Seoul's Misguided Desire for a Nuclear submarine

By

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ABSTRACT:

In response to North Korea's missile submarine threat, South Korean President Moon Jae-in has endorsed the development of an indigenous South Korean nuclear attack submarine. Yet, developing a nuclear submarine offers limited advantages in combating North Korean submarines versus improving the proven anti-submarine capabilities the ROK currently employs. Economically, a South Korean nuclear submarine program would sacrifice overall military readiness in favor of naval prestige. Worse, even if a nuclear submarine program was free, it would take so long to develop, it would come on line far later than the North Korean threat. Finally, pursuing such a program, could raise nonproliferation concerns about uranium enrichment (needed to make naval reactor fuel) and so diplomatically fortify Pyongyang's own resistance to denuclearization. Seoul's best course would be to expand current anti-submarine warfare (ASW) assets and invest in new technologies, such as drones, laser, magnetic anomaly detection, and artificial intelligence that would increase their ASW effectiveness.

KEYWORDS: South Korea, Nuclear Attack Submarine, enrichment, Anti-Submarine Warfare, ASW

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INTRODUCTION

In 2017, President Moon Jae-in endorsed the development and acquisition of a South Korean nuclear submarines. South Korean proponents of nuclear submarines favor the program for two technical reasons. First, nuclear submarines can stay underwater for months rather days or weeks as conventional diesel/electric submarines do. Second, nuclear submarines can maintain speeds of up to 30 to 40 knots at depth, whereas nonnuclear submarines have difficulty sailing much above 20 knots at depth for any significant duration and must frequently surface to recharge its batteries (which makes them easier detect). These two attributes, South Korean nuclear submarine proponents argue, make nuclear submarines ideal for detecting and neutralizing the North Korean ballistic missile submarines.[1]

Since Moon's 2017 endorsement, South Korean interest in developing an indigenously designed nuclear submarines has only grown. Recent press reports indicate the navy's intention to modify three KSS-III submarines (*Dosan Ahn Chang-ho* class) to 4,000-ton nuclear powered submarines.

This is a major commitment. Not only does the addition of nuclear power to the final three submarines severely impact the defense budget, but South Korea must find a reliable long-term fuel supplier. South Korea has nuclear fuel purchase agreements with the United States, but for civilian applications only. Press reports attributed to unnamed military sources suggest that once the United States agrees to supply low enriched uranium for naval use, the development process will be a breeze.[2] This statement glosses over the complexities associated with

1. Kim Tong-Hyung, "SKorea Scrambles to Improve Weapons Following NKorea Test", *AP News*, 5 Sep 2017, https://apnews.com/1dd5019ccaa94213b59701a4bd8d18dc.
2. Sang-Ho Yun, "S. Korean Military Announces Plan to Develop 3 4,000-ton Submarines", *The Dong-A Ilbo*, 11 Aug 2020, https://www.donga.com/en/article/all/20200811/2147590/1/S-Korean-military-announces-plan-to-develop-3-4-000-ton-submarines.

renegotiation of the existing South Korean-US 123 agreement and the difficulties of building nuclear submarines.

In fact, acquiring nuclear submarines dictates a dedicated line of funding that would affect other ROK Navy programs. This trade off immediately raises the issue of how useful the operational advantages of nuclear submarines are for South Korea, whose navy operates in relatively shallow, local, regional waters.

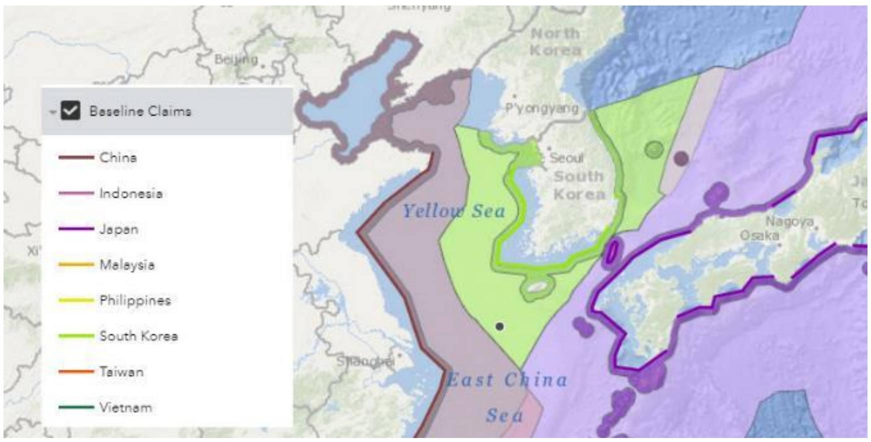

Figure 1: National claims to sea lanes in Northeast Asia

In addition, South Korea must consider the legal aspects of promoting a nuclear submarine program. Can the Moon Administration negotiate with nuclear fuel suppliers to acquire the necessary enriched fuel to power a nuclear submarine fleet? South Korea will likely have to renegotiate its 123-Agreement with the United States to utilize purchased enriched fuel for military purposes.

Weighing the pros and cons of acquiring nuclear submarines, South Korea should consider alternatives. The ROK Navy is updating its surface and underwater fleets with highly capable anti-submarine warfare (ASW) systems. It can rely on the United States to support state of the art airborne anti-submarine assets to enhance the South Korean navy’s capabilities to detect, track, and if necessary, prosecute hostile sub threats. The Moon Administration may seek to create and foster cooperative ASW agreements with Japan and/or the United States. As a highly technical economy, South Korea might invest in technologies, such as drones, laser, magnetic anomaly detection, and artificial intelligence (AI), that could enhance all facets of

ASW. The high costs of nuclear submarine permit acquisition of only a very limited number; whereas, the same money could purchase greater nonnuclear ASW capabilities. Finally, nuclear submarines typically operate as an ASW platform, while the surface and air assets can perform multiple missions beyond just those associated with ASW.

EVOLVING NORTH KOREAN THREAT

North Korea left the Nonproliferation Treaty (NPT) in 2003 and tested its first nuclear weapon in 2006. Between 2009 and 2016, the Kim regime tested four additional nuclear devices with the final test stated as a thermonuclear device with an estimated 250 kiloton yield. Throughout the testing period, North Korea continued to refine its nuclear warhead miniaturization for integration on a missile.[3]

As the Kim regime refined its nuclear warhead designs, it developed more capable missiles, including intercontinental ballistic missile (ICBMs). Under the guise of a peaceful space launch vehicle program, the DPRK eventually developed and tested the *Hwasong-15* ICBM.

Figure 2: Test launch of Hwasong-15 ICBM

The *Hwasong-15* with a range of nearly 13,000km can threaten the entire continental United

3. “North Korea: Nuclear,” Nuclear Threat Initiative (NTI.org), Oct. 2018, https://www.nti.org/learn/countries/north-korea/nuclear.

States. After the successful testing of the Hwasong-15, North Korean state media claimed that the country had "finally realized the great historic cause of completing its nuclear force".[4] The inference from this statement indicates that the United States is the deterrent objective of these strategic weapon systems, not South Korea.

