National Defence Défense nationale

Canadian Forces College

Collège des Forces Canadiennes

DEEPLY COMPLICATED: CANADIAN SUBMARINE PROCUREMENT OPTIONS

Lieutenant-Commander A.J. March

JCSP 40

Exercise *Solo Flight*

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.

PCEMI 40

Exercice *Solo Flight*

Avertissement

Les opinons 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.

Canada

CANADIAN FORCES COLLEGE / COLLÈGE DES FORCES CANADIENNES

JCSP 40 / PCEMI 40

DS 554 ADVANCED TOPICS IN INSTITUTIONAL POLICY DEVELOPMENT

SOLO FLIGHT PAPER

DEEPLY COMPLICATED: CANADIAN SUBMARINE PROCUREMENT OPTIONS

By LCdr A.J. March

26 May 2014

Word Count: 5,370

Compte de mots : 5,370

Submarines are some of the most complex machines ever built.
– Commonwealth of Australia, *Future Submarine Industry Skills Plan*

INTRODUCTION

Canada has operated submarines for almost a century with the *Victoria* (ex-*Upholder*) class being the current platform. These submarines have a complicated history having entered service in the Royal Navy in the early 1990's, only to be taken out of service in 1994, sold to Canada in 1998, and re-entering service in 2002-04. The original service life was 26 years,[1] with the potential for an extension of perhaps 5-10 years, making the mid-2020s to mid-2030s the timeframe for a replacement Canadian submarine capability. This paper will explore some of the potential risks associated with the various possible replacement options and will show that the optimum solution for Canada is to procure a minimally modified Military Off The Shelf (MOTS) design, built off-shore, but supported in Canada.

To reach this conclusion, it will first be necessary to define the solution space. There is a wide range of possible options, ranging from fully indigenous to fully offshore, with varying costs, schedules, operational capabilities, industrial benefits, and risks. Also, the current naval submarine marketplace as it pertains to Canada will be briefly summarized. This will be followed by a more detailed analysis of the factors influencing submarine design, with a focus on the skill, cost, schedule, and scope considerations. A similar analysis will be conducted for submarine construction, contrasting domestic and offshore build options using case study examples. Finally, the design and build arguments

---

[1] P. G. Wrobel, "Design of the Type 2400 Patrol Class Submarine," *The Naval Architect*, no. 1 (1985).

will be synthesized in a Canadian context, including the recent National Shipbuilding Procurement Strategy (NSPS) and national In Service Support (ISS) capabilities.[2] This analysis is all occurring in the context of the contemporary resource constrained Canadian military procurement environment.

Prior to proceeding with the details of the argument, it is appropriate to establish two key assumptions that limit the scope of this paper. The first is that a follow-on submarine capability is something Canada will proceed with. This is by no means clear and it is acknowledged that neither the Canada First Defence Strategy (CFDS) nor the NSPS refer to replacement submarines.[3] However, since the mid-1960's Canada has consistently invested in a submarine capability with the *Oberon* class, which were updated in the early 1980s[4] and replaced in the late 1990s with the *Upholders*. The ongoing investment in the *Victoria* class illustrates the contemporary place submarines have in what the CFDS describes as "a fully integrated, flexible, multi-role, and combat-capable military."[5] Parliamentary reports on the procurement of the *Victoria* class highlighted the long history of Canadian submarine operations and the 1994 White Paper provided qualified support for submarine acquisition and identified their unique

---

[2]The NSPS is a 30-year strategy for the provision of vessels to the Canadian Government (Navy and Coast Guard). The largest portion of NSPS is large vessel construction. Two shipyards have been selected as sources of supply, one for combat vessels (Irving Shipbuilding) and the second for non-combat vessels (Vancouver Shipyards). NSPS uses a design-then-build approach whereby a design is selected by the Government and then developed for production at the respective shipyard. NSPS also includes provisions for smaller vessels and ship repair and maintenance.
Public Works and Government Services Canada, "National Shipbuilding Procurement Strategy (NSPS)," http://www.tpsgc-pwgsc.gc.ca/app-acq/sam-mps/snacn-nsps-eng html (accessed May 6th, 2014).

[3]Department of National Defence, *Canada First Defence Strategy* (Ottawa: DND Canada, 2006). Public Works and Government Services Canada, "National Shipbuilding Procurement Strategy (NSPS)," http://www.tpsgc-pwgsc.gc.ca/app-acq/sam-mps/snacn-nsps-eng html (accessed May 6th, 2014).

[4]Marc Milner, *Canada's Navy: The First Century*, 2nd ed. (Toronto: University of Toronto Press, 2010), 306.

[5]Department of National Defence, *Canada First Defence Strategy*, 14.

surveillance capabilities and utility in the joint environment.[6] While there is ongoing debate about the future, this paper will assume that Canada will choose to continue to invest in a submarine capability within existing resource means.

The second assumption is a focus on only conventionally propelled submarines. The principal rationale behind this is the significantly greater acquisition and support costs associated with nuclear propulsion. Historically, the unit production cost is approximately three times more expensive, with an American *Virginia* class costing USD 2.7 billion in 2013[7] and a French Barracuda costing USD 2.1 billion in 2011.[8] For comparison, a large modern SSK have a unit cost of approximately USD 650 to USD 800 million.[9] Furthermore, additional sustainment costs to safely maintain a nuclear propulsion plant, along with larger crew sizes, drive resource requirements higher. There is also an emotive, and largely negative reaction, to the word *nuclear* amongst the Canadian public that poses an additional political challenge.[10] While offering a significantly greater operational capability, the cost argument alone is sufficient justification to exclude the nuclear option from further analysis.

[6]Canada. Report of the Standing Committee on National Defence and Veterans Affairs, *Procurement of Canada's Victoria Class Submarines: Report of the Standing Committee on National Defence and Veterans Affairs*, 2005), 5.
Department of National Defence, *1994 Defence White Paper* (Ottawa: Canada Communications Group, 1994), 17.

[7]Congressional Budget Office, *An Analysis of the Navy's Fiscal Year 2014 Shipbuilding Plan* (Washington, DC: U.S. Government Printing Office, October 2013).

[8]J. A. C. Lewis, "France Orders Third Barracuda Submarine," *Jane's Defence Weekly*, 7 July 2011, .

[9]Department of Defence, *Future Submarine Industry Skills Plan: A Plan for the Naval Shipbuilding Industry* (Defence Materiel Organisation: Commonwealth of Australia, 2013), 36.

[10]Julie H. Ferguson, *Through a Canadian Periscope: The Story of the Canadian Submarine Service* (Toronto: Dundurn Press, 1995). 364.

