté la Reine du Chef du Canada, représentée par le ministre de la Défense nationale, 2018.

CANADIAN FORCES COLLEGE – COLLÈGE DES FORCES CANADIENNES
JCSP 38 – PCEMI 38
2011 – 2012

MASTER OF DEFENCE STUDIES – MAÎTRISE EN ÉTUDES DE LA DÉFENSE

A Submarine Replacement Project For Canada

Cdr K.H. Coffen

“This paper was written by a student attending the Canadian Forces College in fulfilment of one of the requirements of the Course of Studies. The paper is a scholastic document, and thus contains facts and opinions, which the author alone considered appropriate and correct for the subject. It does not necessarily reflect the policy or the opinion of any agency, including the Government of Canada and the Canadian Department of National Defence. This paper may not be released, quoted or copied, except with the express permission of the Canadian Department of National Defence.”

Word Count: 31,700

“La présente étude a été rédigée par un stagiaire du Collège des Forces canadiennes pour satisfaire à l'une des exigences du cours. L'étude est un document qui se rapporte au cours et contient donc des faits et des opinions que seul l'auteur considère appropriés et convenables au sujet. Elle ne reflète pas nécessairement la politique ou l'opinion d'un organisme quelconque, y compris le gouvernement du Canada et le ministère de la Défense nationale du Canada. Il est défendu de diffuser, de citer ou de reproduire cette étude sans la permission expresse du ministère de la Défense nationale.”

Compte de mots: 31,700

ABSTRACT

In Navy Strategic Guidance published 9 November 2011, then Chief of Maritime Staff VAdm Paul Maddison placed a marker for the establishment of a submarine replacement program office. This thesis aims to provide an advance look at some of the discussions that will need to take place as the replacement program office commences its work. Broadly, arguments in favour of a replacement submarine capability for Canada will hinge on three pillars. First, it must be established that the submarine capability remains relevant to Canada. Secondly, feasible options to realize this capability must be determined. Finally, an affordable option must be selected. This thesis will commence with a historical retrospective on submarines and submarine acquisition projects in Canada, and then will turn to examine each of relevancy, feasibility, and affordability in turn. This thesis will contend that the capability itself remains relevant, that there are a wide range of feasible options, and that the capability is indeed affordable, if the will exists.

TABLE OF CONTENTS

Abstract	i
List of Tables	iii
Introduction	1
Chapter 1: A SHORT HISTORY OF CANADIAN SUBMARINES	3
Chapter 2: RELEVANCY PART I: GEOPOLITICAL CONTEXT	13
Chapter 3: RELEVANCY PART II: CANADA'S MARITIME INTERESTS AND THE SUBSURFACE DIMENSION	23
Chapter 4: OPTIONS AND FEASIBILITY	36
Chapter 5: COST AND AFFORDABILITY	74
Conclusion	98

List of Tables:

Table 1: Capital Acquisition Cost of Selected Test Cases	86
Table 2: Through Life Cost Assessment of Selected Test Cases	88
Table 3: Annualized Cost of Selected Test Cases, 30 Year Asset Life	88
Table 4: Cost of Delaying Acquisition	93
Table 5: Cost Effects of Reducing Procurement Numbers	96

INTRODUCTION

Submarines are essential to any adult country that takes a serious approach to protecting its land and waters.

Senator Colin Kenny¹

Canada operates the ex-Royal Navy UPHOLDER class submarine, acquired from the UK Ministry of Defence over the period 1998-2004 and renamed the VICTORIA Class. Barring extension, these submarines are due to retire from Naval Service in the late 2020's to early 2030's, at which time they will be in the range of 30-35 years old. Navy Strategic Guidance, published in 2011, envisages the stand-up of a submarine replacement project office in the 2014-2016 timeframe.² The navies of several allies are working on their own submarine replacement programs. Australia established its SEA 1000 project office in 2008 to commence the work of defining and then building Australia's future submarine capability. Norway has begun the planning process for the replacement of its Type 210 submarines. The Netherlands has started discussions with industry on the replacement of the Walrus Class. The United Kingdom and United States are well into building the Astute and Virginia Class submarines, respectively, while France has commenced construction of its replacement Barracuda class submarines.

Arguments in favour of replacing RCN submarines with a follow on class will hinge on three essential elements: relevancy, feasibility, and affordability. This work will contend that a submarine capability continues to be relevant to Canada and that a variety of alternatives are feasible. With respect to affordability, this work will contend that even a large scale replacement program is affordable in the context of other

¹ Colin Kenny, "The Sinking of Canada's Submarine Defence: A Lot of Good Money Chasing Bad," [article on-line]; available from <http://colinkenny.ca/en/p102492>; Internet; accessed 18 June 2013.

² VAdm Paul Maddison, "Commander RCN'S Guidance FY 2012/2013 Through FY 2015/2016," 9 November 2011, 3371-1948-1 (DMSC – RDIMS 225233). DND Internal Only.

government program spending. Fundamentally however, perceptions of affordability hinge on timing and choice.

This work is structured in chapters that corresponding broadly to matters of relevancy, feasibility and affordability. Chapter 1 will provide a historical retrospective on previous Canadian submarine acquisition efforts in order to set the stage for the current discussion. Chapters 2 and 3 will discuss relevancy in the frame of Allied and Canadian geopolitical perception and the utility of a submarine capability as part of a balanced mix of Canadian Armed Forces capabilities available in response to a wide range of contingencies. Chapter 4 will discuss options and the feasible solution space, and Chapter 5 will discuss costs and affordability.

Chapter 1: **A SHORT HISTORY OF CANADIAN SUBMARINE ACQUISITION**

Canada has significant roots in submarine construction, as well as more current capability than may be apparent at first blush. The first Canadian submarines, CC1 and CC2, were procured in response to the British Columbia government's concern over potential German commerce raiding on the west coast. Shortly afterward, the Canadian Vickers yard in Montreal set to work producing H-class submarines for Russia and the United States. Although Canadian Vickers did not produce submarines after World War 2, it remained a vital yard until its demise in the mid 1980's, engaged not only in shipbuilding, but also heavy submarine construction in support of the Walrus class SSK for the Netherlands and the Los Angeles class SSN for the United States. This section will provide a brief summary of the history of submarines in Canada, including a retrospective look at Canada's previous submarine acquisition projects.

Canadian H boats

The emergence of modern submarines has been very well documented and is the subject of a large body of work which need not be repeated here. However, what is important to understand is that, at least in the North American context, both John Holland and Simon Lake are considered the fathers of the modern submarine, and that it was a company started by Holland, but not necessarily under his full control - the Electric Boat Company - that went on to become perhaps the first industrial producer of boats fit to fight, drawing off the work of both Holland and Lake. Further refinement and development of the concept led to the C-class, produced in the United States during the lead up to World War I. Two of these were bought by the government of British Columbia in 1914 and transferred almost immediately to Canadian ownership. Later, Canadian Vickers in Montreal proposed that Canada procure two or three additional

Electric Boat Company (improved C-class) submarines. Canada declined, however in November 1914 the British government contracted for 10 submarines (H-class) to be produced in the Canadian Vickers yard. All 10 were completed on time. As J. David Perkins noted in his book, *The Canadian Submarine Service in Review*, this was “an extraordinary industrial accomplishment for Canada, and much of the credit must go to the Electric Boat Company management team and the workforce at Canadian Vickers.”³ After this success, Canadian Vickers made a second proposal for the construction of two Canadian submarines, however it was again rebuffed. Canadian Vickers built 8 more submarines for the Italian navy in 1916/17.⁴

Another submarine company, the British Pacific Construction & Engineering Company, was formed by American businessman James Paterson on the Burrard Inlet near Vancouver, to create 5 submarines in kit form for delivery to Imperial Russia. At the Vancouver facility, frames and plate were fabricated, and pack-ups were assembled from components delivered by rail from Electric Boat Company suppliers throughout the United States. A further 6 kits were delivered to Russia by this company. A final six kits were assembled in Vancouver bound for Russia, but could not be delivered as a result of the Russian revolution. The kits were eventually purchased by the United States.⁵

Submarine Acquisition Projects – 1958-1967

Despite overtures from Canadian Vickers, the Government of Canada declined the purchase of submarines of its own once CC1 and CC2 were decommissioned, and Canadian Vickers moved on to building submarines for other paying customers, then

³ J. David Perkins, *The Canadian Submarine Service in Review* (St. Catherine’s ON: Vanwell Publishing Ltd, 2000), 81.

⁴ *Ibid.*, 83.

⁵ *Ibid.*

into subcontract work – building components for other submarine builders.

Consequently, for the period 1918 to 1965, the only “Canadian” submarine arm that existed was not within the RCN, but rather within the RN, where several Canadian officers and men found a home in the interwar years and during World War 2. Post war, in recognition of the requirement for Anti-Submarine Warfare proficiency training in Canada, an agreement was reached between the RN and RCN to establish the RN’s 6th Submarine Squadron in Halifax, taking some pressure off the requirement to develop an RCN submarine service. The Squadron, which ultimately saw a decade of service in Canada, was established for an initial four years with the 4 April 1955 arrival of Her Majesty’s Submarine (HMS/M) Astute in Halifax.⁶

Meanwhile the RCN investigated procurement options for its own submarines. Given the transit of USS Nautilus under the North Pole in 1955, there was particular Canadian interest in atomic propulsion. To this end, the Chief of Naval Staff (CNS), VAdm Harry DeWolf established the Nuclear Submarine Study Team (NSST) in 1958, under the leadership of RAdm Brian Spencer. The NSST report was delivered in Jun 1959 and recommended the acquisition of twelve of the US Navy’s Skipjack Class SSNs, to be purchased from US Shipyards at a notional cost of \$52.5M each, or built in Canada at a notional cost of \$65M each. However, uncertainty over the validity of the NSST estimates and concerns over the affordability and appropriateness of a Canadian SSN service led to the establishment of the Conventional Submarine Survey Committee (CSSC) in 1960 and a reduction in target from 12 to 6-9 submarines. The CSSC provided cost estimates for the Barbel and Oberon Class SSKs, at \$22M and \$11M each, respectively. In 1961 the US withdrew the Barbels from offer, and in March 1962 the Cabinet Defence Committee recommended the purchase of three Oberon

⁶ Julie Ferguson, *Through a Canadian Periscope* (Toronto: Dundurn Press, 1995), 237.

submarines from Britain. It was this endeavour that ultimately came to fruition, and the three RCN Oberon submarines were delivered between 1962 and 1967.⁷

Concurrently, separate action was underway to provide for ASW training needs on the West Coast. The result was the acquisition of two US fleet boats; HMCS Grilse was leased from the USN in 1961 and HMCS Rainbow was purchased in 1966. The acquisition had the benefit of providing RCN submariners with a close-up look at US technology as well as deepening ties with the USN submarine community. Each of these benefits was considered useful in the context of a still-possible acquisition of USN submarines, whether SSK or SSN. It also, however, created a second submarine Navy, with a completely different culture from that developing in Halifax. Once the acquisition program over and above the Oberons was put into abeyance, however, the capability atrophied. Rainbow was paid off in 1975 and with it the West coast was placed into abeyance until the arrival of HMCS VICTORIA in 2003.⁸

Submarine Acquisition Projects – 1986-Present

The Canadian Submarine Acquisition Project, or CASAP, was established in 1985 to consider alternatives for replacement of Canada's Oberon Submarines. By 1986, a source qualification document was distributed to potential Canadian Submarine builders.⁹ Seven designs were considered, of which three qualified, the German TR1700, the British Type 2400, and the Dutch Walrus.¹⁰ Interestingly the Type 2400

⁷ Paraphrased from Julie Ferguson's research as presented in *Through a Canadian Periscope*, Chapter 20, 244-252.

⁸ Paraphrased from J. David Perkin's research as presented in *The Canadian Submarine Service in Review*, 140-154.

⁹ Perkins, 155.

¹⁰ Ferguson, 306.

was the ultimate outcome of the process launched in 1985. It simply took much longer to arrive at this outcome than anyone might have thought at the outset.

It is interesting to note that very early in the life of the CASAP project office, following an introductory brief to then Minister of National Defence (MND) Erik Nielsen, the Navy and CASAP were directed to consider Nuclear submarines (SSNs). Unlike the situation in 1958 when the NSST was established, this was not the RCN's initiative, but rather that of Government. Key figures in Cabinet including the Prime Minister appeared to support the idea at least in principle. As a result, an old idea was resurrected into a new one with the blessing of the Minister of National Defence and the 1987 White Paper on Defence – *Challenge and Commitment* – was born. Several key considerations motivated the move toward nuclear submarines: a shift in Government thinking from Atlantic-focused toward the Pacific and Arctic domains, recognition that a single nuclear submarine could do the work of three diesel submarines as a result of differences in its ability to get on station for its patrols (specifically, a much higher transit speed to station and the elimination of the need for refueling stops), and an appreciation that the cost differential between nuclear and diesel-electric submarines had narrowed.¹¹ A 1988 report on this matter from the Standing Committee on National Defence quoted the Chief of Maritime Staff, VAdm Thomas, as stating that the cost differential between nuclear and diesel-electric submarines was considered to be 1.7 to 1.¹² In light of what was viewed a small, if not non-existent cost differential relative to the capability being delivered, the Assistant Deputy Minister (Materiel), Eldon Healey, quipped:

¹¹ Paraphrased from an article by the then Minister of National Defence, Perrin Beatty, "Underwater Maple Leafs," in *A New Submarine For Canada*, Wings Magazine, Special Edition 1986, pp. 8-10.

¹² Canada, "The Canadian Submarine Acquisition Project: A Report of the Standing Committee on National Defence," (Ottawa: House of Commons, 1988), 34.

...the move from being a little bit pregnant to fully pregnant, if I can use the analogy, was not very great. Mr. Neilsen [Erik Neilsen, MND prior to Beatty] made the decision that we should...look at the feasibility of acquiring fully capable nuclear submarines, which is what we did.¹³

The Canadian Maritime Industries Association, in testimony before Parliament in 1988, held that “Canadian industry is capable of manufacturing virtually all of the major components of the nuclear-powered submarines and assembling all the boats in Canada.”¹⁴ Given these factors, it seemed reasonable to pursue the option.

Notwithstanding such enthusiasm however, the Standing Committee on National Defence (SCOND) noted that the official opposition (Liberal) and NDP members rejected the idea that Canada required such submarines, whereas the Conservative members supported it.¹⁵ Much like the SCOND, public debate predictably fell into camps that either strongly supported or strongly opposed the purchase. As part of the constructive case, in addition to the MND’s points above, Dr. Harriet Critchley noted that developments in Submarine Launched Ballistic Missiles (SLBMs) between 1950 and the late 1970s had led the Soviet Navy to move its SLBM armed submarines away from the lower North Atlantic, and toward the Barents and Norwegian Seas, and the Arctic. The strategy of remaining in waters that were more difficult to access and easier to defend while holding all North American and European targets at risk was termed the “Bastion” strategy. The appropriate response in the estimation of US Defense planners, would be “Forward Maritime Defense,” by which the USN would lay contingency plans to penetrate the area with attack submarines and to deal

¹³ Ibid., 37.

¹⁴ Ibid., 52.

¹⁵ Ibid., 2.

decisively with the SSBN threat.¹⁶ RCN nuclear submarines would be able to participate in such action. Additionally, there was some concern, expressed by VAdm Thomas, the Chief of Maritime Staff of the day, that Soviet attack submarine forces, which had been built up to a level much higher than solely those required (in his estimation) to defend the Bastion, and as such posed a much greater threat than U-boats ever had to Allied sea lines of communication (SLOCs) in the event of a war.¹⁷ While the Greenland-Iceland-UK gap was closely monitored and would have posed difficulty for the Northern fleet in terms of achieving the Atlantic breakout that would be necessary as a pre-requisite to the start of a new Battle of the Atlantic, there was concern that at least some Soviet attack submarines could use the so-called “back door” to the North Atlantic, travelling from bases on the Barents and Norwegian seas, over the top of the world via the Arctic ocean, then down through the Nares Strait to the open waters of Baffin Bay and then into the Atlantic.

In terms of the contrarian case, there were several different concerns. A number of groups having interest in disarmament generally contended that nuclear propelled submarines were somehow linked to nuclear armed submarines, that possession of the capability was somehow inconsistent with Canadian values, and raised fears of a nuclear accident.¹⁸ The Liberal opposition cited concern that the acquisition would be provocative in nature rather than part of a credible deterrent to the Soviet Union,¹⁹ and the Ministers of Finance and External Affairs were reported to be opposed on financial

¹⁶ VAdm C. M. Thomas, “A Maritime Response in Three Oceans,” in William J. Yost (ed.), *In Defence of Canada’s Oceans* (Ottawa: Conference of Defence Associations, 1988), 2.

¹⁷ Dr. W. Harriet Critchley, “From Sea Unto Sea...Unto Sea,” in Yost (ed.), 13.

¹⁸ Perkins, 158.

¹⁹ Ferguson, *Through a Canadian Periscope*, 314.

grounds and substantially the same strategic/foreign policy grounds as the Liberals.²⁰ While these arguments and the changing political situation across Russia and Eastern Europe (culminating in the fall of the Berlin Wall later in 1989) tended to weigh heavily against those elements of the constructive case for SSNs that rested on the Soviet threat, a much more important issue was on the mind of Government – the national debt. The most cogent rationale for the demise of the nuclear submarine program was contained in the April 1989 budget speech by Michael Wilson:

Only 20 years ago, Canada had no deficit, and our total debt after an entire century of Confederation was only \$18 billion. The cost of servicing our debt was well within our means... When I became Finance Minister, the \$18 billion debt had risen to nearly \$200 billion. And the annual deficit was more than \$38 billion... The interest payments on the debt are also increasing rapidly. Only 20 years ago, just 12 cents of every dollar taxpayers sent to Ottawa went to interest payments. When I became Minister of Finance, four-and-a-half years ago, that figure had already increased to 32 cents. This year, it is over 35 cents... Major reductions in program spending have been achieved. When fully implemented, these will total about \$2.5 billion a year.

...Defence spending will increase in each of the next five years, but at a slower rate than previously planned. This will yield savings of \$575 million this fiscal year and \$600 million next year. Savings over the five-year period will total \$2.7 billion. The basic parameters of the White Paper remain the defence policy of the government. In the current fiscal context, however, that policy will need to be implemented more slowly... For these reasons, the government has decided not to proceed with the acquisition of nuclear-propelled submarines. The government will immediately examine alternatives for the continued rebuilding of an effective navy, so vital to Canada's national security.²¹

Ferguson contends that there was another, precedent rationale, in the form of a Treasury Board report on the SSN project that was reviewed by the Minister of Defence, the Minister of Finance, and the Acting Prime Minister that concluded that the

²⁰ There is mention of this in Ferguson, 310, and from Derek Blackburn, MP in “Maritime Defence Policy – A New Democrat’s Perspective,” In Yost (ed.), 24.

²¹ Canada, “Budget 89,” Speech in the House of Commons by the Minister of Finance, 27 Apr 1989, 6.

costing presented by the SSN project was flawed and lacked an independent program analysis and concluded that the infrastructure and a few SSNs, probably five, could be had for \$8 billion.²² Doubtless this document would have been influential, but as noted above it is much more likely that the program was the victim of government austerity measures.

The closure of the SSN project after Minister Wilson's announcement did not quite signal the end for the Canadian submarine service. After a time, the Canadian Submarine Acquisition Project (CASAP) project office was closed, and a new project - Canadian Patrol Submarine Project (CPSP) was established. Following the pre-1987 roots of CASAP, the new project focused on requirements development for a diesel-electric submarine to replace the Oberons. Shortly thereafter, in 1994, the Royal Navy elected to discontinue the Type-2400 build program and decommission the four - nearly new - submarines that had been built. This was a cost savings measure intended to redirect resources toward the SSN capability. Domestically, also in 1994, a Liberal government under Jean Chretien came to power, and the CPSP project office was stood down as it appeared that approval for a replacement submarine would not be forthcoming. In its place, the Submarine Capability Life Extension project, or SCLE, was established with the sole objective of working out a deal with the RN for the Upholder acquisition. After many years of negotiation and some hesitation on the part of the Liberal government, on 6 April 1998, Canada announced the purchase of all four existing Type 2400 or Upholder class submarines from Britain, to be renamed the Victoria class. The overriding factor supporting the decision was the acquisition cost. The RN is reported to have spent \$2.28 billion to build the four Upholder class submarines, whereas the four boats were offered to Canada for \$750 million – 33 cents on the dollar. Whether or not the submarine was a match to Canada's military

²² Ferguson, *Through a Canadian Periscope*, 324.

requirement in an objective sense was less important than that it was a match to the Navy's fundamental requirement to retain a submarine capability, and to the Government's overriding requirement to do so in a fashion that was demonstrably cost effective. As a result, the Navy could be said to still be figuring out how to match the capability delivered to its mission sets, 15 years after the decision to proceed was made.

Chapter 2:
RELEVANCY PART I: GEOPOLITICAL CONTEXT

Lower probability does not automatically mean less resource, because some capabilities are inherently more costly than others.

UK Strategic Defence and Security Review, 2010²³

Coming away from a decade of counter insurgency operations in Afghanistan and Iraq, the attitude of a significant swath of Western thought is that the most likely forms of conflict moving forward will in fact be more of the same. This thought is not new. In the mid 1960's Roger Trinquier simply labeled insurgent warfare "Modern Warfare,"²⁴ and in the early 1970's Lt Gen Sir Frank Kitson, analyzed future trends in conflict against the backdrop of an essentially bipolar (or roughly balanced) nuclear world to conclude that insurgent conflicts were indeed most likely.²⁵ What is remarkable about these views, expressed as they were in an entirely different geopolitical context, is how remarkably similar they are to views that have weight some forty years later in a world where there is no longer a balance of nuclear power. However, while it may be true that the future security environment is likely to continue to be shaped by a number of non-state conflicts, the state-level strategic environment is not without risk. Therefore, at the most fundamental level of strategic planning, it could reasonably be stated that there is now tension between the "most likely" and "most dangerous" strategic futures.

²³ HM Government, *Securing Britain in an Age of Uncertainty: Strategic Defence and Security Review* (London: Her Majesty's Stationery Office, 2010), 10.

²⁴ Roger Trinquier (translated from the French by Daniel Lee), *Modern Warfare: A French View of Counter Insurgency* (London: Pall Mall Press, 1964).

²⁵ Lt Gen Sir Frank Kitson, *Low Intensity Conflict: Subversion, Insurgency, Peacekeeping* (London: Faber and Faber, 1991), Chapter 1.

Surveying the white papers of countries sharing Canada's fundamental values, it can be seen that this view is echoed by the states concerned. Australia expressed its appreciation of security futures in its white paper, *Force 2030*, as follows:

*After careful examination, it is the Government's view that it would be premature to judge that war among states, including the major powers, has been eliminated as a feature of the international system. While growing economic and other interdependencies between states will act as a brake on the resort to force between them, and high-intensity wars among the major powers are not likely over the period to 2030, such wars cannot be ruled out.*²⁶

Similarly, the United States Quadrennial Defence Review 2010 contains the following statement:

*Operations over the past eight years have stressed the ground forces disproportionately, but the future operational landscape could also portend significant long-duration air and maritime campaigns for which the U.S. Armed Forces must be prepared.*²⁷

Then Chairman of the Joint Chiefs of Staff, Admiral Mike Mullen, phrased an assessment of this dimension of the QDR this way:

*We expect to be increasingly challenged in securing and maintaining access to the global commons and must also be prepared for operations in unfamiliar conditions and environments. The QDR gives solid direction on developing capabilities that counter the proliferation of antiaccess and area-denial threats, which present an increased challenge to our maritime, air, space, and cyber forces.*²⁸

²⁶ Commonwealth of Australia, *Defending Asia in the Pacific Century, Force 2030* (Canberra: Commonwealth of Australia, 2009), p.22

²⁷ United States, *Quadrennial Defense Review Report* (Washington DC: Department of Defense, 2010), vi.

²⁸ *Ibid*, 103.

The UK assessment is somewhat differentiated from the US and Australian assessment in that the Strategic Defence and Security Review of 2010 clearly emphasizes that the priority for the UK is indeed counter terrorist operations, with Afghanistan and Northern Ireland singled out for mention. With respect to preparation for conventional state on state conflict, the SDSR indicates that in order to:

*...respond to the low probability but very high impact risk of a large-scale military attack by another state, we will maintain our capacity to deter, including through the nuclear deterrent and by ensuring, in partnership with allies, the ability to regenerate capabilities given sufficient strategic notice. Lower probability does not automatically mean less resource, because some capabilities are inherently more costly than others.*²⁹

All three nations appear to agree that the short run prospect tends very much toward isolated ‘brush fire’ conflicts dealing generally with the attempts of political groups to gain control of a state in furtherance of their own ends. Similarly, all three agree that in many cases the intervention of the West would be considered desirable to resolve these conflicts in a way that preserves the existing international system and minimizes the human cost of the tragedy. All three, however, also agree that there is ongoing risk that one or more established state actors will act in a way that destabilizes the international system, putting economies and ultimately a way of life at risk. To mitigate against such risks, a level of capability is required. The fundamental question is what types of capabilities, and how much of each, are required? What capabilities are appropriate to the task, and what should be the size of the investment to generate them?

²⁹ HM Government, *Securing Britain in an Age of Uncertainty: Strategic Defence and Security Review* (London: Her Majesty’s Stationery Office, 2010), 10.

CANADA'S STRATEGIC SITUATION

In 1923, Canada's strategic situation was famously likened by Senator Raoul Dandurand to "living in a fireproof house."³⁰ Geopolitically, notwithstanding the Great Depression, two World Wars, the Korean War, the Cold War, the Vietnam War, the Falklands War, the invasion of Panama and Grenada, two Gulf Wars and the War on Terror, little has changed to alter this assessment. Conventional attacks on Canada, with the possible exception of an odd terrorist plot, seem unlikely. No one borders us other than the Americans, and since the relationship between British North America and the United States improved following the war of 1812, the US has posed no threat to Canadian sovereignty. In fact, US policy articulated in 1823 and thereafter known as the Monroe Doctrine provided a de-facto guarantee of stability, as it became the express policy of the United States to resist any foreign interference in the affairs of the Americas.³¹ This unique geopolitical situation drastically affects Canadian public perception of the requirement for military forces and attitude toward them. The Canadian Centre for Policy Alternatives, for example, views Canadian military expenditure through the lens of "humanitarian opportunity costs," where every dollar spent on military hardware, people, training, or employment is a dollar lost to the improvement of the human condition.³² Indeed, this view is not without merit, as dollars spent in the Defence portfolio are lost to health care and education here at home, and for the most part are lost to the types of development expenditures made by the

³⁰ Roy Rempel, *Dreamland: How Canada's Pretend Foreign Policy Has Undermined Sovereignty* (Kingston: Queen's University Press, 2006), 14.

³¹ US Department of State, "Monroe Doctrine, 1823," [article on-line]; available from <http://history.state.gov/milestones/1801-1829/monroe>; Internet; accessed 1 December 2013.

³² Bill Robinson, "Canadian Military Spending 2010-2011," Canadian Centre for Policy Alternatives Foreign Policy Series, March 2011, [article on-line]; available from <http://www.policyalternatives.ca/sites/default/files/uploads/publications/National%20Office/2011/03/Canadian%20Military%20Spending%202010.pdf>; Internet; accessed 20 February 2012.