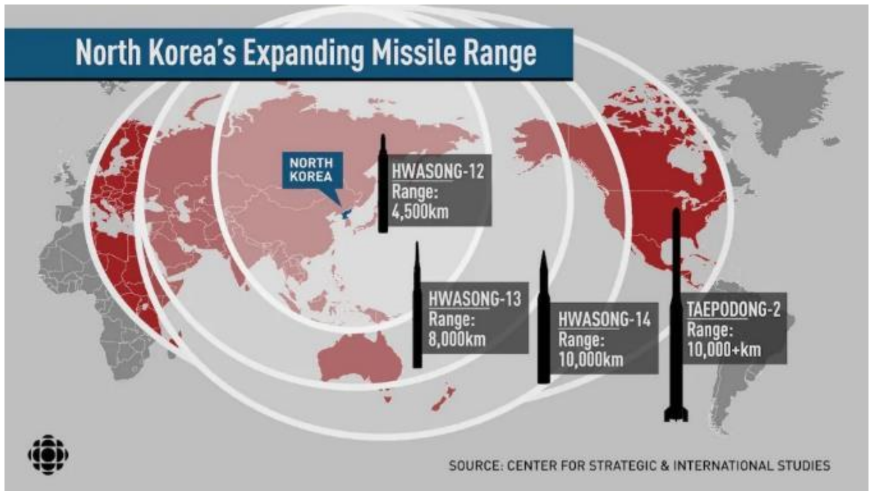

Figure 3: Estimated ranges of DPRK missile

North Korea's supplement to land-based nuclear missiles has been its development of submarine launched ballistic missiles (SLBM). In 2015, North Korea began the testing of its SLBMs which culminated in the launching of four missiles in 2016. After a hiatus of three years, North Korea launched a new generation SLBM, the *Pukgukson-3* with a range of 1,900 km.[5]

4. Uri Friedman, "North Korea Says It Has "Completed" Its Nuclear Program," *The Atlantic*, 29 Oct 2017, www.theatlantic.com.
5. Jack Kim, "Explainer: North Korea's Suspected Submarine Missile Pushes the Envelope," *Reuters*: World News, 2 Oct 2019.

North Korea possess a submarine fleet of over 70 vessels, but most are relatively obsolete designs from the late 1950s to mid-1960s. North Korea's first indigenous missile submarine, the *Sinpò* class, finished construction in late 2014. However, the base design is still relatively antique compared to current attack submarines available to South Korea and Japan. South Korean analysis of the *Sinpò* class missile submarine may have just one vertical launch tube for SLBMs.[6] North Korea possesses missile submarines, but still must master the challenge of ejecting and launching an SLBM from an operational submarine.

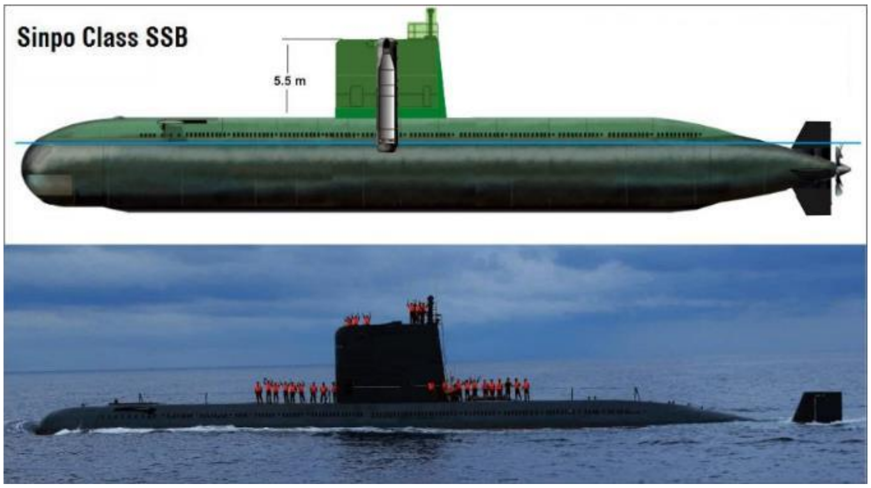

Figure 4: DPRK Singpò Class ballistic missile submarine

North Korean short and intermediate missiles already accomplish deterrence against any South Korean incursion or attempt to eliminate the Kim regime. The addition of ICBM and SLBM capabilities presents not a deterrent aimed South Korea, but a deterrent directed at the United States. Thus, a South Korean nuclear-powered submarine is an unnecessary luxury, not a clear military requirement.

SOUTH KOREAN NUCLEAR SUBMARINE ANSWER

South Korean nuclear submarine proponents claim nuclear submarines are the most effective counter against a DPRK or another hostile nuclear-capable missile submarine. The

6. Sukjoon Yoon, "Expanding the ROK NAVY's Capabilities to Deal with the SLBM Threat from North Korea", *Naval War College Review*, Vol. 70, Number 2, Article 4, 2017.

South Korean press has reported that the proposed South Korean nuclear submarine fleet would consist of a minimum of three nuclear submarines. The belief is that three will guarantee at least one continuous submarine at sea capability. The cost estimates for the three submarines plus supporting infrastructure approach $9 billion excluding operating costs.[7] For fiscal year 2020, the South Korean defense budget is approximately $41.3 billion of which $13.7 billion is set aside for arms purchases.[8] South Korea has already begun to over emphasize the advantages of nuclear-powered submarines to justify so much spending on it (see Appendix I).

Retired Navy captain, Moo Keun-sik, claims that the basic submarine and miniaturized nuclear reactor designs were completed during the "326 initiative".[9] The "326 initiative" was a secret development program started in 2003, but shut down after exposure to the International Atomic Energy Agency (IAEA) and Korean public. Captain Moo Kean-sik's claims seem overly optimistic: Basic designs for US navy submarines, for example, take up to four years and an additional nine years to complete detail design.[10] Five years is the minimum reported timeframe for South Korea's first nuclear-powered submarine even with outside assistance, according to naval experts."[11] Yet, how long it might take Seoul to acquire nuclear submarines is perhaps the least of the problems it submarine acquisition effort faces.

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7. Franz-Stefan Gady, "Will South Korea Build Nuclear Attach Subs?", *The Diplomat*, 8 Nov 2017, https://thediplomat.com/2017/11/will-south-korea-build-nuclear-attack-subs/.
8. Yonhap, "S. Korea's 2020 Defense Budget Rises 7.4% to Over 50tr Won", *The Korea Herald*, 11 Dec 2019.
9. Jeff Jeong, "South Korea Eyes French Design for Indigenous Nuclear Sub, Sources Say", Defense News, 28 Mar 2018, https://www.defensenews.com/industry/techwatch/2018/03/28/south-korea-eyes-french-design-for-indigenous-nuclear-sub-sources-say.
10. J. Schank, M. Arena, P. DeLuca, J. Riposo, K. Curry, T. Weeks, & J. Chiesa, (2007). *The Submarine Design Process. In Sustaining U.S. Nuclear submarine Design Capabilities* (pp. 7-24). Santa Monica, CA; Arlington, VA; Pittsburgh, PA: RAND Corporation. Retrieved August 16, 2020, from www.jstor.org/stable/10.7249/mg608navy.10
11. Franz-Stefan Gady, "Will South Korea Build Nuclear Attach Subs?", *The Diplomat*, 8 Nov 2017, https://thediplomat.com/2017/11/will-south-korea-build-nuclear-attack-subs/.

