Seoul’s Misguided Desire for a Nuclear Submarine

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In 2017, President Moon Jae-in endorsed the development and acquisition of a nuclear submarine for the Republic of Korea (ROK—South Korea). South Korean proponents of nuclear submarines favor the program for two technical reasons. First, nuclear submarines can stay underwater for months, rather than the days or weeks of which conventional diesel-electric submarines are capable. Second, nuclear submarines can maintain speeds of up to forty knots at depth, whereas nonnuclear submarines have difficulty sailing much above twenty knots at depth for any significant duration, and must surface frequently to recharge their batteries—which makes them easier to detect. These two attributes, South Korean nuclear-submarine proponents argue, make nuclear submarines ideal for detecting and neutralizing the ballistic-missile submarines of the Democratic People’s Republic of Korea (DPRK—North Korea). 

Since Moon’s 2017 endorsement, South Korean interest in developing an indigenously designed nuclear submarine only has grown. Recent press reports indicate the intention of the ROK Navy (ROKN) to modify three KSS-III submarines (of the Dosan Ahn Chang-ho class) into four-thousand-ton nuclear-powered submarines. 

Doing so would constitute a major commitment. Not only would the addition of nuclear power to the final three submarines in the class impact the defense budget severely, but South Korea also would have to find a reliable, long-term fuel supplier. South Korea has nuclear-fuel purchase agreements with the United States, but for civilian applications only. In press reports, unnamed military sources assert that once the
United States agrees to supply low-enriched uranium for naval use, the development process will be a breeze. This claim glosses over the complexities associated with and the many difficulties involved in building nuclear submarines.

Acquiring nuclear submarines would dictate the establishment of a dedicated line of funding that would affect other ROKN programs—a significant trade-off. This immediately raises the question of the relevance of nuclear submarines’ general operational advantages to South Korea’s specific needs, since the regional waters in which its navy operates are relatively shallow. 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 likely would have to renegotiate the existing South Korean–U.S. “123 agreement” if it is to use purchased, enriched fuel for military purposes.

Given the pros and cons of acquiring nuclear submarines, South Korea should consider alternatives. The ROKN is updating its surface and underwater fleets with highly capable antisubmarine warfare (ASW) systems. The ROK can rely on the United States to support state-of-the-art airborne ASW assets to enhance the ROKN’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, the United States, or both. Given its highly technical economy, South Korea might invest in technologies—drones, lasers, magnetic-anomaly detection, artificial intelligence (AI)—that could enhance all facets of

FIGURE 1
NATIONAL CLAIMS TO SEA-LANES IN NORTHEAST ASIA

ASW. Nuclear submarines’ high costs would permit acquisition of a very limited number of them, whereas the same money could purchase substantially greater nonnuclear ASW capabilities. Finally, nuclear submarines typically operate as ASW platforms, whereas the alternative surface and air assets can perform multiple missions beyond ASW.

THE EVOLVING NORTH KOREAN THREAT

North Korea left the Nonproliferation Treaty in 2003 and tested its first nuclear weapon in 2006. Between 2009 and 2016, the Kim regime tested four additional nuclear devices, then announced that the final one had been a thermonuclear device with an estimated 250-kiloton yield. Throughout the testing period, North Korea continued to refine its nuclear warhead miniaturization to enable integration onto a missile.5

As the Kim regime refined its nuclear-warhead designs, it also developed more-capable missiles, including intercontinental ballistic missiles (ICBMs). Under the guise of a peaceful space-launch-vehicle program, the DPRK eventually developed and tested the Hwasong-15 ICBM. The Hwasong-15, with a range of nearly thirteen thousand kilometers (km), can threaten the entire

FIGURE 2
TEST LAUNCH OF HWASONG-15 ICBM

continental United 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.” The inference is that the United States, not South Korea, is the deterrence objective of these strategic-weapon systems.

North Korea’s supplement to land-based nuclear missiles has been its development of submarine-launched ballistic missiles (SLBMs). In 2015, it began testing its SLBMs, culminating in the launching of four missiles in 2016. After a hiatus of three years, in 2019 North Korea launched a new-generation SLBM, the Pukguksong-3, with a range of 1,900 km.