Canadian International Development Agency, which is still underfunded relative to the presumptive UN development contribution of 0.7% GDP.³³

Inside the Government, however, there is recognition of what R.J. Sutherland once termed the corollary to the Involuntary American guarantee³⁴ – that providing forces sufficient for the defence of Canada is one of the factors influencing US disinterest in Canadian annexation, and therefore equates to an investment in sovereignty. More recent thinkers than Sutherland, notably former Canadian Minister of Foreign Affairs Lloyd Axworthy, sponsored the development and propagation the concept of the Responsibility to Protect (R2P), largely in response to unmitigated humanitarian disasters like the Rwanda massacre in 1994 and the fall of Srebrenica in 1998, either of which might have been stopped had there been willingness to commit sufficient military force to the problem.³⁵ Moving nearer to present day, since the September 11, 2001 attack on the United States, the notion of forward defence is becoming more important, where intervention in failed and failing states is becoming perhaps more likely not only on the humanitarian grounds of R2P, but also to prevent the weak or failed state from becoming, wittingly or not, a base for international terrorists. On the domestic front, in view of the significant and direct economic impact to Canada should the US border close or “thicken,” it has been a justifiable preoccupation of the Government of Canada to ensure that Canada is seen to be doing its part to provide for the security of North America, whether this means a security focus on the continent, or the commitment of forces to security and Military Assistance

³³ Organization for Economic Cooperation and Development, “History of the 0.7% ODA Target,” [article on-line]; available from <http://www.oecd.org/dac/stats/45539274.pdf>; Internet; accessed 2 February 2012.

³⁴ Robert J. Sutherland, “Canada’s Long-Term Strategic Situation,” *International Journal* 17, No. 3 (Summer, 1962), 201.

³⁵ Lloyd Axworthy, “Navigating a New World: Canada’s Global Future” (Ottawa: Random House, 2004), 157.

missions abroad. It is not difficult to understand why. In 2011 alone, \$597.4Bn in trade crossed the border in both directions, with \$35.6Bn as a raw surplus to Canada,³⁶ yet what would be the impact if the border thickened as a result of Canada being found wanting in terms of its provision for its own defence? There is, therefore, a direct relationship between defence spending and the economic health of the nation. These pressures figure prominently in the Government of Canada's National Security Policy, published in 2004.³⁷

An issue with the National Security Policy, or indeed any forward looking assessment of Defence requirements is that of latency, or the tendency to assume that future requirements correlate to those immediately past. Coming fresh off the Canadian experience in landlocked Afghanistan, the temptation exists to assume simply that conflicts from this point forward will be similar – asymmetric battles against weak states and international terrorists requiring mostly land forces, mostly participating as coalition partners in a counter insurgency effort. Such a view, however, requires nearly willful ignorance of the role of maritime and other military forces in counter insurgency and law enforcement. It has been pointed out, for example, that the first expeditionary action of the United States Navy was against piracy sponsored by weak Muslim states in the form of the Barbary pirates.³⁸ Today such action continues, although the targets of Combined Task Force 151 are now generally of Somali origin. Such a view also requires nearly willful ignorance of some of the earliest actions to secure footholds in

³⁶ United States, *Census Bureau Statistics*, [source on-line]; available from <http://www.census.gov/foreign-trade/balance/c1220.html>; Internet; accessed 22 May 2012.

³⁷ Canada, *Securing an Open Society: Canada's National Security Strategy*, (Ottawa: Privy Council Office, 2004).

³⁸ Roger W. Barnett, *Navy Strategic Culture: Why the Navy Thinks Differently* (Annapolis, MD: Naval Institute Press, 2009), 6.

Afghanistan, such as the 26th Marine Expeditionary Unit's entry into Afghanistan and airfield capture at Camp Rhino where forces from the BATAAN and PELIAU Amphibious Response Groups - supported by Canadian warships deployed on Operation Apollo - helped to pry open Afghanistan by crossing "the biggest beach the unit ever crossed,"³⁹ 500 miles inland to Afghanistan via Pakistan. The view that future conflict will be limited to asymmetric battles against non-state actors ignores a world history replete with state on state conflict where strategic success or failure hinged on a number of factors, but prime among them being control of the seas and the denial of use of the seas to the enemy. That the dawn of the era of nuclear weapons has changed the strategic calculus attached to state on state conflict is undeniable. However, what can be debated is the extent to which the strategic calculus is altered when the monopoly on the use of such weapons is lost. Would states consider conventional actions against one another when both possess a nuclear deterrent? When two powers possess nuclear capabilities, do nuclear weapons deter state on state conflict, or do they simply deter the use of nuclear weapons in such conflict? These are deep questions, and they need to be considered in the strategic planning and force postures of those nations with an interest in preserving a world free enough from conflict for people to be free.

In this vein, Andrew Krepinevich's *7 Deadly Scenarios* is excellent reading for strategic planners, and a useful extrapolation of some of the current instabilities in the world order to provide food for thought in terms of the 'what if?'⁴⁰ An interesting case

³⁹ LCol Jerome Lymes, CO of the 26th MEU quoted in Jim Garamone, "U.S. Marines Return From Afghanistan Tour," American Forces Press Services, 18 April 2002, [article on-line]; available from <http://www.defense.gov/News/NewsArticle.aspx?ID=44153>; Internet; accessed 23 February 2012.

⁴⁰ Andrew F. Krepinevich, *7 Deadly Scenarios* (New York: Bantam Books, 2009).

in point is that of Iran, which in 2012 was threatening to close the Strait of Hormuz.⁴¹ According to the US Energy Information Administration, in 2011 the Strait of Hormuz carried 17 Million barrels per day of oil, or 35% of the world's seaborne traded oil, and 20% of all traded oil worldwide. Eighty-five percent of this oil is destined for markets in Asia.⁴² Much like Egypt's threat to close the Suez canal in the 1950's, it seems likely that action by Iran would prompt an immediate international response.⁴³ It could be argued that Iran has good reason to refrain from such action given the probability of response, but what if Iran were armed with nuclear weapons? How would the strategic calculus be altered?

China's ascendancy is another interesting case. It could be argued that there was more reason to worry, perhaps, while Mao was alive than there is today. Certainly the shift from an arguably evangelical and expansionist form of communism under Mao to a secular and pragmatic form under Deng Xiaopeng⁴⁴ and his successors has been noted and welcomed in the West, yet China has interests in the Pacific that are opposed to one degree or another by her neighbours and by the allies of her neighbours, not the

⁴¹ David Blair, "Iran Threatens to Close Strait of Hormuz over EU Oil Sanctions," The Telegraph, 23 January 2012, [journal on-line]; available from <http://www.telegraph.co.uk/news/worldnews/middleeast/iran/9032948/Iran-threatens-to-close-Strait-of-Hormuz-over-EU-oil-sanctions.html>; Internet; accessed 20 February 2012.

⁴² US Energy Information Administration, *World Oil Transit Chokepoints*, (Washington: US Energy Information Administration, 2011), [source on-line]; available from <http://www.eia.gov/countries/regions-topics.cfm?fips=WOTC#hormuz>; Internet; accessed 20 February 2012.

⁴³ Elisabeth Bumiller, Eric Schmitt and Thom Shanker, "US Sends Top Iranian Leader a Warning on Strait Threat," The New York Times, 12 January 2012 [article on-line]; available from http://www.nytimes.com/2012/01/13/world/middleeast/us-warns-top-iran-leader-not-to-shut-strait-of-hormuz.html?_r=1; Internet; accessed 20 February 2012.

⁴⁴ With respect to Communism as a form of government, Deng was famously quoted in 1961 to say something that loosely translates as "...whether a cat is black or white makes no difference. If it catches mice, it is a good cat." The cat, in this case, is the form of government. The mice could be held to be prosperity. Whether democracy is represented by black or white is for the reader to decide.

least of which is the interest in the assimilation, forced or otherwise, of Taiwan. From a strategic perspective, it is important to note that a Chinese military buildup is underway. Over the past decade, China's military spending has risen by an estimated (inflation adjusted) 9.7% per year.⁴⁵ China has been increasingly assertive, harassing US Navy vessels in contested waters,⁴⁶ and surfacing a submarine within visual range of a USN aircraft carrier.⁴⁷ While Chinese military strategists study so-called Assassin's Mace⁴⁸ and Anti-Access/Area Denial (A2AD) tactics,⁴⁹ the government appears to have largely carried on with Comrade Deng's plan, and concentrates on the wealth of the country and its people. This concentration does, however, have some worrisome undertones in terms of Chinese territorial claims and behavior. Further abroad, China has been working on establishing international relationships in an effort to secure access to resources, while contesting claims of other nations in the Arctic and elsewhere. The implications of Chinese behavior to the world order are unclear.

So how does the Canadian view, most recently expressed in the Canada First Defence Strategy of 2008, compare to the views of the United States, the United Kingdom and Australia? Very simply, it does capture the reality that it is too early to call an end to state on state conflict. Much like the UK thinking, terrorist risks are at the forefront, but that does not mean that the entire suite of Canadian Forces

⁴⁵ United States Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China* (Washington: Department of Defense, 2013), 45.

⁴⁶ David Morgan, "US Says Chinese Vessels Harrassed Navy Ship," Washington, Reuters, 9 March 2009 [article on-line]; available from <http://www.reuters.com/article/2009/03/09/us-usa-china-navy-idUSTRE52845A20090309>; Internet; accessed 12 February 2012.

⁴⁷ Matthew Hickley, "The Uninvited Guest: Chinese Sub Pops Up in the Middle of US Navy Exercise, Leaving Military Chiefs Red Faced," Daily Mail, 10 Nov 2007 [article on-line]; available from <http://www.dailymail.co.uk/news/article-492804/The-uninvited-guest-Chinese-sub-pops-middle-U-S-Navy-exercise-leaving-military-chiefs-red-faced.html>; Internet; accessed 12 February 2012.

⁴⁸ Krepinevich, 169.

⁴⁹ US SecDef Report on China (see note 17), 32.

capabilities will be aimed at counter insurgency, as there are capabilities required to respond to contingencies that occur without strategic warning.

The proliferation of advanced weapons and the potential emergence of new, nuclear-capable adversarial states headed by unpredictable regimes are particularly worrisome, as is the pernicious influence of Islamist militants in key regions. The ongoing buildup of conventional forces in Asia Pacific countries is another trend that may have a significant impact on international stability in coming years.⁵⁰

Even this statement, acknowledging the China and Iran contingent threats if not by name, fails to capture other contingencies such as recent events in Libya and the Ukraine. Noting the presence of significant pressures and threats to the world order and Canada's place in it, another issue that should affect Canada's strategic calculus is the time required to generate and field effective military capabilities. How long does it take to build complex military platforms such as fighters, submarines, and ships? Once made, how long does it take to train people to use this equipment proficiently, and then to command operations proficiently? At a very fundamental level, it could be said that if the nation does not possess capabilities on the first day a contingency strikes, it may not possess them for the duration. The enduring nature of the conflict in Afghanistan offered an opportunity to close capability gaps, but not without drawing criticism for procurement process shortcuts,⁵¹ and not without leaving the soldiers deployed there without capabilities that they arguably should no have lacked when the crisis struck. While the Canadian "house" may be fairly fireproof, the "city" we live in is not. It certainly should not be the policy of the Government of Canada to wait until the city is burning to start construction on the fire hall.

⁵⁰ Canada, *Canada First Defence Strategy* (Ottawa: National Defence, 2008), 6.

⁵¹ Canada, *Fall 2009 Report of the Auditor General of Canada to the House of Commons* (Ottawa: Office of the Auditor General, 2009), Chapter 5.

Chapter 3:
RELEVANCY PART II: CANADA'S MARITIME INTERESTS AND THE
SUBSURFACE DIMENSION

While the last chapter was somewhat broader in focus, this one will narrow down from the maritime domain to the submarine dimension of the maritime domain, and from what might happen to what has happened. First, some selected examples of historic and modern submarine missions will be discussed in order to show how the capability can be used. Then, specifically with respect to the Canadian context, linkages will be made between submarine missions and the Canada First Defence Strategy. Finally, theoretical constructs developed by Canadian authors to explain the relevancy of submarines to Canadians will be highlighted.

When initially conceived, the submarine was intended to deliver underwater explosive charges onto the hulls of enemy ships without being detected. Less than 150 years ago, in 1864, the Confederate States of America made use of CSS Hunley in this fashion to sink USS Housatonic in waters off Charleston, South Carolina.⁵² Some thirty years later, John Holland was to develop a submarine for the Fenian Brotherhood, and later, several for the US Navy, whose contracts and the involvement of other key leaders eventually gave rise to the Electric Boat Company.⁵³ Later the Germans recognized the platform's value as a commerce raider, and employed it in this role during World War I, and again to greater effect in World War II. The effectiveness of

⁵² Naval History and Heritage Command, "H.L. Hunley, Confederate Submarine," [article on-line]; available from <http://www.history.navy.mil/branches/org12-3.htm>; Internet; accessed 12 February 2012.

⁵³ Edward C. Whitman, *John Holland: Father of the Modern Submarine*, Undersea Warfare, Summer 2003 [article on-line]; Internet, http://www.navy.mil/navydata/cno/n87/usw/issue_19/holland.htm, accessed 12 February 2012.

German submarines in disrupting Allied Supply lines during the Battle of the Atlantic was so great that Winston Churchill himself stated that “the only thing that ever really frightened me during the war was the U-boat peril.”⁵⁴ Drawing from hard lessons learned from the Battle of the Atlantic, the Allies employed similar tactics during portions in the Pacific to choke off vital oil and rubber supplies to Japan.⁵⁵

It was not only combat effectiveness that made submarines useful, however. By the middle of World War II the range, endurance and stealth of submarines were becoming considerable, giving rise to alternative missions such as the insertion and extraction of covert agents, direct intelligence gathering in the form of imagery and signals intelligence, deceptive operations, and combat search and rescue, to name a few. Two famous and noteworthy non-combat submarine missions during World War II were the Royal Navy’s Operation Mincemeat in the Mediterranean,⁵⁶ and the US Navy’s rescue of a young pilot and later President named George H.W. Bush in the Pacific during a Combat Search and Rescue (CSAR) mission.⁵⁷ After World War II, the US - having developed both nuclear power and nuclear weapons – integrated first

⁵⁴ Winston Churchill, *The Second World War: Volume II – Their Finest Hour*, (London: Penguin Books, 1985 (reprinted)), p. 259.

⁵⁵ With reference to RN and USN adoption of the tactic of unrestricted submarine warfare, evidence presented at the Nuremberg trial of Grand Admiral Doenitz including the direct testimony of Admiral Chester Nimitz indicated that both navies had used this tactic in contravention of the Naval Protocol of 1936, leading to the Nuremberg trial declining to sentence Doenitz for this breach of international law, from -----, “Judgment: Doenitz,” [article on-line]; available from, <http://avalon.law.yale.edu/imt/juddoeni.asp>; Internet; accessed 12 February 2012.

⁵⁶ Ben MacIntyre, *Operation Mincemeat: How a Dead Man and a Bizarre Plan Fooled the Nazis and Assured an Allied Victory* (New York: Harmony Books, 2010).

⁵⁷ Naval History and Heritage Command, “Biographies in History: Lieutenant Junior Grade George Bush, USNR,” [article on-line]; available from <http://www.history.navy.mil/faqs/faq10-1.htm>; Internet; accessed 12 February 2012.

one and then the other into its submarines, yielding USS Nautilus in 1955,⁵⁸ and USS George Washington in 1959.⁵⁹ Submarines that were capable of so-called ‘special’ missions were then built or adapted for purpose. USS Halibut and USS Parche, for example, participated in a covert mission to fit a listening device on a Russian undersea communication cable in the Sea of Okhotsk, codenamed Operation Ivy Bells.⁶⁰

Additionally, the USN built NR-1, a miniature deep-diving nuclear powered submarine capable of ‘driving’ on the ocean floor, equipped with viewports and robotic arms, and capable of a variety of scientific, military, or covert operations that are alluded to in a replacement options report prepared by the RAND corporation.⁶¹ The Royal Navy, as has recently come to light, modified HMS Conqueror to capture Russian Towed Array Sonars during the Cold War.⁶² Still more recently, with the development of the cruise missile, as well as advanced technology for surveillance, submarines have become popular choices for intelligence gathering and joint fire support missions. Modern submarines, both conventionally powered and nuclear, are

⁵⁸ Naval History and Heritage Command, “USS Nautilus Pamphlet,” seemingly from the 1950’s, scanned and preserved [source on-line]; available at <http://www.history.navy.mil/Special%20Highlights/Nautilus/pamphlet.htm>; Internet; accessed 12 February 2012.

⁵⁹ Jessica Taylor, “USS George Washington: The Nation’s First Boomer,” *Undersea Warfare*, Issue 39, Winter 2000, [article on-line]; available from http://www.navy.mil/navydata/cno/n87/usw/usw_winter_09/george.html; Internet; accessed 12 February 2012.

⁶⁰ Special Operations.com Feature, “Operation Ivy Bells,” [article on-line]; available from <http://www.specialoperations.com/Operations/ivybells.html>; Internet; accessed 3 Nov 2012. Also see Sherry Sontag and Christopher Drew, *Blind Man’s Bluff: The Untold Story of American Submarine Espionage* (New York: Public Affairs, 1998).

⁶¹ Frank W. Lacroix, Robert W. Button, Stuart E. Johnson and John R. Wise. *A Concept of Operations for a New Deep-Diving Submarine* (Santa Monica, CA: RAND Corporation, 2002), Chapter 4.

⁶² Stuart Prebble, *Secrets of the Conqueror* (London: Faber and Faber, 2012).

generally capable of conducting any or all of the missions noted above, sometimes concurrently, and often at great distances from home.

MODERN SUBMARINE MISSIONS

Recalling that the strategic reviews presented in Chapter 1 noted tension between the “most likely” and “most dangerous” futures and that certain high end capabilities were being retained essentially as risk mitigation against those “most dangerous” futures, a review of open source literature on submarine missions may shed some light on the applicability of submarines to the task of risk mitigation. There have been several international crises involving submarine deployment both during and since the Cold War period. One of the most commonly cited examples of the utility of submarines is the Falklands War of 1982. As tensions between Argentina and Great Britain flared, Great Britain deployed a number of naval assets to the islands, as well as several civilian ships called up as troop carriers. Five nuclear submarines and one diesel submarine were deployed to the Falklands, with orders to enforce an exclusion zone around the Falklands and defend British surface forces. In order to carry out these orders, the submarines tracked and identified all shipping activity in the area and actively searched for the Argentinean submarines San Luis, Santa Fe and Santiago del Estero.⁶³ An important window into this operation was released by the UK Ministry of Defence in 2012, in the form of a previously classified Secret “Record of Proceedings” for HMS Conqueror.⁶⁴ The key moment in the campaign from the point of view of

⁶³ LCDR Stephen R. Harper, “Submarine Operations During the Falklands War,” US Naval War College Rhode Island, 1994, [article on-line]; available from www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA279554; Internet; accessed 10 December 2013.

⁶⁴ HMS Conqueror, *Op Corporate: Record of Proceedings*, [source on-line]; available from <https://www.gov.uk/government/publications/hms-conqueror-op-corporate-report-of-proceedings>; Internet; accessed 20 September 2012. Part 2 covers the sinking of the Belgrano and Conqueror’s subsequent evasion. Part 3 deals with an effort to locate and destroy other surface ships from Argentinian Task Group 79.3 after the SAR mission to rescue Belgrano survivors concluded.

Argentinean surface forces was when HMS Conqueror, having been authorized to engage Argentinean warships in or near the exclusion zone, sank the General Belgrano. While the sinking was a somewhat ignominious end for a light cruiser with a storied World War II history (as USS Phoenix prior to decommissioning and sale to Argentina), it represented a turning point in the conflict and the essential end of Argentinean naval participation in the conflict.⁶⁵ Conversely, the threat of Argentinean submarines tied down RN capability in the search effort.⁶⁶

Moving forward a decade, to 1991, and the First Gulf War, one of the key elements of the “shock and awe” strategy espoused by General Schwartzkopf was over 1000 strikes from the air, not by bombers or fighter/bombers, but by Tomahawk land attack missiles. On 19 January 1991, USS Louisville became the first submarine in history to launch a Tomahawk Land Attack Missile against an undisclosed target while submerged in the Red Sea.⁶⁷ Many more such firings followed.

Moving forward again to the conflict in the Balkan conflict of the late 1990’s, submarines were deployed into the Adriatic in a variety of roles. To date, little has been written on the submarine dimension of these missions. Nevertheless, there are some tantalizing hints available from public sources. For example, the Dutch submarine *Zwaardvis* suffered atmospheric contamination while in the Adriatic in 1994,⁶⁸ however details of why she was there are not available. The US Navy, on one of its own websites, mentions that:

⁶⁵ Admiral Sandy Woodward, “One Hundred Days: The Memoirs of the Falklands Battle Group Commander,” (Annapolis, MD: Naval Institute Press, 1992), 164.

⁶⁶ Harper, 18.

⁶⁷ Naval History and Heritage Command, “US Navy in Desert Shield/Desert Storm War Chronology, January 1991,” [article on-line]; available from <http://www.history.navy.mil/wars/dstorm/dsjan2.htm>; Internet; accessed 20 September 2012.

⁶⁸ _____, “Zwaardvis CO2 Poisoning,” [article on-line]; available from http://www.dutchsubmarines.com/pictures/pictures_zwaardvis2_co_%20poisoning_1994.htm; Internet; accessed 20 September 2012.

*...SSNs comprise a surprisingly high percentage of the total Tomahawk capability in each U.S. Battle Group (about 20 percent) and launched approximately 25% of all Tomahawks during the Kosovo conflict. Their capabilities as submarines were also critical to their ability to provide sustained presence and conduct critical surveillance prior to the conflict and to surge to the Adriatic Sea with other naval forces when hostilities commenced.*⁶⁹

Moving forward again to present day, submarines are rumoured to be deployed along the coast of the failed state of Somalia in an effort to deter and disrupt pirate activity.⁷⁰ In conjunction with more visible ‘law and order’ forces, particularly the ships of CTF 150, the EU Naval Forces assigned to operation Atalanta, and NATO forces assigned to Operation Ocean Shield (TF-508),⁷¹ these forces (along with the establishment of best practices for merchant shipping in the area and the use of armed security companies onboard some of the ships) have been very successful in countering the pirate threat, whereas in 2009-2011 there were over 800 confirmed pirate attacks and suspicious incidents in the area resulting in the pirating of 118 ships, in 2012 there were only 108 attacks and suspicious events resulting in the pirating of only 5 ships. Up to December 7, for calendar year 2013, there have been 24 incidents, only 6 of which were confirmed as pirate attacks, and no ships have been taken.⁷²

⁶⁹ US Navy Submarine Warfare Division, “Submarine Themes: Submarine Innovation,” [source on-line]; available from <http://www.navy.mil/navydata/cno/n87/themes/subinno.html#InnoFuture1>; Internet; accessed 20 September 2012.

⁷⁰ See the Blog - Information Dissemination, “Another Dutch Sub to Horn of Africa,” available from <http://www.informationdissemination.net/2012/01/another-dutch-sub-to-horn-of-africa.html>. As a source of rumour, this item will not be formally referenced.

⁷¹ One open source example of commentary on these forces is _____, “EU NAVFOR, NATO and CTF151 to Enhance Counterpiracy Cooperation,” [article on-line]; available from <http://worldmaritimeneeds.com/archives/64081/>; Internet; accessed 20 September 2012.

⁷² EU Naval Forces, “Key Facts and Figures, EU Naval Force Somalia, Operation Atalanta,” [source on-line]; available from <http://eunavfor.eu/key-facts-and-figures/>; Internet; accessed 7 December 2013.

Narrowing the focus to Canadian submarines, it was noted in Chapter 1 that the initial *raison d'être* of RCN submarine forces – following an abortive attempt to acquire 12 nuclear submarines – was to support RCN and allied anti-submarine warfare training. Why? Ken Hansen has recently put this into perspective.⁷³ In the first instance, it takes time to develop proficiency, and certainly Mr. Hansen makes the point that a dear price was paid in the early days of the Battle of the Atlantic for a lack of proficiency. While world geopolitics may have changed over the past 70 years or so, the effect of a lack of proficiency has not. The threat posed to surface ships by hostile submarines is real, as South Korea witnessed in the sinking of ROKS Cheonan in 2010.⁷⁴ As the threat is real, the requirement for proficiency training is also real – and there is no better way to learn than by doing. The Western world has simply been fortunate that the conflict scenarios of the past several decades have not involved an opponent with a high-end submarine capability, a strategic motive, and the will to attempt the destruction of Allied naval forces in the area. For those readers who may be dismissive of this as a scenario, it is useful to read some of the operational analysis following the Falklands war, where the point is made that the Argentinian Naval objective should have been the sinking of one of the two British aircraft carriers operating in the vicinity of the Malvinas.⁷⁵ Recalling the discussion in Chapter 2, it may be useful also to consider whether Iran, in attempting to close the Strait of Hormuz as she has threatened to do in the recent past, would not choose to target a USN carrier;

⁷³ Ken Hansen, “More Criticism ‘Surfaces’ of Byers-Webb Report on Submarines,” *Naval Review*, August 2013 [journal on-line]; available from <http://www.navalreview.ca/2013/08/more-criticism-surfaces-of-byers-webb-report-on-submarines/>; Internet; accessed 7 December 2013.

⁷⁴ Choe Sang-Hun, “South Korea Publicly Blames the North for Ship Sinking,” *New York Times*, 19 May 2010, [article on-line]; available from http://www.nytimes.com/2010/05/20/world/asia/20korea.html?pagewanted=1&_r=0&ref=global-home; Internet; accessed 13 Apr 15.

⁷⁵ Harper, 21.

or whether China, if she committed to an invasion of Taiwan, would not do likewise. ASW training and proficiency remains as real and as vital a rationale for the possession of submarine forces as at any time in the last 60 years of submarines in Canada.

The Canada First Defence Strategy identifies the three essential contexts that the Canadian Armed Forces are expected to operate in: Defending Canada, Defending North America, and Contributing to International Peace and Security.⁷⁶ RCN submarines contribute to all three of these today, and have contributed in the recent past. To “Defend Canada,” RCN submarines are more than capable of conducting a variety of surveillance missions to ensure that smugglers, lawbreakers, and terrorists are quite literally “on the radar” of the Naval commanders responsible for Canada’s ocean areas and the shorelines they cover. For instance, Dr. Sean Maloney noted the participation of RCN Oberon class submarines in Operation Ambuscade, a fisheries protection operation conducted for the Department of Fisheries and Oceans.⁷⁷ Commander Michael Craven noted Operation Jaggy, a counter drug operation conducted for the Office of the Solicitor General.⁷⁸ In both of these instances, covert surveillance is what made the difference. It is covert surveillance that has the greatest chance of catching offenders in the act. It is covert surveillance that permits the collection of vital photographic evidence even as offenders, becoming aware of an impending interception by surface forces, attempt to destroy evidence. In higher-end scenarios, for instance a case where a vessel of interest suspected to be carrying a weapon of mass destruction is headed toward Canada, submarines can be deployed covertly to support an overt interdiction operation as the quintessential “goaltender.” If

⁷⁶ Canada, *Canada First Defence Strategy*, (Ottawa: National Defence, 2008).