SOUTH KOREAN OBSTACLES TO NUCLEAR SUBMARINE

Assuming the South Korean Navy's acquisition price (without supporting infrastructure) is between $1.6 - $2.5 billion for the proposed nuclear submarines, Seoul may need as much as $7.5 billion to build just three submarines. Operationally, South Korea's navy will need as many as nine nuclear submarines to protect its regional sea lanes as all submarines cannot deploy simultaneously. Generally, half of the submarine fleet is undergoing maintenance or crew rest and retraining operations outside of tracking adversary submarines.

Thus, a realistic nuclear submarine fleet for South Korea would be six to nine submarines. That could cost as much as $22.5 billion. The Moon administration's planned budget for 2019 was approximately $415 billion, which included nearly $42 billion in defense spending. Money spent acquiring nuclear submarines might be better spent on missile defense, air forces, ground forces, or reinvestment in the national economy.[12]

More important, South Korea will need to overcome several additional structural barriers to build it nuclear submarines.

Shipbuilding Infrastructure. South Korea is the number one shipbuilder in the world, but that is of civilian ships, not warships. Adding a nuclear submarine program to the ROK defense budget would require additional workers trained in design, development, and production of highly complex nuclear submarines. In addition, the shipbuilder would have to secure and isolate construction facilities dedicated only to the nuclear submarine program to ensure the security of the related nuclear technology and materials.

12. Franz-Stefan Gady, "Will South Korea Build Nuclear Attach Subs?", *The Diplomat*, 8 Nov 2017, https://thediplomat.com/2017/11/will-south-korea-build-nuclear-attack-subs/.

The major shipbuilders in Korea consist of the following: Daehan Shipbuilding, Samsung Heavy Industries, Daewoo Shipbuilding & Marine Engineering (DSME), and Hanjin Heavy Industries & Construction (HHIC). Of these four only DSME and HHIC build military vessels. Currently, DSME is the shipbuilder constructing the Korean Navy's conventionally-powered submarines. Both DSME and HHIC build military and civilian vessels in the same shipyard.

South Korea requires dedicated port facilities for its proposed nuclear submarine fleet. The ROK Navy could convert existing harbor facilities or develop a new site. Either way, the Moon Administration will require infrastructure funding in addition to the submarine construction funding.

Design/Construction. South Korean shipbuilders must also develop the design parameters for marrying a nuclear reactor with a submarine hull. Towards this end, designers will need educational facilities to teach nuclear reactor operations and design. The US Navy has identified the following eight characteristics critical to the submarine design:

1. **"Compactness**: Reactor must be small enough to fit within space and weight constraints of a warship while still being able to provide adequate power to drive at necessary speeds for engagement or rapid transit,
2. **"Crew Protection**: The crew lives and works very close to the reactor for extended amounts of time,
3. **"Public Safety**: U.S. Navy ships use various ports around the world; it is a necessity that the safety of the public at these ports be guaranteed so that our ships are continued to be welcomed,
4. **"Reliability**: The reactor must be able to continuously provide power and electricity to the ship to ensure a self-sufficient operational status in the most demanding environments,
5. **"Ruggedness**: The reactors must be able to tolerate extreme conditions of being at sea as well as severe shocks during battle conditions,
6. **"Maneuverability**: The reactor must be able to provide rapid and frequent power changes to support the ships' tactical maneuvering,
7. **"Endurance**: It is crucial that the reactor to be able to operate for many years before refueling, the best-case scenario is a lifetime core. This will maximize ship availability,

minimize occupational exposure, minimize life-cycle cost, and minimize demand on the support infrastructure,

8. **"Quietness**: This is especially important for submarines so to minimize the threat of acoustic detection."[13]

South Korean designers would have to address each characteristic equally and become proficient in each characteristic to field a capable nuclear submarine fleet. To quote US Navy reactor design community, "Failure to meet any of these requirements would jeopardize the operational status of the reactor, therefore compromising the ability of the ship to carry out its mission and potentially putting the crew in danger."[14]

The warfare systems incorporated within the nuclear submarine align with the current ROK Navy's diesel/electric fleet. What the designers would have to be cognizant of is the increased electrical power within the nuclear submarine and the effective distribution of that power to the warfare systems along with the increasingly advanced sensors incorporated in future hulls and modernizations.

Another consideration is the retention of the knowledge base once construction of the nuclear submarine fleet commences. Maintaining the knowledge base for future nuclear submarine upgrades requires an effective strategy for workforce stability over decades. If the government intends a strategy of a 25-30-year submarine service life before replacement by a new-generation nuclear submarine, then the government must develop long-term plans to maintain that trained design workforce.

The ROK Navy and its associated shipbuilder must overcome other construction constraints. Unlike the current construction requirements for conventional submarines, a nuclear

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13. "Report on Use of Low Enriched Uranium in Naval Nuclear Propulsion", Director, Naval Nuclear Propulsion, June 1995, http://large.stanford.edu/ courses/2014/ph241/reid1/docs/onnp95.pdf.
14. Ibid.

submarine program would have much greater safety requirements to deal with special nuclear materials and the accidental release of radioactivity in irradiated fuels.

South Korea could learn from the experiences that the US Navy has with submarine construction. Due to design and construction errors, the US Navy experienced a tragic accident with the USS Thresher which sank with all hands during trials. A result of that experience was the implementation of the SubSafe program. SubSafe establishes a strict quality control regime that is external to the shipbuilder and program office overseeing construction. South Korea would need such a program if they pursue a nuclear submarine program.

Like the requirement for trained submarine designers, the nuclear submarine shipyard must compete against the public shipyards for trained construction personnel. Generally, private sector jobs are higher paying than their public equivalents. For a program of national security interest, the nuclear submarine shipyard would have to offer comparable salaries and the incentive of contributing to the well-being of the nation. Korean designers would have to address each characteristic equally and become proficient in each characteristic to field a capable nuclear submarine fleet. To quote US Navy reactor design community, "Failure to meet any of these requirements would jeopardize the operational status of the reactor, therefore compromising the ability of the ship to carry out its mission and potentially putting the crew in danger."[15]

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15. "Report on Use of Low Enriched Uranium in Naval Nuclear Propulsion", Director, Naval Nuclear Propulsion, June 1995, http://large.stanford.edu/ courses/2014/ph241/reid1/docs/onnp95.pdf.

of that power to the warfare systems along with the increasingly advanced sensors incorporated in future hulls and modernizations.

Another consideration is the retention of the knowledge base once construction of the nuclear submarine fleet commences. Maintaining the knowledge base for future nuclear submarine ship upgrades or replacement designs requires an effective strategy for workforce stability over decades. If the government intends a strategy of a 25-30-year nuclear submarine service life before replacement by a new-generation nuclear submarine, then the government must develop long-term plans to maintain that trained design workforce.

The ROK Navy and its associated shipbuilder must overcome other construction constraints. Unlike the current construction requirements for its conventional submarine program, the nuclear submarine program would have to have greatly increased security. Security is mandatory for the construction of the reactor compartment and the nuclear fuel planned for installation. Planning for the shipyard must include handling of special nuclear materials. Protection against accidental release of the radioactivity in irradiated fuel would be critical for the safety of the construction workers and the surrounding community.