North Korea possesses a submarine fleet of over seventy vessels, but most are of relatively obsolete designs from the late 1950s to the mid-1960s. Construction of North Korea’s first indigenous missile submarine, the Sinpo class, wrapped up in late 2014. However, the base design is still relatively antique compared with current attack submarines available to South Korea and Japan. South Korean analysis indicates that the Sinpo-class missile submarine may have just one vertical-launch tube for SLBMs. And while North Korea does possess missile submarines, it still must master the challenge of ejecting and launching an SLBM from an operational submarine.

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

THE SOUTH KOREAN NUCLEAR-SUBMARINE ANSWER

South Korean nuclear-submarine proponents claim that nuclear submarines are the most effective counter against a nuclear-capable missile submarine from the DPRK or any other hostile state. The South Korean press has reported that the proposed South Korean nuclear-submarine fleet would consist of a minimum of three boats. The belief is that having three will guarantee the capability to keep at least one at sea continuously.⁹

The cost estimates for the three submarines plus their supporting infrastructure approach $9 billion, excluding operating costs.¹⁰ For fiscal year 2020, the South Korean defense budget totaled approximately $41.3 billion, of which $13.7 billion was set aside for arms purchases.¹¹ South Korea already has begun to over-emphasize the advantages of nuclear-powered submarines to justify spending so much on the program (see sidebar).

Retired ROKN captain Moo Keun-sik claims that basic designs for the submarine and a miniaturized nuclear reactor were completed during the “326 initiative.”¹² This was a secret development program started in 2003 but shut down
Nuclear-Powered Submarine Advantages

The greatest advantage the nuclear submarine offers is its ability to remain underwater and on station for months at a time without surfacing; in fact, 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 the nuclear submarine must near the surface is for critical communications between the submarine and higher authorities.

ROKN nuclear submarines could use either low-enriched uranium (LEU) or high-enriched uranium (HEU) fuel. If the submarine is LEU fueled, its operational period generally encompasses five to ten years without refueling. The ROK design could incorporate features like those of French nuclear submarines, which refuel with 6 percent LEU every ten years.

If the nuclear submarine is HEU fueled, the option exists for the entire nuclear-submarine fleet never to require refueling, which is a complex and time-consuming operation. However, the drawbacks are a dramatic increase in the cost per ship and the substantial proliferation risks associated with weapon-grade fuel.

Regardless of the type of nuclear fuel used, the limiting factor for the nuclear submarine is 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 ROKN could employ the USN nuclear-missile-submarine doctrine of two independent crews per ship. This enables the ship to spend a greater amount of time at sea and the crews to recover from a highly stressful job.

The nuclear submarine’s ability to transit long distances at high speed permits the boat to meet far-flung operational needs. Britain’s Royal Navy (RN) used this feature to great effect during the Falklands War. The RN nuclear submarines had to traverse the length of the Atlantic in a timely manner to establish a sea-denial zone against any Argentine navy interference with British naval vessels attempting to land ground forces. This illustrated that the nuclear submarine can project force anywhere on the globe; however, unlike those of the United Kingdom and the United States, the ROK government does not have far-flung possessions or allies it must protect.

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, unlike the battery bank of a diesel-electric boat during submerged operations. This power source enables the nuclear submarine to maintain all sensors for detecting and tracking hostile submarines. The associated penalty is a submarine of greater size and complexity than the diesel-electric boat. The reactor compartment requires additional space and increased buoyancy to counteract reactor weight.

The nuclear submarine’s advantages in extended underwater operations, available power density, technical prestige, and operational tempo make it suited for worldwide operations—but the ROKN’s area of operations is regional, not global.

after it was exposed to the International Atomic Energy Agency and the Korean public. Captain Moo’s projections seem overly optimistic, considering that basic designs for USN submarines take up to four years to create, with an additional nine years needed to complete the detailed design.\(^{13}\) “Five years is the minimum time frame to complete South Korea’s first nuclear-powered submarine, even with outside assistance, naval experts project”; even this counts only production, not actual entry into service.\(^{14}\) Yet how long it might take Seoul to acquire nuclear submarines is perhaps the least of the problems its submarine-acquisition effort faces.