⁷⁷ Sean M. Maloney, “Canadian Subs Protect Fisheries,” *United States Naval Institute Proceedings Magazine*, March 1998, vol 124/3/1,141, [article on-line]; available from <http://www.usni.org/print/8648>; Internet; accessed 29 October 2013.

⁷⁸ Cdr Michael Craven, “A Rational Choice Revisited – Submarine Capability in a Transformational Era,” *Canadian Military Journal*, Winter 2006-2007, pp. 21-32.

the boarding is repelled, the boarding party killed or taken, or if the boarding party's ship is attacked and disabled (for instance by the use of Man Portable Air Defence Systems (or so-called shoulder-launched missiles) from the deck of an otherwise unarmed vessel), the submarine can ensure that the vessel of interest never reaches Canadian shores. These types of missions apply equally well to the Defence of North America, where it would be possible for a submarine operating with permission under a joint Canada-US command structure to provide the same service to the United States within an appropriate legal framework. It is interesting then that NORAD has extended its role over the last few years into surveillance of the maritime approaches to North America.⁷⁹ Also in the wider context of Defence of North America, the RCN has deployed submarines to the "War on Drugs"⁸⁰ in an effort to stem the flow of illicit drugs northward from South America. The last of the Canadian Armed Forces roles, "Contribute to International Peace and Security" could be looked at in several different ways. By assisting with the preparation of forces deploying into potentially hostile operational zones, RCN submarines are performing a service vital to International Peace and Security, which is to provide training that ensures that allied forces are prepared for what they will face on deployment. Similarly, RCN submarines could themselves be deployed on missions in the service of International Peace and Security. In this, several different mission profiles could be assigned. First and foremost, submarines can be deployed to provide security for deployed surface forces. Such security can be provided for in two ways – first by advance intelligence gathering, and secondly by clearing areas to be occupied by the surface forces and/or by screening

⁷⁹ LGen Tom Lawson, Capt Michael Sawler, "NORAD in 2012 – Ever Evolving, Forever Relevant," Canadian Military Journal, Vol. 12 No. 3, Summer 2012, 12-14.

⁸⁰ Canada, "Minister MacKay Congratulates Crews for Their Role in Multi-National Counter-Drug Operation," Press Release 14 Nov 2013, [source on-line]; available from http://marketwired.com/printer_friendly?id=1586567; Internet; accessed 29 Oct 2013.

such forces against hostile action. While currently most of the operational areas where such a scenario might be envisioned are quite distant from Canadian shores, it is reasonable to assume that a Combined operation would initially assign the submarine forces of an ally to these roles, and that RCN submarines would provide relief on station when they arrive.

These are, of course, very tactical considerations, and Dr. Paul Mitchell has written at least two articles that offer pause from the tactical level, and encourage observers to think about the capability more strategically. He noted that, by virtue of stealth, submarines can:

...operate in a state's backyard, unsupported and in the face of opposing sea control efforts; conduct politically unobtrusive operations in forward areas; be inserted for a wide range of operational tasks (intelligence indication and warning, special operations); and conduct a wide range of operations with a high degree of survivability.⁸¹

Similarly, Commander Michael Craven prepared an excellent 2006 article for the Canadian Military Journal in which he posited four enabling features by which Canadian submarines achieve their effects at home and abroad – strategic impact, balance, sovereignty/surveillance and non-combat capability. Much like Dr. Mitchell, Cdr Craven noted that submarines can be assigned to mission either covertly, which can be important to position capabilities or conduct missions without risk of escalation, or they can be assigned (or not assigned) overtly, when the intention is to deter a potential opponent from deploying forces. An interesting example of overt assignment was the filing of a Notice of Intention for a submarine to operate off the Grand Banks during the so-called “Turbot War,” a diplomatic spat over fishing rights with Spain in the mid 90’s. It was ultimately unnecessary to deploy a submarine, all that was necessary to

⁸¹ Dr. Paul T. Mitchell, “Submarines and Canadian Security: Tactical Perspectives and Strategic Rationales,” [article on-line]; available from <http://www.canadianmilitaryhistory.ca/submarines-and-canadian-security-tactical-perspectives-strategic-rationales-by-paul-t-mitchell/>; Internet; accessed 9 December 2013.

change the character of the little spat and deter a publicly announced deployment of a Spanish frigate into the area was for Canada to seem to be preparing to deploy a submarine. The other strategic impact revolves around the closure of waterways, which can be done ‘on paper’ through the declaration of an exclusion zone or the imposition of a trade embargo of one form or another by governments or governmental organizations – or in reality through the deployment of naval assets including submarines to the area. Given the dependence of most nations on maritime trade, this is a common disciplinary tactic used by the United Nations against errant nations, with the former Yugoslavia, Iran, Iraq, North Korea and Libya all finding themselves subjected to such measures in the past decades. Balance refers to the ability of submarines to ‘round out’ naval capabilities such that RCN operational commanders, might have situational awareness that includes the subsea dimension; and might on the basis of experience in the command, control and coordination of their own submarine forces be credibly entrusted with the command of Combined Forces that include a submarine component. This should be important to the RCN given aspirations explicitly stated in *Securing Canada’s Ocean Frontiers: Charting the Course From Leadmark*, to prepare officers to lead Combined operations.⁸² In sovereignty/surveillance, Commander Craven highlighted again the covert nature of the submarine and its ability to monitor maritime activity without worrying about the creation of ‘observer bias.’ If one does not realize they are being observed, they tend to go about their business without attempts to mask their activities. In the case of legal activity there is no concern, however in the case of illegal activity, it provides an opportunity for a submarine to collect evidence that other air or naval assets cannot.

⁸² Canada, *Securing Canada’s Ocean Frontiers: Charting the Course From Leadmark*, (Ottawa: National Defence, 2005), 24.

Returning to Dr. Mitchell, we find the ‘so what’ for these capabilities. Dr. Mitchell identified three roles that ascribe more or less naturally to submarines: Strategic Conventional Deterrence, Intelligence Collection, and Operational Support.⁸³ All of the mission profiles and tactical level discussion of what RCN and other submarines have done above can be linked to one or the other of these roles. Therefore, this framework provides a very good rationale for what it is, exactly, that submarines (SSK or SSN) bring to the table in the Canadian context.

Whether the intent is to establish control of an area, to operate within an otherwise denied area, to hold down enemy forces, to shield friendly forces, to conduct reconnaissance, to insert and extract special forces, or to conduct strike missions against selected hostile targets at sea and ashore, the submarine has demonstrated in several instances since the Cold War ended that it is a valuable tool of stabilization, and that together with other balanced and combat capable forces, submarine forces are a powerful weapon in the arsenal of democracy. Even if ‘all’ that Canadian submarines were doing was preparation of RCN and USN forces for deployment into areas where there may be hostile SSKs; it would be rationale enough to have the capability here on the basis of what Dr. Mitchell calls ‘operational support.’ But that is not all submarines can do, particularly when equipped with advanced intelligence gathering equipment, when working jointly with special operations forces, when armed with missiles that can strike targets at sea or ashore with little or no warning, and/or when deployed into an operational area as a Vanguard element of a larger force. Any RCN Maritime Component Commander who aspires to command a Combined contingency task force needs to understand these capabilities implicitly and should not expect to be afforded the opportunity if he or she has not previously commanded formations that included

⁸³ Mitchell, “Submarines and Canadian Security: Tactical Perspectives and Strategic Rationales.”

submarines. All of these issues together form a part of the rationale supporting the relevancy of a submarine capability in Canada.

Chapter 4

OPTIONS AND FEASIBILITY

While the U.S. Navy does not have a requirement for diesel submarines, we do not object to U.S. industry participation in the diesel submarine market⁸⁴

Options can be grouped in different ways, but for the purposes of this discussion both Nuclear propelled (SSN) and Diesel Electric (SSK) submarine options will be considered. Within each of these major headings there are many subordinate ones relating to individual builders of Military off the Shelf (MOTS) submarines and approaches that may be taken if a decision is made not to pursue a MOTS design in favour of a more bespoke Canadian-designed SSN or SSK. Also the question of whether a replacement submarine should be built – domestically or offshore – must be considered. If the decision to build domestically is undertaken, then the potential relationship between this project and the National Shipbuilding Procurement Strategy should also be considered.

While the RCN may be reticent to re-engage the Department or the Government in a discussion on SSNs for the simple reason that this matter has been discussed twice before at the Cabinet level with no tangible results, to presume that a third initiative cannot get off the ground is somewhat fatalistic and may deprive the nation of an opportunity to achieve a significantly more flexible capability at nominal added cost.

MOTS SSKs may appear attractive at first blush, but in all cases they will involve tradeoffs on capabilities, and they may deprive Canada of the ability to collaborate closely with the United States for the combat systems suite. This would probably reduce capability, and would certainly reduce interoperability and supportability. A Canadian-designed SSK may offer some interesting advantages from

⁸⁴ Jim Mann, “US Promised Subs to Taiwan it Doesn’t Have,” LA Times, 15 July 2001.

the point of view of meeting Canadian performance requirements, but the involvement of any nation other than the United States would likely generate the same issue in terms of the ability to collaborate with the US for the combat systems suite. With respect to domestic or offshore production, offshore options promise lower cost and higher quality, but would complicate the business of fitting out US-origin Combat Systems to the point that either the use of US-origin systems is minimized or additional cost and delay are incurred to deliver the submarine minus its fighting capability and fit it out in Canada. The capacity of offshore yards may also be an issue. Domestic build can be attractive to the Government because of job creation, however costs are likely to be higher due to the requirement for investment in submarine construction facilities and quality is likely to be lower until personnel in the new submarine shipyard(s) gain experience. Additionally the utility of domestic production would have to be questioned absent the integration of submarines into a coherent defence industrial strategy to ensure that a national capability generated at great expense is not allowed to atrophy from neglect.

OPTIONS FOR CANADA: SSN

It was noted in previously that in both the first and second instances of Canada mounting serious effort toward the procurement of submarines, nuclear boats were recommended and pursued without success. The second instance, having as it did the qualified support of Government, and particularly two successive Ministers of Defence, came much closer to delivering this capability. While the Soviet Union may be gone and the Cold War ended, nothing has changed with respect to Canada's physical position on the globe. We are blessed to be within the Monroe Doctrine, and to be at the 'bottom' of three oceans that offer the protection of nearly impenetrable strategic depth. This isolation can be a two edged sword however. While we are relatively well protected against all but the highest end (Intercontinental Ballistic Missiles) and lowest

end (backpack bomber or knife wielding lunatic) threats, we are also very far away from most places where we might propose to employ our forces, and the general trend since the end of the Cold War has been – perhaps surprisingly – toward more, rather than less, regional conflict. In many instances, whether for the purpose of stabilizing the region so as to stabilize the international system, or for altruistic rationales associated with the philosophy of the Responsibility to Protect, Canada will choose to intervene in these conflicts. The Minister of National Defence was quoted in 2012 as saying nuclear submarines would be the solution for Canada “in an ideal world.”⁸⁵ Perhaps this is a misstatement, since in an ideal world there would be no requirement for high end military capabilities. However, this is not an ideal world. In fact, as noted in Chapter 2, this is a world in which there are some relatively fundamental and ever-present threats to the established world order.

Assuming that Canada wishes to retain the capability to respond to worldwide contingencies that occur with little warning but that threaten the global economic system, it makes strategic sense for Canada to consider, once again, whether or not to acquire nuclear submarines. Diesel boats are a worthwhile choice for Canada, however they are subject to a number of key limitations of which the two of greatest concern are the radius of action and the transit speed. Considering that the Navy operates on the task group concept, it seems anomalous that a Canadian task group cannot be deployed with submarines in company, such that when the task group arrives in its intended Area of Operations, a submarine has already reconnoitered the area and is ready to defend the task group. The simple fact of Canada’s position on the surface of the globe requires that for this concept to be realized, Canadian submarines must either be

⁸⁵ Greg Weston, “Canada May Buy Nuclear Submarines” [article on-line]; available from <http://www.cbc.ca/news/politics/canada-may-buy-nuclear-submarines-1.1043179>; Internet; accessed 22 Oct 2012.

nuclear propelled, or must be forward deployed in order for them to arrive where needed, when needed. Otherwise, the RCN must accept a requirement to be wholly dependent on allies to provide this service for Vanguard forces, with a follow-on force potentially containing a RCN submarine. Alternatively, the RCN could choose another type of dependency, and forward deploy a submarine to a US, UK, or Australian base in the Pacific and/or the Mediterranean. This would allow RCN SSKs to reach a distant theatre of operation ahead of (or concurrently with) a RCN Task Group, but would require political agreements with the host nations and would come at some human and fiscal cost. Only the SSN avoids the kind of operational dependency that SSK forces produce by virtue of limited speed.

Another consideration is that of the Arctic and the role of submarines in carrying out sovereignty patrols there. While it is true that the ice is receding, there should be no illusions over the scale of distances in Canada's North. Short of the establishment of a significant submarine basing capability in the Arctic (and Nanisivik is not intended to be such a base), diesel-electric submarines will have difficulty getting into and out of the Canadian Arctic, even from Halifax where the journey is much shorter. This is not a question of under ice capability – it is a question of unrefueled range. In months other than July and August ice will be a factor, but even equipped with Air Independent Propulsion systems which might permit them to venture a short way under the ice, there still needs to be fuel available for the boat to get it to and from an Arctic area of operations and the submarine itself must be capable of sufficient patrol endurance to make it feasible to survey a large ocean area in a reasonable time period. On both fronts, nuclear propelled submarines are far superior in comparison to diesel-electric submarines as a platform for Canadian exercise of sovereignty over the

region. Nuclear propulsion in general is preferable, hence the presence of many nuclear propelled ships in the Arctic.⁸⁶

With respect to arguments against nuclear submarines, the issue of nuclear proliferation was raised particularly during the late 80's SSN project as a cause for the then-intended acquisition to be challenged.⁸⁷ Although this intervention was characterized by supporters of the submarine project as the confused meddling of an ill-informed group of people unable to distinguish between nuclear propulsion and nuclear weapons, the truth is somewhat deeper. The fact that most submarine reactors require the use of highly enriched uranium (HEU)⁸⁸ to achieve sufficient power density in a small reactor core means that stores of fissile material will have to be built ashore in order to sustain these reactors through their lives. While it is unlikely the submarines themselves would be attacked or compromised, the shore facilities supporting them could be could be compromised by terrorist organizations and new or spent fuel could be diverted toward a Radiological Dispersion Device (RDD). Therefore, the position of the disarmament community is that the existence of such material must be minimized, even if not employed in a weapon. Concern over other world stockpiles of HEU led the US Department of Energy to establish the Global Threat Reduction Initiative (GTRI) to reduce the risk that extremists would get their hands on radioactive material from the Cold War era, particularly that in Russia and former Eastern Bloc countries. The purpose of the GTRI is to consolidate and secure world supplies of Highly Enriched

⁸⁶ Russia has been using nuclear powered ships in the Arctic for many years, and continues to build them. See for example Katia Moskvitch, "Russia to Build Biggest Nuclear Powered Icebreaker," BBC News, 12 September 2012, [source on-line]; available from <http://www.bbc.com/news/technology-19576266>; Internet; accessed 15 April 2014.

⁸⁷ As noted previously, this is discussed in various sources covering the period, such as Ferguson, *Through a Canadian Periscope*, Yost (ed.), *In Defence of Canada's Oceans*, and in the 1988 Report of the Standing Committee of National Defence on the Canadian Submarine Acquisition Project.

⁸⁸ Greater than 20% U-235 content in the fuel.

Uranium (HEU). Through consolidation, it is hoped that supplies of HEU will be held at lesser threat of theft or illegal sale to organized crime or terrorist organizations, or hostile state actors.⁸⁹

As an alternative to the use of HEU, the disarmament community has argued that nuclear submarines could use Low Enriched Uranium (LEU) (defined as less than 20% U-235 – the fissile isotope of Uranium) in their cores and still realize many of the benefits of nuclear propulsion without adversely impacting efforts to reduce and consolidate world HEU supplies, thereby reducing risks that HEU or weaponizable fission by-products could find their way illegally into the hands of international terrorists.⁹⁰ In fact, one of the two contenders for the mid 1980's submarine project – the Canadian Amethyste, as a derivative of the Rubis class submarine - proposed (and the Rubis class continues to use) a reactor with only 7% enrichment,⁹¹ although the difference was little remarked upon in the published narratives of the time. The tradeoffs that come with this are in power (and therefore maximum speed) as well as in the number of refuellings required and the volume of spent fuel to manage, however perspectives on the trade off would vary.

To the US Navy, already possessed of ample supplies of HEU (none has been produced since 1991 for the simple reason that there is a large surplus unallocated to weapons in existence as a result of the end of the Cold War and the signing of the Strategic Arms Reduction Treaties)⁹² and having submarines capable of very high submerged speeds, there would be no compelling reason to decrease capability and

⁸⁹ A description of the Global Threat Initiative may be found at <http://nnsa.energy.gov/aboutus/ourprograms/dnn/gtri>; Internet; accessed 10 December 2013.

⁹⁰ Chunyan Ma and Frank von Hippel, "Ending the Production of Highly Enriched Uranium for Naval Reactors," *The Nonproliferation Review*, Spring 2001 [journal on-line]; available from <http://cns.miis.edu/npr/pdfs/81mahip.pdf>; Internet; accessed 20 March 2013.

⁹¹ Ibid.

⁹² Ibid.

accept a speed limitation.⁹³ Such a limitation would mean a decrease in mission availability as it would take longer to get to a patrol area from base. It would also mean a decrease in survivability, as once detected by hostile forces, a submarine's best course of action is to leave the area where its position was noted - the faster the better to avoid being attacked. If attacked, speed evasion can be used to increase the time a torpedo takes to reach the submarine, allowing for the employment of countermeasures or other manoeuvres that may disrupt the torpedo's guidance, and possibly permit the submarine to get beyond the range of the weapon before it can catch up. These concerns aside, in a world where the daily role of the submarine is more closely aligned to intelligence gathering and strike than to high intensity submarine on submarine conflict, the tradeoff may be acceptable. The refueling tradeoff may in fact be worse than the performance tradeoff, since frequent refueling will increase the requirement for fuel handling and storage facilities, for waste storage facilities, and a decrease in operational availability as the submarines will be required to be held alongside for refueling – a months-long operation – much more frequently.

Notwithstanding the tradeoffs, in the Canadian context where swift transit to a distant operating area and the ability to operate under the ice may well continue to be two of the most desirable characteristics for RCN submarines, reconsideration of whether a LEU-fuelled nuclear submarine should be sought may be warranted, so long as there is a level of commitment from Government toward providing the funding. As a leader in the peaceful uses of nuclear technology, Canada could in fact design and field such a reactor for submarine application and could set itself up as an example for other nations considering the use of nuclear submarines. And so an interesting possibility could open – the development of a militarily relevant nuclear propelled submarine that is not of primary concern to the disarmament community.

⁹³ Ferguson, *Through a Canadian Periscope*, Table 3, p. 317.

This then generates three essential SSN options for Canada, a Military Off The Shelf Low Enriched Uranium SSN (MOTS LEU SSN), a Canadian LEU SSN, and a MOTS Highly Enriched Uranium Fueled SSN (MOTS HEU SSN). These options will be discussed briefly over the next few pages.

MOTS LEU SSN

In this category, there is so far only one contender – the French Barracuda. The Barracuda has been developed to replace the Rubis class nuclear submarine, and will feature a LEU-fueled reactor that is a further evolution of designs in use in French industry and in the Rubis class submarine. The submarine will displace 5500 tonnes and have a top speed of “>25kts.”⁹⁴ It is estimated that cost per submarine is 1.4Bn Euros.⁹⁵ This submarine could and perhaps should be closely examined as an alternative for Canada pursuant to the discussion above. It nicely meets the requirement for long range, fast transit and the ability to get under the ice safely. It is slightly less expensive than either the US or UK options. Refueling the submarine would pose a slight challenge. Options to complete the task would be to return to France for refueling and the associated major maintenance, to develop a Canadian refueling facility and import fuel from France, or to develop both a refueling facility and an enrichment facility capable of producing fuel to French commercial standards here in Canada. The most complicated part of doing this work would be the site and facility licensing required. An enrichment facility could probably be built on an existing nuclear site in Canada, but a refueling facility would need to be built in

⁹⁴ _____, “Barracuda SSN: Ocean Control and Deep Strike,” DCNS Brochure, [source on-line]; available from <http://en.dcnsgroup.com/wp-content/uploads/2010/10/61893.pdf>; Internet; accessed 10 December 2013.

⁹⁵ Defense Industry Daily Staff, “France’s Future SSN: The Barracuda Class,” Defense Industry Daily, 6 November 2012 [journal on-line]; available from <http://www.defenseindustrydaily.com/frances-future-ssns-the-barracuda-class-02902/>; Internet; accessed 10 November 2013.

proximity to the ocean, and there are no sites in Canada meeting such criteria today. Licensing such a facility adjacent to any major population centre would likely not be technically challenging, but would be politically sensitive.

Canadian LEU SSN

Pursuit of a homegrown SSN is not beyond the technical capability of Canada, however the level of effort should not be underestimated. Reactor design is likely the less difficult proposition given the presence of a robust nuclear research organization in Canada under the aegis of Atomic Energy Canada Limited in Chalk River. Submarine design would potentially be more of a challenge. There is no design base for this work in Canada, however capability could be developed through cooperation with an existing submarine designer. Brazil has contracted the French submarine builder DCNS to assist with non-nuclear parts of the design of its domestically produced SSN. In the Canadian case, we live in the shadow of the world's pre-eminent submarine designer, the Electric Boat Company, a mere 10 hours drive south of Ottawa. If a clean sheet design is not deemed to be desirable, alternatives would be to adapt an existing SSN design for the use of LEU fuel vice HEU fuel, or to adapt an existing SSK design to incorporate a Canadian LEU fuelled reactor. All Canadian-unique options, however, should be regarded with great skepticism. Canadian designs for major weapon system have never met with export success, and the country would likely have no desire to export a Canadian SSN for political reasons. Any such project would depend on steady demand for its output. Therefore no Canadian-designed SSN project, or Canadian-designed SSK project, should be entertained unless it is included as part of the National Shipbuilding Procurement Strategy and unless the intent is to keep production going over many years. The question of who might assist with such a project is an interesting one as well. Fundamentally, only the UK, US and France can be considered to be in

contention, and only France uses LEU fuel. This tends to throw the question of where to source assistance for such a submarine into stark relief.

MOTS HEU SSN

There are two options in this category: the USN's Virginia Class Submarine and the RN's Astute Class Submarine. Subject to review and approval by both the executive and legislative branches of US government, Canada could "buy in" to the Virginia class submarine program. This program is widely regarded as one of the best acquisition programs in the United States and has been able to build some of the most capable submarines in the world faster and at lower cost than even the aggressive targets that the Navy had set for the Program Office and Industry to meet.⁹⁶ If Canada were to buy into the program, it would ensure that RCN submarines were fully interoperable with USN submarines. Additionally, it would provide options to the Government of Canada for the rapid deployment of a submarine to complement surface forces or independently at short notice anywhere in the world. Additionally, use of US infrastructure for fuel handling and some plant maintenance could lessen or obviate entirely the need for Canada to develop facilities to deal with nuclear maintenance, since the submarines could be planned for maintenance availabilities in US public or private shipyard as though they were part of the USN fleet. Conversely, there would be many issues with such a proposal, not least of which would be perceptions over the overall cost of the program, concerns over Canadian sovereignty if Canada operated a foreign origin submarine, and the culture of the current Royal Canadian Navy, which is not at all aligned to the Engineer-centric service that Admiral Rickover required of the US Nuclear Navy primarily as a means of keeping wrecked US-origin reactors off the

⁹⁶ A very good article along this line is by RDML (retired) John Butler, "The Sweet Smell of Acquisition Success," USNI Proceedings Magazine, vol 137/6/1, 300, June 2011, [journal on-line]; available from <http://www.usni.org/magazines/proceedings/2011-06/sweet-smell-acquisition-success>; Internet; accessed 4 November 2013.

ocean floor. Culture clash might in fact be more of an issue than cost or the willingness of the USN to cooperate with the RCN.

The second option in this category is the British Astute Class submarine. Astute is the product of an intensive effort by the United Kingdom to preserve its submarine industrial base. Notwithstanding some early challenges, the program is now well into the production phase. The costs of production are declining and the quality of the cost estimates is improving. The National Audit Office reported in 2012 that the current estimate to complete boats 1-3 stood at 3.386Bn Pounds Sterling (GBP) against an initially estimated cost of 2.233Bn GBP. The 2012 ‘single submarine’ cost estimate for boat 4 is 1.448Bn GBP against an initial estimate of 1.279Bn GBP. Similarly the 2012 estimate for boat 5 was 1.453Bn GBP against an initial estimate of 1.464Bn.⁹⁷ There are some distinct advantages to buying British. First, Canada has never actually purchased submarines from any other nation although we have rented submarines (HMCS Grilse and HMCS Rainbow) from the United States. The value of the relationship that has developed through both the Oberon and the Upholder purchase should not be discounted. Secondly, the RN intends on building far fewer Astute submarines than the USN intends to build Virginia class. The beneficial effect of a Canadian purchase, even at low volumes, on the UK submarine industrial base would therefore be much greater in relative terms than the effect of a Canadian purchase on the US industrial base. Finally, the culture of the RN and the RCN is much more similar. The Engineer-centric USN submarine culture established under Rickover simply does not exist in the RN context, although nuclear safety is still taken extremely seriously. In terms of disadvantages however, there is still the issue of distance. As noted in the discussion on the US origin SSN, Electric Boat is a 10 hour drive from

⁹⁷ United Kingdom National Audit Office, *The Major Projects Report 2012* (London: Her Majesty’s Government, 2012), 32.

Ottawa. The corresponding trip to British Aerospace in Barrow-in-Furness, Cumbria, would take a minimum of 8 hours in the air from Ottawa, a layover in Heathrow, a flight from Heathrow to Manchester and a 2 hour drive from Manchester to Barrow. Apart from the difficulties of simply getting to the builder, facilities that could be used to aid in the nuclear maintenance of a US-origin MOTS SSN operated by Canada are much closer to Canadian ports than are UK facilities, particularly when considering that many of the trips would originate from British Columbia. The other issue is that where the UK and Canada have shifted to the Metric system of measures, the United States has not. This has the potential of greatly complicating the establishment of North American sources of supply for plate steel, pipe, valves and fasteners, all required to maintain the submarines in service.

OPTIONS FOR CANADA - SSK:

Quite apart from nuclear powered submarines, there is a robust worldwide marketplace of diesel-electric submarines (SSKs) to choose from. Similar to the case of SSN's, there are two quintessential options for a future RCN SSK – buy someone else's or develop our own either alone or jointly. Each alternative has arguments for and against. In broad brush terms, the arguments are as follows: we would control the operational requirements for a Canadian-designed SSK, whereas the same could not be held to be true for a MOTS acquisition other than design changes that can only be made at a cost premium over the base design. Capability addition will cost extra; capability substitution will cost extra; even capability deletion is likely to cost extra although perhaps offset to some extent by the removed, foregone, or cheaper equipment selection. Once the design sourcing decision is made, another decision awaits, which is whether the submarine would be built by a foreign shipyard or here in Canada. A Canadian built SSK, regardless of whether or not it was designed here, would probably be more expensive to develop and produce. The reason is simple – construction costs

for such a submarine must necessarily include the costs of establishing the facilities to produce the submarines. This section will highlight some of the available MOTS options, discuss options for a Canadian-designed SSK, and discuss the question of whether or not the submarines should be built here or abroad.

