National Defence Défense nationale

Canadian Forces College

Collège des Forces Canadiennes

RED OCTOBER FOR CANADAS SUBMARINES – THE FUTURE IS UNDER THE ICE

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JCSP 44	PCEMI 44
SERVICE PAPER	**ÉTUDE MILITAIRE**

Canada

CANADIAN FORCES COLLEGE – COLLÈGE DES FORCES CANADIENNES
JCSP 44 – PCEMI 44
2017 – 2018

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Word Count: 2476

Compte de mots: 2476

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AIM

1. The aim of this service paper is to discuss the current and, due to technological innovations, future propulsion systems for conventional submarines. It will show that conventional submarines are a good alternative to costly nuclear submarines, and could support Canada's geostrategic and security requirements, as well as meet the Royal Canadian Navy's (RCN) task to operate in the Arctic. It should stimulate the discussion in the RCN for the eventual successor to the Victoria class submarines with some possible options.

INTRODUCTION

2. With the end of the Cold War came a requirement for reorientation of the naval forces of most countries. During the East-West conflict, many naval forces were focused on the defense of their territorial waters and therefore their sea endurance was limited. With the demise of the former Soviet Union and the relative improvement in East-West relations, there has been a decline in global defense spending and navies have gone from a "traditional "blue water" missions to littoral operations".[1]

[1] Psallidas, Konstantinos, Clifford A. Whitcomb, and John C. Hootman. *Design of Conventional Submarines with Advanced Air Independent Propulsion Systems and Determination of Corresponding Theater-Level Impacts*. Cambridge, MA: Massachusetts Institute of Technology, 2010,.111-112.

3. The terrorist attacks of 11 September 2001 revealed a new threat which led to new security considerations. Additionally, former security threats have grown, such as the fight against piracy and smuggling. For today's navies, this means that industrialized nations, in particular, are fighting conflicts where they arise and no longer wait until their own borders or those of Allies are threatened. While today's conventional submarines provide an excellent means for countries dealing with local conflict, risk from superior naval forces of potential adversaries, and deployment scenarios for many developed nations have shifted significantly. At the same time, nuclear submarines, while superior in speed and firepower, have significant disadvantages in terms of signature and lifecycle costs, not to mention the political implications of operating this type of technology.[2]

4. The ability of covert reconnaissance away from support bases, such as operating in arctic waters under the ice-cap, transferring and supporting special operation forces, and launching land capable missiles gives the submarine an important role within navies and international forces.

5. Canadian submarine interests can be divided into three categories: “the Defense of Canada and North America; supporting Canadian expeditionary deployments; and supporting Canada's interest in global maritime stability”.[3] With the current four Victoria class submarines, these interests can only be somewhat achieved. Additionally, the submarines will reach their life-time-

[2] OnlineScience. “Nuclear submarines (Nuclear Powered Ships) advantages and disadvantages”, last access 29 January 2018, https://www.online-sciences.com/the-energy/nuclear-submarines-nuclear-powered-ships-advantages-and-disadvantages/

[3] Canadian Naval Review. “Canada`s Future Submarine”, last access 29 January 2018, http://www.navalreview.ca/2017/09/canadas-future-submarines/

cycle in the next 10 years and must be upgraded or replaced by new acquisitions. The technological innovations in the field of submarine propulsion technology offer current and future alternatives.

6. Unlike nuclear-powered submarines (SSNs), diesel-electric submarines (SSKs) like the Victoria Class are of limited use in the high Arctic due to their inability to operate under the ice cap. This presents a significant challenge to Canada, as an Arctic nation, due to the exorbitant cost of maintaining a fleet of SSNs and the political sensitivities attached to acquiring such a capability. An answer might lie in advances in technology as applied to propulsion systems that would permit SSKs to remain submerged for longer periods.

7. This service paper will present three options of conventional submarines. It will focus on the propulsion systems and submergeable capabilities in order to identify if these submarines are suitable for the RCN. However, it will not take into account that further modifications like an artic suitable hull and sensors would be necessary for these options.

DISCUSSION

Class 212 A

8. German 212 A Class submarines have one of the most unique hybrid propulsion systems in the world. This system was designed with the intention of enabling submerged tasks over several

weeks with an Air Independent Propulsion (AIP) system.[4] This hybrid system consists of a diesel generator, a battery, a fuel cell system and a motor.

