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Conventional Submarines Move to Centrestage

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ABSTRACT This brief traces the history of the development and deployment of conventional submarines. It analyses their shortcomings and examines how these have been progressively addressed over the years, particularly in the realm of battlefield transparency. Greater stealth, long-range weapons and large weapon loads, when coupled with accurate positional information of targets, have improved the combat capability of modern conventional submarines, narrowing the capability gap when compared to their nuclear counterparts. With such developments, it is prudent for nuclear submarine operators to reassess their force structures in future acquisitions.

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INTRODUCTION

Despite their evolution over the years, diesel submarines have retained their fundamental character since the early part of the last century. Early versions, with all their battery and consequent submerged manoeuvring limitations, were essentially submersible ships. They would spend a large part of their deployed time on surface, submerging only to stealthily approach a prey. While the surface speeds of these submarines were generally slower than that of warships, they were faster than most merchant ships of the time. This allowed them some flexibility in positioning and ensuring they could get into an attacking position for bringing to bear either their torpedoes or deck guns. If a submarine was forced to submerge by an escort/aircraft while in the process of positioning itself, speed and battery limitations would rapidly come into play, effectively reducing combat effectiveness.

Since these submarines routinely operated on surface, they became adept at functioning together in small groups. Coordinated operations of this nature were particularly effective against convoys during World War II, a fact that the Allies learnt much to their chagrin when confronted by the "wolf packs" of Admiral Karl Doenitz. The wartime invention of the snorkel allowed submarines to charge their batteries while at periscope depth. While this contributed significantly towards enhanced stealth, it arrived too late to stem the tide in the battle of the Atlantic. Radar-equipped Allied aircraft and escorts cued by accurate positional intelligence based on the compromised Enigma Code[#], decimated German U-Boats in large numbers, eventually leading to the failure of the German submarine campaign.

Following the Second World War, the employment of submarines in combat—apart from being used as platforms for the launch of Land Attack Cruise Missiles (LACMs)—has been seen during the 1971 India-Pakistan war and the 1982 Falklands conflict. During the Falklands war, the ability of nuclear-powered attack submarines to cover vast distances and make an early impact on the progress of operations was amply demonstrated by the *HMS Conqueror* in its sinking of the Argentinian cruiser, *ARA General Belgrano*. Even if the Royal Navy had conventional submarines in their orbat (Order of Battle) at the time, it would have been nearly impossible to bring them into conflict, given the tyranny of distance.

CONVENTIONAL SUBMARINES: LIMITATIONS

Conventional submarines have two lacunae that restrict their operational potential. The first is stealth. While undoubtedly quiet when submerged and running on batteries, the energy available to do so is finite. Every diesel submariner knows that the biggest concern of the captain on these boats is residual battery power. Indeed, it would be fair to say that the stress level of the captain is inversely proportional to this critical parameter: it

The Enigma Code was an encryption system used by the Germans during the Second World War. Thought to be unbreakable, it was extensively utilised for obtaining positional reports and repositioning submarines. The code was eventually cracked by Alan Turing. Compromised communications played a key role in turning the tide against German U-Boats in subsequent operations.

increases as the other diminishes. Batteries have to be topped up periodically. For this, the boat is required to become indiscrete by rising to periscope depth and extending the snort mast above the water line so as to ingest air for running relatively noisy diesel generators. Because of the high self-noise during this period, the performance of integral sonar also gets substantially degraded. Therefore, the submarine exposes itself not only to aerial and surface threats but also to attacks by sub-surface hunter-killer submarines (SSKs).[$] It would be fair to say that the probability of detection and persecution of a conventional submarine rises manifold while snorkelling.

The second constraint to a successful mission by conventional submarines relates to their mobility. Given the limitations of batteries and the desire to remain discreet, diesel boats are severely hampered in their ability to cover large distances in a short span of time. While high speeds may be employed for short bursts, this results in immense and rapid depletion of battery power. To get around this shortcoming, great care is taken in terms of positioning conventional submarines. To increase their effectiveness, more often than not, they have to be deployed within the operating radii of maritime reconnaissance aircraft that can cue them into an attacking position. If this is not feasible, the alternative course of action is to deploy them in areas where there is a high probability of encountering targets. This is typically off enemy harbours or at the approaches to straits and other confined waters in which enemy shipping is likely to ply during the period of conflict.