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Logistics/Training. The ROK Navy would need to develop new logistics methods for handling nuclear fuel. Transport and storage facilities would be needed to minimize nuclear submarine maintenance periods. A secure source of nuclear fuel would be essential. At a minimum, South Korea would need to renegotiate its agreement on peaceful nuclear cooperation with the United States and build a uranium enrichment plant and fuel fabrication plant.

Then, there is the training required for nuclear submarine sailors. In the US Navy, such training takes a year to complete. To conduct this training, the ROK Navy would need an on-shore training reactor in a facility convenient to the nuclear submarine fleet. Any modifications or changes to the ships' reactors would require the same updates to the training reactor ensuring that the sailors train on the same equipment that is currently in the fleet. To gain proficiency operating a naval reactor, US Navy sailors require three years of training. The ROK Navy, which would be new to nuclear operations, might need more.

Disposal. Unlike conventional submarines dismantled at a scrapyard, nuclear submarines require special facilities to handle irradiated materials. The reactor core plus the reactor vessel demand facilities designed to safely remove and transport the core and vessel. The ROK Navy should review the disposal issues that both Russia and the United Kingdom are experiencing with their decommissioned nuclear submarines. Both nations are struggling to dismantle their out-of-service submarines, specifically the removal and storage of the reactor core and associated irradiated materials.

Priority. Any delay regardless of cause, creates a potential technology gap between the fielded nuclear submarine and the adversary's submarine capabilities. South Korea can learn from Brazil's experience by ensuring dedicated long-term funding.

South Korea, unlike Brazil, possesses extensive experience in modern shipbuilding, and more important, more nuclear engineering expertise. Defense specialist Bernardo Wahl de Araújo Jorge notes that in addition to the Brazil's budget constraints, the delay in completing the project has been due to difficulties with mastering the fuel cycle needed to support nuclear propulsion.[16] South Korea may not experience the same learning curve as it has an advanced nuclear power industry, but it does not enrich nuclear fuel. Also, nuclear propulsion is not within South Korea's shipbuilding repertoire.[17] South Korea would have to understand this important issue by making the acquisition of a nuclear submarine a national priority with full government backing independent of changes in administrations.

Nuclear material agreements. The biggest obstacle for Seoul's acquisition of a nuclear submarine is nuclear fuel. South Korea's does not have an indigenous uranium supply. It imports most of its fabricated uranium fuel from the United States. South Korea recently

16. Domingos Zaparolli, "Renewing the Fleet", *Naval Engineering*, Issue #274, December 2018, https://revistapesquisa.fapesp.br/en/2019/06/24/renewing-the-fleet/.
17. Ibid.

renewed its civilian nuclear cooperative 123 agreement with the US in 2015. The agreement prohibits Seoul from using US supplied uranium for any military purpose but permits South Korea to enrich up to 20 percent for civilian applications if Washington gives its consent. South Korea could purchase fuel from alternative suppliers such as China, France, and Russia. But they have similar peaceful use requirements.[18] [19] If South Korea is unable to obtain the necessary enriched uranium from a foreign source, the alternative would be indigenous enrichment that breaks nuclear cooperative agreements by diverting enriched uranium to the nuclear submarine program.

Denuclearization of peninsula. If the ROK government authorizes an enrichment program, denuclearizing the peninsula will become more complicated. The latter is a major goal of the South Korean government. In addition, both North and South Korea agreed to eschew enriching and reprocessing in 1991. North Korea is in violation of this agreement.

SOUTH KOREA'S BEST RESPONSE

The ROK Navy possesses several very capable ASW platforms that provide a greater return on investment over a limited nuclear submarine fleet. Considering the expenditure necessary for a nuclear submarine fleet, the Moon administration could purchase a greater quantity and mix of currently available ASW assets. Likewise, additional funds could enable pursuit of new technologies providing ASW coverage of greater regional territory.

18. Frank von Hippel, "Mitigating the Threat of Nuclear Weapon Proliferation via Nuclear-Submarine Programs", *Journal for Peace & Nuclear Disarmament*, vol. 2, issue 1, 2019, https://doi.org/10.1080/25751654.2019.1625504.
19. Sharon Squassoni, Conversation regarding nuclear cooperative agreements between US and South Korea, 25 Aug 2020. One nuclear supplier that doesn't include a "no military usage" provision is India.

Current Assets

The ROK Navy's surface ships rival many of the great power's surface fleet in ASW capability which includes decades of development of cooperative tactics with the US Navy. The ROK Navy can purchase more ASW capability with such a multidimensional program than through the expenditure of scarce defense funds on a single ASW dimension. Reviewing historical precedent, diverse assets overcome a focus on one kind of asset, even nuclear submarines.

Surface Naval Combatants.

The ROK Navy currently fields the *Incheon* Class guided missile frigates, currently configured for the surface warfare mission, are upgradable to accept anti-submarine rockets as well as land attack missiles. At a cost of only $250 million per ship, the ROK Navy could acquire multiple highly cable ASW frigates for less than the costs of a single nuclear submarine. The new *Daegu* Class guided missile frigates have incorporated ASW systems specifically to counter the DPRK threat including antisubmarine missiles, torpedoes, and sonar systems at a cost per ship of approximately $300 million.

Figure 1: ROK Navy Daegu class frigate

The ROK Navy is currently building and fielding the *Sejong the Great* Class of destroyers. This class of ships provides the ROK Navy with a true-blue water capability, plus an important upgrade to ballistic missile defense capability. At approximately $925 million per ship, the *Sejong the Great* ships provide an extensive ASW suite of weapons and sensors. The ship has a storage and launch capacity for 128 missiles configurable for missile defense, land attack or, antisubmarine warfare. The ship also carries two helicopters for use in ASW operations. The cost is significantly less than a nuclear submarine but provides an extra capability of ballistic missile defense that a nuclear submarine is unable to deliver.

Figure 2: ROK Navy Sejong the Great class destroyers

Airborne ASW.

To fully integrate all dimension of ASW warfare, the ROK Navy requires airborne assets that can perform and integrate with the surface and subsurface fleet. The US has a very capable aircraft, the P-8A Poseidon, that can perform integrated ASW missions. The P-8A

Figure 3: US Navy P-8A Poseidon deploying Mk-54 aerial ASW torpedo

has a patrol radius of 1200 nautical miles (nm) with a capability to remain on station for 4 hours. It carries up to 11 torpedoes and 120 sonobouys. The P-8A can also monitor up to 64 sonobouys and relay that data to integrated fleet units for prosecuting hostile submarine contacts. For the US NAVY, "the P-8A Poseidon and MH60R Seahawk are a formidable team that holds at risk the surface and subsurface adversary to allow our carrier strike groups and joint forces access and freedom to maneuver."20 The cost for this capability is $125 million per aircraft which the ROK defense could integrate with its surface and underwater ASW operations. In 2018, the US State Department approved the sale of eight P-8A Poseidon aircraft to South Korea at an estimated cost of $2.1 billion.[21]

While the P-8A is a land-based asset, the MH-60R or equivalent helicopter is sea based. Both ROK NAVY frigates and destroyers have the capability to operate ASW helicopters from their decks. The ASW helicopter permits the frigate or destroyer to increase its area coverage during ASW operations. The MH-60R can carry up to three ASW torpedoes and, 25 sonobouys, and it contains the advanced airborne low-frequency dipping sonar (ALFS)

Figure 4: MH-60R deploying dipping sonar

20. Walter Massenburg, "Why We Need Maritime Patrol and Helicopters", http://hrana.org/wp-content/uploads/2013/03/Maritime-Patrol0001.pdf, Summer 2016.
21. Franz-Stefan Gady, "US State Department Approves Sale of 6 P-8 Poseidon Sub-Hunting Planes to South Korea", *The Diplomat*, 14 Sep 2018, https://thediplomat.com/2018/09/us-state-department-approves-sale-of-6-p-8-poseidon-sub-hunting-planes-to-south-korea.

with both passive and active capability. The unit cost for the MH-60R is approximately $40 million per aircraft.