SOUTH KOREAN OBSTACLES TO A NUCLEAR SUBMARINE

Assuming the ROKN’s acquisition price (without supporting infrastructure) is between $1.6 and $2.5 billion for each proposed nuclear submarine, Seoul may need as much as $7.5 billion to build just three submarines. However,
operationally the navy will need as many as nine nuclear submarines to protect its regional sea-lanes, as it cannot deploy all its submarines simultaneously; generally, at any one time half of a submarine fleet is undergoing maintenance, crew rest, and retraining—activities separate from 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 spent better on missile defense, air forces, ground forces, or reinvestment in the national economy.15

More important, South Korea will need to overcome several additional structural barriers to build its 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 the design, development, and production of these highly complex vessels. In addition, the shipbuilder would have to isolate and secure construction facilities dedicated solely to the nuclear-submarine program, to ensure the security of the related nuclear technology and materials.

The major shipbuilders in Korea are 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, and both build military and civilian vessels in the same shipyards. Currently, DSME is constructing the ROKN’s conventionally powered submarines.16

South Korea would require dedicated port facilities for its proposed nuclear-submarine fleet. The ROKN 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 and Construction
South Korean shipbuilders also must develop the design parameters for marrying a nuclear reactor with a submarine hull. Toward this end, designers will need educational facilities to teach nuclear-reactor operations and design. The U.S. Navy has identified the following eight characteristics as being critical to submarine design.

1. Compactness: Reactor must fit within the space and weight constraints of a warship, leaving room for weapons and crew, yet be powerful enough to drive the ship at tactical speeds for engagement or rapid transit to an operating area.
2. Crew protection: Crew lives and works for months at a time in close proximity to the reactor.

3. Public Safety: Ship makes calls into populated ports throughout the world. Maintaining national and international acceptance demands the most conservative engineering and operational approach toward assuring safety of the public.

4. Reliability: Ship requires continuous propulsion and electrical power to be self-sufficient in a hostile and unforgiving environment—undersea, under ice, in combat.

5. Ruggedness: Reactor must tolerate ship’s motion and vibration, and withstand severe shock under battle conditions.

6. Maneuverability: Ship may require rapid and frequent power changes to support tactical maneuvering.

7. Endurance: Reactor must operate many years between refuelings, ideally for the life of the ship, to minimize life-cycle cost, minimize demand on support infrastructure, minimize occupational radiation exposure, and maximize ship availability to the fleet for service at sea.

8. Quietness: Submarines must be extremely quiet to minimize the threat of acoustic detection and to be able to detect other ships.¹⁷

To field a capable nuclear-submarine fleet, South Korean designers would have to address each of these characteristics equally and become proficient in them. To quote a 1995 report from the USN reactor-design community, “Failing to satisfy any of [these requirements] would make the reactor unusable in the ship, or would compromise the safety and survivability of the ship and its ability to carry out its mission,” potentially putting the crew in danger.¹⁸

The warfare systems incorporated within a nuclear submarine should integrate seamlessly with the ROKN’s current diesel-electric fleet. The designers would have to be cognizant of the increased electrical power available within a nuclear submarine, as well as the need for effective distribution of that power to the warfare systems and the increasingly advanced sensors to be incorporated in future hulls and modernizations.

Another consideration is retaining the workforce knowledge base once construction of the nuclear-submarine fleet commences. Maintaining a knowledge base sufficient to accomplish future upgrades requires an effective strategy to extend workforce stability over the long term; if the government predicates its strategy on a service life of twenty-five to thirty years before the nuclear submarine is replaced by a new generation, it must develop plans to maintain that trained design workforce for decades.
The ROKN and its associated shipbuilder must overcome other construction constraints. Unlike the current construction requirements for conventional submarines, a nuclear-submarine program would have much greater safety requirements, to deal with special nuclear materials and the possibility of accidental release of radioactivity via irradiated fuels.

South Korea could learn from the U.S. Navy’s experiences with submarine construction. Owing to design and construction errors, the U.S. Navy experienced a tragic accident in the sinking of USS Thresher (SSN 593) with all hands during trials in 1963. Out of that experience came implementation of the SubSafe program. SubSafe establishes a strict quality-control regime that is external to the shipbuilder and the program office overseeing construction. South Korea would need such a program if it were to pursue a nuclear-submarine program.