There is a downside for adopting either of these two approaches. Insofar as Maritime Reconnaissance – Submarine (MR – Sub) cooperation is concerned, such aircraft tend to be large, slow and lumbering. They are vulnerable when operating in the vicinity of well-armed surface groups with credible anti-air capability. Their operating radii, though significant, are still limited. Further, aircraft of this nature are generally Anti-Submarine Warfare (ASW) capable and therefore have to be time-shared with other critical tasking requirements. With regards to positioning submarines off enemy harbours or at choke points, this is a difficult environment to operate in. More often than not, such waters tend to be shallow with dense traffic that includes neutrals. Being close to the enemy coast, these areas are robustly patrolled by a wide range of ASW assets. Prolonged deployments in such areas leads to the rapid onset of crew fatigue and, consequently, lower combat effectiveness.

MODERN TECHNOLOGICAL DEVELOPMENTS

Over time and with the allocation of adequate resources, solutions to the challenges facing submarines began to emerge. For one, the advent of nuclear propulsion provided an all-encompassing solution to the issues highlighted earlier. However, the adoption of this approach remains beyond the reach of most navies across the world. Nuclear propulsion is inherently complex, requires massive funding and is heavy on maintenance. A Virginia Class SSN, for example, costs four to

$ One of the key methods to hunt a submarine is by using another submarine. Platforms designed to undertake such tasks are called 'Hunter Killers or Submarine Killers (SSKs)'.

six times as much as a top-of-the-line *Soryu* Class diesel submarine.[1] Further, nations that have developed the technology to build such platforms guard it zealously. They do so by creating technology denial frameworks that hamper the transfer of such assets and their underlying technology to other countries.

There are, however, developments underway that have the potential to dramatically improve the combat capability of conventional submarines. Three of the most significant are discussed in turn in the following paragraphs.

1. Reduction in Indiscretion Rate[2]

There are several factors that have contributed to a drop in indiscretion rate. These include the improved efficiency of propulsion systems largely based on Permanent Magnet Synchronous (PERMASYN) motors, more capable and powerful generators, adoption of Air Independent Propulsion (AIP) systems, and improvements in battery technology. The last two are of significant importance and deserve more attention.

- **Air Independent Propulsion (AIP).** A successful approach to address the indiscretion-rate problem of conventional submarines has been in the field of AIP. While several solutions were developed in the early years, two of them had only limited success: the closed cycle diesel engine which was pioneered by the Dutch, and the turbine-driven MESMA plant developed by the French. The Swedish Stirling engine gained more traction and has been used in submarines operated by Japan, Singapore and China, in addition to Sweden. However, the true victor in this field has been the Fuel-Cell, a technology that was first adopted by the Germans and is now witnessing widespread use in the fleets of most submarine operators. The fuel-cell-based AIP system has been developed to a point where in 2013, a German Navy 212A set a world record in doing an underwater transit for 18 days without snorkelling.[3] The added advantage of this form of AIP is that for all practical purposes, it is solid state as the plant has few moving parts. Consequently, a submarine can be nearly as stealthy under AIP as when powered by batteries.

- **Lithium-Ion Batteries (LIB).** Another key determinant of the indiscretion-rate of a conventional submarine is the capacity of the battery bank embarked and the ability of the on-board generators to recharge it rapidly. The bigger the quantum of power stored, the longer a submarine can operate submerged without recharging. Previously, the dominant technology for submarine batteries was the lead-acid cell. While various improvements have been made to such cells over the past decades, these have been incremental in nature. Though robust in their basic design, lead acid cells suffer from inherent disadvantages: they are heavy and consequently have a low energy storage density (typically about 40 percent of lithium ion cells of equal weight).[4] They tend to evolve highly combustible hydrogen gas when under charge, particularly in the final stages. They therefore require close monitoring and fail-safe ventilation systems. They offer relatively low cycle-life, more so in deepdischarge applications. If stored for prolonged periods in a discharged state, sulfation of the electrodes may occur, damaging the battery and necessitating complex treatment cycles to reverse.[5] With the growing electrification of the global economy, particularly in the field of transportation, Research and Development (R & D) on battery technology has increased manifold. As a consequence, issues related to insulation, power management and overheating of highly efficient Lithium-ion batteries have been resolved to a point that they are considered safe for submarine application. Japan has taken the lead in this field, launching the first submarine *JS Oryu (SS 511)* powered by Lithium-Ion batteries in October 2018. The battery that powers this submarine will have double the storage capacity of its lead-acid brethren, albeit at a substantial increase in cost (US$ 97 million versus US$ 13 million for a lead acid battery).[6] Given the advantages of such a battery bank, not only in terms of storage capacity but also in its ability to support rapid recharges (reportedly 1.4 hours for a normal charge against the earlier 2.7 hours),[7] the Japanese Navy has decided to dispense with the Stirling AIP engines altogether, and have done so without adversely impacting the indiscretion rate of the boat.[8] By adopting such an approach, they have recouped most of the cost increase of the improved battery. Korea too plans to use LIB technology in the Batch II of its *KSS-III* submarine programme.[9] It is reported that even China is experimenting with this technology for the follow-on of the *Type 039A Yuan* class.