With air assets combined with surface ships and submarines, the ROK Navy would be able to detect and prosecute hostile nuclear armed missile submarines over a much greater area than with one nuclear submarine at sea. Combining new technologies into the existing ROK Navy assets such as drone systems and artificial intelligence, the detection probability for hostile submarines would increase.

Nonnuclear submarines.

The ROK NAVY submarine fleet consists of the *Chang Bogo* Class and the *Sohn Wonyil* Class. Both classes have diesel/electric propulsion and each submarine has 8 torpedo tubes. The *Sohn Wonyil* ships have an endurance capability of 84 days, while the *Chang Bogo* class ships endurance is 50 days. Though these periods of endurance are significantly less than possible with a nuclear submarine, they satisfy the requirements of regional patrol operations. Additionally, at approximately $300 million per attack submarine, the ROK Navy cold acquire a greater number of subs for continuous patrol operations in its regional security zones.

Figure 5: ROK Navy Chang Bogo class submarine at sea

The ROK Navy is in process of constructing the new *Dosan Ahn Chang-ho* Class of submarines. Significantly larger than the previous ROK Navy submarines, the *Dosan Ahn Chang-ho* class incorporates an air independent propulsion (AIP) system. AIP provides for greater underwater endurance over the previous diesel/electric submarines. While the *Dosan Ahn Chang-ho* class is larger, it has 2 fewer torpedo tubes than previous ROK Navy submarines. However, it has vertical launch missile cells as an added capability. The cost of this class at approximately $900 million per ship is still significantly less than a nuclear submarine.

Figure 6: ROK Navy Dosan Ahn Chang-ho first in class submarine on sea trials

Not only are the existing ROK Navy submarines capable of ASW missions at a fraction of the cost of nuclear submarines, they offer a quieter operating platform. Radiated noise is the key method for detecting submarines and thus avoiding potential attack. The quieter the submarine, the more difficult the mission of ASW. While operating on electric or AIP, the submarine is nearly undetectable by an adversary. In 2015 joint exercises, Sweden demonstrated the AIPs advantage, "when the HMS *Gotland*, a Swedish AIP submarine, "sank" many US nuclear fast-attack subs, destroyers, frigates, cruisers, and even the USS *Ronald Reagan* (CVN-76) aircraft carrier during joint exercises."[22]

Future Assets

Technology continues to reduce or eliminate ASW barriers. The increased usage of drone or autonomous systems can limit exposure of personnel and increase coverage of vast swaths of the ocean. New technologies open avenues in ASW by making submarines "visible" and

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22. Sebastian Roblin, James Holmes, Doug Bandow, Robert E. Kelly, "Did Sweden Make America's Nuclear submarines Obsolete?", *The National Interest,* 30 Dec 2016, https://nationalinterest.org/blog/the-buzz/did-sweden-make-americas-nuclear-submarines-obsolete-18908.

reducing the threat of surprise. The computer age also increases the effectiveness of ASW sensors through their ability to crunch vast amounts of data and provide information to military and political decision makers. South Korea has a highly technical economic infrastructure that can exploit these new technologies at much less cost than a nuclear submarine program.

Drones.

Current drones consist not only of aerial types, but also surface and underwater types. The aerial drone commonly used for ASW is the MQ-4 Triton. While this drone does not possess offensive weaponry, it does carry a powerful Multi-Function Active Sensor (MFAS) with an active electronically scanned array radar. As the Triton has a 30-hour endurance at a speed more than 300 knots, this drone can monitor large areas using radar or magnetic anomaly detection for locating potential adversary submarines. At a cost of $125 million per copy, the ROK NAVY could purchase plenty to cover important sea lanes at a fraction of the cost of a single nuclear submarine. Also, the Triton is fully interoperable with all military assets enabling immediate sharing of intelligence. The Triton has another advantage of utilizing commercial off-the-shelf architecture which means that

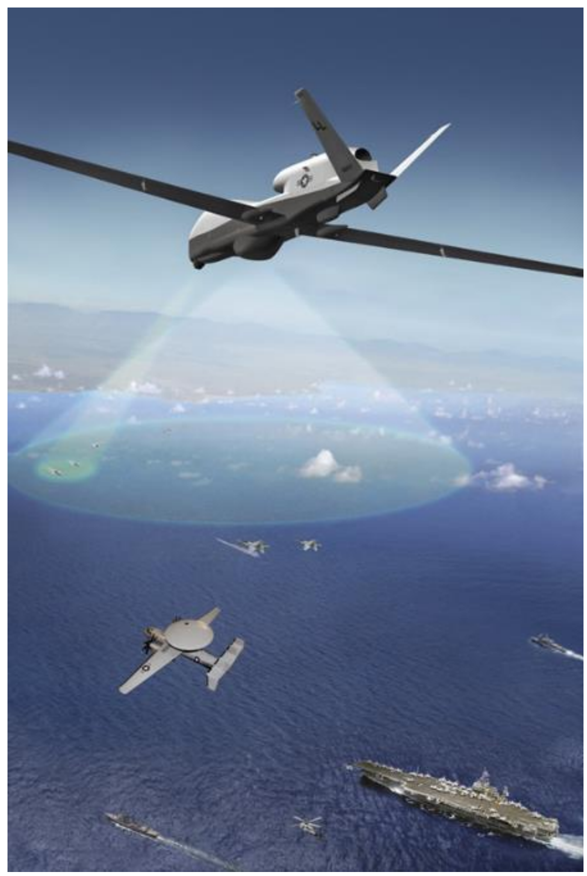

Figure 7: Depiction of MQ-4 Triton conducting surface scanning forward of fleet

upgrading the operating system is less complex and easy to keep with the latest technological advances.

One example of a surface drone is the Liquid Robotics Wave Glider which cost approximately $300 thousand per copy. The wave glider can host several payloads and underwater sensors for the detection of hostile submarines and provide connectivity between underwater vessels and surface or air units for complete multi-dimension ASW. The solar-powered wave glider has approximately a one-year endurance and maintain its location within a 30-meter radius. As the wave glider has an extremely low profile, it is ideally suited for monitoring hazardous waters providing early detection and data relay to quick response aerial assets for prosecution of hostile submarines in times of crisis.

The Slocum buoyancy glider operates underwater utilizing the energy in the ocean waves to move in a sawtooth pattern up and down in the sea. At only $125-$150 thousand dollars per copy, this autonomous vehicle provides yet another method of detecting and communicating the locations of hostile submarines. When operating in swarms, the Slocum glider provides coverage over large ocean areas reducing the requirement for manned vessel sorties. The Slocum glider is easily operable using web-based navigation and has an endurance range measured in days or months depending upon payload and mission. Each time the glider surfaces, it can transmit its data and receive new task orders as needed.