SOLUTION SPACE

The options for design and build of a submarine span a range from a completely indigenous solution to one that is pure MOTS design built overseas. It is important to note that currently only seven countries have a complete, proven submarine design and build capability: the United States (US), United Kingdom (UK), Japan, Sweden, China, Russia, France, and Germany. Notably, only the last four offer conventional MOTS submarines for export.[11] The marketplace is evolving with Spain offering an export version of its indigenous S-80A design under development, Sweden in the midst of repatriating its submarine capability back to national control from German ownership, and Japan is exploring the limited export of defence technology.[12] The absence of the US from this list is of particular note. While the US (and the UK) have the capability, neither offer a production-ready conventional design. The end result is a very limited market where, excluding Russia and China for practical concerns, there are a maximum of four international submarine design-and-build options.

From a build perspective, a range of options exists. In addition to the full-spectrum constructors noted above, there are a number of countries that have licence-produced submarines in the last decade, including: South Korea, Italy, Australia, Turkey, and Pakistan. There is a range of build competencies, and in some of these cases

---

[11]Department of Defence, *Future Submarine Industry Skills Plan: A Plan for the Naval Shipbuilding Industry*, 35.

[12]Julian Kerr, "Sea 1000: Australia's Future Submarine is Slow to Surface," *Jane's Navy International*, 13 April 2012.
Niklas Magnusson, "Saab is in Talks to Buy ThyssenKrupp's Sweden Submarine Unit," Bloomberg, http://www.bloomberg.com/news/2014-04-14/saab-is-in-talks-to-buy-thyssenkrupp-s-swedish-submarine- unit html (accessed May 6th, 2014).
Corey Wallace, "Japanese Media Now Openly Talking about Japan-Australia Soryu Deal," Asia Security Watch: New Pacific Institute, http://jsw newpacificinstitute.org/?p=10783 (accessed May 6th, 2014).

extensive materiel kits, and sometimes even complete or partially complete sections, were supplied by the Original Equipment Manufacturer (OEM) with varying degrees of assistance were provided to the local shipyards. Domestic production is a feasible option for Canada and the specific issues with this will be explored in more detail later.

The marketplace for western MOTS submarines is limited, with only France and Germany currently offering new-build export submarines. French shipbuilder DCNS currently offers the several variants of the Scorpene, with displacements ranging from 1,790 to 2,010 tonnes.[13] It is currently in service in Chile and Malaysia and has been selected by India and Brazil with a total of 14 built or planned. Germany's Howaldtswerke-Deutsche Werft (HDW) is the prominent Western conventional submarine builder and offers four MOTS options. The legacy Type 209 dates from the late 1960s but continues to be built for export.[14] Since 2005 the German Navy has operated the more modern 1,830 tonne Type 212A, a total of 10 of which are in-service or planned (including four for Italy). The improved Batch II versions entering service in 2014 are the most modern conventional submarines in any NATO navy.[15] The export Type 214 does not offer the same level of technology as the Type 212A, but does offers greater range and endurance. [16] It has been successful in the market, with 21 built or planned.[17] HDW also builds the Type 800 Dolphin class for Israel, with the last (of six) planned to enter service in 2017. The details of this design are sparse, although the

---

[13]DCNS, "Scorpene" http://en.dcnsgroup.com/naval/products/scorpene (accessed May 6th, 2014).
[14]Clifford Funnell, ed., *Jane's Underwater Warfare Systems 2011/2012*, 23rd edition ed. (Couldson, UK: IHS Jane's, 2011), 68-69.
[15]*Ibid*., 69-71.
[16]*Ibid*., 71-72.
[17]*Ibid*.

second batch is the largest submarine made by HDW, displacing over 2,300 tonnes.[18] DCNS and HDW both offer smaller coastal submarine designs, but these have not yet been proven in service.[19]

When considering MOTS options, it is important to differentiate between a complete, proven design and a concept. For example, Sweden has the A 26 design, similar in size and concept to the Type 212A, but the earliest it will enter service is 2019.[20] Spain has offered a variant of the 2,426-tonne S-80A for export to Australia.[21] This is slightly larger than the existing designs, offering greater endurance and range. However, the S-80A program has been troubled with design, cost, and funding difficulties. These collectively have delayed the in-service date from 2012 to 2017 and the design remains unproven.[22] Similarly, HDW offers the larger, long-endurance 4,000-tonne Type 216 design, targeted at Australia, but this exists as a concept and is not yet ready for production.[23] The modern Japanese *Souryu* class is a large (4,100 tonnes) and capable platform.[24] However, Japan has not historically exported military hardware, and while recent policy changes have slightly opened this door, the export of sensitive national submarine technologies, let alone complete submarines is far from a given.[25]

---

[18]Stephen S. Saunders, ed., *Jane's Fighting Ships 2013-2014*, 116th ed. (Couldson: IHS Global, 2013), 389.

[19]ThyssenKrupp Marine Systems, "HDW Class 210mod," https://www.thyssenkrupp-marinesystems.com/en/submarines html (accessed May 6th, 2014).
DCNS, "Andrasta" http://en.dcnsgroup.com/naval/products/andrasta (accessed May 6th, 2014).

[20]Saunders, *Jane's Fighting Ships 2013-2014*, 780.

[21]*Ibid*., 753.
Kate Tringham, "Australia Looks to Off-the-Shelf Submarine Options," *Jane's Defence Industry*, 15 December 2011, .

[22]David Ing, "Spain Injects Additional Funding into S 80 Submarine Programme," *Jane's Navy International*, 28 November 2013.

[23]Alex Pape, "HDW Reveals Concept for High-Enduance Submarine," *Jane's Navy International*, 26 October 2011.

[24]Kerr, *Sea 1000: Australia's Future Submarine is Slow to Surface*.

[25]Wallace, *Japanese Media Now Openly Talking about Japan-Australia Soryu Deal*

How Canada's potential requirements align with the MOTS solution space is an important consideration. Historically, Canada's Navy has favoured submarines with the range and capability for expeditionary operations long distances from homeport, rather than those designed for a coastal-defence concept of operations.[26] The capabilities desired were demonstrated by the contenders identified for the short-lived Canadian Patrol Submarine Project that followed the aborted nuclear submarine acquisition of the 1980s. All were larger, long-range, conventional submarine designs of over 2,000 tonnes displacement.[27] Assuming the requirement set remains similar, a valid assumption given the similar strategic situation, there is no MOTS option that clearly aligns with Canadian requirements. The available options tend to be slightly smaller with less endurance. Supporting this perspective, Australia, which has a similar long-range, long-endurance requirement, found in 2012 that no MOTS design met the requirement for the *Collins* class replacement.[28]

While no MOTS design precisely meets the desired requirements, there are a number of options in the marketplace that could provide an acceptable level of capability, particularly when viewed in the context of a cost-capability trade-off. Both the Type 214 and Type 212A have deployed across the Atlantic and have greater-than-30 and 50 day endurance respectively.[29] The baseline Scorpene has a quoted 60 day endurance and the

---

[26]Canada. Report of the Standing Committee on National Defence and Veterans Affairs, *Procurement of Canada's Victoria Class Submarines: Report of the Standing Committee on National Defence and Veterans Affairs*, 6.