2. Enhancement in the Range and Quantity of Embarked Weapons

- **Weapon Capability.** Conventional submarines have been handicapped by the limited range of embarked weapons. Great skill had been the forte of erstwhile submarine captains in positioning their boats at a location from which a torpedo attack would have a high probability of success. The early generation of tube launched anti-ship missiles did address this issue to some extent, though here too ranges remained short and more often than not, depended on targeting data from integral sensors which were range-limited too. Weapon ranges, however, have been progressively increasing, as too their capabilities in terms of speed, electronic counter-counter measures (ECCM) and target discrimination. It is now not uncommon for tube-launched missiles to have a range in excess of 500 kilometres. The submarine launched version of the Russian *Kalibr 3M-54T,* for instance, has an estimated range between 270 and 410 miles. Further, as it closes in on its target, it accelerates from a cruising speed of Mach 0.8 to Mach 3, and descends to just 4.6 meters in altitude, thereby making it extremely difficult for a ship's antimissile defences to shoot down.[10] The Chinese *YJ-18B*, a clone of the *Kalibr,* is credited with similar if not better capabilities. Weapon ranges of this order give tremendous flexibility for a submarine to position itself. However, as integral sensors are unlikely to provide accurate target coordinates at such ranges, some form of external targeting data is essential.

- **Weapon Carrying Capacity.** Conventional submarines are invariably space-limited when compared to their nuclear counterparts. As a consequence, considerable thought has to be given to deciding on the weapon outfit in terms of the combination of missiles and torpedoes. The problem is compounded if one is not equipped with a universal torpedo.[&] However, over the years, there has been a steady growth in the size and consequent internal volume of these boats. The Japanese *Soryu*, Russian *Kilo*, Chinese *Yuan* and Australian *Collins* are all well above 3,000 tonnes in their submerged displacement. Conventional submarines currently on the drawing board or in early stages of construction are even bigger. The South Korean *KSS III*, for instance, is large and well suited for distant blue-water operations. In a first for conventional submarines, the boat is being equipped with a six-silo Vertical Launch System (VLS) for anti-ship/land attack cruise missiles in addition to its torpedo tubes. Later versions will feature 10 VLS tubes and may even be armed with a ballistic missile.[11] While the exact specifications of the Australian '*Short Fin Barracuda Block 1A*' conventional submarine are not in the public domain, the displacement will reportedly be between four to five thousand tonnes and it will carry close to 30 torpedoes/equivalent weapons. As part of the same completion, HDW offered the Type 216 with similar specifications.[12] It can thus be seen that conventional submarines have grown to a point where they are not very different from the smaller variants of their nuclear counterparts in respect of weapon carrying capability. A collateral benefit of the increase in dimensions has been the added space available for sighting of large aperture sonar transducer arrays as well as handling and winching arrangements for towed arrays. This has improved sensor performance, in turn contributing to enhanced combat effectiveness.

3. Battlefield Transparency

Transparency in the maritime domain has witnessed dramatic changes over the last two decades. There are many drivers for this. The first is due to the rollout of International Maritime Organization (IMO)-mandated requirements such as the Automatic Identification System (AIS) and Long Range Identification and Tracking (LRIT). These, coupled with nationally legislated ship reporting schemes, have resulted in much more clarity with regards to traffic at sea. Range limitations of the VHF-based AIS are being progressively addressed by an increasing use of satellites to overcome line-of-sight limitations. In this respect, *exactEarth* of Canada has gone into partnership with *Harris Corp.* of the United States to place maritime data-collection payloads on 58 Iridium Next low-orbiting satellites.[13] *ORBCOMM* is providing similar services with next generation OB2 satellites.