9. The fuel cell system, which converts hydrogen and oxygen directly into electrical energy without noise and emissions, is characterized by high efficiency and low maintenance. In addition to the direct current (DC), distilled water is the only byproduct during energy conversion. This type of power generation for the drive offers great advantages in submarine technology. In contrast to the diesel generator, the noise level and heat radiation is significantly reduced, so that locating such a submarine is many times more difficult. This is also helped by the fact that purified water is the only byproduct of this type of energy production with no detectable residues. Furthermore, the hybrid propulsion system has an advantage of being submerged much longer than submarines with diesel generator. Diesel engines require atmospheric oxygen for operation, so these submarines often have to come closer to the surface at so-called "snorkel times" in order to absorb it. With this hybrid drive, dive times of up to two weeks were achieved during a transit from Germany to the Caribbean Sea.[5]

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[4] ThyssenKrupp Marine System."HDW Class 212A", last access 29 January 2018, https://www.thyssenkrupp-marinesystems.com/en/hdw-class-212a.html

[5] GlobalSecurity.org. "Type 212 Multi Purpose Submarine", last access 29 January 2018, https://www.globalsecurity.org/military/world/europe/type-212.htm

10. Class 212 A submarines carry pure oxygen and hydrogen for the fuel cells in their tanks, which make them independent of outside air supply.[6] Since the only waste product in the fuel cell is pure water, this drive is particularly environmentally friendly. This is not the case with a nuclear engine, which produces radioactive waste and requires a high level of safety in terms of disposal and operation. Along with this, there is a high space requirement and the considerable noise emission when cooling the reactors. Due to the heat and noise radiation nuclear submarines are much easier to locate than the new fuel cell submarines.

11. In order to take full advantage of the performance of the class 212 A submarines, they are also equipped with a diesel generator in case of a necessary sprint during surfaced or snorkeling situations, which supplies the traction battery and recharges it when needed. It has many more technical improvements that make it more efficient, more assertive, more operational, and more comfortable for its crew.

12. Class 212 A submarines are currently employed in several navies (214 Class is the export version of 212A) and have proven their operational capabilities since 2005.[7] This boat type is sophisticated and available immediately.

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[6] Psallidas, Konstantinos, Clifford A. Whitcomb, and John C. Hootman. *Design of Conventional Submarines with Advanced Air Independent Propulsion Systems and Determination of Corresponding Theater-Level Impacts*. Cambridge, MA: Massachusetts Institute of Technology, 2010,.112.

[7] Ibid,. 112

13. Although the 212A class has proven itself, one of the next technological breakthroughs for the submarine application will certainly be the shift of battery technology to lithium-based batteries. Compared to today's conventional lead-acid battery, the maintenance of a lithium battery is minimized. You can store more power in a lithium battery and charge the battery at any time to maximum levels. Therefore, the visibility of submarines with long submerged endurance in conventional diesel electric mode can be significantly reduced. This will be used for the first time in the submarines of the class 216.

Class 216

14. Class 216 is a symbiosis of proven technology coupled with innovation from years of research and development. Many of the design approaches, systems and components have proven themselves over the years. The approximate 40 percent longer boat length compared to the 212A is due to the driving forces, power generation and storage systems, flexible payload, weapon guidance and deployment system, and generous living space.[8]

15. A Siemens Permasyn motor generates propulsion to reach a maximum speed of > 20 knots. The motor is much smaller and lighter than a DC motor of conventional design and allows the ability to control speed quickly and infinitely. Another advantage of the engine is the smooth running and the low rotational speed – thus generating low signatures. Smaller

[8] ThyssenKrupp Marine System."*HDW Class 216*", last access 29 January 2018, https://www.thyssenkrupp-marinesystems.com/en/hdw-class-216.html

Permasyn motors are already successfully deployed on Class 212A and Class 214 (the export version of 212A) submarines.

16. Two sub-batteries store the energy for electrical consumers and the propulsion system. The conventional lead-acid battery used today is replaced by a lithium-ion battery, the advantages of which are higher energy density, shorter charging time and longer life. The comparison of lead-acid with lithium-ion technology with the same battery compartment dimensions shows that the driving range multiplies in creeping speed and especially in high-current discharge. By charging four modern diesel generators and using energy-optimized consumers, the snorkel rate is reduced to less than five percent for low speeds and sets standards even at high installation speeds

17. The lithium-ion battery is a combination for the AIP fuel cell system. With the fuel cell, Class 216 can operate concealed four weeks without snorkeling.[9] The required oxygen for the fuel cell modules is carried in liquid form, while the required hydrogen from methanol is produced by splitting - so-called reforming - in two independent reformer plants. The process-related exhaust gas carbon dioxide is compressed and dissolved within the boat structure in seawater, without leading to a signature increase.

[9] GlobalDefence.net." *Deutschland – Die Klasse 216: U-Boote für den weltweiten Einsatz*", last access 29 January 2016, https://www.globaldefence.net/technologie/deutschland-die-klasse-216-u-boote-fuer-den-weltweiten-einsatz/

18. The propeller blades are made of damping composite material.[10] The number and shape of the blades and the propeller speed were designed for less cavitation, downstream and propulsion optimization. The asymmetric rudder surfaces improve the propulsion efficiency by about six percent compared to conventional rudders and provide a very uniform wake field. Gray and black water are passed through a treatment plant, screened and micro-filtered. The resulting filtrate meets MEPC 159 (55) environment regulations and may be transfered outboard. The concentrate is collected and released in port after the mission, along with various biologically inactive-processed wastes. Through this process waste is minimized and the latest environmental requirements are met.