[27]Ferguson, *Through a Canadian Periscope: The Story of the Canadian Submarine Service*, 331.

[28]John F. Shank et al., *Learning from Experience Volume 4: Lessons from Australia's Collins Submarine Program* (Santa Monica, CA: RAND Corporation,[2011a]). 9-10.
Richard Scott and Kate Tringham, "Narrowing the Focus, Widening the Aperture for Australia's Next-Generation Submarine," *International Defence Review*, 6 November 2013.

[29]Xander Gamble, "Italian Submarine Visits Norfolk," United States Navy, http://www navy mil/submit/display.asp?story id=38881 (accessed May 6th, 2014).

Brazilian variant has been lengthened to provide for more crew, stores, and fuel.[30] These range and endurance capabilities parallel the 49-day endurance and transoceanic range of the *Victoria* class.[31] MOTS designs are not fixed and are frequently modified to better suit requirements. Changing the overall length of a submarine, while maintaining the key pressure hull diameter and overall system architecture unchanged, is technically feasible and provides options for greater range, endurance, and weapons/sensor capabilities. The Scorpene is offered in lengths varying from 66 to 76 meters[32] and the Type 212A and Dolphin designs have been extended by 1.2 and 11 meters respectively for their second batches.[33] This option opens up the cost-capability trade space and provides a means modified MOTS design to more closely fulfill the desired requirement set. While this will not provide the same overall level of capability as a bespoke design, the benefit to a MOTS solution is lower program risk and reduced cost.[34] To properly assess this trade-off requires an examination of the risks associated with a new design.

DESIGN CONSIDERATIONS

The alternative to the constraints on operational capability resulting from MOTS or modified MOTS options is a new design. Any warship design process involves the coordination of a range of different competencies. Submarine design requires additional,

---

Karen Blakenship, "Portuguese Submarine Visits Naval Station Norfolk for FLEETEX," United States Navy, http://www navy.mil/submit/display.asp?story_id=67812 (accessed May 6th, 2014).
Funnell, *Jane's Underwater Warfare Systems 2011/2012*, 70-72.

[30]"New Clues about the 'S-BR', the New Brazilian Conventional Submarine." Naval Power, http://www.naval.com.br/blog/2010/05/06/novas-pistas-sobre-o-s-br-o-novo-submarino-convencional-brasileiro/ (accessed May 6th, 2014).

[31]Wrobel, *Design of the Type 2400 Patrol Class Submarine*, 6.

[32]DCNS, *Scorpene*.

[33]Funnell, *Jane's Underwater Warfare Systems 2011/2012*, 71.
Saunders, *Jane's Fighting Ships 2013-2014*, 389.

[34]Kerr, *Sea 1000: Australia's Future Submarine is Slow to Surface*.

often unique, skillsets.[35] With this in mind, it is worthwhile to examine the common considerations, including resource requirement and rough order of magnitude costs and timelines, in order to better understand the risks pertinent to an indigenous submarine design.

From a cost perspective, the head of the Royal Australian Navy (RAN) Future Submarine Programme, Rear Admiral Rowan Moffitt, commented in 2012 that a full, production ready, submarine design costs equate to the unit production costs of one to two submarines.[36] This is consistent with the United States' experience with the *Virginia* class design costing USD 2 billion.[37] For a modern conventional submarine, such as those noted above, this places the design costs in the USD 650 million to USD 1.7 billion range. These costs roughly scale on a per-ton basis; so larger, more capable, submarines have a higher cost.[38]

The design phase is typically split into a concept and detail design phases, which take a statement of requirements and develop it to the point where production can commence. The design is rarely 100% complete at this point and maturity varies programme to programme, complicating the use of the construction-start milestone as a basis for comparison. [39] From a schedule perspective, the US *Virginia*, *Seawolf*, and *Ohio* classes all had design phases lasting between six to seven years.[40] The UK *Astute* Class took eight years to achieve this same milestone, but was still a relatively immature

[35]John Birkler et al., *Australia's Submarine Design Capabilities and Capacities: Challenges and Options for the Future Submarine.* (Santa Monica, CA: RAND Corporation,[2011]). 9.

[36]Kerr, *Sea 1000: Australia's Future Submarine is Slow to Surface*.

[37]Congressional Budget Office, *An Analysis of the Navy's Fiscal Year 2014 Shipbuilding Plan*, 18.

[38]*Ibid*.

[39]John F. Shank et al., *Learning from Experience Volume 1: Lessons from the Submarine Programs of the United States, United Kingdom, and Australia* (Santa Monica, CA: RAND Corporation,[2011c]). 55.

[40]John F. Shank et al., *Learning from Experience Volume 2: Lessons from the U.S. Navy's Ohio, Seawolf, and Virginia Submarine Programs* (Santa Monica, CA: RAND Corporation,[2011b]).

design.[41] While these programmes all feature the additional complexity of a nuclear propulsion plant, the Australian Future Submarine Programme offers a conventional example with a planned seven to eight year design phase.[42]

Within these cost and schedule windows, there are significant specialized resources required to design a submarine. The design effort for the *Upholder* (late 1970s) and *Collins* (mid-1980s) classes consumed approximately 7 million person-hours and the more complex, nuclear propelled, *Virginia* class took approximately 18 million person-hours.[43] In response to contemporary performance requirements and more demanding safety standards modern submarines are more complex, taking more time to design. [44] In a study for the RAN Future Submarine Programme the RAND corporation estimated that an entirely new submarine design would range between 8 to 12 million person-hours with a peak workforce of 600 to 900 engineers and drafters required, with 400-600 required over a five-year period.[45] This represents a significant resource demand over a lengthy period on some specific skillsets that do not immediately transfer to other industries. Ultimately, a submarine design capability requires a significant, specialized, and highly skilled workforce. For context, at its peak the Canadian Patrol Frigate had 500 personnel employed in the Project Management Office and Irving Shipbuilding, the lead combat

---

[41]John F. Shank et al., *Learning from Experience Volume 3: Lessons from the United Kingdom's Astute Submarine Program* (Santa Monica, CA: RAND Corporation,[2011d]).