To fulfill the requirement for trained submarine designers, the nuclear-submarine shipyard would have to compete against the public shipyards for trained construction personnel. Generally, private-sector jobs pay more than their public-sector 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.

The government would need not only a skilled ship-construction workforce but also a skilled workforce for the infrastructure required to construct, house, maintain, and eventually dispose of the nuclear-submarine fleet.

**Logistics and Training**

The ROKN 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 with the United States the two nations’ agreement regarding peaceful nuclear cooperation, and build both a uranium-enrichment plant and a fuel-fabrication plant.

Then there is the classroom training required for nuclear-submarine sailors. In the U.S. Navy, such training takes a year to complete. To conduct this training, the ROKN would need an onshore training reactor in a facility convenient to the nuclear-submarine fleet. Any modifications, updates, or other changes to the ships’ reactors would need to be replicated on the training reactor to ensure that the sailors train on equipment that is the same as that in the fleet. To gain superior proficiency operating a naval reactor, USN sailors require three years on the job; the ROKN and its sailors, being new to nuclear operations, might need even more time.
Disposal
Unlike conventional submarines, which can be dismantled at a scrapyard, nuclear submarines require special facilities to handle irradiated materials. The reactor core and the reactor vessel demand facilities designed to remove and transport them safely.

The ROKN 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.\textsuperscript{20}

Prioritization
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. Defense specialist Bernardo Wahl G. de Araújo Jorge notes that in addition to Brazil’s budget constraints, the delay that country has experienced in completing its own nuclear-submarine project has been caused by difficulties with mastering the fuel cycle needed to support nuclear propulsion.\textsuperscript{21}

South Korea may not experience the same learning curve, since unlike Brazil it possesses extensive experience in modern shipbuilding and, more important, more nuclear-engineering expertise. But while it already has an advanced nuclear-power industry, it does not enrich nuclear fuel, and at present nuclear propulsion is not within South Korea’s shipbuilding repertoire.\textsuperscript{22} Understanding the significance of this issue is important; South Korea would have to make the acquisition of a nuclear submarine a national priority, with full government backing irrespective of changes in administrations.

Nuclear-Material Agreements
The biggest obstacle to Seoul’s acquisition of a nuclear submarine is nuclear fuel. South Korea does not have an indigenous uranium supply, so it imports most of its fabricated uranium fuel from the United States. South Korea renewed its civilian nuclear cooperative 123 agreement with the United States in 2015. The agreement prohibits the ROK from using U.S.-supplied uranium for any military purpose, but permits Seoul to enrich uranium 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 all three have similar peaceful-use requirements.\textsuperscript{23} If South Korea is unable to obtain the necessary enriched uranium from a foreign source, the alternative would be indigenous enrichment, which would break its nuclear cooperative agreements by diverting enriched uranium to the nuclear-submarine program.
Denuclearization of the Korean Peninsula

If the ROK government authorizes an enrichment program, denuclearizing the peninsula will become more complicated. Ostensibly, achieving that is a major goal of the South Korean government. In the April 2018 Panmunjom Declaration, Kim Jong-un and President Moon stated that North and South Korea would implement fully their previous agreements and declarations. “The previous 1992 South/North Denuclearization Declaration is clear: ‘South and North Korea shall not test, manufacture, produce, receive, possess, store, deploy, or use nuclear weapons. South and North Korea shall use nuclear energy solely for peaceful purposes.’” North Korea clearly is in violation of this agreement.

SOUTH KOREA’S BEST RESPONSE

The ROKN possesses several very capable ASW platforms that provide a greater return on investment compared with a limited nuclear-submarine fleet. For the funds it would take to create and maintain a nuclear-submarine fleet, the Moon administration instead could purchase more of the current mix of available ASW assets. Likewise, making additional funds available could enable pursuit of new technologies that would provide ASW coverage over a greater swath of territory within the region.

Current Assets

The ROKN’s surface ships rival those in the surface fleets of many of the great powers in their ASW capability, augmented by decades spent developing cooperative tactics with the U.S. Navy. The ROKN can purchase more ASW capability within such a multidimensional program than it could by expending scarce defense funds on a single ASW dimension. Historical precedent shows that diverse assets overcome a focus on one kind of asset—even nuclear submarines.