19. Class 216 features high transit speed, long range, long mission duration, and flexibility in equipment and design. The combination of proven components, proven philosophies and future technologies results in a balanced design that meets the requirements of modern marines for out-of-area operations. The Class 216 submarine allows autonomous operations away from the home port for periods of more than twice that of today's 212A. Based on this, the use of this submarine class seems suitable for Arctic operations. The long submerged endurance allow such an application, however, it must be noted that occasionally this submarine still has to surface for snorkeling.

[10] ThyssenKrupp Marine System."*HDW Class 216*", last access 29 January 2018, https://www.thyssenkrupp-marinesystems.com/en/hdw-class-216.html

20. The biggest risk to this system is that ThyssenKrupp Marine Systems has no experience in the construction of large submarines. Under certain circumstances, this could have a negative effect on the construction phase, which will likely experience delays. Although this type of boat is already available for purchase (Australia), the lithium ion propulsion system is still under development and has not yet proven its operational readiness. Full maturity is expected in 5-7 years.

Scorpène Class

21. The French Scorpène class is a ship class of conventionally diesel-electric powered submarines. The construction is a joint design of the French defense company DCNS and the Spanish defense company Navantia. The submarines are intended exclusively for export and are not used by either the Spanish or the French Navy. The Scorpène class was developed from the old Agosta class and new Barracuda class, which is the current French nuclear submarines. Components like the steel alloy of the hull were used.

22. The modular design provides for three types of construction. In addition to the basic concept, a larger model, which is equipped with the AIP MESMA[11] system, is offered. MESMA is a AIP system developed in France for non-nuclear submarines. Submarines with this propulsion system can operate underwater three to four times longer than the boats of the basic

[11] MESMA= Module d'Energie Sous-Marin Autonome

version without the use of the snorkel. As a cost-effective alternative to the basic version is a third variant, which is smaller and less powerful.

23. The Scorpène propulsion system consists mainly of a steam turbine. The fuel used is ethanol. The oxygen required for combustion is stored in high-pressure tanks in liquid form.[12] In contrast to other drive variants, the turbine does not act directly on the drive shaft, but drives an electric generator. The drive power is transmitted to the propeller with the aid of an electric motor. The mechanical decoupling serves to reduce noise and allows greater design freedom in the placement of the turbine in the pressure hull of the submarine. With this drive concept, a submerged Agosta submarine can travel three to four times further than with conventional lead-acid batteries.

24. Since development of the project back in the early 1980s, the system has been used on at least one Pakistani Agosta boat. Since the French Navy uses only nuclear submarines, the MESMA system was never used in French military submarines. The Scorpène class, which was jointly developed with Spain for export, offers one variant with the MESMA drive.

25. With the expected submerged endurance, the Scorpène class is a candidate for the RCN. A disadvantage is with the MESMA propulsion system itself. Even with its higher power output when compared to the alternatives, which allows higher underwater speeds, its major drawback

[12] Dr. Hoffmann, Joachim. "Emissionsreduzierte Antriebe", last access 29 January 2018,(Page 13) http://www.schiffsingenieure.de/images/pdf/20150910_SiemensvortragHH.pdf

is it's lower efficiency".[13] Also the rate of oxygen consumption is said to be very high and the system itself is very complex. Therefore, this type of boat with its modern drive technology should first prove its operational readiness before any procurement process is started. Despite this, Australia has ordered twelve of these boats from DCNS, which seems to indicate that this drive will be fully operational in the near future.

CONCLUSION

26. This paper has shown that Canada has many options for the replacement of the Victoria Class submarines. Three options have been shown. The requirement of long submerged endurance can be fulfilled by every option presented, therefore, in order to further narrow the choices, Canada will have to be more specific in its requirements. The Class 212 A has proven it can operate submerged for two weeks or longer. The Class 216, despite not built yet, is also expected to dive for a couple of weeks without the necessity to surface. While the Scorpène Class is on the verge of proving its capability of operating submerged for even longer, which is supported by Australian confidence by procurement.

27. The fuel cell propulsion system of class 212 A submarines has been used in the German Navy and other navies for several years. The "teething troubles" involved in the implementation of this propulsion system are therefore ruled out and it has proven its effectiveness in operations.

[13] Defencyclopedia, "Explained : How Air Independent Propulsion (AIP) Works!", last access 29 January 2018, https://defencyclopedia.com/2016/07/06/explained-how-air-independent-propulsion-aip-works/

The shorter submerged endurance in relation to the other two submarines suggest that this type of submarine is not suitable for the Canadian Navy.

28. The lithium ion propulsion system of class 216 is a new development and is considered incomplete. Expected risks are complications in further development and likely delays in the introduction of this propulsion system. Nevertheless, this drive represents a pioneering technology that will certainly set new standards and seems to be a sophisticated submarine for the RCN.

29. The MESMA propulsion of the Scorpène class coupled with its long air-independent diving time, has already been used in a submarine. Therefore, this propulsion system seems to be suitable for RCN requirements.

RECOMMENDATION

30. It is therefore recommended that discussion continues in order to further specify the requirements for the role of future Canadian submarines. An AIP submarine is important for Artic operations, however, since a submarine is an overall weapon system, procurement can not limited to the propulsion system alone. Therefore all other aspects have to be taken into account to achieve all requirements satisfactorily.

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