[42]Julian Kerr, "Australia's Future Sub 'Facing 20-Year Incubation'," *Jane's Defence Weekly* (5 July 2011).

[43]Wrobel, *Design of the Type 2400 Patrol Class Submarine*.
Department of Defence, *Future Submarine Industry Skills Plan: A Plan for the Naval Shipbuilding Industry*, 55.

[44]*Ibid*.

[45]Birkler et al., *Australia's Submarine Design Capabilities and Capacities: Challenges and Options for the Future Submarine*, 119.

shipyard for NSPS, as of 2013 has a total of 1,200 employees for design *and* manufacture, lagging behind the specific design capacities required.[46]

In addition to the cost and schedule necessities, designing a submarine is an extremely demanding and challenging technical endeavour. In a 2014 speech, the Australian Minister of Defence stated: "a submarine design and build is one of the most complicated engineering projects a nation can undertake. And some of the more experienced countries have struggled to achieve excellence on every design occasion."[47] The minister was referring to the inherent program risk associated with submarine design activities. As noted above, only a limited number of countries maintain an indigenous design and production capability. Even the US and the UK, historically major players, have seen submarine force structures and the corresponding industrial base shrink over the past decades as funding levels have decreased.[48] Large and complex programmes, such as submarine design, require unique skillsets and ongoing practical experience to maintain perishable skills.[49] These competing forces have stressed the western submarine industrial base, as there are fewer new-build projects. The result can be a less-skilled workforce, resulting in program disruption, even for experienced organizations. The UK experience with *Astute* is an example of how perishable submarine design skills can be, even for a nation with a long pedigree. As a result of a post-Cold War budget cuts, there

---

[46]Department of National Defence and Public Works and Government Services Canada, *Interdepartmental Review of the Canadian Patrol Frigate Project: Report on Security.*(Chief of Review Services,[1999]).
Jane Taber, "Irving Ramps Up for Halifax Shipyard Contract," *The Globe and Mail.* 21 August 2013.

[47]David Johnston, "Address for the ASPI Conference: The Submarine Choice, 9 April 2014," Australian Strategic Policy Institute, https://www.aspi.org.au/ data/assets/pdf_file/0011/20720/Johnston-Speech.pdf (accessed May 6th, 2014).

[48]Shank et al., *Learning from Experience Volume 1: Lessons from the Submarine Programs of the United States, United Kingdom, and Australia,* 4.

[49]*Ibid.*, iii.

was a gap of 15 years between *Astute* and preceding *Vanguard*/*Upholder* class submarine programmes that resulted in atrophy of specialized skillsets, the impact of which was not fully appreciated at the time. [50] The consequences of this atrophy were problems during the *Astute* programme, where design challenges contributed to cost growth of 53% (GBP 1.53 billion) above the original contract price and a delay of 58 months.[51]

The Spanish experience with the S-80A programme offers a further example. Although Spain has robust naval surface vessel industrial base, has constructed French-designed submarines in the past, and collaborated on the Scorpene design and build, the S-80A represented its first truly indigenous design.[52] Concept design began in 2002, with a EUR 2.13 billion detail design-and-build contract signed in 2004. [53] In 2013, after construction of the first of class hull was nearing completion, a design error was discovered resulting in the submarines being 75 tonnes overweight.[54] In order to rectify this error, attributed to a single misplaced decimal point, the vessels were redesigned, adding three to four metres to the overall length. This late-notice change resulted in a two-year delay and contributed to the 36% cost growth.[55]

It is important to note that steps can be taken to manage these design risks. In both the *Astute* and S-80A cases, General Dynamics Electric Boat (GDEB), the centre of excellence for US submarine design and build expertise, was contracted to provide

---

[50]Shank et al., *Learning from Experience Volume 3: Lessons from the United Kingdom's Astute Submarine Program,* xi.

[51]United Kingdom. National Audit Office, *Ministry of Defence Major Projects Report 2011* (London: The Stationary Office). 45.

[52]Richard Scott, "Spain's S-80A Submarine Comes Up to the Surface," *Jane's Navy International,* December 2007, .

[53]Funnell, *Jane's Underwater Warfare Systems 2011/2012*, 91-92.

[54]Tom Kington, "Navantia Gets US Help to Fix Overweight Sub," *Defense News.*5 June 2013, 2013.

[55]Ibid.

assistance. [56] The Australians are being proactive and are collaborating with the US and GDEB for their Future Submarine Programme.[57] However, these arrangements can only provide so much assistance and capacity is not unlimited. In the lead up to the *Virginia* class program GDEB significantly reduced its submarine-specific workforce in order to align capacity to the post-Cold War situation, resulting in less excess capacity.[58] The assistance provided to *Astute* consisted of approximately 100 designers and managers; however, only a dozen of these were dedicated full-time onsite GDEB employees.[59] This contrasts with the peak design demand for several hundred technical staff.[60]

The challenges associated with a bespoke new submarine design can be summarized as follows: It takes approximately seven years, costs a minimum of several hundred million dollars, requires several hundred personnel with specialized skillsets, and is a complex and risky endeavour. Internationally, there are only a handful of countries that maintain such a capability and the current international military procurement climate makes it challenging for them to maintain the perishable skills and necessary practical experience to maintain competency. Even countries with long histories of naval design and construction struggle with the complexities inherent in modern submarine design and the consequence of error are hundreds of millions of dollars in cost overrun and schedule

---

[56]Ibid. Shank et al., *Learning from Experience Volume 3: Lessons from the United Kingdom's Astute Submarine Program*, 44-45.

[57]Jon Grevatt, "Australia Seeks US Collaboration on Submarine Programme," *Jane's Defence Industry*, 25 July 2011.

[58]Shank et al., *Learning from Experience Volume 2: Lessons from the U.S. Navy's Ohio, Seawolf, and Virginia Submarine Programs*, xv-xvi, 62-63.

[59]Shank et al., *Learning from Experience Volume 3: Lessons from the United Kingdom's Astute Submarine Program*, 44.

[60]Department of Defence, *Future Submarine Industry Skills Plan: A Plan for the Naval Shipbuilding Industry*, 57.

delay measured in years. However, potential issues do not end with completion of the design, construction of a submarine poses a different set of challenges.