Surface Naval Combatants. The ROKN currently fields the Incheon-class guided-missile frigates. At present they are configured for the surface-warfare mission but can be upgraded to accept antisubmarine rockets as well as land-attack missiles. At a cost of only $250 million per ship, the ROKN could acquire multiple highly capable ASW frigates for less than the cost of a single nuclear submarine.

The new Daegu-class guided-missile frigates incorporate ASW systems specific to countering the DPRK threat. The ships incorporate antisubmarine missiles, torpedoes, and sonar systems, at a per-ship cost of approximately $300 million. The ROKN currently is building and fielding the Sejong the Great class of destroyers. This class provides the ROKN with a true blue-water capability, plus an important upgrade to its ballistic-missile-defense capability.
$925 million per ship, the *Sejong the Great* destroyers provide an extensive ASW suite of weapons and sensors. The ship can store and launch 128 missiles configurable for missile defense, land attack, or ASW. It also carries two helicopters for use in ASW operations.\(^\text{28}\)

The cost per ship is significantly less than that of a nuclear submarine, while the ship provides an extra capability of ballistic-missile defense that a nuclear submarine cannot deliver.
Airborne ASW. To integrate fully all dimensions of ASW warfare, the ROKN requires airborne assets that can operate and integrate with the surface and subsurface fleets. The United States has a very capable aircraft, the P-8A Poseidon, that can perform integrated ASW missions. The P-8A has a patrol radius of 1,200 nautical miles, with a capability to remain on station for four hours. It carries up to eleven torpedoes and 120 sonobuoys. The P-8A also can monitor up to sixty-four sonobuoys and relay their data to integrated fleet units for prosecuting hostile submarine contacts. For the U.S. Navy, “the P-8A Poseidon and [ASW helicopter] 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.” The cost for this capability is $125 million per aircraft. In 2018, the U.S. State Department approved the sale of eight Poseidons to South Korea, at an estimated cost of $2.1 billion.

While the P-8A is a land-based asset, the MH-60R or equivalent helicopter is sea based. Both ROKN frigates and destroyers can operate ASW helicopters from their decks. Having a helicopter enables a frigate or destroyer to increase its coverage area during ASW operations. The MH-60R can carry up to three ASW torpedoes and twenty-five sonobuoys, and it contains the advanced airborne low-frequency dipping sonar, which has both passive and active capabilities. The unit cost for the MH-60R is approximately $40 million per aircraft.

Combining air assets with surface ships and submarines would enable the ROKN to detect and prosecute hostile nuclear-armed missile submarines across a much greater area than would be possible with a single nuclear submarine at sea.

Figure 7
USN P-8A POSEIDON DEPLOYING MK-54 AERIAL ASW TORPEDO

Combining new technologies, such as drone systems and AI, with existing ROKN assets would increase the probability of detection of hostile submarines even further.

**Nonnuclear Submarines.** The ROKN submarine fleet consists of the *Jang Bogo* class and the *Sohn Won-il* class. Both classes use diesel-electric propulsion, and each submarine has eight torpedo tubes. The *Sohn Won-il* boats have an endurance capability of eighty-four days; the *Jang Bogo*, fifty. Although a nuclear submarine can boast of significantly higher endurance figures, these satisfy the requirements of regional patrol operations. Additionally, at approximately $300 million per conventionally powered attack submarine, the ROKN could acquire a greater number of submarines to enable continuous patrol operations in its regional security zones.  

The ROKN is in the process of constructing the new *Dosan Ahn Chang-ho* class of submarines. Significantly larger than previous ROKN submarines, this class incorporates an air-independent propulsion (AIP) system. AIP provides greater underwater endurance than that of previous diesel-electric submarines. While the *Dosan Ahn Chang-ho*-class boat is larger, it has two fewer torpedo
tubes than previous ROKN submarines; however, it has the added capability of vertical-launch missile cells. The per-ship cost of this class, at approximately $900 million, is still significantly less than that of a nuclear submarine.\(^{33}\)