New unmanned surface vessels continue to advance through testing phases, with deployments following within 3-5 years. Specifically, the US NAVY *Sea Hunter* is a fully autonomous surface vessel that has the capability to navigate the seas without human input. The *Sea Hunter* equipped with the latest tow array sonar systems can assist detection of hostile submarines. Its relatively small and low profile reduces its radar signature relative to manned

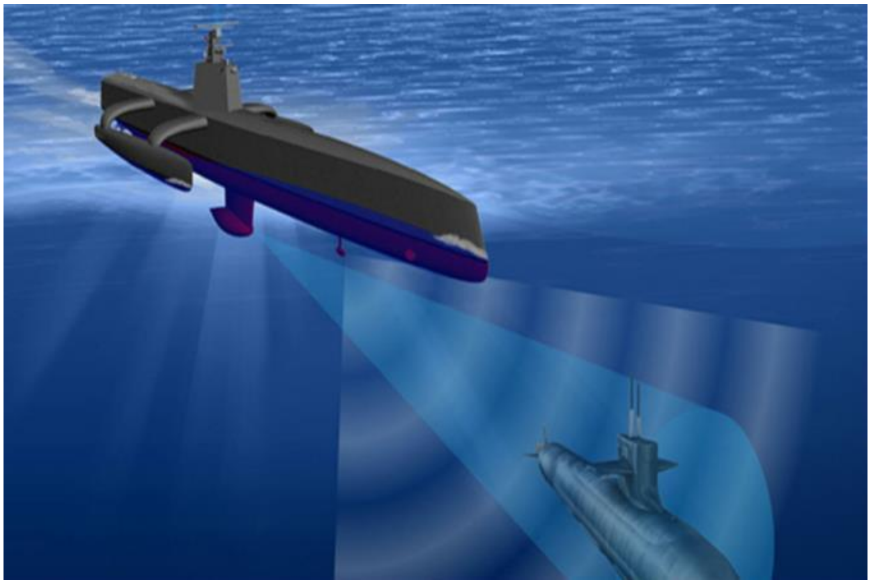

Figure 8: Depiction of Sea Hunter USV in submarine hunting role

surface vessels. The *Sea Hunter* has an endurance of between 30-90 days dependent upon sea conditions, transit speed, and payloads. At approximately $100 million per ship, the *Sea Hunter* provides a very low-cost alternative to nuclear submarines. Its daily operating costs are a fraction of manned surface vessels. In the future, the *Sea Hunter* could outfit with missiles for attacking hostile submarines or surface vessels, with the attack decision remaining with a remote human operator.

Sensor technologies.

The ships, planes and drones are only as effective as the ASW sensors employed on them or elsewhere providing data to the command and control network. Continual development provides new sensors systems designed to detect and/or prosecute hostile submarines. Early detection would contribute to the Navy's ability to track and counter hostile submarines and during a crisis prosecute an attack. There are several different types of systems that have great potential to further reduce the missile submarine threat.

The first, the Deep Reliable Acoustic Path Exploitation System (DRAPES) system deploys as a stand-alone system that listens to the ocean. It is a system of sonar arrays placed at the bottom of the ocean. The advantage of sea floor-based arrays is that they are not subject to weather effects. This permits the arrays to communicate submarine contact along the array chain back to the shore-based command and control facility. “DRAPES will assist the US Navy in finding the lone submarine amid the vast swathes of ocean.”[23] Implementation of DRAPES or similar system would provide the ROK Navy to early warning detection and tracking of DPRK missile submarines obviating the requirement of sacrificing a significant portion of the ROK defense budget to an nuclear submarine program.

During the Cold War, the US Navy deployed the Sound Surveillance System (SOSUS) to monitor and track Soviet submarines. “SOSUS is being replaced by two next-generation fixed-position detectors: The Transformational Reliable Acoustic Path System (TRAPS) and the Fixed Distributed System. The TRAPS passive array sonar system relies on big data and advanced signal processing which provide greater performance over the old SOSUS system and active sonar. These use large arrays of detectors with a much smaller range to filter out other ocean noise and focus on signals from “even the quietest submarines at natural chokepoints in the ocean”.”[24] South Korea is situated near natural oceanic chokepoints that an adversary’s nuclear armed missile submarines would have to transit.

Historically acoustic sensors predominate amongst ASW sensors for tracking and detection of hostile submarines. However, new lasers technology advances may offer alternative submarine detection methods. The US Navy is experimenting with LIDAR (light detection and ranging) technology. The blue light solid state laser operating on a 455-nm wavelength effectively detect submarines. “A compact LIDAR sensor suite aboard submarines and

23. Tim Broderick, “Underwater Sensors Bolster Anti-Submarine Capabilities”, *Defense Systems*, https://defensesystems.com/articles/2016/10/31/drape2.aspx, 31 Oct 2016.
24. Robert Elliott, “Finding the Enemy Below”, *Proceedings*, October 2019, pg. 28, https://www.usni.org/magazines/proceedings/2019/october/finding-enemy-below.

unmanned underwater vehicles (UUVs) may vastly improve sub-to-sub detection."[25] If the ROK Navy were to marry this technology to a fleet of UUVs, then they can effectively monitor likely hostile nuclear armed missile submarine in transit to the ocean. Once detected, the ROK Navy could dispatch the necessary ASW forces to deal with the threat.

Another non-acoustic technology that holds promise regarding submarine detection is magnetic anomaly detection (MAD). Submarine detection near the ocean surface already utilizes existing MAD technology. What is new is the increased availability of big data and computers necessary to process that big data. For example, "when a pair (or more) of MAD sensors move across an area, magnetic gradiometry – the mapping of magnetic signatures – is enabled. With an array of sensors capturing multiple axes, continuous streams of data can be processed by advanced computer algorithms which filter out natural fluctuations in electromagnetic fields."[26]

A final non-acoustic sensor is in the development process. The whiskers of seals provide the model for this new development. "The passage of a submerged vessels creates small whirlpools, called a "Kármán vortex street". When struck by a vortex, the whiskers vibrate, with the input from several telling the seal the approximate size, bearing, and velocity of the target. As submarine generated vortices can last for hours, a large window is open for any pursuer to pick up the submarine's trail."[27] This type of future sensor is ideal for congested water and natural chokepoints, but it is limited to submarine trailing. It doesn't pick up submarines from the side or front as there is no vortex until the submarine passes over the detector.

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25. Evan Lisman, "Non-acoustic Submarine Detection", *ON THE RADAR*.CSIS.org, 5 Nov 2019, pg. 5, https://ontheradar.csis.org/issue-briefs/non-acoustic-submarine-detection/.
26. Ibid.
27. Robert Elliott, "Finding the Enemy Below", Proceedings, October 2019, pg. 28, https://www.usni.org/magazines/proceedings/2019/october/finding-enemy-below.