BUILD CONSIDERATIONS

Once a design has been settled upon, the next step is build. This can take two principal forms. The first is an offshore build by an experienced design-agent shipyard, the second being domestic construction. It is worthy to note that research by the author on Western post-war submarine projects does not feature a single example of a nation developing an indigenous design and then commencing indigenous construction without either having previous submarine construction experience, going through the intermediate step of either licence-production of an offshore design, or having significant technical assistance from abroad to help develop the capability. With this in mind, this section will focus on contrasting the licence production of a foreign design with construction at an Original Equipment Manufacturers (OEM) shipyard. Licence production has been common in industry with OEMs providing assistance consisting of production drawings and procedures, material component packages, and on-site technical assistance. There is a spectrum of this assistance, ranging from the host nation effectively only ‘assembling’ a foreign design with significant assistance, to a scenario where more sub-systems from a host-nation are incorporated. A graduated approach has also been employed, whereby the first of class, and/or completed sections are built in the OEM shipyard, and follow-on vessels are constructed in the purchasing nation. Pakistan, Greece, Turkey, and South Korea are all examples of this approach.[61]

---

[61]Saunders, *Jane's Fighting Ships 2013-2014*.

In order to explore build considerations further, it is helpful to determine a baseline. France, Germany, and Japan will be used as examples as they are Western nations with proven, in-service designs. The Japanese have a robust conventional submarine industrial base driven by domestic demand. After re-establishing a domestic submarine industry in the late 1950s, Japan has maintained a robust national design and build capability and a regular submarine production drumbeat. In the 51 years between 1963 to 2014, a new submarine has been laid down annually with only two exceptions, 1973 and 2010, with delivery of finished submarine reliably being four years after keel laying. [62] The most recent *Souryu* class, ordered in 2013, had a unit cost of USD 505 million.[63] This offers capability value when compared with a MOTS options such as the Dolphin Batch II at USD 700 million.[64]

However, while demonstrating what a capable industrial base can do, Japanese designs are not exported or licence produced, so it is difficult to draw comparisons. The French Scorpene has been directly exported to Chile and Malaysia, and is also being licence produced in Brazil and India. In the most recent direct export case, the time elapsed from contract signature to first delivery was 6.7 years.[65] In contrast, India signed a licence production contract in 2005 with first delivery planned for 2012. No submarine has yet to be delivered and the project is at least three years delayed.[66] Brazil ordered Scorpene in December 2008, with the forward section of the first boat being built in

---

[62] *Ibid*., 421-422.
Richard Sharpe, ed., *Jane's Fighting Ships 1993/94*, 97th ed. (Couldson: Jane's, 1993). 334-345.
John E. Moore, ed., *Jane's Fighting Ships 1977/78*, 80th ed. (Couldson: Jane's, 1977). 278.

[63] Japan. Ministry of Defence, *Defence Program and Budget of Japan: Overview of FY2014 Budget*,[2013]).

[64] Yaakov Katz, "Germany to Sell Sixth Dolphin Submarine to Israel," *Jane's Navy International*, 6 May 2011.

[65] Saunders, *Jane's Fighting Ships 2013-2014*, 115, 498.

[66] *Ibid*., 324.

France. Delivery of the first of class is not anticipated until 2017, over eight years after contract award.[67] HDW has demonstrated better direct exporting performance. Portugal ordered two Type 214s in 2005 with the first delivered 6.2 years after contract award. Similarly Israel took delivery of its first Dolphin Batch II 5.8 years after contract award.[68] In summary, these international examples of licence production of various MOTS designs show a rough-order two to four year increase in construction timelines for inexperienced builders.

The Australian experience provides another example. The *Collins* class, which is a Swedish design, took 9.1 years from contract award to first delivery, which was only achieved with a degraded combat system that was not rectified until a number of years later.[69] The average build time was 7.3 years which, contrary to what would be expected in an industrial process, increased over the life of the program as work began to backlog. Although *Collins* is a larger submarine than the Scorpene or Type 214, it is smaller than contemporary Japanese designs. Corrected for inflation, and accounting for design costs as specified above, the *Collins* class unit production cost was approximately USD 900 million to USD 1 billion. In comparisons to the larger Japanese *Souryu* class detailed above, both costs and production time were almost double.

Not all licence production has resulted in increases in construction timelines. South Korea and Turkey have both produced HDW designs at rates matching the OEM.[70] However, in both cases there is a long history of licence production. Additionally, South Korea is a world-leader in ship manufacturing, limiting this examples wider applicability.

---

[67] *Ibid*., 68-69.
[68] *Ibid*., 389.
[69] Shank et al., *Learning from Experience Volume 4: Lessons from Australia's Collins Submarine Program*, 19.
[70] Saunders, *Jane's Fighting Ships 2013-2014*, 466, 839-840.

However, licence production does offer benefits, particularly regarding employment and a stronger domestic industrial base that can support long-term in-service support through maintenance and refit activities. This was one of the factors that lead Australia to build the *Collins* class domestically.[71] Additionally, there is a significant direct labour hour contribution to industry, with submarines taking several million labour hours to build.[72] However, along with these economic benefits come costs.

While is it difficult to make precise comparisons due to a large number of complicating factors, including the variance in purchasing nations industrial and workforce capabilities and what costs are included, analysis of which is beyond the scope of this paper, some broad conclusions can be made. It is safe to say that licence production of submarines increases the overall cost and time required relative to direct purchase from the OEM. HDW in Germany has consistently demonstrated the ability to delivers submarines within six years of contract award, with DCNS not far behind. International examples of licence production amongst inexperienced buildings show timelines of approximately a third longer with increased risk of unplanned cost overruns and schedule delays. There are benefits to domestic industry arising from licence production, but they do not come without risk.

CANADIAN CONTEXT

This paper has examined the issues associated with MOTS options, the design of a bespoke submarine, and domestic versus offshore production. The final section will

[71] Shank et al., *Learning from Experience Volume 4: Lessons from Australia's Collins Submarine Program*, 6.