Not only are the existing ROKN submarines capable of performing ASW missions at a fraction of the cost of nuclear submarines, but they offer a quieter operating platform. Detecting radiated noise is the key method for detecting submarines themselves, and thus avoiding potential attack by them. The quieter the submarine, the more difficult the ASW mission. While operating on electric power or AIP, a submarine is nearly undetectable by an adversary. In 2015 joint exercises, Sweden demonstrated the AIP’s advantage “when HMS Gotland, a Swedish AIP submarine, ‘sank’ many U.S. nuclear fast-attack subs, destroyers, frigates, cruisers, and even the USS Ronald Reagan (CVN-76) aircraft carrier in joint exercises.”\(^{34}\)
Future Assets
Technology continues to reduce or eliminate ASW handicaps. The increased use of drone and 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 reducing the threat of surprise. Improved computers also increase the effectiveness of ASW sensors through their ability to crunch vast amounts of data and provide actionable information to military and political decision makers. South Korea has a highly technical economic infrastructure that can exploit these new technologies at a much lower cost than that of a nuclear-submarine program.

Drones. Current drones consist not only of aerial but also of surface and underwater types. The aerial drone commonly used for ASW is the MQ-4C Triton. While it does not possess offensive weaponry, it does carry a powerful multifunction active sensor, with an active electronically scanned array radar. As the Triton has a thirty-hour endurance at a speed of more than three hundred knots, this drone can monitor large areas using radar or magnetic-anomaly detection to locate submarines of potential adversaries. At a cost of $125 million per copy, the ROKN could purchase plenty of Tritons to cover important sea-lanes at a fraction of the cost of a single nuclear submarine. Also, the Triton is fully interoperable with all other military assets, enabling the immediate sharing of intelligence. An additional advantage of the Triton is that it uses commercial, off-the-shelf architecture, which means that upgrading the operating system is less complex, making it easy to keep up with the latest technological advances.35

One example of a surface drone is the Liquid Robotics Wave Glider, which costs approximately $300,000 per copy. The Wave Glider can host several payloads and underwater sensors to detect hostile submarines and provide connectivity among underwater vessels and surface or air units for complete, multidimensional ASW. The wave- and solar-powered Wave Glider has approximately a one-year endurance, and can maintain its location within a thirty-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 prosecuting hostile submarines in times of crisis.36

Teledyne’s Slocum G3 Glider operates underwater, using the energy in ocean waves to move in a sawtooth pattern up and down in the sea. At only $125,000–$150,000 per copy, this autonomous vehicle provides yet another method of detecting and communicating the locations of hostile submarines. When operating in swarms, Slocum Gliders can provide coverage over large ocean areas, reducing the requirement for manned-vessel sorties. The Slocum Glider is easy to operate using web-based navigation and has an endurance range measured in days or
FIGURE 11
DEPICTION OF MQ-4C TRITON CONDUCTING SURFACE SCANNING FORWARD OF FLEET

months, depending on payload and mission. Each time the glider surfaces, it can transmit its data and receive new task orders as needed.37

New unmanned surface vessels (USVs) continue to advance through testing phases, with deployments following within three to five years. Specifically, the U.S. Navy’s Sea Hunter is a fully autonomous surface vessel that has the capability to navigate the seas without human input. Equipped with the latest towed-array sonar systems, the Sea Hunter can assist in detecting hostile submarines. Its relatively small and low profile reduces its radar signature compared with those of manned surface vessels. The Sea Hunter has an endurance of thirty to ninety days, depending on sea conditions, transit speed, and payloads. At approximately $36 million per ship, the Sea Hunter provides a very-low-cost alternative to nuclear submarines. Its daily operating costs are a fraction of those of manned surface vessels. In the future, the Sea Hunter could be outfitted with missiles for attacking hostile submarines or surface vessels, with the attack decision remaining with a remote human operator.38

Sensor Technologies. Ships, planes, and drones are only as effective as the ASW sensors they employ or those located elsewhere that provide data to the command-and-control (C2) network. Continual development provides new sensor
systems designed to detect and prosecute hostile submarines. Early detection would contribute to the ROKN’s ability to track and counter hostile submarines, and during a crisis to prosecute an attack on them. Several different types of systems hold great potential for reducing further the missile-submarine threat.