The rapid technology development of acoustic and non-acoustic sensors could provide the ROK Navy a better return on investment than a nuclear submarine program. Advances in miniaturization, powerful computing systems and unmanned systems mated with artificial intelligence may provide the best protection against hostile submarine threats to South Korea. "If sensor systems are developed and deployed, significantly advanced non-acoustic detection technology can increase a nation's advantage to monitor their surrounding waters for adversary attack vehicles."[28]

Cooperative ASW

Recent ASW exercises conducted by the NATO Centre for Maritime Research and Experimentation (CMRE) illustrated the advantages of multi-dimensional ASW in detecting and tracking of submarines. The true advantage derived from the CMRE annual ASW exercise, *Dynamic Manta,* was a multi-state cooperation. CMRE deployed numerous passive sensors on autonomous vehicles, buoys, and seabed devices off the coast of Sicily prior to start of *Dynamic Manta*.

28. Evan Lisman, "Non-acoustic Submarine Detection", *ON THE RADAR*.CSIS.org, 5 Nov 2019, pg. 8, https://ontheradar.csis.org/issue-briefs/non-acoustic-submarine-detection/.

"For active submarine hunting, CMRE focused on the concept of multi-nation multistatic ASW, where an active sonar source creates pings for dozens or hundreds of passive sensors. The array of passive sensors detects the resulting sound waves bouncing off enemy submarines. The more sensors in the water, the better detection and recognition of type of submarine and the direction the submarine is heading. The *Dynamic Manta* exercise utilized a combination of several Ocean Explorer 21-inch diameter autonomous underwater vehicles and Liquid Robotics' Wave Gliders to serve as communication nodes between ships and AUVs.

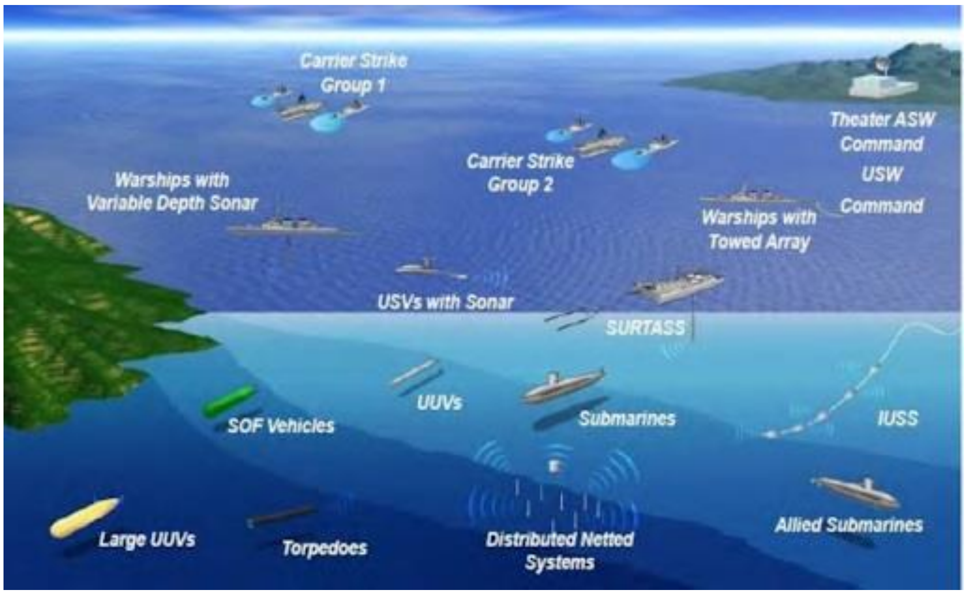

Figure 9: Multi-faceted view of cooperative anti-submarine warfare capabilities

The key to multi-nation multistatic ASW is information sharing. Each participant must know where exactly the active sonar source is located. That data enables each participant to accurately detect the sound source and relocate assets to intercept or track the enemy submarine."[29]

The *Dynamic Manta* exercise illustrates multi-dimension ASW and multi-nation cooperation. A multistatic ASW system in cooperation with the US and Japan might better serve Seoul's defense against the DPRK threat. Given the open-water constraints faced by the DPRK

29. Megan Eckstein, "Sonar Equipped Drone Fleets Could be Key to Future Submarine Warfare", *USNI News,* 9 Mar 2020, https://news.usni.org/2020/03/09/sonar-equipped-drone-fleets-could-be-key-to-future-submarine-warfare.

and China, the multi-nation, multi-dimension solution may be South Korea's better investment versus the nuclear submarine program.

Artificial intelligence.

Artificial intelligence (AI) has the potential to be a major game changer in the realm of ASW. The continued development of more powerful sensors and the resulting increase in raw data requires powerful AI algorithms to process. AI can turn mountains of data into actionable knowledge required by Navy leadership for the prosecution of hostile submarine threats. Additionally, increased development of unmanned systems requires AI to operate in both friendly and hostile environments. AI provides the potential for unmanned systems to act in concert with each other. This aspect of AI opens the possibility to coordinate a complete multi-dimension ASW mission without putting humans in harm's way.

Researchers at the US Naval Postgraduate School conducted a recent demonstration utilizing swarm technology. Without any human control, two flights of 10 drones each engaged in an aerial combat exercise. An algorithm called Greedy Shooter controlled each drone. The objective was for a drone to maneuver against an opponent to obtain a kill shot.[30] This demonstration illustrated the power and potential of AI in future military combat; the entire exercise proceeded without human intervention or control. Such is the power contained in fully autonomous systems, but ethics issues associated with fully autonomous weapon systems require serious consideration moving forward.

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30. Paul Scharre, *Army of None*, W.W. Norton & Company, New York / London, pg. 16-18.

CONCLUSION

Seoul's case for acquiring nuclear submarines assumes South Korea must have nuclear submarines for its strategic defense. As North Korea develops missile submarines and Russia and China deploy new nuclear submarines, South Korean officials insist South Korea must have "corresponding military power."[31] In fact, South Korean spending on a nuclear submarine fleet will actually undermine its overall national security as compared to spending intelligently on a nonnuclear ASW force.

Certainly, the current planned timeline for deploying the first nuclear submarines is inappropriate: Seoul may be lucky to deploy before 2035. South Korea may reduce that timeline by modifying its existing KSS-III design, but a reasonable assumption is that the timeline will not shrink significantly. This makes acquisition of nuclear-powered submarines a poor response to the current DPRK submarine threat.

Also, South Korea's surrounding seas make nuclear submarine operations problematic, at best. The West Sea (Yellow Sea) is too shallow (50 meters deep) for large nuclear submarines. While the East Sea (Sea of Japan) at average depth of 1,500 meters provides the necessary operating environment for large nuclear submarines, the addition of a few South Korean nuclear submarines there will do little to reduce the DPRK missile submarine threat. In 2015, North Korea sallied about fifty submarines simultaneously. Countering such a large number of submarines demands higher quality ASW capabilities than a handful of nuclear submarines could ever afford.[32]

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31. Sang-Ho Yun, "S. Korean Military Announces Plan to Develop 3 4,000-ton Submarines", *The Dong-A Ilbo*, 11 Aug 2020, https://www.donga.com/en/article/all/20200811/2147590/1/S-Korean-military-announces-plan-to-develop-3-4-000-ton-submarines.
32. Sanghoon Kim, "Time for South Korea to Build Nuclear submarines?", *The National Interest*, 22 Aug 2020, https://nationalinterest.org/blog/korea-watch/time-south-korea-build-nuclear-submarines-167496.