MOTS SSK

The concept of a Military Off The Shelf (MOTS) SSK has been often pitched, not only here in Canada, but in Australia as well. The advantages of buying MOTS are rather simple economic ones to fathom – by buying an existing design, the time and cost of working up a design is avoided. In general the MOTS submarine options are in production and can be built either in their home shipyards in order to take full advantage of learning curve efficiencies in the manufacturers’ shipyard or in a national shipyard set up with assistance from the submarine manufacturer to take advantage of a partial learning curve and to create jobs and potentially a viable industry in the purchasing country. The drawback of MOTS is that every nation will have unique requirements for its submarines, and MOTS options may not be able to meet enough of these requirements without considerable adaptation. With adaptation comes expense and delay. In the words of Dr. Stephen Gumley, the former Chief Executive Officer of the Australian Defence Materiel Organization, “if you’ve got a MOTS piece of equipment and you combine it with another MOTS piece of equipment, you do not necessarily have a MOTS piece of equipment.”⁹⁸ For this essential reason perhaps, the Commonwealth of Australia announced in its 2013 White Paper on defence that it will not proceed with the acquisition of a MOTS submarine.⁹⁹ MOTS promises to deliver,

⁹⁸ Dr. Stephen Gumley, “Remarks to the Defence+Industry Conference 2011,” [source on-line]; available from http://www.defence.gov.au/dmo/ceo/speeches/CEO_DI_Conf11.pdf; Internet; accessed 10 Dec 2013.

⁹⁹ Commonwealth of Australia, White Paper on Defence 2013, (Canberra: Department of Defence, 2013), 83.

where Collins Class detractors would state that a better alternative might have been to procure a submarine that was in ‘common’ use elsewhere in the world, and simply build or buy such a submarine, whatever was the ‘best fit’ to the requirements. The difficulty with such an approach is that every country has different requirements, based on its own unique geopolitical situation. For example, we might assume that a country faced with the geography of Australia would require submarines capable of operating at very long ranges from home, therefore the fuel capacity would be a concern. Canada, however, will have to make up its own mind once a replacement project office is established. Therefore the following brief précis of the MOTS SSK market is presented.

The MOTS SSK Market:

Japan: Soryu Class

The Soryu class is a large ocean-going submarine, of 2950tons surfaced displacement/4100 tons dived displacement,¹⁰⁰ fitted with a Swedish origin Stirling Air Independent Propulsion system (a type of closed cycle diesel engine into which oxygen from onboard storage tanks can be introduced in order to sustain combustion without the need for outside air), the Type 89 torpedo and Harpoon missiles.¹⁰¹ Japan currently has six boats in the class, with construction alternating between Mitsubishi Heavy Industries and Kawasaki Shipbuilding Corporation. The 6th submarine, *Kokuryu* was

¹⁰⁰ Kate Tringham, “Japan Launches Sixth Soryu-Class Submarine,” *Jane’s Defence Weekly* [journal on-line]; available from <https://janes.ihs.com/CustomPages/Janes/DisplayPage.aspx?DocType=News&ItemId=+++1592139>; Internet; accessed 10 December 2013.

¹⁰¹ Deagel.com, *Soryu* [source on-line], available from http://www.deagel.com/Conventional-Attack-Submarines/Soryu_a002707001.aspx; Internet; accessed 10 November 2013.

delivered in early November 2013. A total of 8 boats in this class are planned.¹⁰² Although Soryu is large by SSK standards, it has a relatively short unrefueled range of 6100nm, presumably due to its role as a defensive rather than expeditionary vessel, consistent with the post-WWII approach to Japanese defence. Up to the point that Australia announced publicly the discontinuation of its pursuit of MOTS options for a replacement submarine, there had been considerable speculation that this submarine was being considered for the Australian Sea 1000 project. Although there would be a requirement for Japanese lawmakers to approve the export of a submarine design from Japan to Australia, such a move is not out of the question. Japan modified its defence equipment export control laws in 2011 to permit joint weapons system developments with other nations.¹⁰³ Japan's willingness to entertain discussion with Australian representatives may indicate that they would be receptive to an approach from Canada.

Germany: Type 212/214/216

Germany is an extremely well established submarine exporting nation, with arguably the best engineered and most innovative submarine designs to offer. The German submarine builder Howaldtswerke-Deutsche Werfte (HDW) in Kiel, currently owned by Thyssen Krupp Marine Systems, has long enjoyed a reputation as one of the best submarine builders in the world. Its current submarine offerings are the Type 212, a novel design with an amagnetic steel hull and the Type 214 which is an export variant of the 212 that – surprisingly – dives deeper and has longer range (12000 nm – approximately double the range of the Soryu class submarine above, at half the dived

¹⁰² Kyle Mizokami, "Asia's Submarine Race," USNI News 13 November 2013, [journal on-line]; available from <http://news.usni.org/2013/11/13/asias-submarine-race>; Internet; accessed 20 November 2013.

¹⁰³ _____, "Japan Relaxes Decades-Old Arms Exports Ban – Kyodo," Reuters News Agency, 26 December 2011 [journal on-line]; available from <http://www.reuters.com/article/2011/12/27/japan-defence-idUSL3E7NQ1HU20111227>; Internet; accessed 10 November 2013.

displacement) while preserving the low magnetic signature characteristic of the 212 hull.¹⁰⁴ Both designs feature Fuel-cell based Air Independent Propulsion (AIP) systems that are capable of sustaining the submarines at low speeds and any operating depth for weeks without the requirement to return to periscope depth to recharge batteries.

HDW has previously expressed a great deal of willingness to work with potential clients to identify unique country requirements and adapt their designs to suit, over the past several years signing contracts with Norway (Type 210), Italy (Type 212), Portugal (Type 209PN), Israel (Type 209/Dolphin), South Korea (Type 209) and Greece (Type 214). The one criticism of the German submarine builder HDW is that it may not have, in the case of its unsuccessful bid in Australia, have listened closely enough to the requirements of the customer. This point is made by Steve Yule and Derek Woolner in their history of the Collins Class submarine acquisition, and is advanced as one of the factors in the ultimate decision by the Commonwealth to acquire a Kockums designed-submarine.¹⁰⁵

With respect to German facilities, there is an extremely well developed submarine-building yard in Kiel. Because HDW was acquired by Thyssen Krupp Marine Group along with Nordseewerke and Kockums, the Germans also have access to the Nordseewerke shipyard in Emden, Germany, and the Kockums shipyard in Malmo, Sweden. Both of these yards have built submarines in the last decade. HDW has previously expressed willingness to assist other nations in the development of national yards for submarine building, and offered to do so for Canada in submissions to the CASAP project. HDW does, however tend to concentrate on smaller submarines

¹⁰⁴ A very good description of the German Type 212 and 214 is available from _____, "A German Success Story," Asia-Pacific Defence Reporter, 22 December 2010, [article on-line]; available from <http://www.asiapacificdefencereporter.com/articles/98/A-German-Success-Story>; Internet; accessed 10 December 2013.

¹⁰⁵ Steve Yule and Derek Woolner, *Steel Spies and Spin, the Untold Story of the Collins Class* (New York: Cambridge University Press, 2008), 115.

that may not have the range Canada would likely require to deploy submarines to the Arctic, the western Pacific, or the middle east. That said, in more recent years HDW has started to increase the unrefueled range of its designs, and even went to the extraordinary length of pitching a purpose built long range SSK, the Type 216¹⁰⁶ – probably as a means of attracting Australian interest or the interest of any country with a requirement for a large blue-water submarine.

HDW may suffer from a capacity constraint when or if Canada orders boats, since the ages of most European and Canadian submarines are similar, meaning that most of Europe will be trying to buy submarines at around the same time as Canada, potentially leading to delay. It is worth noting in addition to the HDW yards in Kiel and Emden, that the Italian Type 212s are being built at Fincantieri's Muggiano shipyard under license to HDW. Conceivably, Canadian submarines of HDW design could be built in Italy.

Additionally, for interoperability reasons, to minimize the retraining burden and to maximize the value of the investment in systems that are well managed for obsolescence, it is possible if not likely that a Canadian requirement would be the retention of US-origin combat systems (and their successors) currently in use on the Victoria class. This creates two potential issues. On the one hand, the use of “non-standard” systems (submarines can and perhaps should be thought of in much the same way as fighter jets – they are not really intended to be modular) would become a cost driver as the alternative systems would require integration – neither a low cost nor short activity as Canada noted during the Canadianization of the Victoria class. On the other hand, there may also be security concerns. US-origin systems used in the Victoria class are for the most part subject to the provisions of US Code Title 22, International Traffic

¹⁰⁶ _____, HDW Class 216, Thyssen Krupp Marine Systems, 2012, [source on-line]; available from <http://www.thyssenkrupp-marinesystems.com/en/hdw-class-216.html>; Internet; accessed 10 December 2013.

in Arms Regulations (ITAR).¹⁰⁷ It is possible that the involvement of other national actors in a Canadian submarine project and in after sales service would alter unfavorably the willingness of the US to export submarine technology to Canada. Such cooperation would need to be requested by Canada, and in fact it is likely that a Third Party Transfer agreement would require approval by the United States. It is far from a foregone conclusion that access to US systems at the level that Canada currently enjoys would be assured in this situation. A final issue with Germany, depending on the direction taken by a Canadian submarine project office, is that they do not have nuclear propelled submarines to offer nor is this likely to change.

France: Andrasta / Scorpene

At the present time France has two SSK designs that could be offered. The Andrasta is a small coastal defence submarine that is designed for low cost operation. While the price tag would doubtless attract interest, the submarine itself - at 900 tonnes displacement and >3000 nm range¹⁰⁸ - is suited only to littoral operations at short distances from home.

The Scorpene is a middleweight contender, and is available in several variants according to the preferences of the customer, much like the German approach with the earlier Type 209 submarine. The Scorpene has a dived displacement of between 1800 and 2000 tonnes depending on the configuration. It has been exported to Brazil, India, Malaysia, and Chile, with India and Brazil both establishing a domestic build capability. The Scorpene is available with the MESMA Air Independent Propulsion (AIP) System.¹⁰⁹ The advantages of MESMA over other AIP systems are simplicity

¹⁰⁷ The official ITAR is located at the United States Department of State website; http://www.pmdtc.state.gov/regulations_laws/itar.html; Internet; accessed 10 December 2013.

¹⁰⁸ _____, "Andrasta: Ocean Efficiency, Littoral Supremacy," DCNS Brochure, [source on-line]; available from <http://en.dcnsgroup.com/wp-content/uploads/2010/10/61864.pdf>; Internet; accessed 10 December 2013.

and ease of refueling. The system uses regular marine grade diesel fuel oil and stored oxygen to heat a steam boiler to propel the submarine economically at low speeds.¹¹⁰ DCNS also conducted an innovative submarine design study for a vessel called SEPIA.¹¹¹ The objectives of the program were to find ways to reduce the environmental impact of the submarine. Innovations adopted for the design exercise included the use of a pumpjet in lieu of a propeller, a design feature initially adopted in British and then US submarines, the use of composite (rather than heavy copper-nickel) pipework, the use of a silicon coating that both avoids the accumulation of marine growth and reduces the acoustic detectability of the submarine, and the use of aluminum vice copper electrical cabling. Any or all of these features, subject to further proofing, could be added to future submarine requirements.

Like Germany, France is an extremely well established submarine exporting nation. Canada interacted extensively with France during the CASAP project as a result of the French offer of Amethyste class nuclear propelled submarines. As it was in 1989, France remains the only Western industrialized nation with a nuclear propulsion program free from US involvement, although Brazil is progressing toward its own nuclear submarine capability. Like Germany, France seems willing to provide assistance with the development of a national submarine building capability based on their export track record which includes not only the platforms, but also technology transfer and licensing to permit the establishment of submarine building facilities in countries where the capability is lacking. Brazil and its PROSUB project is the most

¹⁰⁹ _____, "Scorpene Family: Multipurpose Oceangoing Submarines," DCNS Brochure, [source on-line]; available from <http://en.dcnsgroup.com/wp-content/uploads/2010/10/61838.pdf>; Internet; accessed 10 December 2013.

¹¹⁰ _____, "MESMA: AIP Module for Conventional Submarines," DCNS Brochure, [source on-line]; available from <http://en.dcnsgroup.com/wp-content/uploads/2010/10/61983.pdf>; Internet; accessed 10 December 2013.

¹¹¹ _____, "SEPIA, The Eco-Designed Submarine," Naval Experts: DCNS Business Magazine No. 19, December 2012, 26.

recent example of this approach, construction of the submarine construction facility commenced in Sepetiba, Brazil in March 2010 and the facility was officially opened in July 2013.¹¹² DCNS also highlighted in their 2012 annual report that they are assisting with non-nuclear aspects of the Brazilian domestic nuclear submarine program.¹¹³ DCNS is also actively investigating Lithium Ion batteries for submarine application, to replace conventional lead-acid cells.¹¹⁴ This could greatly reduce charging time and extend the time between charges, reducing the “Indiscretion Rate” of the submarine (% of the time on average that the submarine is at periscope depth with diesels running to recharge the main batteries, during which time the submarine is much more prone to detection).

The acquisition of a French origin submarine that is actively exported worldwide would have similar issues to the acquisition of a German one in the domain of the US Government’s technology transfer regime. If a decision were made to retain US-origin technology in a Canadian variant of a French designed submarine, it is likely that outfitting would have to be done in Canada, therefore integration costs would rise. To accomplish this, it would be necessary to negotiate either the purchase or the use of the Intellectual Property Rights for the submarine and it may be necessary to have engineering specifications for the installation work done in Canada. This would add cost and schedule risk to the program, and would likely result in an absolute cost increase. It would also render in-service support arrangements more complex, since the

¹¹² _____, “Brazil Opens New Submarine Shipyard,” DCNS Press Release 5 March 2013, [article on-line]; available from <http://www.defencetalk.com/brazil-opens-new-submarine-shipyard-47028/>; Internet; accessed 10 December 2013.

¹¹³ _____, “DCNS Annual Corporate and Social Responsibility Report,” [source on-line]; available from http://fr.dcnsgroup.com/flipbook/GB/DCNS_Annual_Report_2012/sources/index.htm; Internet; accessed 10 December 2013, 30-31.

¹¹⁴ _____, “Li-Ion Batteries for DCNS-Designed Scorpene Submarines,” SAFT Press Release 4 November 2011, [source on-line]; available from <http://www.saftbatteries.com/press/press-releases/li-ion-batteries-dcns-designed-scorpene-submarines>; Internet; accessed 10 Dec 2013.

presence of third party foreign nationals aboard Canadian submarines equipped with sensitive US technology would have to be tightly controlled.

Apart from the technology transfer issue, a French submarine acquisition would likely face the same shipyard capacity issue as a German one if the submarines were ordered for construction offshore. Submarine building in France is done primarily in Cherbourg, with support from Nantes-Indret and Rouelle. Additionally there is collaboration between DCNS and Navantia; some Scorpene orders are being filled from the Navantia yard in Cartagena.¹¹⁵ However, this yard has its own work to complete for the Spanish Navy and project scheduling would have to consider whether capacity constraints would impede timely completion of the submarines and impact the cost.

Spain: S-80

Spain, through its national shipbuilder Navantia, has invested significant effort in recent years to develop the capability to produce submarines. A derivative of the French Scorpene design, the S-80 is a large ocean-going submarine (2200t displacement) that may be suitable for Canada. One issue that may impede the selection of a Spanish partner is that - unlike Kockums, HDW, or DCNS – Navantia has no direct experience with submarine export although as noted above it is filling DCNS orders on behalf of foreign customers for Scorpene. Additionally the S-80 design is unproven and there has been recent media coverage around the difficulties with the S-80 failing to meet a key specification for weight, leading to significant program delay and likely adding many millions of dollars to the cost of each submarine. To date, \$2.3Bn Euros is committed to the construction of four S-80 submarines in Spain.¹¹⁶

¹¹⁵ _____, “Scorpene Family: Multipurpose Oceangoing Submarines.”

¹¹⁶ _____. “Navantia Announce [sic] Delays in the S-80 Submarine Programme.” Murcia Today, 9 May 2013 [journal on-line]; available from http://murciatoday.com/navantia-announce-delays-in-the-s_80-submarine-programme_16545-a.html; Internet; accessed 10 November 2013.

The same export control and capacity issues noted above would likely apply to a S-80 build programme as well.

Sweden: A-26

Sweden has advanced capabilities in submarine construction and experience in submarine export, having supplied the Collins-class submarine to Australia. In recent years, Kockums has been acquired by the German Defence company Thyssen, meaning that both the German manufacturer, HDW, and the Swedish manufacturer Kockums are now subsidiaries of the same company. The A26 is a current design being offered for Swedish use and potential export. The latest development of the design was funded via a contract awarded 2010 from the Swedish Defence Materiel Organization, FMV.¹¹⁷ The submarine will have several advanced capabilities that will be of interest to Canada, notably an Air Independent Propulsion system based on the Stirling closed cycle diesel engine and a large “Multimission Portal” that could serve as a launching point for special forces, and/or Unmanned Underwater Vehicles.¹¹⁸ The likely drawback, however is that as a simple function of geography, the Swedes, much like the Germans, tend not to optimize their designs for long range. The dived displacement of this submarine is intended to be 1900t, implying a more limited range.¹¹⁹ Accordingly the A26 may require design adaptation before being suitable for Canadian use.

¹¹⁷ _____, “Kockums Receives Overall Design Order for Next Generation Submarine,” Thyssen Krupp Marine Systems, Internet; <http://www.kockums.se/en/news/k/>, accessed 17 November 2013.

¹¹⁸ Kockums, “Kockums A26,” [source on-line]; available from <http://www.kockums.se/en/products-services/submarines/kockums-a26>; Internet; accessed 17 November 2013.

¹¹⁹ Deagel.com, “Type A26,” [source on-line]; available from http://www.deagel.com/Conventional-Attack-Submarines/Type-A26_a000438001.aspx; Internet; accessed 10 November 2013.

Korean SSK:

As part of its overall economic expansion in the last 30 years, South Korea has developed a number of heavy industries including possibly the most successful shipbuilding industry in the world today. In recent times, there has been interest in the extension of Korean industrial capability into the domain of submarine construction, including the development of domestically produced submarines under a technology transfer agreement from Germany. Korea in fact recently signed an export agreement to deliver three 1400t submarines to Indonesia at a cost of \$1.1 Bn USD.¹²⁰ While no existing Korean design might be suitable for Canadian use, it would be very interesting to further investigate whether or not a Korean offering for a Canadian submarine could be developed.

Netherlands SSK:

The Royal Netherlands Navy developed the Walrus class submarine in the 1970s and 80s. The class has been relatively successful, deploying in ASW exercises and ISR operations. Although the corporate entity (RDM Shipyard) that built the Walrus class is gone, a significant maritime industrial base is still resident in the Netherlands, including NEVESBU, arguably one of the best engineering companies in the world, and Imtech, a production powerhouse that has expanded to have global reach. The Dutch have commenced exploratory work toward a new design submarine that will be derivative of the existing Walrus class. In recent years there has been a tightening of the relationship between the RCN and the Dutch Konigsklikke Marine, (literally, King's Navy), including a relationship built on a common torpedo, the Mk 48

¹²⁰ Defensenews.com, "South Korea Exports Submarines to Indonesia," Agence France-Presse, 21 Dec 2011, [journal on-line]; available from <http://www.defensenews.com/article/20111221/DEFSECT03/112210305>; Internet; accessed 23 October 2013.

Mod 7AT, that may render the Dutch a good potential partner for Canada in new submarine design and construction.

Canadian-Designed SSK:

Having reviewed the marketplace of potentially available MOTS designs, the next area to examine is the degree to which it would be possible to design a submarine in Canada. Canada possesses no domestic submarine design base. While it may be possible for a design base to form, the only two ways are through a decades-long process of upscaling technologies that are produced in Canada today (for example, large Unmanned Underwater Vehicles), or through a years-long process of understudying a country that currently possesses the capability and is willing to share. Obviously, the latter is a much more practicable way to accomplish the objective, and there are options to consider.

UK-Assisted Canadian SSK:

The UK ceased production of SSKs with the Upholder (now Victoria) class in 1994, selling the 4 completed submarines of a planned class of 12 to Canada starting in 1998. Meanwhile however, submarine design capabilities have been retained under the ownership of British Aerospace Systems. While contracting for UK assistance with an SSK design may be a relatively more expensive option, there are certain advantages that come with doing so. Britain is an extremely experienced submarine building nation, with more than a century of experience in this domain. Close relationships exist between the RCN and the RN, and even more importantly to a Canadian submarine using US-origin systems, a close relationship exists between the RN and USN. As a result, integration of US-origin equipment into a UK origin submarine may not pose the

same level of ITAR challenge that might be expected from procurement of other European submarines. The same drawbacks apply here as with the UK-origin MOTS SSN: distance, and the use of the metric system by the UK industrial base.

US-Assisted Canadian SSK:

With the exception of a deep diving research submarine, USS Dolphin, the USN has not built conventional submarines since the Barbel class of the 1960's. There are, however, two documented instances where SSK construction in US shipyards has been offered since the early 1990s. In April 1994, the US State Department (US DoS) authorized the construction of German Type 209 submarines at the Ingalls shipyard in Pascagoula, to be provided to Egypt as security assistance with the costs partly subsidized by the Foreign Military Financing (FMF) program. The FMF program is primarily a foreign policy tool, used by the United States to increase the military capabilities of key regional partners and to increase their interoperability with US forces.¹²¹ Additionally, the program is intended to assist with the maintenance of a robust defence industrial base (DIB) in the United States, a feature the US DoS expresses as follows:

*By increasing demand for U.S. systems, FMF also contributes to a strong U.S. defense industrial base, an important element of U.S. national defense strategy that reduces cost for Department of Defense acquisitions and secures more jobs for American workers.*¹²²

Although US-origin SSKs were never actually produced for Egypt, the discussion actually occurred twice, with a second significant action occurring from

¹²¹ _____, "Foreign Military Financing," US Department of State, Bureau of Political-Military Affairs, [source on-line]; available from <http://www.state.gov/t/pm/65531.htm>; Internet; accessed 10 December 2013.

¹²² Ibid.

2001 to 2008, when the Bush Administration responded favorably to a request from Taiwan. Such decisions are not taken lightly; there is significant literature on the relationship between the US and Taiwan, and the US and the People's Republic of China. The process leading up to the 2001 approval started during the 1995-96 Taiwan Strait crisis, where China appeared to place into doubt key principles agreed by both China and the United States with respect to a peacefully decided future for Taiwan by conducting missile firings across the Strait into waters immediately adjacent to the island, and by conducting a large scale amphibious landing exercise. The US response to these events was to send two carrier battle groups into the Strait and to renew enthusiasm for arms exports to Taiwan.¹²³

In this context, serious consideration was given to the provision of submarines to Taiwan, however progress was slow. Although the initial request for submarines was made by Taiwan in 1995, the program was not approved by the United States until April 2001 under the Bush Administration, at which time US effort commenced. Despite rumours of opposition from some elements of the US Navy, Navy Public Affairs offered the official position:

*While the U.S. Navy does not have a requirement for diesel submarines, we do not object to U.S. industry participation in the diesel submarine market*¹²⁴

By December 2002 and after several rounds of industry consultation, SECNAV informed Congress in a Determination of Findings memo that the submarine bidders would be restricted to four US companies and the submarines would be of US origin. Program costs were estimated by the USN at \$10.5Bn, although it was believed that this figure may have included risk premiums associated with the availability of a

¹²³ Robert Ross, "The 1995-96 Taiwan Strait Confrontation: Coercion, Credibility and the Use of Force," *International Security* Fall 2000, Vol. 25, No. 2: 87–123, 110.

¹²⁴ Jim Mann, "US Promised Subs to Taiwan it Doesn't Have," *LA Times*, 15 July 2001.

European design (and the understanding that costs would be higher if a US-origin design was involved instead of a build to print using a European design), and associated with the willingness or ability of Taiwan to finance the project.¹²⁵ As a result of uncertainty over the program cost, in 2003 the Bush Administration investigated with Italy a potential sale of 8 used Italian Sauro class submarines to Taiwan, at a cost of \$2Bn. Although agreement in principle from Italy was obtained, the Legislative Yuan (or Parliament) of Taiwan, however, was disinterested and preferred to consider only alternatives involving new submarines.¹²⁶ In February 2006, with Taiwan having stated a clear indication of preference for new submarines, but absent a design to build and funding for construction, US Congressman Rob Simmons, representing Connecticut (home of Electric Boat) proposed a two phase design and build approach. Both the US and Taiwan were amenable to this proposal, and in June 2006, Deputy Undersecretary of Defense Richard Lawless offered the approach to Taiwan with a preliminary estimate of \$360M for the design phase. Taiwan approved 1/6th of this amount in its December 2007 budget, and in January 2008 submitted a Letter of Request to commence the design phase. However, a change of government in May 2008 effectively terminated the program. Ma Ying-jeou was elected president of Taiwan. Ma offered to re-start negotiations with China on a peaceful resolution of the relationship between the island and the mainland, based on the results of a 1992 high level exchange between the People's Republic of China and the Republic of China (the 1992 Consensus). This action had an immediate and beneficial effect on more than a decade of Taiwan-China relations characterized by tension. Although a Letter of Request for the submarine design phase had been submitted by Taiwan, the Bush

¹²⁵ Paraphrased from Shirley Kan, "Taiwan: Major Arms Sales Since 1990" (Washington DC, Congressional Review Services, November 29, 2012), 11-14.

¹²⁶ Wendell Minnick, "Submarine Decisions Show Lack of Creativity," Taipei Times, 16 October, 2004.

Administration did not notify Congress of its intent to follow through with the program – a deliberate omission signaling the end of the program.

Although the foregoing discussion does not deal with the US response to a request by Canada for assistance, there are some inferences we can draw with respect to possible or probable outcomes of a Canadian request for US assistance. First and foremost, depending on the strategic imperatives in play, the US is in fact willing to build SSKs. Secondly, as a reflection of startup costs, low production volumes and the level of US technology, such SSKs are likely to be more costly than MOTS SSKs. Thirdly, US industry is likely to be highly supportive of such an endeavour. There is no closer or more compatible industrial base for Canada to draw on than that of the United States. Leveraging US assistance into a functioning submarine industrial base here in Canada offers potential benefits for Canadian industry and guarantees interoperability for our submarine force. Such a pairing may well be the best strategic play for Canada.

Australian Cooperative SSK

A final developmental option for a Canadian SSK would be to collaborate with the Australians. When Sea 1000 was announced, Australia went through a similar exercise of options identification and analysis as that presented here. In the final analysis however, the Commonwealth rejected MOTS procurement, and rejected SSNs, leaving further development of the Collins class design itself or the development of a new design as the only two remaining alternatives.¹²⁷

There are several benefits to cooperation with the Australians. First, the relationship between the RCN and RAN is a close one. Both navies are responsible for the defence of vast ocean areas but with resources sourced from a sparse population.

¹²⁷ Commonwealth of Australia, *White Paper on Defence 2013* (Canberra: Department of Defence, 2013), 82-83.