[72] Department of Defence, *Future Submarine Industry Skills Plan: A Plan for the Naval Shipbuilding Industry*, 161.

synthesize these themes in the Canadian context, first addressing design, and the build considerations. Defence procurement is in a period of change in Canada, particularly in naval shipbuilding. The 2010 NSPS clearly positioned Canada as a domestic builder of government vessels.[73] In 2013, the Canadian Government commissioned successful businessman Thomas Jenkins to report on how to best leverage defence procurement for domestic economic benefit. The resulting Jenkins report identified that shipbuilding and In Service Support (ISS) of military platforms are both proposed Key Industrial Capabilities (KICs).[74] However, it should be noted that neither the NSPS, nor the Jenkins report, nor the Canadian Association of Defence and Security Industries (CADSI – the largest national industry association) identified vessel *design* as a national capability.[75] As noted above, submarine design is a specialized, complicated, and risky endeavour that Canada does not have expertise in. Illustrating the complexity and difficulty of such an endeavour, the current Australia Government has revisited a decision articulated in the 2013 White Paper that discarded MOTS designs in favour of a indigenous solution and is now intending to use an experienced foreign designer.[76] In the Canadian context, a domestic design is not a realistic option. In addition to the minimum several hundred million dollar cost increase a domestic design would entail, Canada lacks the design expertise necessary. More importantly, the specialized nature of submarine design,

---

[73]Public Works and Government Services Canada, "National Shipbuilding Procurement Strategy (NSPS)," http://www.tpsgc-pwgsc.gc.ca/app-acq/sam-mps/snacn-nsps-eng html (accessed May 6th, 2014).

[74]Tom Jenkins, *Canada First: Leveraging Defence Procurement through Key Industrial Capabilities*(Public Works and Government Services Canada, 2013). 17.

[75]Public Works and Government Services Canada, *National Shipbuilding Procurement Strategy (NSPS)*.
Jenkins, *Canada First: Leveraging Defence Procurement through Key Industrial Capabilities*.

[76]Australian Department of Defence, *Defence White Paper 2013.*(Commonwealth of Australia, 2013). 83.
Cameron Stewart, "Swedish Designs on our Sea Power." *The Australian.*12 April 2014.

combined with the long time intervals between submarine programmes, make any effort to develop this capability a high-cost, single-use activity. With NSPS, focussing on production, an expensive and risky domestic submarine design does not align with government policy.

Build considerations are less clear-cut. NSPS is best described as a means for industry to produce a selected design. However, question remains whether or not the NSPS is the best means to build submarines. Nowhere in the NSPS is a submarine construction programme mentioned.[77] This is not surprising, given that there is no programme of record for the replacement of the *Victoria* class. But this does seem to open the door to a potential offshore build. However, despite the complexities and risks associated with submarine construction detailed above, it is reasonable to assume that selection of an international supplier for such a major procurement would still be met with opposition from domestic industry.[78] However, despite what domestic suppliers may indicate, submarine construction is a different, more complicated, endeavour than building surface ships. Internationally, the trend is towards specialized submarine builders. Australia built a shipyard virtually from scratch specifically for the *Collins* class, despite having existing shipbuilding facilities. HDW in Germany, BAE Systems in the UK, and GDEB in the US are all specialized submarine building shipyards.[79] Even Australia, having already gone through a domestic submarine build programme is seriously examining the economic and defence merits of domestic build for its Future

---

[77]Public Works and Government Services Canada, *National Shipbuilding Procurement Strategy (NSPS)*.

[78]Craig Stone, "Chapter 5: Defence Procurement and the Need for Disciplined Capital Investment," in *The Public Management of Defence in Canada*, ed. Craig Stone (Toronto: Breakout, 2009). 96.

[79]Shank et al., *Learning from Experience Volume 4: Lessons from Australia's Collins Submarine Program*. 22-23.

Submarine Programme. In a speech to the Australian Strategic Policy Institute, Minister of Defence David Johnston stated:

> As a government we want to give Australian industry every chance of success, but let me be clear our primary and dominant purpose is to ensure that we provide Navy [sic] with a submarine which meets its requirements. A submarine is not industrial or regional policy by other means or another name. Industry must demonstrate an ongoing capacity to meet international benchmarks with respect to productivity, cost and schedule. Furthermore, we see military shipbuilding as a strategically important industry and certainly it is desirable that the new submarine would be built in Australia but it is not a blank cheque.[80]

For a country with a greater commitment to a submarine capability than Canada *and* a pre-existing domestic production capacity to be seriously considering offshore build should serve as a warning. [81] Canada has not built a submarine since 1914 and a major surface combatant since 1996.[82] Outside of the Canadian Patrol Frigate and the nascent NSPS, Canada has not undertaken the domestic design and build option for any major military platform over the last fifty years.[83] The last time domestic production was contemplated in 1988, a House of Commons report indicated that Canadian inexperience with submarine construction would likely lead to cost overrun.[84]

Building in Canada will result in the increased risk and thus increased probability that the project will require repeated approvals for greater funding. Such repeated approvals are not uncommon in Canada, and inject a separate source of programmatic

---

[80]Johnston, *Address for the ASPI Conference: The Submarine Choice, 9 April 2014*.
[81]Jenkins, *Canada First: Leveraging Defence Procurement through Key Industrial Capabilities*, 54.
[82]Ferguson, *Through a Canadian Periscope: The Story of the Canadian Submarine Service*, 48-50. Saunders, *Jane's Fighting Ships 2013-2014*, 96-100.
[83]Jenkins, *Canada First: Leveraging Defence Procurement through Key Industrial Capabilities*, 36.
[84]Canada. Report of the Standing Committee on National Defence and Veterans Affairs, *The Canadian Submarine Acquisition Project: A Report of the Standing Committee on National Defence* (Ottawa: House of Commons, Canada, 1988). 42.

delay in the procurement process.[85] Schedule slippage, both programmatic and construction, inevitably lead to cost growth. While appropriate risk management techniques, such as assigning an appropriate contingency and having risk held by the appropriate stakeholders, can help manage this, the fact remains that domestic production is an inherently riskier activity than purchasing from an established OEM.[86] This factor is exacerbated by the fact that these risks tend to be systematically underestimated in new submarine projects.[87] Schedule is also of concern. As seen above, the time from contract award to initial delivery can reach over nine years for a licence-built submarine. In Canada, where the timeline to first reach contract award is already lengthy, this places further stresses and costs on the project. [88] Furthermore, with the objective timeline from contract award to initial delivery being five years, only an offshore build can come close to meeting this goal.[89] Offshore build of a MOTS solution provides a higher-fidelity initial cost estimate, shorter build time, and increases the probability that a single contract and approval process will lead to a operational submarine in the shortest amount of time. This reduction in overall program cost and schedule risk is a significant consideration in the Canadian domestic political context where delayed procurement projects such as the Maritime Helicopter and Next Generation Fighter Capability have been politically embarrassing.