Rather than waste its money on nuclear submarines, South Korea can lock down a superior suite of ASW capabilities that would have multiple mission capabilities. A recent study on. ASW concluded that "Based on Cold War experience, some U. S. experts assume the United States would need to possess five nuclear submarines to keep track of each Chinese SSBN at sea."[33] Based on that assessment, the ROK Navy's desire for 3-6 nuclear submarines will prove to be insufficient. Instead, the ROK Navy requires a fleet of 15-20 submarines to deal with DPRK and Chinese missile submarines. At a conservative cost of $1.6 billion per copy, the ROK defense budget would have to absorb an acquisition cost of between $24 and $32 billion dollars, that does *not* include associated ancillary costs. As noted previously, the ROK annual defense budget was approximately $45 billion in 2019. Funding for pushing forward down a nuclear submarine acquisition path would compete with funding for the ROK Army and Air Forces risking the ROK's overall defense posture against the Kim regime.

The better investment of limited ROK defense funds is the expansion of current ASW assets, frigates, destroyers, diesel/electric & AIP submarines and ASW aircraft. Acquisition of these assets cost less than acquiring nuclear submarines, and Seoul already has the infrastructure to support and maintain such assets. The ROK's shipbuilding industry would not suffer from the lack of a nuclear submarine program. Instead, the ROK Navy would be purchasing additional conventional fleet units which would support the ROK's shipbuilding industry.

The ROK Navy also could partner with leading technology industries to research and field new ASW sensors both acoustic and non-acoustic. This would allow the ROK to leverage the technical expertise that domestic industry is developing in the robotic and AI sectors. Combining new technologies with existing ROK Navy platforms would provide a multi-

33. Tong Zhao, "U.S. Anti-Submarine Warfare & It's Impact", Carnegie-Tsinghua Center for Global Policy, 24 Oct 2018, https://admin.carnegieendowment.org/2018/10/24/u.s.-anti-submarine-warfare-and-its-impact/jzdx.

dimensional ASW capability versus a nuclear submarine program that would provide a single-dimension response.

As one analyst noted, "Nuclear submarines are superior for travel to distant employment areas, not for tracking a neighbor's diesel/electric submarines in nearby waters."[34] South Korea is *not* a global military nation. It is a nation with regional security requirements. Producing and operating nuclear submarines would constitute a costly venture that will do little to increase Seoul's national security.

34. Frank von Hippel, "Mitigating the Threat of Nuclear Weapon Proliferation via Nuclear-Submarine Programs", *Journal for Peace & Nuclear Disarmament*, vol. 2, issue 1, 2019, https://doi.org/10.1080/25751654.2019.1625504.

APPENDIX I – NUCLEAR-POWERED SUBMARINE ADVANTAGES

The greatest advantage offered by the nuclear submarine is its ability to remain underwater and on station for weeks or months at a time without surfacing. Unlike a diesel/electric submarine, a nuclear submarine can stay submerged for its entire deployment. It never needs to surface to recharge batteries as a diesel/electric submarine must do periodically. The only time that the nuclear submarine must near the surface would be for critical communications between the submarine and higher authorities.

If the ROK Navy nuclear submarine is LEU fueled, then its operational period generally encompasses a period of 5-10 years without refueling. This interval is dependent upon the energy management doctrine of the fleet, the level of LEU enrichment, and the uranium density in the fuel. The ROK design could incorporate features like the French nuclear submarines, which refuel with 6-percent LEU every 10 years. A LEU fueled boat would provide the ROK Navy with a submarine that is mission capable for a minimum of five years.

If the nuclear submarine is HEU fueled, then the option exists for that nuclear submarine fleet to never require refueling. The US Virginia class nuclear submarine boat's design do *not* need refueling for their entire design lives of 33 years. The drawback to this option is twofold, the cost per ship increases dramatically, and the proliferations risks associated with weapon-grade fuel. The advantage with this option is the nuclear submarine does *not* require complex and time-consuming refueling service operations. It is possible also that, with high-density fuel a lifetime core is achievable with a larger LEU core.[35]

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35 U.S. Department of Energy, Report to Congress, Report on Low Enriched Uranium for Naval Reactor Cores (2014) http://fissilematerials.org/library/doe14.pdf; Report to Congress, Conceptual Research and Development Plan for Low-Enriched Naval Fuel (2016) http://fissilematerials.org/library/doe16.pdf.

Regardless of nuclear fuel type utilized, the limiting factor for the nuclear submarine is the crew endurance. Available food stores limit the nuclear submarine crew endurance; while, the nuclear submarine can provide fresh water and oxygen, it must return to port to replenish food stores. To increase the operational tempo of the nuclear submarine fleet, the ROK Navy could utilize the US nuclear missile sub doctrine of two independent crews per ship. This enables the ship to spend a greater amount of time at sea and time for crews to recover from a highly stressful job.

If the ROK Navy mirrors US submarine doctrine, their nuclear submarines would perform some combination or stand-alone role as defined in US doctrine. According to US Navy doctrine, "the primary roles of the nuclear submarine are:

- Peacetime Engagement,
- Surveillance and Intelligence,
- Special Operations,
- Precision Strike,
- Battlegroup Operations,
- Sea Denial."[36]

Of these missions, the ROK Navy should focus upon sea denial with their proposed nuclear submarine fleet. The objective is the prevention of a DPRK nuclear armed submarine launching a missile undetected off the South Korean coast. The nuclear submarines ability to remain on station and undetected ideally suits the sea denial role and acts as a counter to the DPRK missile submarine.

The nuclear submarine offers increased deployment ranges beyond most diesel/electric submarines. The true advantage comes from the nuclear submarine's ability to transit long distances at high speed. The British Navy utilized this feature to great effect during the Falklands War. The British nuclear submarines had to traverse the length of the Atlantic in a timely manner

36 "Submarine Warfare", FAS, https://fas.org/man/dod-101/sys/ship/submarine/htm.

to establish a sea denial zone against potential Argentinian Navy interference with British Naval vessels landing ground forces. This event illustrated the advantage of the nuclear submarine projecting force anywhere on the globe. The caveat is that the ROK government does not have far flung possessions or allies to protect like the British or American Navies.

A major technical advantage the nuclear submarine possesses over the diesel/electric boat is its available electrical power for warfare systems. The nuclear submarine provides a constant source of electrical power that will not diminish over time as a battery bank does on the diesel/electric boats during submerged operations. This power source enables the nuclear submarine to field numerous sensors for the detection and tracking of hostile submarines in support of the ROK Navy sea denial mission. The penalty for this electrical power source is a submarine of greater size and complexity than the diesel/electric boat. The requirement for additional space is due to the reactor compartment and to increase buoyancy from the reactor weight. Additionally, the increased number of sensors and support equipment require more space. The technical advantage associated with any submarine is regardless of its propulsion system. The true technical advantage lies within the warfare suites and sensors integrated into the submarine.

Despite the nuclear submarine's advantages in extended underwater operations, available power density, technical prestige, and operational tempos, it is suited for worldwide operations. The ROK Navy's area of operations are regional, not on the global scale. Under this reality, president Moon's endorsement might be counterproductive to overall South Korean security.

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