Both navies are descended from RN tradition and both maintain close ties, including participation in joint exercises, the exchange of officers, and the occasional permanent migration. The submarine forces of both navies have drawn closer to the US in recent years by way of equipment acquisition. The RAN modernized their US-origin heavyweight torpedo, replaced the legacy Collins-class combat system with a variant of the system used in Virginia Class attack submarines, and replaced key communication equipment with US-origin systems. The RCN has done likewise through the Canadianization process – the UK legacy combat system was replaced by a US-origin export system, the US-origin heavyweight torpedo is being modernized, and the legacy sonar systems processing and display are being replaced by a variant of the system used in Virginia Class attack submarines. Both navies recognize the importance of interoperability with the US, particularly in response to the shifting strategic situation in the Pacific.

It is possible if not likely, therefore, that US and potentially UK assistance will figure prominently in the Australian Sea 1000 project. In this respect, the Australian project may resemble the project Canada would choose for itself if a decision was made to move toward a Canadian SSK in lieu of a MOTS SSK. Certainly a Canadian SSK could just as well be one where assistance is provided by France, or Germany, or the Netherlands. But if this were the direction taken, particularly in the case of France or Germany where there is less equipment commonality with the US, it may have far reaching effects on the interoperability and fundamental compatibility of the RCN submarine service with the USN, RN, or RAN services. As such, who provides assistance is just as important a decision as whether such an option is pursued.

OPTIONS: Design and Build

Having reviewed the various SSN and SSK options, it is worth the time to pause for additional reflection on whether a Canadian submarine should be designed in Canada, and on whether the replacement submarine, designed in Canada or not, should be built in country. Although Canada does not currently possess established industrial capability to do either, there is nothing that prevents the nation from doing so other than choice. Following onto experience with designs around which Canada had export aspirations, most recently the CPF program, it should be clear that a Canadian design/build program for submarines will most probably only be for Canada. Building here or offshore is less of an economic decision, and more a matter of national policy. In this section we will examine further the question of just how difficult it would be to design a Canadian submarine for construction here or abroad, or to modify a design for construction here.

It is very common for the complexity of a submarine to be underestimated. A submarine is far more comparable to a space shuttle than it is to an automobile. It is a highly complex machine made to operate in one of the harshest environments known to man. Like a space shuttle, submarines are comprised of a myriad of highly integrated systems packed tightly into a small volume. Like the space shuttle, submarines will be used for only a fraction of their lives due to the level of maintenance required. Like the space shuttle, the submarine is exposed to severe pressure differentials across its hull. Unlike the space shuttle, the pressure differential across a submarine hull is much greater than 1 atmosphere. Unlike the space shuttle, the submarines hull sits at all times in a corrosive medium and is subjected to corrosive attack.

Submarine design is therefore highly complex – certainly no less so than the design of the space shuttle. While submarines may be designed at a fundamental level by teams of university engineering students every day, the actual nuts and bolts of generating the tens of thousands of production drawings required to bring a living,

breathing boat into being is daunting. According to the RAND corporation, engaged to study this question for the Commonwealth of Australia (CoA), a typical submarine design could be expected to take 8-12 million manhours over 15-20 years, requiring a peak production effort of 600 engineers and 900 draughtsmen.¹²⁸ Assuming an average labour rate of \$100 per hour (2013), the design of a submarine is a \$800M-1.2Bn (2013) endeavour. The effort would span 15-20 years, and best practice (“Design then Build”) requires that this process complete fully before production start. On this assumption, if design commenced today, construction of the first submarine could start in 2028-2032. Production might be able to start a little earlier, but not much. Construction would likely take 6-8 years, perhaps declining as the shipyard repeated tasks and improved processes. The process would therefore deliver its first submarine 2034-2040. Is this feasible? The answer; a qualified yes. Yes, if the Victoria Class submarine were extended to a service life of approximately 40 years. Yes, if appropriate funding were set aside. Yes, if the design contract were awarded in a timely manner. Yes, if it was the choice of the Government of Canada to do so.

The picture could be improved significantly by licensing a design and building it locally. In this case the journey to production readiness would be shorter, and related to the requirement to establish facilities, adapt a design to Canadian requirements, and establish a Canadian supply chain. This was essentially the approach that gave rise to the Collins class submarine under project SEA 1111. Rather than starting from a blank sheet, the process that was followed saw the Commonwealth of Australia (CoA) engage Kockums engineers to modify an existing design (the Vastergotland Class), enlarging it and modifying it to suit Australian requirements. Concept development started in 1983 with many bidders in the field, funded design definition occurred starting in May 1985 with only two bidders IKL/HDW (the combination of Ingenieur Kontor Lubeck and

¹²⁸ John Birkler et al., *Australia’s Submarine Design Capabilities and Capacities: Challenges and Options for the Future Submarine* (Arlington VA: RAND Corporation, 2011).

Howaltswerke-Deutsche Werft) and Kockums. On the basis of the designs that had been completed up to 1987, on 18 May 1987¹²⁹ Kockums was declared the winner and continued designing. The first submarine keel was laid in 1990. The resulting submarine was one that is well suited to the requirements of the Australian Navy, but is highly customized. Even the steel in the hull is a custom Australian alloy.¹³⁰ Whether or not the Collins class is a good submarine in an absolute sense continues to be the subject of some debate within the Commonwealth, although as noted previously, the Government of Australia announced in its 2013 White Paper on Defence that it will not pursue a MOTS option for a submarine. Therefore it would appear that the intention is to adapt the Collins design or another suitable design currently available. To support this approach, the Intellectual Property Rights for the Collins design were purchased from Kockums in 2013.¹³¹

Canadian Submarine Industrial Capacity

Once a design is either developed or procured and adapted, there must be facilities ready to build. Each of the MOTS alternatives has one or more established build yards with optimized facilities and processes for the construction of their product, which in turn leads to lower cost production. If, however, a decision were made to build submarines here in Canada, it would be necessary to select a build yard and to fit

¹²⁹ Derek Woolner, "Procuring Change: How the Kockums was Selected for the Collins Class Submarine," Research Paper 4, 2001-02, Parliamentary Research Papers, Commonwealth of Australia, [article on-line]; available from http://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/rp/rp0102/02RP04; Internet; accessed 10 December 2013.

¹³⁰ Chris Jenkins, "Risk and Value: A CEO's Perspective," in ASPI Special Report November 2011, "Three Views of Risk: Selecting and Acquiring Military Equipment," pp. 19-21, 20, [source on-line]; available from https://www.aspi.org.au/publications/special-report-issue-42-three-views-of-risk-selecting-and-acquiring-military-equipment/SR42_Risk.pdf; Internet; accessed 10 December 2013.

¹³¹ Commonwealth of Australia, "Minister for Defence – Media Release – Submarine Technology," 16 May 2013, [source on-line]; available from <http://www.minister.defence.gov.au/2013/05/16/minister-for-defence-media-release-submarine-technology/>; Internet; accessed 10 December 2013.

it out with construction facilities suitable to the task of submarine construction. This would be no mean feat, but neither is Canada totally without an industrial support base that could be adapted to the task of completing a domestic build program. It is therefore worthwhile to spend a moment in discussion of the industrial base in Canada as it was and as it is.

Notwithstanding the lack of a domestic submarine build program, the Canadian shipbuilding industry maintained capabilities that were employed by other navies. Particularly, the former Canadian Vickers yard in Montreal, which had been acquired by MIL in the 1980's, and renamed MIL Vickers was engaged to produce torpedo tubes for Dutch Walrus class submarines as well as for US Navy Los Angeles class submarines. This capability is commented on in a backgrounder published March 3rd, 1988 by the Canadian Submarine Consortium, formed to bid on the Nuclear submarine program in Canada (discussed briefly below):

...after all, Canadian industry already builds sections of nuclear submarines and submarine systems components, designed to withstand the high pressures of the submarine environment. Also, many Canadian companies regularly fabricate and weld sophisticated steels to high-quality requirements which are very similar to those needed for submarines.¹³²

The Canadian industry referred to is the MIL Group shipyards, of which there were three, all in Quebec, MIL Davie at Lauzon, MIL Tracy and MIL Vickers in Montreal. The MIL Vickers yard (formerly Canadian Vickers) was the one with the submarine experience although a “company profiles” document published on the same day as the backgrounder indicates that the Lauzon yard would be used for assembly. With respect to MIL Vickers,

¹³² Canadian Submarine Consortium, *Backgrounder: Building Nuclear Submarines in Canada: Handling the Technology Transfer*, (Ottawa: Canadian Submarine Consortium, 1988 (copy available from the DND Directorate of History and Heritage)).

...MIL Vickers at Montreal currently manufactures nuclear submarine pressure hull sections. Vickers is thoroughly familiar with the welding and quality standards required for nuclear submarines. Vickers also builds torpedo tubes and a host of other submarine components requiring high-quality precision work and sophisticated materials. It has also built a large number of calandria for CANDU nuclear power stations, to demanding nuclear quality standards. Thus, Vickers has a great deal of experience specifically relevant to building nuclear submarines and components. (As a matter of historical interest, Vickers built 24 British-designed H-class submarines in Canada in World War I.)¹³³

Today, although there are no shipyard facilities engaged in submarine module manufacture, there are still companies with expertise in submarine manufacture, working to make components for USN ships and submarines. Indal technologies in Mississauga is an interesting example. Indal manufactures shipboard helicopter recovery and towed array sonar handling systems. In 2005, Indal was acquired by Curtiss Wright Flow Systems and currently operates as a subsidiary.¹³⁴ Curtiss Wright Flow Systems is a large multinational diversified company working in heavy industrial construction, nuclear support and naval shipbuilding support, headquartered in Falls Church, Virginia. Three of its other subsidiaries, Target Rock (Farming Dale, NY), Electromechanical Division (Cheswick, PA) and Engineered Pump Division (Phillipsberg, NJ) are key suppliers to USN Submarines.¹³⁵ Although these latter three subsidiaries are not Canadian companies, they are all less than 10 hours' drive from the Eastern Ontario/Western Quebec border, and they are all heavily involved with USN

¹³³ Canadian Submarine Consortium, "Company Profiles of Canadian Submarine Consortium Members" (Ottawa, Canadian Submarine Consortium, 1988 (copy available from the DND Directorate of History and Heritage)).

¹³⁴ Indal Technologies Press Releases, [source on-line]; available from http://indaltech.cwfc.com/company/spokes/02_pressreleases.htm#Acquired; Internet; accessed 23 December 2013.

¹³⁵ Curtis Wright Flow Controls Company Profiles are available from http://www.cwfc.com/Defense/Defense_Products.htm; Internet; accessed 23 December 2013.

submarines, supplying hull valves, system isolation valves, and vital onboard pumps. Another company – this time exclusively Canadian – that supplies valves to both USN and French submarines for use in their nuclear propulsion systems is Velan Valves in Montreal.¹³⁶ American Alloy Steel in Sorel-Tracy Quebec produces HY80 and HY100 steel plate for submarine pressure hulls.¹³⁷ Additionally, there are companies that manufacture submarine search and rescue systems and large, complex Unmanned Underwater Vehicles. Oceanworks of Burnaby, BC, manufactures deep diving Atmospheric Diving Suits,¹³⁸ and International Submarine Engineering of Port Coquitlam, BC, manufactures large complex Unmanned Underwater Vehicles such as the Explorer AUV systems and Dorado tethered mine hunting UUV.¹³⁹ The Davie shipyard in Lauzon Quebec (on the south side of the St. Lawrence river, a short way east of Quebec city) still exists and has facilities that could be adapted to submarine construction.¹⁴⁰ Its proximity to American Alloy Steel (2.5 hours by road, or heavy items can be barged from AAS to Davie) is interesting as well, since there would be synergies if there were work.

While Canadian industry has not built complete submarines since the World War I era, there is a wealth of experience at the component level. Canada has a considerable industrial base that could be built up for the task of submarine

¹³⁶ A Velan company profile is available from <http://www.velan.com/en/resources/literature>; Internet; accessed 23 December 2013. See BRO-NUC-09-13 for references to the use of Velan valves in all USN and French nuclear submarines.

¹³⁷ The American Alloy Steel Corporate Profile can be found at <http://www.aasteel.com/index.html>; Internet; accessed 23 December 2013.

¹³⁸ Details are available on the Oceanworks website, <http://www.oceanworks.com/military/index.html>; Internet; accessed 23 Dec 2013.

¹³⁹ Details for International Submarine Engineering are available from http://www.ise.bc.ca/index_Dec_13.html; Internet; accessed 23 December 2013.

¹⁴⁰ Details for Davie Shipbuilding are available from <http://www.davie.ca/about-us/our-facility/>; Internet; accessed 23 December 2013.

construction. While there would doubtless be costs and challenges, there is no technical limitation precluding the work from being done in Canada. All that is required is the will and a source of steady income for the companies that may wish to participate in such a build program.

The National Shipbuilding Procurement Strategy (NSPS)

The Government of Canada adopted the National Shipbuilding Procurement Strategy in June 2010. The purpose of doing so, as stated by then Minister of Public Works Rona Ambrose was as follows:

Our Government made the decision to support the Canadian marine industry, to revitalize Canadian shipyards and to build ships for the Navy and Coast Guard here in Canada...The Strategy will bring predictability to federal ship procurement and eliminate cycles of boom and bust, providing benefits to the entire marine industry.¹⁴¹

Despite claims from detractors that the NSPS will add costs through the creation of a monopoly environment,¹⁴² it has been pointed out that other traditional Canadian procurement practices, particularly those of requiring offsets and requiring a maximum of Canadian industrial involvement in in-service support, also add costs to the projects.¹⁴³ Fundamentally the establishment of a viable shipbuilding enterprise in Canada serves a strategic end by providing guaranteed access to production facilities where modern, combat capable warships can be built as and when required. It should also allow Canadian industry to become more cost effective through a defined order

¹⁴¹ Canada, "Government of Canada Announces National Shipbuilding Procurement Strategy," Public Works and Government Services Canada, 2010, [source on-line]; available from <http://news.gc.ca/web/article-en.do?crtr.sj1D=&mthd=advSrch&crtr.mnthndVI=12&nid=537299>; Internet; accessed 10 December 2013.

¹⁴² Michael Byers and Stewart Webb, *Blank Cheque: National Shipbuilding Procurement Strategy Puts Canadians at Risk* (Ottawa: Canadian Centre for Policy Alternatives/Rideau Institute, December 2013).

¹⁴³ Eric Lehre, *The National Shipbuilding Procurement Strategy: An Update* (Ottawa: Canadian Defence and Foreign Affairs Institute, Strategic Studies Working Group Papers, 2012).

book, permitting investment in more modern and efficient design and production techniques such as 3-D Computer Aided Design (CAD); the use of ‘numerical controlled’ machines that are able to directly fabricate objects from the CAD data file (instead of tradesmen reading drawings); the use of computational models to verify performance before build (instead of rules of thumb), and the use of modular construction and automated processes such as welding during build. Also, and perhaps even more importantly than the facilitation of technology investments, a defined order book should permit learning curve effects to be felt.¹⁴⁴

The policy likely serves an end with the electorate as well, inasmuch as it guards well paid, high technology jobs from being exported overseas. In light of Government policy and practice around a preference for domestic construction and domestically-sourced in-service support or the use of offsets when goods and services are not produced domestically, it could be argued that it is the policy of the Government to ensure that Canadian industry is on a level playing field against overseas competitors, in such an environment cost effectiveness may not be the, or even a, primary concern. The concentration of Defence planners therefore should not be on finding the most cost effective supplier, but on finding ways to ensure that Canadian suppliers become more competent and more cost effective. This is the real spirit of NSPS, whether or not publicly stated or even fully understood by those involved: given that offshore options may not be pursued, contracting with a competent and cost effective monopoly domestic supplier is preferable to contracting within a competitive field of less cost effective and less competent domestic suppliers. If a decision is made to build submarines in Canada, such a decision should also entail adding the

¹⁴⁴ A good definition of the Learning curve is contained in United States, *GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs* (Washington DC, Government Accounting Office, March 2009), 119-122.

submarines to the NSPS to allow these benefits to be felt, and possibly used again for the follow on class of submarine.

This chapter has studied the substantial range of alternatives available for Canadian consideration. Broadly speaking, the conclusion to draw is that all options are feasible. Canadian industry does not build submarines today but the bones of an industry are still here and can serve as the nexus around which a capability could be built, subject to a decision being made to invest in the development of facilities. NSPS is a philosophical approach as well as a program that can and should apply if a decision were made to build in Canada in order to ensure that facilities investment is only required once, and that a capability built on the strength of Government investment is not then permitted to atrophy from neglect when the platforms to be built under the aegis of the next RCN submarine replacement project are completed. There are five essential platform options: MOTS SSK, Canadian SSK, MOTS LEU SSN, Canadian SSN, and MOTS HEU SSN. Within these categories there are many nuances that have been touched on briefly. Next, the five platform options will be examined for cost and affordability.

Chapter 5

COST AND AFFORDABILITY

Costing of complex military acquisition is always a challenge.¹⁴⁵ Technically difficult in and of itself, filled with uncertainties and subject to impacts from exchange rates, inflation, and delays outside the control of the project, military acquisition has the added complication of being for the most part quite expensive and therefore subject to heated public debate. Submarines are no different in this milieu and as a result, the cost estimate for a future submarine project will require a high level of attention to detail and careful message management. This section will seek to accomplish three objectives. First, to situate submarines in the context of other defence spending and the economy overall; secondly to derive rough cost estimates for the various options described above, and finally to review the cost implications of a Canadian submarine replacement program.

Context

The Victoria Class acquisition cost has been reported in various open sources as \$897M (2003).¹⁴⁶ The in-service support costs in personnel, operations and maintenance (PO&M) were estimated unofficially in 2007 as \$250M.¹⁴⁷ To some, these costs are appallingly high.¹⁴⁸ Yet it is necessary to view them in context. The

¹⁴⁵ An excellent discussion on the topic is contained in, *GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs* (Washington DC, Government Accounting Office, March 2009).

¹⁴⁶ This figure for the most part was drawn from Canada, *Review of the Submarine Acquisition/Capability Life Extension Program* (Ottawa: DND/Chief Review Services, May 2003), IV.

¹⁴⁷ Cdr Michael Craven, "A Rational Choice Revisited – Submarine Capability in a Transformational Era," *Canadian Military Journal*, Winter 2006-2007, 21-32, 22.

acquisition cost, adjusted for inflation (assumed 2%), at \$1.03Bn (2010 dollars) is slightly less than the anticipated \$1.2Bn (2010 dollars) cost of one 23.4km Light Rail Transit line that was proposed to connect the Toronto suburb of Etobicoke with the subway at the Finch Station on Yonge Street.¹⁴⁹ The annual operating cost estimate, adjusted for inflation (again assumed 2%), at an adjusted \$281.5M (2012 dollars) is substantially less than the \$389M the City of Ottawa Transit Authority – OC Transpo – reported spending on its operations in 2012.¹⁵⁰

In 2011, DND announced plans for the fiscal year ending 31 March 2012 to spend \$21.3Bn, of which \$4.665Bn (21.9%) was earmarked for Capital acquisition, including equipment acquisition and infrastructure investment.¹⁵¹ The RPP further indicates that 10.3% (\$2.2Bn) of the total would be set aside for Maritime Readiness (loosely, Navy PO&M). So, assuming that the \$281.5M (2012 dollars) estimate for submarine PO&M is correct, submarines account for 13% of the Navy’s PO&M expenditures.

Where discussions of affordability will come into focus however, are the lean years. In the 2012/13 RPP, the expenditure plan was announced with a forecasted expenditure of \$20.1 Bn,¹⁵² a raw reduction of \$1.2Bn (- 5.6%). Adjusting for inflation

¹⁴⁸ Michael Byers and Stewart Webb, *That Sinking Feeling: Canada’s Submarine Program Springs a Leak* (Ottawa: Canadian Centre for Policy Alternatives/Rideau Institute, June 2013).

¹⁴⁹ James Bow, “Toronto’s Transit City LRT Plan,” Toronto Transit Commission, 2011, [source on-line]; available from <http://transit.toronto.on.ca/streetcar/4121.shtml>; Internet; accessed 10 December 2013.

¹⁵⁰ OC Transpo, “2012 Facts and Figures,” [source on-line]; available from http://www.octranspo1.com/images/files/reports/Facts_Brochure_201.pdf; Internet; accessed 1 November 2013.

¹⁵¹ Canada, “Department of National Defence Report on Plans and Priorities, 2011-12,” National Defence, 2011, [source on-line]; available from <http://www.tbs-sct.gc.ca/rpp/2011-2012/inst/dnd/dnd-eng.pdf>; Internet; accessed 10 November 2013, 15.

¹⁵² Canada, “Department of National Defence Report on Plans and Priorities 2012-13,” National Defence, 2012, [source on-line]; available from <http://www.tbs-sct.gc.ca/rpp/2012-2013/inst/dnd/dnd-eng.pdf>; Internet; accessed 10 November 2013, 19.

at 2%, (\$21.3Bn (2012 dollars) becomes \$21.7Bn (2013 dollars) if real spending remains the same), the reduction is actually \$1.7Bn (or -8%). This is a far cry from the commitment articulated in the 2008 Canada First Defence Strategy to CFDS to increase defence spending ‘automatically’ by 2% per year.¹⁵³ Fortunately for the Navy however, the 2012-13 RPP indicates that Navy funding would “increase” to 11.4% of total departmental planned spending – i.e. would remain roughly constant in real terms at \$2.3Bn (2013 dollars). However, with \$1.7Bn in funding disappearing, now may not be the time to initiate a discussion on a submarine replacement program. Timing will be commented upon further later in this chapter.

As a final thought on context, at the end of 2013, Canada’s GDP for the year stood at \$1.888 trillion in today’s prices.¹⁵⁴ The amount of GDP allocated to defence for fiscal 13/14 was \$20.1Bn (or \$0.0201 trillion). The 2013 Canadian ratio of defence to GDP is therefore approximately 1.06% (approximate because the GDP data required to align perfectly to the defence allocation would be 2013 Q2, 3 and 4 as well as 2014 Q1). The annual support cost for submarines, using the \$281.5M (2012 dollars) estimate above, barely registers at 0.015% of GDP. Contrast this to spending on health care in Canada, which for 2013 is estimated to be \$211Bn, or 11.2% of GDP.¹⁵⁵ Canada could stop spending on submarines, on any other defence capability, or on defence itself tomorrow, and still not meet the perceived needs of its population for spending on entitlements.

Submarine Unit Costs – Allied Programs

¹⁵³ Canada, “Canada First Defence Strategy” (Ottawa: National Defence, 2008), 12.

¹⁵⁴ Canada, “Canada: Economic and Financial Data,” Statistics Canada webpage, [source online]; available from <http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/dsbbcan-eng.htm>; Internet; accessed 30 December 2013.

¹⁵⁵ Canadian Institute for Health Information, *National Health Expenditure Trends, 1975 to 2013* (Ottawa ON: CIHI, 2013), Executive Summary, 1.

In an effort to understand how much a Canadian submarine replacement project might cost, the best initial place to look is at allied programs. This section will examine the potential costs of the Australian submarine replacement program as a sanity check on estimates to be developed for a Canadian project. Following this, examples of the unit cost of acquisition for various SSK and SSN options will be presented in order to establish a probable unit cost for Canadian submarines by analogy.

Australia is, in many ways, the nation most like Canada. Its population is roughly 2/3 that of Canada, yet its military is similar in size. Its geopolitical factors are somewhat dissimilar however. Whereas our geographic reality serves to isolate us from strategic threats elsewhere in the globe, Australia has the added complexity of proximity to neighbours with uncertain strategic objectives, and distance from other Western democracies. She is defended by great strategic depth, yet this same strategic depth serves to cut her off from support by allies. For this reason, Australia favours a measure of self sufficiency, including the ability to defend Australia from direct attack without assistance, and the retention of significant domestic defence industrial capability. This reality, along with certain economic factors, has led to the decision to replace the Collins class submarine with a class of 12 highly capable diesel electric submarines, as well as to the decision to build the new class in Australia. In the Australian context, these decisions will be cost drivers.

With respect to the potential cost of the Collins replacement project, a 2009 study by the Australian Strategic Policy Institute (ASPI) outlined four alternatives with rough costing, as follows (all costs in 2009 Australian dollars):

New Build Collins: \$12Bn
4000 tonne boat at Collins cost per tonne: \$16.8Bn
4000 tonne boat at historical trend: \$36.5Bn
Type 212/214: \$8.8Bn (assumes A\$1=US\$.75)¹⁵⁶

¹⁵⁶ Sean Costello and Andrew Davis, *How to Buy a Submarine: Defining and Building Australia's Future Fleet* (Canberra: Australian Strategic Policy Institute, 2009), 10.

The authors indicate that the “4000 tonne boat at historical trend” estimate was derived parametrically by using media reports on a number of submarines at various points since 1920, correcting for inflation, and deriving the rate of cost increase in submarines as a function of the hull size over and above inflation. Overall, the authors found a 3.8% annual increase above inflation in the cost per tonne of the submarines included in the survey.¹⁵⁷ Extending the line out to 2020, the presumptive delivery date of the first Collins replacement, then discounting to 2009 dollars, the authors report a likely cost per boat of \$3.04 Bn¹⁵⁸, and therefore a capital acquisition cost of \$36Bn. While this estimate can be challenged for its reliance on linear rather than polynomial regression, it is perhaps a good wake-up call in terms of setting the expectations of Government. The \$36.5Bn AUD figure generated some controversy, particularly when juxtaposed against the assumed cost of 12 MOTS submarines at \$8.8 Bn AUD. This was clearly the intent, as the authors go on to point out the considerable advantages to be gained from selection of a MOTS alternative. Potentially misleading, however, is the lack of an assumed growth in cost per tonne for the existing MOTS offerings. Cost growth per tonne is not frozen once a design baseline is declared. Rather, the change continues as capabilities of the submarine change – as they must – across a 20 year build program.

With respect to the low end of the ASPI estimate, Rear-Admiral Rowan Moffatt had this to say:

Andrew Davies in ASPI talks of \$9 billion for off-the-shelf submarines. That's nonsense. That might be the capital acquisition cost of the hull. It doesn't take into account the total program cost, not by a long margin. Let's say that it's the other end of the scale that he uses, which is \$36

¹⁵⁷ Ibid, 9.

¹⁵⁸ Ibid.

*billion. Let's round it for convenience's sake. It's \$40 billion. That's NBN. That's eye-watering.*¹⁵⁹

Other indicators of cost for diesel submarines can be found in the media. It is, however, often difficult to glean unit costs from media, since the base year is seldom referenced and since contracts that are awarded may contain inclusions that would otherwise subtract from the unit costs (for example technology transfer or facilities construction) or exclusions that would otherwise add to the unit cost (for example weapons systems). Bearing this in mind, it is reported that a Japanese Soryu class submarine costs \$540M USD.¹⁶⁰ It has also been reported that the French Scorpene/Spanish S-80 costs in the range of \$578M USD,¹⁶¹ and that the German type 212 costs \$500M USD.¹⁶² These costs, however do not include facilities upgrades and through life support.