These measures are, however, only applicable to compliant vessels. Otherwise, the solution lies in using aerial and space-based reconnaissance assets. While the capabilities

& A universal torpedo is one that can be used against both, surface and submarine targets.

of manned maritime reconnaissance aircraft have improved over the years, the big-ticket changes are taking place in the realm of unmanned platforms. Freed of the requirement of maintaining safe and habitable conditions for on-board crew, space utilisation of such assets is optimised for mission accomplishment. They contain an increasingly wide array of sensors which are progressively getting augmented by mission systems imbued with Artificial Intelligence (AI), enhancing their autonomy and consequent ability to perform, even in the event of a breakdown of communication links. Highly efficient engines and the growing utilisation of electric motor-driven propellers powered by photovoltaic cells has brought within reach the ultimate goal of persistent flight. Such drones will virtually behave as inexpensive pseudo-satellites with the added advantage of near-continuous surveillance, as they will not be limited by orbital physics.

Large and expensive high-resolution satellites with humongous coaxial cameras are facing increasing competition from a new breed of nano-satellites that are being launched by the hundreds. Companies such as *Planet* (formerly *Planet Labs*) have taken the lead in this segment and are progressively launching their trademark 'Dove' satellites in what they call 'Flocks'. One such flock comprising 88 Doves was launched by the Indian Space Research Organisation's (ISRO) Polar Satellite Launch Vehicle (PSLV) in February 2017. In doing so, ISRO set a new world record of the largest number of satellites launched by a single rocket (88 Doves and 16 other payloads including Cartosat 2D to make a total of 104).[14] According to their website, *Planet* currently has over 150 satellites in orbit.[15] With this constellation, they claim that they can image the entire globe once a day, though currently they turn off their cameras when over the ocean as there are few takers for such data. Even though the weight of the Dove is only 4.2 Kg, it packs a significant capability in that its images have an average resolution of 3.7 m.[16]

Nano-satellites of the type described above, primarily make use of commercial mobile-phone technology. As a consequence, they are cheap and easy to manufacture. Launch costs, driven by increasingly efficient rockets as well as by reusability of launchers have come down to a point where the approximate cost of putting such a satellite into low earth orbit is under US$ 100,000.[17] It is only a matter of time before satellites of this nature become more ubiquitous, providing several positional updates of every ship at sea on a daily basis. Under such circumstance, positional ambiguity will become a thing of the past and warfare at sea will be characterised less as a game of poker—where players hold their cards close—and more like a game of chess, where there is complete transparency of both forces.

CONCLUSION

The big-ticket changes to conventional submarines are well underway: enhanced indiscretion rate, prolonged endurance, and large weapon carrying capability. Their weapons have improved to a point where ranges in the order of several hundred kilometres have now become the norm. They will increasingly operate under a realm of battlefield transparency, wherein their situational awareness is akin to that of a ship and it will be easy for them to exploit their weapons to their maximum range based on externally furnished targeting data. While each of these developments is significant, as a combination, they have the potential to make a monumental change to the operating philosophy and combat potential of diesel boats. This is because together, they have the ability to address their only remaining lacuna—that of mobility.

Given a long range weapon and accurate targeting data, there is no requirement for the launching platform to travel vast distances to be effective. This addresses the tyranny of distance that conventional boats suffer from. Thus while comprehensive battlefield transparency takes away the requirement to operate within the radii of maritime reconnaissance aircraft or at choke points, enhanced weapon ranges erases the necessity to physically move a boat to employ it effectively. The preferred area of submarine deployment with these changes would be mid-sea in deep waters where the submarine can manoeuvre unhindered and is likely to encounter far less opposition. Acting in essence as a concealed mobile missile battery mid-sea, a conventional submarine will have the ability to impact the conduct of warfare several hundred kilometres around its position, a capability previously beyond the reach of this class.

Speaking for attack submarines (SSNs), if the requirement to move large distances is dispensed with, particularly in a regional context, then the motivation to adopt expensive, complex and maintenance-heavy nuclear propulsion diminishes substantially. While undoubtedly SSNs have been progressively getting quieter over the years and have done so at considerable cost; by the simple laws of physics, their turbine and reduction gear driven propulsion trains will never be able to match the negligible noise generated by a slowly turning electric motor powered by batteries. Conventional submarines will thus be able to usurp the tasking of nuclear submarines to a considerable extent in a far more cost effective manner. Residual shortfall of capability could be bridged by increasing their numbers and adopting a dispersed and distributed architecture in their deployment. In a globally slowing economy with strong budgetary pressures, navies that operate nuclear submarines may like to recalibrate their options in this respect.

ABOUT THE AUTHOR

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ENDNOTES

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