The Deep Reliable Acoustic Path Exploitation System (DRAPES) deploys a stand-alone system of sonar arrays onto the seafloor to listen to the ocean. The advantage of seafloor-based arrays is that they are not subject to weather effects. The arrays can communicate submarine contacts along the array chain back to the shore-based C2 facility. DRAPES will assist the U.S. Navy in tracking down “one lone submarine amid vast swathes of oceans.” Implementation of DRAPES or a similar system would provide the ROKN with early-warning detection and tracking of DPRK missile submarines, obviating the need to sacrifice a significant portion of the ROK defense budget to a nuclear-submarine program.

During the Cold War, the U.S. Navy deployed the Sound Surveillance System (SOSUS) to monitor and track Soviet submarines, but changes are afoot. Two next-generation, fixed-position detectors—the Transformational Reliable Acoustic Path System (TRAPS) and the Fixed Distributed System—are replacing existing SOSUS sensors. 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.’” South Korea is situated near natural oceanic choke points through which an adversary’s nuclear-armed missile submarines would have to transit.

Another nonacoustic technology that holds promise for submarine detection is advanced magnetic anomaly detection (MAD). Submarine detection near the ocean surface already uses existing MAD technology; what is new is the increased availability of big data and the computers necessary to process those
data. For example, “[w]hen 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.”

A final nonacoustic sensor is in the development process. Actually, it was the whiskers of seals that provided the model for this new development. “The passage of a submerged vessel creates small whirlpools, called a Karman 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. This type of sensor will be ideal for use in congested waters and natural choke points, but will be limited to submarine trailing; it will not pick up submarines from the side or front, as there is no ability to detect the vortex until the submarine passes over the detector.

The rapid development in the technology of acoustic and nonacoustic sensors could provide the ROKN a better return on investment than a nuclear-submarine program. Advances in miniaturization, powerful computing systems, and unmanned systems mated with AI 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 [ad]vantage to monitor their surrounding waters for adversary attack vehicles.”

**Cooperative ASW.** ASW exercises that the NATO Centre for Maritime Research and Experimentation (CMRE) conducted in February–March 2020 and again in the same months in 2021 illustrated the advantages of multidimensional ASW in the detecting and tracking of submarines. CMRE deployed numerous passive sensors on autonomous vehicles, buoys, and seabed devices off the coast of Sicily prior to the start of the exercise. For active submarine hunting, CMRE focused on the concept of multination multistatic ASW, “where an active sonar source would create 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 used a combination of several Ocean Explorer twenty-one-inch-diameter autonomous underwater vehicles and Liquid Robotics’ Wave Gliders to serve as communication nodes between ships and autonomous underwater vehicles.

“The key to multi-nation multistatic ASW is information-sharing.” Each participant must know where exactly the active sonar source is located. Those data
enable each participant to detect the sound source accurately and relocate assets to intercept or track the enemy submarine.45

The true advantage illustrated by these annual DYNAMIC MANTA exercises was multinational cooperation in conducting multidimensional ASW. A multi-static ASW system, in cooperation with the United States and Japan, might serve South Korea better in its defense against the DPRK threat. Given the open-water constraints that Pyongyang and Beijing face, the multinational, multidimensional solution may be Seoul’s better investment, versus the nuclear-submarine program.

**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 require powerful AI algorithms to process. AI can turn mountains of data into the actionable knowledge that naval leaders need to prosecute hostile-submarine threats. Additionally, as the development of unmanned systems continues, AI increasingly is required to operate them, 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 of coordinating a complete multidimensional ASW mission without putting humans in harm’s way.
Researchers at the U.S. Naval Postgraduate School recently conducted a demonstration using swarm technology. With no human control, two flights consisting of ten 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. 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 in the future.

Seoul’s case for acquiring nuclear submarines hinges on the assumption that it is a strategic necessity for South Korea to have them. As North Korea develops missile submarines and Russia and China deploy new nuclear submarines, South Korean officials presume that South Korea should have “corresponding military power.” Yet in fact, South Korean spending on a nuclear-submarine fleet actually may undermine the country’s overall national security, as compared with spending the same amount, or even less, intelligently—on a non-nuclear ASW force.

Certainly, the projected timeline for deploying the first ROKN nuclear submarines is unreasonable; Seoul would 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.