With respect to US nuclear submarines, the US commenced production of the Virginia class at approximately \$2.6Bn USD (BY 2005) with the aim to reach \$2.0Bn (BY 2005) at steady state production for Batch III. This objective was achieved,¹⁶³ however Batch IV and beyond will have different capabilities such as UUV and an

¹⁵⁹ This statement is contained in Nicole Brangwin, "Background Note: Australia's Future Submarines," Parliamentary Research Papers, 24 May 2012, Commonwealth of Australia, [article online], available from http://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/BN/2011-2012/Submarines; Internet; accessed 10 December 2013. NBN is a reference to the National Broadband Network infrastructure project in Australia, which is currently estimated to be a \$56M capital investment.

¹⁶⁰ John Hofilena, Japan Launches Newest Submarine Kokuryu Amid Party Atmosphere, Japan Daily Press, 4 Nov 2013, internet http://japandailynews.com/japan-launches-newest-submarine-kokuryu-amid-party-atmosphere-0438960/?goback=%2Egde_73174_member_5794804489445736448#%21, accessed 10 November 2013.

¹⁶¹ Deagel.com, Scorpene Basic – AIP, internet, http://www.deagel.com/Conventional-Attack-Submarines/Scorpene-Basic-AIP_a000425003.aspx, accessed 10 November 2013.

¹⁶² Deagel.com, U212A, internet, http://www.deagel.com/Conventional-Attack-Submarines/U212A_a000455001.aspx, accessed 10 November 2013.

¹⁶³ Butler, "The Sweet Smell of Acquisition Success."

enhanced missile launch capability to replace the converted Ohio-class SSGNs, therefore the expectation should be that costs will increase slightly. To put the US cost figure into perspective, the 2013 cost in CAD would be in the range of \$2.5Bn (2% inflation and a current exchange rate of 1.06 CAD to 1 USD).

In the UK, the Astute program cost is measured in somewhat piecemeal fashion, by boat. The National Audit Office reported in 2012 that the current estimate to complete boats 1-3 stood at 3.386Bn GBP against an initially estimated cost of 2.233Bn GBP. Much of the variation amounts to the effect of delay and corresponding inflation, however a detailed breakdown is not provided. The current 'single submarine' cost estimate for boat 4 is 1.448Bn GBP (2012 pounds sterling) against an initial estimate of 1.279Bn GBP. Similarly the current estimate for boat 5 is 1.453Bn GBP (2012 pounds sterling) against an initial estimate of 1.464Bn.¹⁶⁴ To put these figures into Canadian context, the 2013 cost in CAD would be \$2.6Bn (2% inflation and a current exchange rate of 1.74 CAD to 1 GBP).

At potentially lower cost, the Barracuda SSN discussed in Chapter 5 is being built by the French shipbuilder DCNS and could be made available for export sale. The program cost for the Barracuda have most recently been reported (2011) at 8.6Bn Euros.¹⁶⁵ Divided across 6 submarines, this is 1.4Bn Euros. The total contract value includes the developmental work to generate the new design including the propulsion plant, however for the purposes of the cost comparison discussion to follow, it is intended to use the more pessimistic figure of 1.4Bn Euros. To put this figure into Canadian context, the 2013 cost in CAD would be \$2.14 Bn (2% inflation and a current

¹⁶⁴ United Kingdom National Audit Office, *The Major Projects Report 2012* (London: Her Majesty's Government, 2012), 32.

¹⁶⁵ Defense Industry Daily Staff, "France's Future SSN: The Barracuda Class," *Defense Industry Daily*, 6 November 2012 [journal on-line]; available from <http://www.defenseindustrydaily.com/frances-future-ssns-the-barracuda-class-02902/>; Internet; accessed 10 November 2013.

exchange rate of 1.44 CAD to 1 Euro).

Based on the data presented above, in broad brush terms a modern and capable diesel electric submarine of approximately 2000 tonnes displacement should be able to be procured for a unit cost of approximately \$550M USD (2005 dollars). Assuming 2% annual inflation since 2005 and using the current 1.06 CAD to 1 USD exchange rate, this equates to \$683M CAD (2013). For the Canadian developmental submarine, it will be assumed that Canada would have similar requirements to Australia for long unrefueled range, Air Independent Propulsion, land attack and SOF capabilities. This implies the submarine will be large and for the purposes of this discussion we will use the Australian notional figure of 4000 tonnes displacement. Using the Davies report referenced earlier as a guide, a probable unit cost of \$1.5Bn (2013 dollars) will be used. This figure is that provided in the report as the cost of “4000 tonne boat at Collins cost per tonne,” inflated to 2013 dollars. This is chosen as a representative midpoint option that does not appear grossly disproportionate to the presumptive cost of a 2000 tonne MOTS submarine. For the MOTS LEU SSN option, there is only the French contender, noted above at a unit cost of \$2.1Bn (CAD, 2013). A Canadian LEU SSN will be assumed to have the same displacement but to have a cost premium added to the unit cost to address the likely impact of developing the design. There are two MOTS HEU SSNs available for roughly the same cost. The higher of the two estimates presented above will be used as the basis of assessment.

A TEST CASE: The 12 SSK/6 SSN Project

Having examined some information on unit costs, the focus should now shift to determination of a cost estimate for a new submarine replacement project. What should such a project look like in terms of an initial form? Without dwelling overmuch perhaps on the Australian initiative to acquire 12 SSKs, perhaps the best place to start is by recalling the previous two serious Canadian initiatives for submarine acquisition.

As noted in Chapter 1, both the 1950s-60s project and the 1980s project commenced with a discussion on the acquisition of 12 platforms, and each considered the acquisition of SSNs. Why? There were likely several rationales, but all would have involved consideration of the RCN's ability to maintain a continuous submarine presence in one or more distant operating areas. In the modern context, given the probable location of regional disturbances that require Canadian intervention, it would be prudent to assess the RCN's ability to maintain a continuous presence in one or more operating areas on the other side of the globe, somewhere between the Suez Canal and the South China Sea. In either scenario, a reasonable assumption is that the approximate transit distance is 7,000 nm from home port so long as the closest Canadian port (Halifax or Esquimalt) serves as the point of departure. Assuming an 8 knot transit for an SSK, it would take 875 hours or 37 days to reach station. Add a refueling and re-provisioning stop of 3 days for a round figure of 40 days. Assuming 70 days on station (including a food and fuel stop) and then a return home, the deployment duration would be 150 days (40 days transit + 70 days patrol + 40 days return transit). Assuming the submarine had crew rest, training and maintenance requirements of 180 days per year, each operational submarine could deploy in this fashion once per year. With some minor adjustment to this profile, 5 SSKs would be needed to maintain coverage of such an area 365 days per year. Assuming that one submarine is always out of action for deep maintenance, 6 submarines are required. To cover two such missions simultaneously, 12 submarines are required. These numbers may be reduced by reducing the transit distance (i.e. forward basing a submarine)¹⁶⁶ or by double crewing the submarine, but absent the exercise of such options, 12 SSKs is

¹⁶⁶ A useful commentary on forward basing is contained in: Congressional Budget Office, *Increasing the Mission Capability of the Attack Submarine Force* (Washington DC: Congressional Budget Office, 2002).

the raw requirement to maintain a continuous submarine presence in two distant operating areas.

By contrast, assuming a 25 knot transit for a SSN, it would take 280 hours, or 12 days, to reach station with no requirement for refueling or to top up food supplies. Assuming 70 days on station (including a food stop) and then a return home, the deployment duration would be 94 days (12 days transit + 70 days patrol + 12 days return transit). Assuming the submarine had crew rest and maintenance requirements of 180 days (and permitting a 3 day allowance for rounding), the submarine could do this twice per year. With some minor adjustment to these profiles 2.5 SSNs could cover such an area 365 days per year. Assuming that one SSN is always in deep maintenance, 5 SSN's are required if operating from one coast, or 6 SSNs are required to have the same capability to deploy from either coast. In essence, 6 SSNs can do the same work as 12 SSKs. If we assume that Canada retained this level of capability on either coast, it would be possible for Canada to maintain a submarine presence anywhere in the world year round. The one caveat to this would be that in the SSK case, Canada would still not be able to maintain a presence under the ice.

Analysis such as this is not new. For instance, the RCNs own strategy document, *Leadmark 2020*, noted that a 3:1 ratio of deployed forces to reserve forces is generally required to maintain a unit continuously on task.¹⁶⁷ This analysis likely applies to surface ships, who are capable of the same transit speeds as SSNs for the most part. Even further into the past, the German Grand Admiral Karl Doenitz indicated that he used a ratio of 2:1 as the basis of his initial appraisal of requirements for what would eventually become the Battle of the Atlantic.¹⁶⁸ The difference in ratio

¹⁶⁷ *Leadmark 2020*, 102.

¹⁶⁸ Karl Doenitz, *10 Years and 20 Days* (Cambridge, MA: Da Capo Press, 1997), 33.

essentially comes down to the assumed distance to the patrol area and the assumed transit speed.

Using the foregoing discussion as the fundamental basis of assessment, some preliminary costing for a Canadian replacement submarine project intended to meet the objective of one RCN submarine on station continuously in two different operational areas may be developed. The costing will be premised on the acquisition of either 12 SSKs or 6 SSNs to meet the theoretical operational requirement articulated above.

Focusing for the moment on the development of unit costs using 2013 as the base year, a 2% constant inflation rate, and assuming any option is built offshore, the options identified in Chapter 5 may be a little more fully developed. For the first option, the MOTS SSK, cost data already presented suggests a unit cost of \$0.7Bn for the procurement of MOTS SSK at an assumed 2000 tonnes displacement, average within the MOTS SSK field. For the second option, the Canadian SSK, data presented already suggests that the development cost would be on the order of \$0.8-1.2Bn. To reflect the inexperience of the Canadian design base for this task the high end development estimate will be used - \$1.2Bn. Spreading this cost across as assumed 12 units and adding it to the \$1.5Bn construction cost estimate for this option discussed earlier results in an adjusted unit cost of \$1.6Bn. For the third option, the MOTS LEU SSN, there is only one non-developmental alternative - the French Barracuda - previously reported at a unit cost \$2.1Bn (CAD 2013). Fourth, for the Canadian LEU SSN, a somewhat more complex calculation is required. The development cost for this submarine could be approximated using the previously noted RAND estimate of \$0.8-\$1.2Bn for SSK design (The high end - \$1.2Bn will be chosen to reflect Canadian inexperience with submarine design) combined with an estimate of the development cost for the propulsion system. To estimate the required level of effort for the development of the propulsion system one might to look at the latest Selected Acquisition Report (SAR) for the Virginia Class submarine. The SAR is a requirement

under Title 10 US Code, Section 2432, whereby the US Secretary of Defense is obliged to report quarterly to Congress on the status of major defense acquisition projects. The SAR for the Virginia Class Attack Submarine as of Dec 31, 2011 identifies that in Base Year 1995 US Dollars, the VA class program accounts for \$5.866Bn in Research, Development, Test and Evaluation (RDT&E) and \$56.320Bn Shipbuilding and Conversion, Navy (SCN) funds.¹⁶⁹ Expressed in “Then Year” (i.e. without adjustment for inflation) USD figures, the RDT&E cost is \$6.993Bn and the SCN cost is \$86.282Bn. The cost to develop the propulsion plant is not directly identified, but “nuclear costs” in the SCN account are identified as \$14.4Bn (Then Year), or 16.7% of the \$86.3Bn (Then Year) overall SCN cost.¹⁷⁰ Assuming that the same approximate relationship holds for RDT&E, the nuclear portion of the total RDT&E could be estimated as 16.7% of \$6.993Bn, approximately \$1.2Bn USD. For the sake of simplicity it will be assumed that the 2013 CAD amount would be roughly equivalent to this (i.e. \$1.2Bn CAD). This would put the development cost for a Canadian LEU SSN at an estimated \$2.4Bn CAD. We could spread this cost across an assumed 6 units and add it to the \$2.1Bn unit cost for the Barracuda submarine to approximate an adjusted unit cost for this option as \$2.5Bn. Finally, for the MOTS SSN option, either the Astute or Virginia class submarines could be procured at a rough unit cost of \$2.6Bn.

¹⁶⁹ US Department of Defence, Selected Acquisition Report, SSN 774, as of December 31, 2011, [source on-line] available from http://www.dod.mil/pubs/foi/logistics_material_readiness/acq_bud_fin/SARs/DEC%202011%20SAR/SSN%20774%20-%20SAR%20-%2031%20DEC%202011.pdf; Internet; accessed 20 April 2014, 12.

¹⁷⁰ Ibid, 23.

This provides the following rough initial procurement assessment:

Option	Development Cost	Construction Cost	Number of Units	Capital Acquisition Cost (\$Bn, Base Year 2013)
12 2000t MOTS SSK	0	0.7	12	8.4
12 4000t Canadian SSK	1.2	1.5	12	19.2
6 5500t MOTS LEU SSN	0	2.1	6	12.6
6 5500t Canadian LEU SSN	2.4	2.1	6	15
6 7500t MOTS HEU SSN	0	2.6	6	15.6

Table 1: Capital Acquisition Cost of Selected Test Cases for a Canadian Submarine Replacement Program

A remarkable feature of this table is that all SSN options are less expensive from the perspective of capital outlay than the initial acquisition cost of a 4000t developmental submarine. This is assuming that a build could be completed at half the cost identified in the Andrew Davis paper. Even if the 4000t SSK could be built at the bargain price of \$1Bn (cheaper than the initial outlay for the Collins class at 3000t), the MOTS LEU SSN is still cheaper as a capital acquisition. That any SSN option would work out to be cheaper than any SSK option is counter intuitive, yet this is a reflection of the fact that the same work can be done with fewer platforms.

Extending the acquisition cost estimate, we may look at the through life costs of each option in an effort to understand the likely Life Cycle Costs for each option. At the beginning of this chapter, a 2012 PO&M cost of \$281.5M (or \$70.4M per hull) for the four VICTORIA Class submarines was surmised. By way of comparison, the 2011 PO&M cost for a Collins class submarine was reported as \$630M (or \$105M per hull).¹⁷¹ Accounting for the exchange rate (Average 1.02 CAD : 1 AUD throughout

¹⁷¹ Ian MacPhedran, "Sub Costs Twice as Much as US Nuclear Version," The Advertiser, Oct 17, 2011, [journal on-line]; available from <http://www.adelaidenow.com.au/news/sub-costs-twice-as-much-as-us-nuclear-version/story-e6frea6u-1226167997465>; Internet; accessed 29 October 2013.

most of 2011)¹⁷² and adjusting for inflation, we can approximate the Australian 2012 PO&M at \$109.2 CAD per submarine per year. The ratio of Canadian submarine PO&M to Australian submarine PO&M is therefore 70.4:109.2, or approximately 0.65:1. Having established this relationship it may also be useful to examine the relationship between hull sizes. The surfaced displacement of a Victoria Class submarine is 2185 tonnes,¹⁷³ whereas for a Collins class submarine it is 3000 tonnes.¹⁷⁴ The ratio of Canadian submarine surfaced displacement to Australian submarine surfaced displacement is therefore 2185:3000, or approximately 0.73:1. Relating PO&M cost to surfaced displacement between the two platforms gives Looking at the two ratios, it is possible to conclude that the difference in hull size accounts for 85% of the difference in PO&M cost. Furthermore, the two ratios are near enough equal to suggest that linear relationship may exist between hull displacement and PO&M cost. While the exact nature of the relationship between PO&M cost and hull size should be further investigated, to do so in great depth and with accurate costing information would require a Program Office working under non disclosure arrangements with peer navies. For the purposes of this study a 1:1 relationship will be assumed.

On the assumption that the PO&M cost of a Victoria class submarine would be approximately equal to that of the 2000t SSK option, and assuming that the relationship between hull displacement and PO&M cost is linear, an annual PO&M cost for each option can be generated and used to estimate a preliminary through life cost for each option. At an assumed service life of 30 years, the through life cost for each option would be as follows:

¹⁷² Drawn from the Bank of Canada's repository of historic exchange rates, [source on-line], available from <http://www.bankofcanada.ca/rates/exchange/10-year-lookup/>; Internet, accessed 30 March 2014.

¹⁷³ Deagel.com, *Victoria*, [source on-line]; available from http://www.deagel.com/Conventional-Attack-Submarines/Victoria_a000400001.aspx; Internet, accessed 10 November 2013.

¹⁷⁴ Deagel.com, *Collins*, [source on-line]; available from http://www.deagel.com/Conventional-Attack-Submarines/Collins_a000456001.aspx; Internet, accessed 10 November 2013.

Option	Capital Acquisition Cost (\$Bn, Base Year 2013)	PO&M (\$Bn, Base Year 2013)	Program Cost 2013 Start (\$Bn, Base Year 2013)
12 2000t MOTS SSK	8.4	25.8	34.2
12 4000t Canadian SSK	19.2	51.7	70.9
6 5500t MOTS LEU SSN	12.6	35.5	48.1
6 5500t Canadian LEU SSN	15	35.5	50.5
6 7500t MOTS HEU SSN	15.6	48.5	64.1

Table 2: Through Life Cost Assessment of Selected Test Cases

Amortizing these costs across an assumed 30 year asset life yields:

Option	Program Cost 2013 Start (\$Bn, Base Year 2013)	Amortized 30 years (\$Bn, Base Year 2013)
12 2000t MOTS SSK	34.2	1.1
12 4000t Canadian SSK	70.9	2.4
6 5500t MOTS LEU SSN	48.1	1.6
6 5500t Canadian LEU SSN	50.5	1.7
6 7500t MOTS HEU SSN	64.1	2.1

Table 3: Annualized Costs of Selected Test Cases, 30 Year Asset Life

Two essential observations fall out of the tables above. Firstly, a replacement submarine project on the scale envisioned above will account for a significant fraction of the defence budget whether or not the budget is increased to compensate for it. Secondly, a replacement submarine project on the scale envisioned above could feasibly deliver SSNs in lieu of SSKs at comparable cost. Even if the capital cost of the 4000t SSK was \$1Bn, it would still be the most costly option under consideration, at \$64.9Bn (or an annualized \$2.2Bn (2013)). Only the 2000t MOTS submarine in this analysis would be less costly.

With respect to the first point, even the ‘worst case’ Parliamentary Budget Office estimate for the through life cost of the F-35 procurement, at \$29.3Bn (BY

2011) for 65 aircraft,¹⁷⁵ is smaller than the lowest estimate here, although it is interesting to note that since the PBO report with respect to the F-35, the cost estimate has increased to \$44.7Bn (BY 2013).¹⁷⁶ If current spending on submarines is subtracted, which can be done by amortizing the Victoria Class in the same way over an assumed 20 years of service life (\$0.34Bn/yr (or \$85M/yr/boat)(BY 2013)), the increase in annual expenditure required would range from \$0.67Bn to \$2.06Bn depending on the option chosen – a 3.35-10.3% rise in real defence expenditure over the 2013 level of \$20.1Bn. This is a significant increase, and could only be considered affordable if offsets were identified (for example personnel reductions or the divestment of obsolete capabilities), or if the defence budget were increased. That said, it would be important to keep such changes in perspective. Even if the change were dealt with as a raw increase to the defence budget, at current spending levels, Canada's ratio of defence expenditure to GDP is 1.06%. The impact of funding the most expensive option above (12 4000t SSKs) would be to cause a rise in the defence to GDP ratio to 1.17%. By way of comparison, our closest ally - the United States - had a 2013 ratio of 3.8%, down from 4.4% in 2012.¹⁷⁷

This might engender a discussion over what constitutes a “fair” sharing of the burden of both defence services and defence expenditure amongst the world's democracies, since certainly the prevailing view in the United States is that the burden

¹⁷⁵ Canada, *An Estimate of the Fiscal Impact of Canada's Proposed Acquisition of the F-35 Lightning II Strike Fighter* (Ottawa: Parliamentary Budget Office, 2011).

¹⁷⁶ Canada, *Next Generation Fighter Capability Annual Update – August 2013* (Ottawa: Department of National Defence, 2013), [source on-line]; available from <http://www.forces.gc.ca/en/about-reports-pubs/next-gen-fighter-annual-update-2013.page#toc7a>; Internet; accessed 15 April 2014.

¹⁷⁷ Stockholm International Peace Research Institute, Military Expenditure Database, [source on-line]; available from <http://milexdata.sipri.org/files/?file=SIPRI+military+expenditure+database+1988-2013.xlsx>; Internet; accessed 15 April 2014.

in today's world is unfairly shared.¹⁷⁸ Perhaps it would be enough to offer that while Canada spends significantly on defence, there is a trade space wherein the nation could do much more. The effect of Canada making a decision to return to a 2% of GDP spending level would be to bring all options for this project well within the affordable scope for the Canadian Armed Forces to consider. Affordability is therefore tied to choice – and the choice is whether or not the Government of Canada believes that the requirement exists to allocate resources to this requirement or to defence generally against other potential uses of the funds.

With respect to the second point on the relative affordability of SSK and SSN options, it appears from this preliminary assessment that all SSN options would be less expensive than 12 4000t SSKs. This defies the conventional wisdom that SSKs are cheaper than SSNs, and tends to call into question the Australian decision not to pursue SSNs for their own program from an operational perspective, although it is recognized that Australia lacks the Canadian experience with nuclear power and that a sustaining industry for submarine construction may be easier to achieve with a greater number of platforms. Operationally, there would be an argument that quantity has a quality all its own – that 12 submarines are always better than 6 in terms of effects delivered and overall survivability of the force if individual members are attacked. There is also a converse argument – that the survivability of a submarine that cannot leave an area expeditiously after conducting an attack thereby avoiding counter-attack (i.e. the SSK) is highly debatable. Additionally, the fact that Canada is so far from the areas where it might desire to deliver effect means that speed is desirable not only from the tactical perspective of attack and evasion, but also both operationally and strategically in order to get effects into a theatre of operations swiftly. In the same vein, unrefueled range is operationally and strategically valuable as well, since the ability to forego refueling

¹⁷⁸ See for example Ellen Hallans and Benjamin Schreer, "Towards a 'Post-American' Alliance: NATO Burden Sharing After Libya," *International Affairs* 88:2 (2012), 313-327.

stops means that effects are delivered into theatre much earlier than would otherwise be possible, and means additionally that greater operational security can be maintained with respect to the deployment, since the submarine need not appear at ports along its transit route, and need not have its crew mingle with the local population. Furthermore, although the quantity of hulls would be less, the intrinsic value of having the ability to get under the ice safely and at will to Canada's ability to assert its sovereignty in Arctic areas should not be discounted. While quantity may have a quality all its own; speed, unrefueled range, and under ice capability each have qualities all their own as well.

It must be noted that these estimates do not consider the cost of infrastructure. RCN facilities at present are only appropriate to support 4 SSKs in homeport, as well as periodic visits of foreign SSKs and SSNs. Estimates for the infrastructure impacts should be prepared as part of the early work by the project office. In any event, the addition of infrastructure costs should not influence the figures above greatly, other than in terms of nuance. It could be said in general terms however that reduced infrastructure investment is another advantage of reducing the number of hulls, although in the case of the LEU fuelled submarine any savings in infrastructure might be offset by the requirement to build fuel handling as well as safety and regulatory infrastructure. In the case of HEU submarine acquisition, it is likely that nuclear infrastructure investment could be largely avoided. On the one hand, the current reactor designs for both Virginia and Astute are intended not to require refueling during the life of the submarine. On the other hand, if the RCN required refueling or specialized maintenance for HEU fuelled reactors, Canada could request access to USN facilities.

It must be noted as well that, although these estimates do include two "designed by Canada" options, they do not directly address the cost of building in Canada. This choice is somewhat deliberate, since the cost difference associated with doing so in terms of setting up industry is somewhat undefined and the subject of considerable

debate. The available literature is extremely subjective and implies a cost premium associated with domestic construction of somewhere between zero and 30%. A semi-quantitative study on the economic impact of purchasing offshore or building in Canada was undertaken on behalf of the Canadian Submarine Acquisition Project in 1989 by Louis Parai and Binyam Solomon.¹⁷⁹ Results were equivocal.

The Effect of Cost Escalation Above Inflation

In an acquisition of this complexity, it is likely that delays will be incurred as the Navy, the Department of National Defence, and Cabinet carefully consider options. This decision time, however, is not without its own cost. Such cost manifests in two essential ways: a requirement to life extend the asset to be replaced, and more importantly, a change in the cost of the replacement. This section will deal only with the latter impact. For the purposes of illustration, the potential cost of a 12 year delay in the commencement of a replacement project will be considered. As noted previously, the Australian Strategic Policy Institute was able to identify a 3.8% per year above inflation cost growth per tonne in submarines from 1910 through to present. This finding is consistent with other studies highlighting that Defence Specific Inflation is generally higher than the overall inflation rate in the general economy.¹⁸⁰ There would be many causes for such growth, amongst which commodity price increases, quality, and complexity are commonly cited. It is therefore likely that there will be a cost impact associated with a later start to the project. Assuming that 3.8% per annum is a reasonable estimate of this effect, and that PO&M costs are not affected (a

¹⁷⁹ Louis Parai and Binyam Solomon, *Project Report 598: Economic and Social Impacts of Submarine Acquisition Options* (Ottawa: National Defence, 1992).

¹⁸⁰ As an example, see David Kirkpatrick, "Is Defence Inflation Really as High as Claimed," Royal United Services Institute, October 2008, 66-71, [source on-line]; available from <https://www.rusi.org/downloads/assets/17kirkpatrick.pdf>; Internet; accessed 15 April 2014.

potentially optimistic assumption), it is possible to estimate the cost impact of waiting until 2025 to start a replacement project, as follows:

Option	Capital Acquisition Cost 2013 Start (\$Bn, BY 2013)	Capital Acquisition Cost 2025 Start (\$Bn, BY 2013)	Cost of 12 Years of Delay (\$Bn, BY 2013)
12 2000t MOTS SSK	8.4	13.1	4.7
12 4000t Canadian SSK	19.2	30.0	10.8
6 5500t MOTS LEU SSN	12.6	19.7	7.1
6 5500t Canadian LEU SSN	15	23.5	8.5
6 7500t MOTS HEU SSN	15.6	24.4	8.8

Table 4: The Cost of Delaying Acquisition

This is real cost growth as opposed to an inflationary one, although it is worth a moment to consider the effect of inflation because all too often the entire gamut of people involved in defence acquisition, defense planners, project managers, the bureaucracy, Cabinet and the Press seem to forget that inflation exists, that it will change the appearance of budgetary figures, and that it does not represent real cost growth unless – as in the scenario above – growth in the economy has failed to keep pace. For this reason, some caution has been exercised in this thesis to ensure that older estimates of cost have been properly framed in a common base year, 2013. This ensures that in some cases where options which some have identified as comparatively inexpensive (for instance MOTS submarines at \$550M per copy), older cost estimates used to support such arguments have been adjusted for current reality (yesterday’s \$550M is today’s \$683M).