However, despite these risks, the NSPS indicates that Government sees domestic shipbuilding as important and any military procurement needs to demonstrate reasonable

---

[85]Stone, *Chapter 5: Defence Procurement and the Need for Disciplined Capital Investment*, 103.
[86]Shank et al., *Learning from Experience Volume 1: Lessons from the Submarine Programs of the United States, United Kingdom, and Australia*, 13-14.
[87]*Ibid*.
[88]Stone, *Chapter 5: Defence Procurement and the Need for Disciplined Capital Investment*, 103-104.
[89]*Ibid*., 104.

industrial benefits.[90] In the context of a Canadian submarine project, In Service Support (ISS) provides an excellent means to achieve these benefits. ISS incorporates not only repair and maintenance, but also developing and maintaining an overall strategy to support the platform in the most effective manner over the entire lifecycle.[91] Typical work includes not only routine repair and maintenance, but also high value work such as engineering support and the development and management of a holistic technical and logistical support strategy. ISS is identified as one of the six KIC clusters in the Jenkins report and CADSI has also identified that naval platform ISS, including integrated logistics support, maintenance, repair and overhaul are domestic Canadian capabilities.[92] ISS activities are spread over the 30-year project lifecycle and can be four or five times the platform unit cost.[93] Canada is demonstrating submarine ISS capabilities through the 15-year, CAD 1.5 billion *Victoria* class ISS Contract (VISSC) signed in 2008.[94] The VISSC is the primary means for the materiel support of Canada's current fleet of submarines with HMCS *Chicoutimi* being the first platform to undergo a VISSC refit. This activity is currently on track to complete 18 months faster than previous refits in government dockyards.[95] Through a similar mechanism, the industrial and regional benefits of a future Canadian submarine procurement can be realized in a manner consistent with national objectives.

---

[90]*Ibid*., 98.

[91]Jenkins, *Canada First: Leveraging Defence Procurement through Key Industrial Capabilities*, 32.

[92]*Ibid*., 32, 58.

[93]*Ibid*., 12.

[94]Industry Canada, "Victoria in-Service Support Contract – VISSC," Industry Canada, http://www.ic.gc.ca/eic/site/043.nsf/eng/00018.html (accessed May 6th, 2014).

[95]Department of National Defence, "Royal Canadian Navy Submarines: Fleet Status," Department of National Defence and the Canadian Armed Forces, http://www forces.gc.ca/en/news/article.page?doc=royal-canadian-navy-submarines-fleet-status/hie8w8fv (accessed May 6th, 2014).

Military procurement in Canada is a complex process with many stakeholders. The inherent complexity and increased risk associated with submarines exacerbates these challenges. Canada lacks a domestic design base and has only a nascent shipbuilding base. While the temptation to use this for licence production to facilitate domestic economic benefits is strong, there are significant cost, schedule, and programmatic risks to this approach. Canada does however have an ISS capability that can be leveraged to provide a lower risk, yet still high value, benefits.

CONCLUSION

This paper has sought to explore the issues surrounding a notional future Canadian submarine procurement. Historically, Canada has sought submarines with a long-range and high-endurance for expeditionary operations. The current MOTS marketplace does not have a clearly identified fit for these demanding requirements. However, the difference in capability is not large and suitable MOTS options do exist. The optimal submarine capability for Canada may not be the one that offers the best cost-capability balance, it may be one that is affordable and offers a tolerable level of risk. This risk space is bounded by the significant resources and time required to enable a new submarine design that takes approximately seven years to complete, costs hundreds of millions of dollars, and needs several million labour hours using specialized skillsets not currently available in Canada. This is occurring in an international environment where experienced players are retrenching and having difficulty maintaining their own capacity. With all of these factors considered, designing a submarine indigenously is simply unrealistic for Canada. When it comes to submarine construction, the millions of labour hours required represent a potential domestic economic windfall. However, international experience with licence production indicates potential cost overruns of hundreds of millions of dollars and possible delays measured in years. Additionally, when compared with buying offshore, building domestically is more expensive and takes longer. While shipbuilding is seen as different and Canada has historically been willing to accept the results of domestic production, submarine construction is a further specialized field, with international best practices seeing dedicated submarine builders become the norm. In countries where licence production has been successful, there is either a history of licence production across multiple programmes, a world-class national shipbuilding capability, or both. Canada has neither. What Canada can offer is the already existing capability to maintain submarines in service, unlocking the high-value ISS work that lasts over the life of the platform, exceeds the initial unit procurement cost several times over, and dominates the total through life cost. Military procurement is about the trade off between risk, domestic industrial benefit, and operational capability. This paper has demonstrated that the calculus of this trade-off is fundamentally different for submarines. A MOTS submarine, built overseas, but maintained in Canada is the lowest risk, lowest cost option that will deliver an operationally relevant future submarine capability.

BIBLIOGRAPHY

"New Clues about the 'S-BR', the New Brazilian Conventional Submarine." Naval Power, accessed May 6th, 2014, http://www.naval.com.br/blog/2010/05/06/novas-pistas-sobre-o-s-br-o-novo-submarino-convencional-brasileiro/.

Australian Department of Defence. *Defence White Paper 2013.* (Commonwealth of Australia, 2013.

Binyam, Solomon. "Chapter 6: The Defence Industrial Base in Canada." Chap. 6, In *The Public Management of Defence in Canada*, edited by Stone, Craig, 111-140. Toronto: Breakout, 2009.

Birkler, John, John F. Shank, Jesse Riposo, Mark V. Arena, Robert W. Button, Paul DeLuca, James Dullea, et al. *Australia's Submarine Design Capabilities and Capacities: Challenges and Options for the Future Submarine.* Santa Monica, CA: RAND Corporation, 2011.

Blakenship, Karen. "Portuguese Submarine Visits Naval Station Norfolk for FLEETEX." United States Navy, accessed May 6th, 2014, http://www.navy.mil/submit/display.asp?story_id=67812.

Canada. Report of the Standing Committee on National Defence and Veterans Affairs. *The Canadian Submarine Acquisition Project: A Report of the Standing Committee on National Defence*. Ottawa: House of Commons, Canada, 1988.

———. *Procurement of Canada's Victoria Class Submarines: Report of the Standing Committee on National Defence and Veterans Affairs* 2005.

Congressional Budget Office. *An Analysis of the Navy's Fiscal Year 2014 Shipbuilding Plan*. Washington, DC: U.S. Government Printing Office, October 2013.

DCNS. "Andrasta." , accessed May 6th, 2014, http://en.dcnsgroup.com/naval/products/andrasta.

———. "Scorpene." , accessed May 6th, 2014, http://en.dcnsgroup.com/naval/products/scorpene.

Department of Defence. *Future Submarine Industry Skills Plan: A Plan for the Naval Shipbuilding Industry*. Defence Materiel Organisation: Commonwealth of Australia, 2013.