Furthermore, the seas surrounding South Korea make nuclear-submarine operations problematic, at best. The West Sea (Yellow Sea) is too shallow (fifty meters deep) for large nuclear submarines. While the East Sea (Sea of Japan), with an 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 sailed about fifty submarines simultaneously. Countering such a large number of submarines demands higher-quality ASW capabilities than a handful of nuclear submarines ever could provide.

Rather than waste its money on nuclear submarines, South Korea could lock down a superior suite of ASW capabilities that would provide multiple mission capabilities. A recent study on ASW concluded, “Based on Cold War experience, some U.S. experts assume that the United States would need to possess five SSNs [nuclear-powered attack submarines] to keep track of each Chinese SSBN [nuclear-powered ballistic-missile submarine] at sea.” On the basis of that statement, the three to six nuclear submarines the ROKN desires would not meet its...
requirements; instead, it would need a fleet of fifteen to twenty 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; that figure does not include ancillary costs. As noted previously, the ROK annual defense budget was approximately $42 billion in 2019. Funding for pushing forward down a path toward acquiring nuclear submarines would compete with funding demands from the ROK Army and Air Force, putting at risk the ROK’s overall defense posture against the Kim regime.

The better investment of limited ROK defense funds is toward the expansion of current ASW assets: frigates, destroyers, diesel-electric and AIP submarines, and ASW aircraft. These assets can be acquired for less than a nuclear submarine costs, and Seoul already has the infrastructure to support and maintain such assets. The ROK shipbuilding industry would not suffer from the lack of a nuclear-submarine program, as the ROKN would be purchasing additional conventional-fleet units.

The ROKN should partner with leading technology industries to research and field new ASW sensors, both acoustic and nonacoustic. The ROK also must leverage the technical expertise that domestic industry is developing in the robotic and AI sectors. Combining new technologies with existing ROKN platforms would provide a multidimensional ASW capability versus a nuclear-submarine program that would provide a single-dimensional response.

As Frank von Hippel charges, “Nuclear submarines are superior for travel to distant employment areas, not for tracking a neighbor’s diesel-electric submarines in nearby waters.” 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 would do little to increase Seoul’s national security.

NOTES

The author received funding and support from the Nonproliferation Policy Education Center.


4. Section 123 of the U.S. Atomic Energy Act generally requires the conclusion of a peaceful nuclear-cooperation agreement for
significant transfers of nuclear material or equipment from the United States.


8. Sukjoon Yoon, “Expanding the ROKN’s Capabilities to Deal with the SLBM Threat from North Korea,” Naval War College Review 70, no. 2 (Spring 2017), pp. 49–74.


10. Ibid.


14. Gady, “Will South Korea Build?”

15. Ibid.

16. Basic information on South Korean shipbuilding is available at the following websites: SP’s Naval Forces, www.spsnavalforces.com/, and Shipyards Directory, shipyards.gr/.


18. Ibid.


22. Ibid.

23. Frank von Hippel, “Mitigating the Threat of Nuclear Weapon Proliferation via Nuclear-Submarine Programs,” Journal for Peace and Nuclear Disarmament 2, no. 1 (2019), doi.org/10.1080/25751654.2019.1625504; Sharon Squassoni, interview by author, 25 August 2020. The subject of the conversation was nuclear cooperative agreements between the United States and South Korea. One nuclear supplier that does not include a no-military-usage provision is India.


27. Ibid.


29. Walter Massenburg [Vice Adm., USN (Ret.)], “Why We Need Maritime Patrol and Helicopters,” Association of Naval Aviation—Hampton Roads Squadron, Summer 2016, hrana.org/.

30. Franz-Stefan Gady, “US State Department Approves Sale of 6 P-8 Poseidon
Sub-Hunting Planes to South Korea,” The Diplomat, 14 September 2018, thediplomat.com/.


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34. Michael Walker [Ens., USN] and Austin Krusz [Ens., USN], “There's a Case for Diesels,” U.S. Naval Institute Proceedings 144/6/1,384 (June 2018).


42. Ibid.


47. Yun, “S. Korean Military Announces Plan.”

48. Kim, “Time for South Korea to Build Nuclear Submarines?”


50. Von Hippel, “Mitigating the Threat of Nuclear Weapon Proliferation.”