Current Fiscal Context

The foregoing discussion highlighted costs and expressed that the acquisition would be affordable in a paradigm where the Government were willing to increase the defence budget even to 1.2% of GDP, and that affordability improves further under a

paradigm where a 2% of GDP level is adopted as a new standard. However, it is worthwhile to explore the existing budgetary constraints and climate when considering what may, or may not, be in the art of the possible with respect to funding. The Canada First Defence Strategy (CFDS) is Canada's articulated vision on the way forward for defence capital acquisitions for the next 20 years, and yet it contains no mention of a plan to replace submarines. Even without this addition, retired Commodore Eric Lehre has noted that from the point of view of a capital-intensive service like the RCN, the CFDS appears wholly imbalanced. As a raw dollar amount, the \$80 Bn capital investment discussed in CFDS may seem impressive, however it masks the fact that as a fraction of the total anticipated defence budget, capital investment is actually quite low in proportion to the overall budget. On this basis, the existing CFDS may be unaffordable, not because of the dollar values involved, but because of the resource fractions in play compared to the stated aspiration to modernize the force. Lehre contends that the CFDS calls for a 12:51 ratio of equipment acquisition to personnel costs, near historic lows experienced by the CAF in the 1970s, and against a reasonably well defined investment of between 23 and 27% required to avoid the "rust out" of the force.¹⁸¹ Lehre suggests that a way of restoring balance without expanding the overall funding envelope is to look at personnel numbers. That said, Binyam Solomon and J.C. Stone have pointed out in their survey of Canadian defence expenditure trends that there is little concrete justification for setting a capital expenditure at any fixed target level, that budget allocation decisions between personnel, operations and capital continue to be somewhat dynamic depending on the activity level of the Canadian Armed Forces and that capital investment is treated largely as a residual matter, after costs for personnel and operations are addressed.¹⁸²

¹⁸¹ Eric Lehre, "Getting the Capital and Personnel Mix Right: Implications for the Future of the Canadian Navy," in Griffiths and Lehre (ed), *Naval Gazing: The Canadian Navy Contemplates its Future* (Centre for Foreign Policy Studies, Dalhousie University, 2010), 56.

Nevertheless, recent statements by both the current Chief of the Defence Staff (CDS), General Tom Lawson,¹⁸³ as well as by former CDS General Rick Hillier, indicate that there may in fact be an appetite for personnel reduction given the current fiscal climate.¹⁸⁴ Retired Commander of the Canadian Army, Lieutenant-General Andrew Leslie advocates personnel cuts of a different sort – taking aim at the \$3 Billion in services contracts spent annually by DND.¹⁸⁵

One potential difficulty with personnel reduction, however, is that where capital reductions arguably strike at the heart of Navy and Air Force capabilities (one need only look at the forecast costs for the Navy’s recapitalization program, and the Air Force’s Next Generation Fighter program), personnel reductions could be argued to strike at the heart of Army capabilities. Additionally, the Government may resist reducing personnel numbers for political reasons.¹⁸⁶ In likely consequence of these types of considerations, alternative means are being pursued to reduce DND expenditures. A Defence Renewal Team has been stood up in an effort to find approximately \$1Bn per year in efficiencies within DND, money that can then be freed

¹⁸² J. Craig Stone and Binyam Solomon, “Canadian Defence and Economic Spending,” *Defence and Peace Economics*, Vol. 16(3), June 2005, pp. 145-169, 156-157.

¹⁸³ General Tom Lawson, quoted following remarks delivered to the Canadian Club, in Lee Berthiaume, “Troop Reductions Could be on the Table, Canada’s Defence Chief Says,” *Canada.com News*, 19 November 2013 [journal on-line]; available from <http://o.canada.com/news/national/troop-reductions-could-be-on-the-table-canadas-defence-chief-says/>; Internet, accessed 20 December 2013.

¹⁸⁴ General (retired) Rick Hillier, quoted in an interview with Andrea Janus, “Canada Just Can’t Get Around Army Cuts,” *CTV News* 23 September 2013 [source on-line]; available from <http://www.ctvnews.ca/canada/canada-just-can-t-get-around-army-cuts-hillier-says-1.1467584>; Internet, accessed 20 December 2013.

¹⁸⁵ Lieutenant-General (retired) Andrew Leslie, quoted in an interview with Evan Solomon, “Retired Generals Take Aim at Ottawa’s Handling of Defence Cuts,” *CBC News* 18 December 2013 [source on-line]; available from <http://www.cbc.ca/news/politics/retired-generals-take-aim-at-ottawa-s-handling-of-defence-cuts-1.2469381>; Internet, accessed 20 December 2013.

¹⁸⁶ David Pugliese, “Is Chief of the Defence Staff Gen. Tom Lawson Playing a Game of Chicken With Prime Minister Stephen Harper,” *Ottawa Citizen*, 20 November 2013 [article on-line]; available from <http://blogs.ottawacitizen.com/2013/11/20/is-chief-of-the-defence-staff-gen-tom-lawson-playing-a-game-of-chicken-with-prime-minister-stephen-harper/>; Internet, accessed 10 December 2013.

up for reinvestment elsewhere in the Department.¹⁸⁷ Additionally, the Army has cancelled a \$2Bn procurement for combat vehicles and deferred a project to replace 1500 trucks.¹⁸⁸ In this environment, a new submarine project will need to tread lightly.

Effect of Reduced Numbers – The 6SSK/3SSN project

Noting from the above discussion that there is a requirement to have lower cost alternatives available, it is worth presenting an assessment of what a reduced purchase quantity project might look like. In this case the operational requirement described earlier could be fulfilled by the SSK options, however the SSN force would have difficulty managing if one was always held out of service in repair. Broadly, the cost table would look as follows:

Option	Capital Acquisition Cost (\$Bn, BY 2013) 6SSK/3SSN	PO&M (\$Bn, BY 2013) 6SSK/3SSN	Program Cost 2013 Start (\$Bn, BY 2013) 6SSK/3SSN	Program Cost 2013 Start (\$Bn, BY 2013) 12SSK/6SSN (for comparison)
2000t MOTS SSK	4.2	12.9	17.1	34.2
4000t Canadian SSK	10.2	25.8	36.0	70.9
5500t MOTS LEU SSN	6.3	17.8	24.1	48.1
5500t Canadian LEU SSN	8.7	17.8	26.5	50.5
7500t MOTS HEU SSN	7.8	24.2	32.0	64.1

Table 5: The cost impact of a reduced order quantity project

Overall, in terms of capital acquisition cost the two developmental options become most expensive, but from a through-life cost perspective there is no change in

¹⁸⁷ Vanguard Staff, “Renewal Team Delivers a Plan to Rebalance CAF Priorities,” Vanguard Magazine, 9 October 2013 [journal on-line]; available from <http://vanguardcanada.com/renewal-team-delivers-plan-to-rebalance-caf-priorities/>; Internet, accessed 10 December 2013.

¹⁸⁸ Canadian Press, “Cancelled \$2B Armoured Vehicle Order Latest Procurement U-Turn,” Canadian Press, 20 December 2013 [article on-line]; available from <http://www.cbc.ca/news/politics/cancelled-2b-armoured-vehicle-order-latest-procurement-u-turn-1.2472020>; Internet, accessed 20 December 2013.

the relative positioning of the projects in terms of their cost. What the table does not communicate, however, is that unlike the 12SSK/6SSN case where all options are feasible, it would probably not be feasible to consider building only three submarines in Canada. Options involving the procurement of 6 SSKs may still be feasible for domestic construction subject to their inclusion in NSPS, but would see price increases associated with the fact that there are fewer platforms to spread the required infrastructure investment cost across, construction might need to be deliberately planned to take longer in order to bridge the gap to a follow-on replacement class, and the build yard would not gain the kind of experience needed to fully drive down costs in the later units to be constructed.

CONCLUSION

As indicated at the outset, the question of whether or not Canada should embark on a replacement submarine project essentially rests on three pillars; relevancy, feasibility and affordability. This paper has argued that a case exists to support the relevancy of submarines for the defence of Canada, fundamentally using roles identified for the Canadian Armed Forces in the Canada First Defence Strategy as the basis of this assessment. Secondly, this paper has outlined a wide array of potential options, all of which should be considered feasible – not on the basis of capabilities that the country possesses today, but rather on the basis of what the country has done in the past and is capable of doing in the future subject to the necessary investments in facilities. Finally, extending the discussion on feasible options, this paper has provided a preliminary cost estimate and noted several observations of interest that fall from the estimates.

With respect to relevancy, it could be argued that submarine capabilities or any other defence capabilities could be likened to insurance. The question is not really whether or not to carry insurance, but rather how much and what kinds. The choice facing Canada with respect to many of its defence capabilities is not fundamentally much different. Put into the context of Senator Dandurand, so long ago, if we are happy to forego fire insurance out of believe that our house is fireproof, yet fire breaks out in our neighbour's house and threatens to consume ours, we may wish we had acted with greater foresight. There are a large number of missions that can be usefully assigned to Canadian submarines, from ASW training of the RCN and allied navies, to covert and overt surveillance activities in domestic, international or foreign waters, to hard edged capabilities like screening RCN or allied ships on deployment in threat areas or carrying out strikes against targets on land or sea. In this vein it is useful to recall that allied submarines in the recent past have participated in UN embargo

operations, in counter-Piracy operations, in strike missions in Kosovo, Iraq and Afghanistan, and in the opening of Afghanistan to land forces in what became a decade long counter insurgent operation. Submarines can cover a wide range of contingency operations and an operate in areas otherwise denied to Naval forces. They continue to be relevant as an important weapon in the arsenal of democracy.

With respect to feasibility, it has been noted that there are a vast array of MOTS SSK options to consider, however MOTS options should not be regarded as a panacea for a capability requirement. Consideration of MOTS SSK options needs to account for the eventuality that RCN submarines may be ordered into action against comparable adversary submarines sourced from the same supplier, and needs to consider the impacts of an acquisition on the relationships with Canada's closest allies, as well as any associated second order effects in terms of lost intelligence or lost technical cooperation. At greater cost and risk, a developmental Canadian design could be worked up with assistance from one or all of the allies above. By no means however should the competitive field be limited to SSK options. There are at least three viable SSN options, of which two are MOTS – one LEU fuelled SSN from France, and two HEU fuelled SSNs from either the US or the UK – and one of which could be developmental Canadian designed SSN, worked up with assistance from an industrial partner. All options should be considered feasible, particularly in light of Canada's historic capabilities, the assessments of those involved in prior generations of submarine replacement projects, the will and know-how of the nation, and the probable availability of assistance from any of the UK, US, or Australia if it is required.

Finally, this thesis has addressed the question of affordability by first deriving a theoretical and very high-level operational requirement to satisfy, then preparing cost estimates against each option that would meet the requirement. Important points falling out of this analysis are that such a project would be very ambitious in the context of

current Canadian defence spending, and that SSN options to meet the requirement should be considered to be both feasible and affordable against the SSK options. The project could be de-scoped to procure fewer submarines, but the probable impact of doing so would be to restrict options and drive up unit costs in the case of domestic construction.

Overall, the question of where to go with a replacement project is wide open, assuming the Government allows a project to proceed. In context, the submarine replacement, if it were authorized at the most expensive option presented in this paper today, would cause a rise in defence expenditures from 1.06% of GDP to 1.17% of GDP. This rise, 10% of overall defence spending per year, should be kept in context. It seems large only because Canada chooses to set a defence expenditure level that represents a much lighter load in relation to the size of the economy than many of its allies, and a much lighter load than the US chooses to carry. A modest increase in the overall level of Canadian expenditure on defence could accommodate even the costliest option presented here.

That said, it may be unwise to show up in the West Block with proposals just yet. For all that it might be desirable to press forward with a new submarine project now, the timing of the project start will be vital. Ideally, it would start in an environment of economic growth, when the Government does not feel compelled to take austerity measures such as forced program reduction and deferral of other programs at the same time that the RCN attempts to carve a place for a replacement submarine in the Strategic Capability Investment Plan. Whatever the costs, timing is likely to be everything.

Bibliography

- _____. "A German Success Story," Asia-Pacific Defence Reporter, 22 December 2010. Journal on-line; available from <http://www.asiapacificdefencereporter.com/articles/98/A-German-Success-Story>; Internet; accessed 10 December 2013.
- _____. "Andrasta: Ocean Efficiency, Littoral Supremacy." DCNS Brochure. Source on-line; available from <http://en.dcnsgroup.com/wp-content/uploads/2010/10/61864.pdf>; Internet; accessed 10 December 2013.
- _____. "Barracuda SSN: Ocean Control and Deep Strike." DCNS Brochure. Source on-line; available from <http://en.dcnsgroup.com/wp-content/uploads/2010/10/61893.pdf>; Internet; accessed 10 December 2013.
- _____. "Brazil Opens New Submarine Shipyard." DCNS Press Release 5 March 2013. Article on-line; available from <http://www.defencetalk.com/brazil-opens-new-submarine-shipyard-47028/>; Internet; accessed 10 December 2013.
- _____. *Canada's Defence Industry: A Vital Partner Supporting Canada's Economic and National Interests Industry Engagement on the Opportunities and Challenges Facing the Defence Industry and Military Procurement*. Ottawa: Canadian Association of Defence and Security Industries, 2009.
- _____. "DCNS Annual Corporate and Social Responsibility Report." Source on-line; available from http://fr.dcnsgroup.com/flipbook/GB/DCNS_Annual_Report_2012/sources/index.htm; Internet; accessed 10 December 2013.
- _____. "EU NAVFOR, NATO and CTF151 to Enhance Counterpiracy Cooperation." Article on-line; available from <http://worldmaritimeneeds.com/archives/64081/>; Internet; accessed 20 September 2012.
- _____. "Foreign Military Financing." US Department of State, Bureau of Political-Military Affairs. Source on-line; available from <http://www.state.gov/t/pm/65531.htm>; Internet; accessed 10 December 2013.
- _____. "HDW Class 216." Thyssen Krupp Marine Systems, 2012. Source on-line; available from <http://www.thyssenkrupp-marinesystems.com/en/hdw-class-216.html>; Internet; accessed 10 December 2013.
- _____. "Japan Relaxes Decades-Old Arms Exports Ban – Kyodo," Reuters News Agency, 26 December 2011. Journal on-line; available from <http://www.reuters.com/article/2011/12/27/japan-defence-idUSL3E7NQ1HU20111227>; Internet; accessed 10 November 2013.

- _____. "Judgment: Doenitz." Source on-line; available at <http://avalon.law.yale.edu/imt/juddoeni.asp>; Internet; accessed 12 February 2012.
- _____. "Li-Ion Batteries for DCNS-Designed Scorpene Submarines." SAFT Press Release 4 November 2011. Source on-line; available from <http://www.saftbatteries.com/press/press-releases/li-ion-batteries-dcns-designed-scorpene-submarines>; Internet; accessed 10 Dec 2013.
- _____. "MESMA: AIP Module for Conventional Submarines." DCNS Brochure. Source on-line; available from <http://en.dcnsgroup.com/wp-content/uploads/2010/10/61983.pdf>; Internet; accessed 10 December 2013.
- _____. "Navantia Announce [sic] Delays in the S-80 Submarine Programme." Murcia Today, 9 May 2013. Journal on-line; available from http://muriatoday.com/navantia-announce-delays-in-the-s_80-submarine-programme_16545-a.html; Internet; accessed 10 November 2013.
- _____. "Report Torpedoes Collins Sub Fleet." The Advertiser, December 15, 2011. Journal on-line; available from <http://www.adelaidenow.com.au/news/chaos-torpedoes-collins-sub-fleet/story-e6frea6u-1226222295974>; Internet; accessed 24 October 2013.
- _____. "Scorpene Family: Multipurpose Oceangoing Submarines." DCNS Brochure. Source on-line; available from <http://en.dcnsgroup.com/wp-content/uploads/2010/10/61838.pdf>; Internet; accessed 10 December 2013.
- _____. "SEPIA, The Eco-Designed Submarine." Naval Experts: DCNS Business Magazine No. 19, December 2012, 26.
- _____. "Zwaardvis CO2 Poisoning." Article on-line; available from http://www.dutchsubmarines.com/pictures/pictures_zwaardvis2_co_%20poisoning_1994.htm; Internet; accessed 20 September 2012.
- Axworthy, Lloyd. *Navigating a New World: Canada's Global Future*. Ottawa: Random House, 2004.
- Barber, Ellen. *Cost As An Independent Variable (CAIV)*, Defence Acquisition University Teaching Note, February 2011. Source on-line; available from https://acc.dau.mil/adl/en-US/30380/file/61353/A4_CAIV_Feb%2011.pdf; Internet; accessed 10 November 2013.
- Barnett, Roger W. *Navy Strategic Culture: Why the Navy Thinks Differently*, Annapolis, MD: Naval Institute Press, 2009.

- Bedford, Christian. "Canada's Eyes and Ears Under the Pacific: A History of Submarines on the West Coast." *Canadian Naval Review*, Volume 6 Number 1, Spring 2010, pp 59-60.
- Berthiaume, Lee. "Troop Reductions Could be on the Table, Canada's Defence Chief Says." *Canada.com News*, 19 November 2013. Journal on-line; available from <http://o.canada.com/news/national/troop-reductions-could-be-on-the-table-canadas-defence-chief-says/>; Internet, accessed 20 December 2013.
- Birkler, John et al. *Australia's Submarine Design Capabilities and Capacities: Challenges and Options for the Future Submarine*. Arlington VA: RAND Corporation, 2011.
- Birkler, John. *Industry and Infrastructure for Future Submarines: An International Perspective*. Arlington VA: RAND Corporation, 2012.
- Birkler, John et al. *The US Submarine Production Base: An Analysis of Cost, Schedule and Risk for Selected Force Structures*. Washington DC: RAND Corporation, 1994.
- Blair, David. "Iran Threatens to Close Strait of Hormuz over EU Oil Sanctions." *The Telegraph*, 23 January 2012. Journal on-line; available from <http://www.telegraph.co.uk/news/worldnews/middleeast/iran/9032948/Iran-threatens-to-close-Strait-of-Hormuz-over-EU-oil-sanctions.html>; Internet; accessed 20 February 2012.
- Bow, James. "Toronto's Transit City LRT Plan." Toronto Transit Commission, 2011. Source on-line; available from <http://transit.toronto.on.ca/streetcar/4121.shtml>; Internet; accessed 10 December 2013.
- Brubaker, Gerald L. "Taking a Dive for a Friend: The Decision to Transfer Nuclear Submarine Technology to Canada." NWC Essay 91-32. National War College, December 10, 1990.
- Bumiller, Elisabeth, Eric Schmitt and Thom Shanker. "US Sends Top Iranian Leader a Warning on Strait Threat." *The New York Times*, 12 January 2012. Journal on-line; available from http://www.nytimes.com/2012/01/13/world/middleeast/us-warns-top-iran-leader-not-to-shut-strait-of-hormuz.html?_r=1; Internet; accessed 20 February 2012.
- Butler, RDML John D. (USN Retd). "The Sweet Smell of Acquisition Success." *United States Naval Institute Proceedings Magazine*, June 2011, vol 137/6/1,300. Journal on-line; available from <http://usni.org/magazines/proceedings/2011-06/sweet-smell-acquisition-success>; Internet; accessed 4 November 2013.

- Byers, Michael and Stewart Webb. *Blank Cheque: National Shipbuilding Procurement Strategy Puts Canadians at Risk*. Ottawa: Canadian Centre for Policy Alternatives/Rideau Institute, December 2013.
- Byers, Michael and Stewart Webb. *That Sinking Feeling: Canada's Submarine Program Springs a Leak*. Ottawa: Canadian Centre for Policy Alternatives/Rideau Institute, June 2013.
- Canada. *An Estimate of the Fiscal Impact of Canada's Proposed Acquisition of the F-35 Lightning II Strike Fighter*. Ottawa: Parliamentary Budget Office, 2011.
- Canada. *Budget 89*. Ottawa: Department of Finance, 1989.
- Canada. *Canada First Defence Strategy*. Ottawa: National Defence, 2008.
- Canada. "Department of National Defence Report on Plans and Priorities, 2011-12." National Defence, 2011. Source on-line; available from <http://www.tbs-sct.gc.ca/rpp/2011-2012/inst/dnd/dnd-eng.pdf>; Internet; accessed 10 November 2013.
- Canada. "Department of National Defence Report on Plans and Priorities 2012-13." National Defence, 2012. Source on-line; available from <http://www.tbs-sct.gc.ca/rpp/2012-2013/inst/dnd/dnd-eng.pdf>; Internet; accessed 10 November 2013.
- Canada. "Canada: Economic and Financial Data." Statistics Canada webpage. Source on-line; available from <http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/dsbbcan-eng.htm>; Internet; accessed 30 December 2013.
- Canada. *Fall 2009 Report of the Auditor General of Canada to the House of Commons*. Ottawa: Office of the Auditor General, 2009.
- Canada. "Government of Canada Announces National Shipbuilding Procurement Strategy." Public Works and Government Services Canada, 2010. Source on-line; available from <http://news.gc.ca/web/article-en.do?crtr.sj1D=&mthd=advSrch&crtr.mnthndVl=12&nid=537299>; Internet; accessed 10 December 2013.
- Canada. *Leadmark 2020*. Ottawa: National Defence, 2000.
- Canada. "Minister MacKay Congratulates Crews for Their Role in Multi-National Counter-Drug Operation." DND Press Release 14 Nov 2013. Source on-line; available from http://marketwired.com/printer_friendly?id=1586567; Internet; accessed 29 Oct 2013.

- Canada. *Next Generation Fighter Capability Annual Update – August 2013*. Ottawa: Department of National Defence, 2013. Source on-line; available from <http://www.forces.gc.ca/en/about-reports-pubs/next-gen-fighter-annual-update-2013.page#toc7a>; Internet; accessed 15 April 2014.
- Canada. *Project Approval Directive*. Ottawa: National Defence (Vice Chief of the Defence Staff), 2012. DND Internal only.
- Canada. *Review of the Submarine Acquisition/Capability Life Extension Program*. Ottawa: National Defence (Chief of Review Services), 2003.
- Canada. *Securing an Open Society: Canada's National Security Strategy*. Ottawa: Privy Council Office, 2004.
- Canada. *Securing Canada's Ocean Frontiers: Charting the Course From Leadmark*. Ottawa: National Defence, 2005.
- Canada. *The Canadian Submarine Acquisition Project: A Report of the Standing Committee on National Defence*. Ottawa: House of Commons, 1988
- Canada. *Treasury Board(TB)/Minister of National Defence (MND) Submission Process Review*. Ottawa: National Defence (Chief of Review Services), 2009.
- Canadian Institute for Health Information, *National Health Expenditure Trends, 1975 to 2013*. Ottawa, ON: CIHI, 2013.
- Canadian Naval Review. "Why Submarines?" Canadian Naval Review, BroadSides Forum. Journal on-line; available from <http://naval.review.cfps.dal.ca/forum/view.php?topic=36>; Internet; accessed 24 Oct 2013.
- Canadian Press. "Cancelled \$2B Armoured Vehicle Order Latest Procurement U-Turn." Canadian Press, 20 December 2013. Article on-line; available from <http://www.cbc.ca/news/politics/cancelled-2b-armoured-vehicle-order-latest-procurement-u-turn-1.2472020>; Internet, accessed 20 December 2013.
- Canadian Submarine Consortium. "Remarks by Robert Tessier at an Industry Luncheon 3 May 1988." Submarines for Canada, Ottawa: Canadian Submarine Consortium, 1988. (Available from DND Directorate of History and Heritage.)
- Canadian Submarine Consortium. "Backgrounder: Building Nuclear Submarines in Canada – Handling the Technology Transfer." Ottawa: Canadian Submarine Consortium, 1988. (Available from DND Director of History and Heritage.)
- Canadian Submarine Consortium. "Company Profiles of Consortium Members." Ottawa: Canadian Submarine Consortium, 1988. (Available from DND Directorate of History and Heritage.)

- Chapin, Paul and George Petrolekas. "Canada Needs a National Security Strategy." iPolitics, 21 February 2012. Journal on-line; available from <http://www.ipolitics.ca/2012/02/21/cda-institute-canada-needs-a-national-security-strategy/>; Internet; accessed 1 November 2013.
- Churchill, Winston. *The Second World War: Volume II – Their Finest Hour*. London: Penguin Books, 1985 (reprinted).
- Commonwealth of Australia. *Defending Asia in the Pacific Century, Force 2030*. Canberra: Commonwealth of Australia, 2009.
- Commonwealth of Australia. "Minister for Defence – Media Release – Submarine Technology," 16 May 2013. Source on-line; available from <http://www.minister.defence.gov.au/2013/05/16/minister-for-defence-media-release-submarine-technology/>; Internet; accessed 10 December 2013.
- Commonwealth of Australia. "Senate Adjournment, Defence Equipment Speech by Senator Gary Humphries, Tuesday 7 Feb 2012." Hansard on-line; available from http://parlinfo.aph.gov.au/parlInfo/genpdf/chamber/hansards/24adae21-1d61-4769-9c99-2f9970fb951a/0220/hansard_frag.pdf;fileType=application%2Fpdf; Internet; accessed 20 October 2012.
- Commonwealth of Australia. *White Paper on Defence 2013*. Canberra: Department of Defence, 2013.
- Congressional Budget Office. *Increasing the Mission Capability of the Attack Submarine Force*. Washington, DC: Congressional Budget Office, 2002.
- Congressional Budget Office. *Options for the Navy's Future Fleet*. Washington, DC: Congressional Budget Office, 2006.
- Costello, Sean and Andrew Davies. *How to Buy a Submarine*. Canberra: The Australian Strategic Policy Institute, 2009.
- Cowan, Simon. *Future Submarine Should Raise Periscope for Another Look*. St. Leonard's, NSW: The Centre For Independent Studies, 2012.
- Craven, Michael. "Making Waves: Response to Gillis Article in Winter Issue." *Canadian Naval Review*, Vol 5 Number 1 (Spring 2005), pp. 28-32.
- Craven, Michael. "A Rational Choice Revisited – Submarine Capability in a Transformational Era." *Canadian Military Journal*, Winter 2006-2007, pp. 21-32.

- Crickard, Fred (ed.). *A New Submarine for Canada*, A Special Edition of the Wings Magazine, Calgary: Corvus Publishing Group, 1986
- Davies, Andrew. *What Price the Future Submarine*, Canberra: The Australian Strategic Policy Institute, 2012.
- Deagel.com. "Collins." Source on-line; available from http://www.deagel.com/Conventional-Attack-Submarines/Collins_a000456001.aspx; Internet; accessed 10 November 2013.
- Deagel.com. "Scorpene Basic – AIP." Source on-line; available from http://www.deagel.com/Conventional-Attack-Submarines/Scorpene-Basic-AIP_a000425003.aspx; Internet; accessed 10 November 2013.
- Deagel.com. "Soryu." Source on-line; available from http://www.deagel.com/Conventional-Attack-Submarines/Soryu_a002707001.aspx ; Internet; accessed 10 November 2013.
- Deagel.com. "Suffren." Source on-line; available from http://www.deagel.com/Nuclear-Attack-Submarines/Suffren_a000424001.aspx; Internet; accessed 10 November 2013.
- Deagel.com. "Type A26." Source on-line; available from http://www.deagel.com/Conventional-Attack-Submarines/Type-A26_a000438001.aspx; Internet; accessed 10 November 2013.
- Deagel.com. "U212A." Source on-line; available from http://www.deagel.com/Conventional-Attack-Submarines/U212A_a000455001.aspx; Internet; accessed 10 November 2013.
- Deagel.com. "Victoria." Source on-line; available from http://www.deagel.com/Conventional-Attack-Submarines/Victoria_a000400001.aspx; Internet; accessed 10 November 2013.
- Defensenews.com. "South Korea Exports Submarines to Indonesia." Agence France-Presse, 21 December 2011. Journal on-line; available from <http://www.defensenews.com/article/20111221/DEFSECT03/112210305>; Internet; accessed 23 October 2013.
- Defense Industry Daily Staff. "France's Future SSN: The Barracuda Class." Defense Industry Daily, 6 November 2012. Journal on-line]; available from <http://www.defenseindustrydaily.com/frances-future-ssns-the-barracuda-class-02902/>; Internet; accessed 10 November 2013.
- Doenitz, Karl. *10 Years and 20 Days*. Cambridge, MA: Da Capo Press, 1997.