Department of National Defence. *Canada First Defence Strategy*. Ottawa: DND Canada, 2006.

———. "Royal Canadian Navy Submarines: Fleet Status." Department of National Defence and the Canadian Armed Forces, accessed May 6th, 2014, http://www.forces.gc.ca/en/news/article.page?doc=royal-canadian-navy-submarines- fleet-status/hie8w8fv.

Department of National Defence and Public Works and Government Services Canada. *Interdepartmental Review of the Canadian Patrol Frigate Project: Report on Security.*: (Chief of Review Services, 1999.

Ferguson, Julie H. *Through a Canadian Periscope: The Story of the Canadian Submarine Service*. Toronto: Dundurn Press, 1995.

Funnell, Clifford, ed. *Jane's Underwater Warfare Systems 2011/2012*. 23rd edition ed. Couldson, UK: IHS Jane's, 2011.

Gamble, Xander. "Italian Submarine Visits Norfolk." United States Navy, accessed May 6th, 2014, http://www.navy.mil/submit/display.asp?story_id=38881.

Grevatt, Jon. "Australia Seeks US Collaboration on Submarine Programme." *Jane's Defence Industry* (25 July 2011, 2011).

Industry Canada. "Victoria in-Service Support Contract – VISSC." Industry Canada, accessed May 6th, 2014, http://www.ic.gc.ca/eic/site/043.nsf/eng/00018.html.

Ing, David. "Spain Injects Additional Funding into S 80 Submarine Programme." *Jane's Navy International* (28 November 2013, 2013).

Japan. Ministry of Defence. *Defence Program and Budget of Japan: Overview of FY2014 Budget*, 2013.

Jenkins, Tom. *Canada First: Leveraging Defence Procurement through Key Industrial Capabilities* (Public Works and Government Services Canada, 2013.

Johnston, David. "Address for the ASPI Conference: The Submarine Choice, 9 April 2014." Australian Strategic Policy Institute, accessed May 6th, 2014, https://.aspi.org.au/__data/assets/pdf_file/0011/20720/Johnston-Speech.pdf.

Katz, Yaakov. "Germany to Sell Sixth Dolphin Submarine to Israel." *Jane's Navy International* (6 May 2011, 2011).

Kerr, Julian. "Australia's Future Sub 'Facing 20-Year Incubation'." *Jane's Defence Weekly* (5 July 2011, 2011).

———. "Sea 1000: Australia's Future Submarine is Slow to Surface." *Jane's Navy International* (13 April 2012, 2012).

Kington, Tom. "Navantia Gets US Help to Fix Overweight Sub." *Defense News.*, 5 June 2013, 2013.

Lewis, J. A. C. "France Orders Third Barracuda Submarine." *Jane's Defence Weekly* (7 July 2011, 2011).

Magnusson, Niklas. "Saab is in Talks to Buy ThyssenKrupp's Sweden Submarine Unit." Bloomberg, accessed May 6th, 2014, http://www.bloomberg.com/news/2014-04-14/saab-is-in-talks-to-buy-thyssenkrupp-s-swedish-submarine-unit.html.

Milner, Marc. *Canada's Navy: The First Century*. 2nd ed. Toronto: University of Toronto Press, 2010.

Pape, Alex. "HDW Reveals Concept for High-Enduance Submarine." *Jane's Navy International* (26 October 2011, 2011).

Public Works and Government Services Canada. "National Shipbuilding Procurement Strategy (NSPS)." , accessed May 6th, 2014, http://www.tpsgc-pwgsc.gc.ca/app-acq/sam-mps/snacn-nsps-eng.html.

Saunders, Stephen S., ed. *Jane's Fighting Ships 2013-2014*. 116th ed. Couldson: IHS Global, 2013.

Scott, Richard. "Spain's S-80A Submarine Comes Up to the Surface." *Jane's Navy International* (December 2007, 2007).

Shank, John F., Cesse Ip, Kristy N. Kamarck, Robert E. Murphy, Mark V. Arena, Frank W. Lacroix, and Gordon T. Lee. *Learning from Experience Volume 4: Lessons from Australia's Collins Submarine Program*. Santa Monica, CA: RAND Corporation, 2011a.

Shank, John F., Cesse Ip, Frank W. Lacroix, Robert E. Murphy, Mark V. Arena, Kristy N. Kamarck, and Gordon T. Lee. *Learning from Experience Volume 2: Lessons from the U.S. Navy's Ohio, Seawolf, and Virginia Submarine Programs*. Santa Monica, CA: RAND Corporation, 2011b.

Shank, John F., Frank W. Lacroix, Robert E. Murphy, Mark V. Arena, and Gordon T. Lee. *Learning from Experience Volume 1: Lessons from the Submarine Programs of the United States, United Kingdom, and Australia*. Santa Monica, CA: RAND Corporation, 2011c.

Shank, John F., Frank W. Lacroix, Robert E. Murphy, Cesse Ip, Mark V. Arena, and Gordon T. Lee. *Learning from Experience Volume 3: Lessons from the United Kingdom's Astute Submarine Program*. Santa Monica, CA: RAND Corporation, 2011d.

Sharpe, Richard, ed. *Jane's Fighting Ships 1993/94*. 97th ed. Couldson: Jane's, 1993.

Stewart, Cameron. "Swedish Designs on our Sea Power." *The Australian.*, 12 April 2014, 2014.

Stone, Craig. "Chapter 5: Defence Procurement and the Need for Disciplined Capital Investment." Chap. 5, In *The Public Management of Defence in Canada*, edited by Stone, Craig, 93-110. Toronto: Breakout, 2009.

Taber, Jane. "Irving Ramps Up for Halifax Shipyard Contract." *The Globe and Mail.*, 21 August 2013, 2013.

ThyssenKrupp Marine Systems. "HDW Class 210mod." , accessed May 6th, 2014, https://.thyssenkrupp-marinesystems.com/en/submarines.html.

Tringham, Kate. "Australia Looks to Off-the-Shelf Submarine Options." *Jane's Defence Industry* (15 December 2011, 2011).

United Kingdom. National Audit Office. *Ministry of Defence Major Projects Report 2011*. London: The Stationary Office),.

Wallace, Corey. "Japanese Media Now Openly Talking about Japan-Australia Soryu Deal." Asia Security Watch: New Pacific Institute, accessed May 6th, 2014, http://jsw.newpacificinstitute.org/?p=10783.

Wrobel, P. G. "Design of the Type 2400 Patrol Class Submarine." *The Naval Architect* no. 1 (1985): 1-20.