- Economic Times. "INS Chakra: Government Inducts Russian-Origin Akula II Class Nerpa into Navy," 4 April 2012. Journal on-line; available from <http://economictimes.indiatimes.com/news/politics-and-nation/ins-chakra-govt-inducts-russian-origin-akula-ii-class-nerpa-into-navy/articleshow/12526102.cms>; Internet; accessed 10 November 2013.
- Erickson, Andrew S., Lyle J. Goldstein, William S. Murray and Andrew R. Wilson. *China's Future Nuclear Submarine Force*. Annapolis, MD: Naval Institute Press, 2007.
- EU Naval Forces. "Key Facts and Figures, EU Naval Force Somalia, Operation Atalanta." Source on-line; available from <http://eunavfor.eu/key-facts-and-figures/>; Internet; accessed 7 December 2013.
- Ferguson, Julie H. *Through a Canadian Periscope*. Toronto: Dundurn Press, 1995.
- Ferguson, Julie H. *Deeply Canadian: New Submarines for a New Millenium*. Port Moody, BC: Beacon Publishing, 2000.
- Friedman, Jonah. "Nuclear vs Diesel Submarines." Center for Strategic & International Studies, 2011. Source on-line; available from <http://csis.org>; Internet; accessed 23 October 2013
- Friedman, Norman. *Submarine Design and Development*, Annapolis MD: Naval Institute Press, 1984.
- Garamone, Jim. "U.S. Marines Return From Afghanistan Tour." American Forces Press Services, April 18, 2002. Journal on-line; available from <http://www.defense.gov/News/NewsArticle.aspx?ID=44153>; Internet; accessed 23 February 2012.
- Gillis, J. Matthew. "An Undersea Identity Crisis: Evaluating Realistic Roles for Canada's Submarine Fleet." *Canadian Naval Review* Vol 4, Number 4, Winter 2009, pp. 4-9.
- Global Security.Org. "Submarine Ship Building." Source on-line; available from <http://www.globalsecurity.org/military/systems/ship/scn-sub.htm>; Internet; accessed 23 October 2013.
- Global Security.Org. "1959-Nuclear Submarine Survey." Source on-line; available from <http://www.globalsecurity.org/military/world/canada/hmcs-ssn-1959.htm>; Internet; accessed 23 October 2013.
- Global Security.Org. "1987 – Submarine Acquisition Project." Source on-line; available from <http://www.globalsecurity.org/military/world/canada/hmcs-ssn-1987.htm>; Internet; accessed 23 October 2013.

- Griffiths, Ann L. (ed.). *The Canadian Navy and The New Security Agenda, Proceedings of the Maritime Security and Defence Seminar, Toronto 26-27 April 2004*. Halifax: The Centre for Foreign Policy Studies, Dalhousie University, 2004.
- Griffiths, Ann L. and Eric Lehre (ed.). *Naval Gazing: The Canadian Navy Contemplates its Future*. Halifax: Centre for Foreign Policy Studies, Dalhousie University, 2010.
- Gumley, Dr. Stephen. "Remarks to the Defence+Industry Conference 2011." Source on-line; available from http://www.defence.gov.au/dmo/ceo/speeches/CEO_DI_Conf11.pdf; Internet; accessed 10 Dec 2013.
- Hallans, Ellen and Benjamin Schreer. "Towards a 'Post-American' Alliance: NATO Burden Sharing After Libya." *International Affairs* 88:2 (2012), 313-327.
- Hansen, Ken. "More Criticism 'Surfaces' of Byers-Webb Report on Submarines." *Naval Review*, August 2013. Journal on-line; available from <http://www.navalreview.ca/2013/08/more-criticism-surfaces-of-byers-webb-report-on-submarines/>; Internet; accessed 7 December 2013.
- Harper, LCDR Stephen R. "Submarine Operations During the Falklands War." US Naval War College Rhode Island, 1994. Article on-line; available from www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA279554; Internet; accessed 10 December 2013.
- Haydon, Peter. "The CHICOUTIMI Accident: Lessons Learned and Not Learned." *Canadian Military Journal* Autumn 2005, pp. 15-24
- Haydon, Peter and Dan Middlemiss. "A Conversation with Rear-Admiral Dan McNeil, Part II." *Canadian Naval Review*, Vol 1 Number 2, Fall 2005.
- Hickley, Matthew. "The Uninvited Guest: Chinese Sub Pops Up in the Middle of US Navy Exercise, Leaving Military Chiefs Red Faced." *Daily Mail*, 10 Nov 2007. Journal on-line; available from <http://www.dailymail.co.uk/news/article-492804/The-uninvited-guest-Chinese-sub-pops-middle-U-S-Navy-exercise-leaving-military-chiefs-red-faced.html>; Internet; accessed 12 February 2012.
- HMS Conqueror. "Op Corporate: Record of Proceedings." Source on-line; available from <https://www.gov.uk/government/publications/hms-conqueror-op-corporate-report-of-proceedings>; Internet; accessed 20 September 2012.
- HM Government. *Securing Britain in an Age of Uncertainty: Strategic Defence and Security Review*. London: Her Majesty's Stationery Office, 2010.

- Hofilena, John. "Japan Launches Newest Submarine Kokuryu Amid Party Atmosphere." Japan Daily Press, 4 Nov 2013. Journal on-line; available from http://japandailypress.com/japan-launches-newest-submarine-kokuryu-amid-party-atmosphere-0438960/?goback=%2Egde_73174_member_5794804489445736448#%21; Internet; accessed 10 November 2013.
- International Submarine Engineering Ltd. "Arctic Explorer AUV." Source on-line; available from http://www.ise.bc.ca/pdfs/ISE_Arctic_Explorer_AUV_Datasheet_2012.pdf; Internet; accessed 15 November 2012.
- International Submarine Engineering Ltd. "Dorado Semisubmersible Minehunting Vehicle." Source on-line; available from http://www.ise.bc.ca/pdfs/ISE_Dorado_Semisubmersible_AUV_Datasheet_2012.pdf; Internet; accessed 15 November 2012.
- International Submarine Engineering Ltd. "Dolphin Mk1 Semisubmersible AUV." Source on-line; available from <http://www.ise.bc.ca/dolphin/ise%20semi-submersible%20dolphin.pdf>; Internet; accessed 15 November 2012.
- International Submarine Engineering Ltd. "Explorer AUV." Source on-line; available from http://www.ise.bc.ca/pdfs/ISE_Explorer_AUV_Datasheet_2012.pdf; Internet; accessed 15 November 2012.
- International Submarine Engineering Ltd. "ISE Delivers Power and Control Systems For US Navy Submarine Rescue System." Source on-line; available from http://www.ise.bc.ca/News/2007-09_PRMS.pdf; Internet; accessed 15 November 2012.
- Ireland, Gavin. "Beyond Artful: Government and Industry Roles in Britain's Future Submarine Design, Build and Support." Whitehall Report 3-07. London: Royal United Services Institute, 2007.
- Jackson, Aaron P. "Keystone Doctrine Development in Three Commonwealth Navies." A Paper Prepared for the King-Hall Naval Conference, Hosted by the Sea Power Centre Australia, Canberra, 30-31 Jul 2009.
- Janus, Andrea. "Canada Just Can't Get Around Army Cuts." CTV News 23 September 2013. Source on-line; available from <http://www.ctvnews.ca/canada/canada-just-can-t-get-around-army-cuts-hillier-says-1.1467584>; Internet, accessed 20 December 2013.
- Japan Times. "China Displays its Marine Muscle with Sub Fleet," 29 October 2013. Journal on-line; available from <http://www.japantimes.co.jp/news/2013/10/29/asia-pacific/china-displays-its-marine-muscle-with-sub-fleet/>; Internet; accessed 10 November 2013.

- Jenkins, Chris. "Risk and Value: A CEO's Perspective." In ASPI Special Report November 2011, "Three Views of Risk: Selecting and Acquiring Military Equipment." pp. 19-21. Source on-line; available from https://www.aspi.org.au/publications/special-report-issue-42-three-views-of-risk-selecting-and-acquiring-military-equipment/SR42_Risk.pdf; Internet; accessed 10 December 2013.
- Kan, Shirley. "Taiwan: Major Arms Sales Since 1990." Washington DC, Congressional Review Services, November 29, 2012.
- Kenny, Colin. "The Sinking of Canada's Submarine Defence: A Lot of Good Money Chasing Bad." Source on-line; available from <http://colinkenny.ca/en/p102492>; Internet; accessed 18 June 2013.
- Kinnaird, Malcolm. "Defence Procurement Review 2003." Report on-line; available from <http://www.defence.gov.au/publications/dpr180903.pdf>; Internet; accessed 10 Nov 2012.
- Kirkpatrick, David. "Is Defence Inflation Really as High as Claimed." Royal United Services Institute, October 2008, 66-71. Source on-line; available from <https://www.rusi.org/downloads/assets/17kirkpatrick.pdf>; Internet; accessed 15 April 2014.
- Kitson, Lt Gen Sir Frank. *Low Intensity Conflict: Subversion, Insurgency, Peacekeeping*, London: Faber and Faber, 1991.
- Krepinevich, Andrew F. *7 Deadly Scenarios*. New York: Bantam Books, 2009.
- Kockums. "Kockums Receives Overall Design Order for Next Generation Submarine." Thyssen Krupp Marine Systems. Source on-line; available from <http://www.kockums.se/en/news/k/>; Internet; accessed 17 November 2013.
- Kockums. "Kockums A26." Thyssen Krupp Marine Systems. Source on-line; available from <http://www.kockums.se/en/products-services/submarines/kockums-a26>; Internet; accessed 17 November 2013.
- Labs, Eric. "An Analysis of the Navy's Shipbuilding Plans, Statement before the Subcommittee on Seapower and Projection Forces." Committee on Armed Services, US House of Representatives, 9 Mar 2011.
- Lajeunesse, Adam. "Sovereignty, Security and the Canadian Nuclear Submarine Program." *Canadian Military Journal*, Winter 2007-2008, pp. 74-82.
- Lacroix, Frank W., Robert W. Button, Stuart E. Johnson and John R. Wise. *A Concept of Operations for a New Deep-Diving Submarine*. Santa Monica, CA: RAND Corporation, 2002.

- Lawson, LGen Tom and Capt Michael Sawler. "NORAD in 2012 – Ever Evolving, Forever Relevant," *Canadian Military Journal*, Vol. 12 No. 3, Summer 2012, pp. 5-17.
- Lehre, Cmdre Eric (RCN Retired). "Getting the Capital and Personnel Mix Right: Implications for the Future of the Canadian Navy." in Griffiths and Lehre (ed), *Naval Gazing: The Canadian Navy Contemplates its Future*, Halifax: Centre for Foreign Policy Studies, Dalhousie University, 2010.
- Lehre, Cmdre Eric (RCN Retired). *The National Shipbuilding Procurement Strategy: An Update*. Ottawa: Canadian Defence and Foreign Affairs Institute, Strategic Studies Working Group Papers, 2012.
- Loo, Bernard (ed.) *Military Transformation and Strategy: Revolutions in Military Affairs and Small States*. New York: Routledge, 2008.
- Ma, Chunyan and Frank von Hippel. "Ending the Production of Highly Enriched Uranium for Naval Reactors." *The Nonproliferation Review*, Spring 2001. Journal on-line; available from <http://cns.miis.edu/npr/pdfs/81mahip.pdf>; Internet; accessed 20 March 2013.
- Maddison, VAdm Paul. "Commander RCN's Guidance FY 2012/2013 Through 2015/2016, 9 November 2011, 3371-1948-1 (DMSC – RDIMS 225233). DND Internal Only.
- MacIntyre, Ben. *Operation Mincemeat: How a Dead Man and a Bizarre Plan Fooled the Nazis and Assured an Allied Victory*, New York: Harmony Books, 2010.
- MacPhedran, Ian. "Sub Costs Twice as Much as US Nuclear Version." *The Advertiser*, Oct 17, 2011. Journal on-line; available from <http://www.adelaidenow.com.au/news/sub-costs-twice-as-much-as-us-nuclear-version/story-e6frea6u-1226167997465>; Internet; accessed 29 October 2013
- Magahy, Ben, Francisco Vilhena da Cunha, and Mark Pyman. *Defence Offsets: Addressing the Risks of Corruption and Raising Transparency*. London: Transparency International-UK, 2010.
- Maloney, Sean M. "Canadian Subs Protect Fisheries." *United States Naval Institute Proceedings Magazine*, March 1998, vol 124/3/1,141. Journal on-line; available from <http://www.usni.org/print/8648>; Internet; accessed 29 October 2013.
- Mann, Jim. "US Promised Subs to Taiwan it Doesn't Have." *LA Times*, 15 July 2001.
- McNamee, Dr. Terence (ed.). *The Innovative Use of Private Finance in Defence Acquisition*. Whitehall Paper 63, London: The Royal United Services Institute, 2004.

- Minnick, Wendell. "Submarine Decisions Show Lack of Creativity." Taipei Times, 16 October 2004.
- Mitchell, Paul T. *Full of Holes: Byers and Webb on Canada's Submarine Programme*, Canadian Defence and Foreign Affairs Institute, Calgary, 2013.
- Mitchell, Paul T. "Submarines and Canadian Security: Tactical Perspectives and Strategic Rationales." Article on-line; available from <http://www.canadianmilitaryhistory.ca/submarines-and-canadian-security-tactical-perspectives-strategic-rationales-by-paul-t-mitchell/>; Internet; accessed 9 December 2013.
- Mizokami, Kyle. "Asia's Submarine Race." USNI News 13 November 2013. Journal on-line; available from <http://news.usni.org/2013/11/13/asias-submarine-race>; Internet; accessed 20 November 2013.
- Morgan, David. "US Says Chinese Vessels Harrassed Navy Ship." Washington, Reuters, 9 Mar, 2009. Journal on-line; available from <http://www.reuters.com/article/2009/03/09/us-usa-china-navy-idUSTRE52845A20090309>; Internet; accessed 12 February 2012.
- Moskvitch, Katia. "Russia to Build Biggest Nuclear Powered Icebreaker." BBC News, 12 September 2012. Source on-line; available from <http://www.bbc.com/news/technology-19576266>; Internet; accessed 15 April 2014.
- Naval History and Heritage Command. "Biographies in History: Lieutenant Junior Grade George Bush, USNR." Article on-line; available from <http://www.history.navy.mil/faqs/faq10-1.htm>; Internet; accessed 12 February 2012.
- Naval History and Heritage Command. "H.L. Hunley, Confederate Submarine." Article on-line; available from <http://www.history.navy.mil/branches/org12-3.htm>; Internet; accessed 12 February 2012.
- Naval History and Heritage Command. "US Navy in Desert Shield/Desert Storm War Chronology, January 1991." Article on-line; available from <http://www.history.navy.mil/wars/dstorm/dsjan2.htm>; Internet; accessed 20 September 2012.
- Naval History and Heritage Command. "USS Nautilus Pamphlet." Source on-line; available at <http://www.history.navy.mil/Special%20Highlights/Nautilus/pamphlet.htm>; Internet; accessed 12 February 2012.

- OC Transpo. *2012 Facts and Figures*. Source on-line; available from http://www.octranspo1.com/images/files/reports/Facts_Brochure_201.pdf; Internet, accessed 1 November 13.
- O'Dwyer, Gerard. *Norway Should Maintain Submarine Fleet: Study*, Defensenews.com, 10 November 2011. Source on-line; available from <http://www.defensenews.com/article/20111110/DEFSECT03/111100305/Norway-Should-Maintain-Submarine-Fleet-Study>; Internet; accessed 23 January 2012.
- Organization for Economic Cooperation and Development. "History of the 0.7% ODA Target." Article on-line; available from <http://www.oecd.org/dac/stats/45539274.pdf>; Internet; accessed 2 February 2010.
- O'Rourke, Ronald, *Navy Virginia (SSN-774) Class Attack Submarine Procurement: Background and Issues for Congress*. Washington DC: Congressional Research Service, 2013.
- Parai, Louis and Binyam Solomon. *Project Report 598: Economic and Social Impacts of Submarine Acquisition Options*. Ottawa: National Defence, 1992.
- Parker, John. *Modern Submarines*. London: Arness Publishing, 2009.
- Perkins, J. David. *The Canadian Submarine Service in Review*. St. Catherine's ON: Vanwell Publishing, 2000.
- Perry, David. *Defence Austerity: The Impact to Date*. Ottawa: Conference of Defence Associations Institute, 2013.
- Prebble, Stuart. *Secrets of the Conqueror*. London: Faber and Faber, 2012.
- Pugliese, David. "Is Chief of the Defence Staff Gen. Tom Lawson Playing a Game of Chicken With Prime Minister Stephen Harper?" *Ottawa Citizen*, 20 November 2013. Article on-line; available from <http://blogs.ottawacitizen.com/2013/11/20/is-chief-of-the-defence-staff-gen-tom-lawson-playing-a-game-of-chicken-with-prime-minister-stephen-harper/>; Internet, accessed 10 December 2013.
- Radford, Phillip. *A Farewell to Nuclear Submarines, For Now*, *The Strategist*, 15 May 2013, Article on-line; available from <http://www.aspistrategist.org.au/a-farewell-to-nuclear-submarines-for-now/>; Internet; accessed 30 Dec 2013.
- Rempel, Roy. *Dreamland: How Canada's Pretend Foreign Policy Has Undermined Sovereignty*. Kingston: Queen's University Press, 2006.

- Robinson, Bill. "Canadian Military Spending 2010-2011." CCPA Foreign Policy Series, March 2011. Article online; available from <http://www.policyalternatives.ca/sites/default/files/uploads/publications/National%20Office/2011/03/Canadian%20Military%20Spending%202010.pdf>; Internet; accessed 20 February 2012.
- Ross, Robert. "The 1995-96 Taiwan Strait Confrontation: Coercion, Credibility and the Use of Force." *International Security* Fall 2000, Vol. 25, No. 2: 87–123.
- Sang-Hun, Choe. "South Korea Publicly Blames the North for Ship Sinking," *New York Times*, 19 May 2010, [article on-line]; available from http://www.nytimes.com/2010/05/20/world/asia/20korea.html?pagewanted=1&_r=0&ref=global-home; Internet; accessed 13 Apr 15.
- Schank, John L., Frank W. Lacroix, Robert E. Murphy, Mark V. Arena and Gordon T. Lee. *Learning From Experience: Lessons From the Submarine Programs of the United States, United Kingdom, and Australia*. Washington DC: RAND Corporation, 2011.
- Shimooka, Richard. *Towards an International Model for Canadian Defence Procurement? An F-35 Case Study*. Ottawa: Conference of Defence Associations Institute, 2013.
- Sloan, Elinor. "The Rise of China: Military Implications for Canada." CDFAI Newsletter, Spring 2011. Article on-line; available from http://www.cdfai.org/newsletters/newsletterspring2011.htm#The_Rise_of_China:_Military_Implications_For_Canada; Internet; accessed 22 Oct 2013.
- Solomon, Evan. "Retired Generals Take Aim at Ottawa's Handling of Defence Cuts." *CBC News* 18 December 2013. Source on-line; available from <http://www.cbc.ca/news/politics/retired-generals-take-aim-at-ottawa-s-handling-of-defence-cuts-1.2469381>; Internet, accessed 20 December 2013.
- Sontag, Sherry and Christopher Drew. *Blind Man's Bluff: The Untold Story of American Submarine Espionage*, New York: Public Affairs, 1998.
- Special Operations.com. "Feature: Operation Ivy Bells." Article on-line; available from <http://www.specialoperations.com/Operations/ivybells.html>; Internet; accessed 3 November 2012.
- Stewart, Cameron. "Obsolete Collins Fleet 'A Lost Cause'," *The Australian.com.au*. Source on-line; available from <http://www.theaustralian.com.au/national-affairs/obsolete-collins-fleet-a-lost-cause/story-fn59niix-1226334791923>; Internet; accessed 22 April, 2012

- Stockholm International Peace Research Institute. *Military Expenditure Database*. Source on-line; available from <http://milexdata.sipri.org/files/?file=SIPRI+military+expenditure+database+1988-2013.xlsx>; Internet; accessed 15 April 2014.
- Stone, J. Craig, and Binyam Solomon. "Canadian Defence and Policy Spending." *Defence and Peace Economics*, Vol 16(3) June 2005, pp. 145-169
- Submarine Institute of Australia. *Keeping Australia's Options Open in Constrained Strategic Circumstances: The Future Underwater Warfare Capacity – Australia's Strategic Sting*. Lyneham ACT: Submarine Institute of Australia, 2008.
- Sutherland, Robert J. "Canada's Long-Term Strategic Situation." *International Journal* 17, No. 3. Summer, 1962.
- Taylor, Jessica. "USS George Washington: The Nation's First Boomer." *Undersea Warfare*, Issue 39, Winter 2000.
- The NATO Council of Canada. *A Future for Canadian Submarines? Costs, Capabilities and Interests*. Online article dated 21 July 2013. Source on-line; available from <http://atlantic-council.ca/a-future-for-canadian-submarines-costs-capabilities-and-interests/>; Internet; accessed 24 Oct 2013.
- TheStar.com. "Return to Sea Offers New Hope for Navy's Submarine Service." TheStar.com, 20 April 2012. Article on-line; available from <http://www.thestar.com/printarticle/1165495>, accessed 22 April 2012
- Thyssen Krupp Marine Systems. "HDW Class 212A." Source on-line; available from <http://www.thyssenkrupp-marinesystems.com/en/hdw-class-212a.html>; Internet; accessed 10 November 2013.
- Thyssen Krupp Marine Systems. "HDW Class 214." Source on-line; available from <http://www.thyssenkrupp-marinesystems.com/en/hdw-class-214.html>; Internet; accessed 10 November 2013.
- Thyssen Krupp Marine Systems. "HDW Class 216." Source on-line; available from <http://www.thyssenkrupp-marinesystems.com/en/hdw-class-216.html>; Internet; accessed 10 November 2013.
- Tringham, Kate. "Japan Launches Sixth Souryu-Class Submarine," *Jane's Defence Weekly*. Journal on-line; available from <https://janes.ihs.com/CustomPages/Janes/DisplayPage.aspx?DocType=News&ItemId=+++1592139>; Internet; accessed 10 December 2013.

- Trinquier, Roger. *Modern Warfare: A French View of Counter Insurgency*. London: Pall Mall Press, 1964.
- United Kingdom National Audit Office. *The Major Projects Report 2012*. London: Her Majesty's Government, 2012.
- United States. Quadrennial Defense Review Report 2010. Washington DC: Department of Defence, 2010.
- United States Census Bureau. Source on-line; available from <http://www.census.gov/foreign-trade/balance/c1220.html>; Internet; accessed 22 May 2012.
- United States Department of State. "ITAR." Source on-line; available from http://www.pmdtc.state.gov/regulations_laws/itar.html; Internet; accessed 10 December 2013.
- US Department of State. Monroe Doctrine, 1823. Source on-line; available from <http://history.state.gov/milestones/1801-1829/monroe>; Internet; accessed 1 December 2013.
- US Energy Information Administration. *World Oil Transit Chokepoints*. Washington DC: USEIA, 2011. Source on-line; available from <http://www.eia.gov/countries/regions-topics.cfm?fips=WOTC#hormuz>; Internet; accessed 20 February 2012.
- United States General Accounting Office. *GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs*. Washington DC, Government Accounting Office, March 2009.
- United States Navy Submarine Warfare Division. "Submarine Themes: Submarine Innovation." Source on-line; available from <http://www.navy.mil/navydata/cno/n87/themes/subinno.html#InnoFuture1>; Internet; accessed 20 September 2012.
- United States Office of the Secretary of Defense. *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China*. Washington: Department of Defense, 2013.
- Van Eendenburg, Reinatta. "The Submarine: NATO's Maritime Force Multiplier." Association of the US Navy, 28 May 2013. Source on-line; available from www.ausn.org; Internet; accessed 15 October 2013.
- Vanguard Staff. "Renewal Team Delivers a Plan to Rebalance CAF Priorities." Vanguard Magazine, 9 October 2013. Journal on-line; available from <http://vanguardcanada.com/renewal-team-delivers-plan-to-rebalance-caf-priorities/>; Internet; accessed 10 December 2013.

- Weston, Greg. “Canada May Buy Nuclear Submarines.” CBC News. Article on-line; available from <http://www.cbc.ca/news/politics/canada-may-buy-nuclear-submarines-1.1043179>, accessed 22 October 2012.
- Williams, Richard. “Weighing the Options: Case Studies in Naval Interoperability and Canadian Sovereignty.” Maritime Security Occasional Paper No. 13. Halifax: Centre for Foreign Policy Studies, Dalhousie University, 2004.
- Whitman, Edward C. “John Holland: Father of the Modern Submarine.” Undersea Warfare, Summer 2003. Article on-line; available from http://www.navy.mil/navydata/cno/n87/usw/issue_19/holland.htm; Internet; accessed 12 February 2012.
- Woodward, Admiral Sandy. *One Hundred Days: The Memoirs of the Falklands Battle Group Commander*. Annapolis, MD: Naval Institute Press, 1992.
- Woolner, Derek. “Procuring Change: How the Kockums was Selected for the Collins Class Submarine.” Research Paper 4, 2001-02, Parliamentary Research Papers, Commonwealth of Australia. Article on-line; available from http://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/rp/rp0102/02RP04; Internet; accessed 10 December 2013.
- Yost, William (ed.). *In Defence of Canada's Oceans*. Ottawa: Conference of Defence Associations Institute, 1988.
- Yule, Steven and Derek Woolner. *Steel Spies and Spin, the Untold Story of the Collins Class*. New York: Cambridge University Press, 2008.

Company Profiles:

- American Alloy Steel: <http://www.aasteel.com/index.html>; Internet; accessed 23 December 2013.
- Indal Technologies:
http://indaltech.cwfc.com/company/spokes/02_pressreleases.htm#Acquired;
 Internet; accessed 23 December 2013.
- Curtiss Wright Flow Controls Companies (other than Indal):
http://www.cwfc.com/Defense/Defense_Products.htm; Internet; accessed 23 December 2013.
- Velan Valves: <http://www.velan.com/en/resources/literature>; Internet; accessed 23 December 2013. See BRO-NUC-09-13 for references to the use of Velan valves in all USN and French nuclear submarines.

Oceanworks: <http://www.oceanworks.com/military/index.html>; Internet; accessed 23 Dec 2013.

International Submarine Engineering: http://www.ise.bc.ca/index_Dec_13.html; Internet; accessed 23 December 2013.

Davie Shipbuilding: <http://www.davie.ca/about-us/our-facility/>; Internet; accessed 23 December 2013.

Governmental Concerns:

Global Threat Initiative: <http://nnsa.energy.gov/aboutus/ourprograms/dnn/gtri>; Internet; accessed 10 December 2013.

International Traffic in Arms Regulations:
http://pmddtc.state.gov/regulations_laws/itar.html; Internet, accessed 10 December 2013.