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Silent Guardians

Part 2: The Overview of Potential Contenders in Poland's ORKA Submarine Program

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Executive Summary

The ORKA program is necessary to provide the Polish Navy with the capabilities that will allow Poland to protect its vital interests in the Baltic, defend critical maritime infrastructure, and support Allied operations around the globe. A key step to acquiring these capabilities is the selection process of the most appropriate vessel, which will effectively complete set out objectives and neutralize designated threats. This paper is dedicated to the detailed analysis of the key required characteristics for the new submarines as well as an overview of the potential contenders in the program.

Based on the available information, ORKA submarines are expected to meet ambitious requirements in key areas, including endurance, air-independent propulsion (AIP), depth capability, combat effectiveness, land-attack and anti-aircraft capabilities, as well as advanced countermeasure systems for defensive purposes. Additionally, Poland's new submarines should be equipped with specialized systems to support special operations, conduct mine warfare, and deploy unmanned underwater systems. An analysis of the aforementioned requirements reveals that no AIP submarine currently in operational service has been fully equipped or integrated with the systems specified in Poland's ORKA program. Some of these technologies, particularly the integration of submarines with unmanned underwater systems and anti-aircraft missiles, remain in the early stages of development. Despite ongoing tests, they have yet to be fully operationalized by the naval forces of NATO member states.

It is therefore crucial to determine the capabilities ORKA submarines should possess by the mid-2030s while ensuring that the selected submarine design allows for future upgrades. This is especially important given that complex systems like AIP submarines can remain in service for up to 40 years. The list of potential contenders in the ORKA program was presented in the Table below, highlighting the designs' key characteristics.

Poland's ORKA Program must evaluate several submarine options, each with distinct strengths and weaknesses. Proven designs, such as the French Scorpene and the South Korean KSS-III, offer reliable, modern platforms equipped with advanced AIP systems. Additionally, their integration with long-range cruise missiles is likely to be less complex compared to other designs that would require the integration of UGM-109 Tomahawk missiles, a process that necessitates separate government-to-government agreements with the United States.

In conclusion, Poland should prioritize larger, modern, and adaptable submarine designs capable of meeting both current and future defense needs. Submarines with advanced AIP systems and the capacity to integrate submarine-launched cruise missiles, would greatly enhance the strategic capabilities of the Polish Navy. While acquiring proven designs offers reduced risks, Poland must ensure that any chosen design can accommodate future upgrades and integration with cutting-edge technologies, including UUVs. The ORKA program should focus on securing platforms that not only bolster Poland's regional defense but also enhance its deterrence capabilities through the ability to conduct strategic strikes and operate beyond the Baltic Sea.

Potential contenders in the ORKA submarine program

Manufacturer	Class	Design overview
SAAB	**A26 / Blekinge**	• Customizable modular design • Multi-Mission Portal – deployment of specialized equipment including UUVs • Propulsion system – Diesel-electric; AIP: Stirling engine-based • Planned integration of SLCM-capable VLS module with Tomahawk missiles (requires missile procurement via additional agreement) • Platform under development (2 units under construction)
Hanwha Ocean	**KSS-III Batch 2**	• Largest and most heavily armed submarine in the program • Propulsion system – Diesel-electric; Lithium-ion Batteries; AIP: PEM Fuel Cells • SLBM-capable VLS (South Korean Hyunmoo missiles) • Reportedly SLCM-capable (South Korean Haeseong missiles) • Fully operational platform (3 base units in service, 3 Batch 2 units under construction)
HD Hyundai Heavy Industries	**KSS-III PL**	• Propulsion system – Diesel-electric; Lithium-ion Batteries; AIP: PEM Fuel Cells • Reportedly SLCM-capable (South Korean Haeseong missiles) • Based on an operational platform (KSS-III Batch 1)
	HDS-2300	• Reportedly the proposal includes extensive industrial cooperation and technology transfers • Propulsion system – Diesel-electric; Lithium-ion Batteries; AIP: PEM Fuel Cells • Reportedly SLCM-capable • Conceptual design
Naval Group	**Scorpène**	• Tried and tested design operated by several countries with 13 vessels produced to date • Propulsion system – Diesel-electric; Lithium-ion Batteries; optional integration of an AIP system • SLCM integration under development (French MdCN missiles) • Operational base platform – new-generation design with more advanced propulsion still under development
Navantia	**S-80 Plus**	• Propulsion system – Diesel-electric; Lead-acid Batteries; AIP: Bio-Ethanol Stealth Technology (BEST) Fuel Cells, an innovative AIP system utilizing bioethanol to generate hydrogen • Reportedly SLCM-capable – potential integration with Tomahawk missiles (requires missile procurement via additional agreement) • Operational platform – the AIP in the process of integration
ThyssenKrupp Marine Systems	**Type 212 CD**	• Innovative IDAS system under development – providing anti-air and reportedly limited anti-ship and land-attack capability • Interoperability with two European allies – Norway and Germany • Propulsion system – Diesel-electric; Lithium-ion Batteries; AIP: Fuel Cells • Reportedly SLCM-capable – potential integration with Tomahawk and NSM (Naval Strike Missile) missiles • New design under development and production – based on a successful 212A design
Fincantieri	**U212 NFS**	• Smallest vessel; still under development; will likely require additional approval from TKMS for procurement • Propulsion system – Diesel-electric; Lithium-Ion batteries; AIP: reportedly Fuel Cells • Reportedly SLCM-capable – missile integration still under development and conceptual work • Conceptual–prototype design still under development based on the 212A design

1 Introduction

On November 28, 2024, during the celebrations marking the 104th anniversary of the establishment of the Polish Navy in Gdynia, Minister of National Defense Władysław Kosiniak-Kamysz reaffirmed the government's commitment to modernizing the Polish Navy. He emphasized that the ORKA submarine program would be a top priority in the coming months.[1] This comes as no surprise, given the escalating tensions between NATO and the Russian Federation, along with the numerous incidents and suspected acts of sabotage in the Baltic Sea. Minister Kosiniak-Kamysz's remarks regarding the ORKA program and other technical modernization initiatives in the maritime domain undoubtedly serve as a positive signal for the Navy and, by extension, for the security of the Baltic Sea region. This is particularly significant given the years of neglect and underfunding that have left the Polish Navy in urgent need of modern warships.

The Ministry's decision to acquire advanced multirole submarines with land-attack capabilities will unquestionably bolster the Navy's deterrence posture and significantly enhance its ability to engage adversaries at the strategic, operational, and tactical levels. Moreover, Poland's pursuit of new submarines should be viewed in the context of limited allied capabilities in this domain, as Sweden and Germany are the only NATO member states with direct access to the Baltic Sea that maintain operational submarine fleets. Therefore, the ORKA program can also be seen as an opportunity to strengthen Poland's influence in the maritime domain – a step that is more critical than ever, given the Baltic Sea's essential role in the country's economy and security. The Baltic serves as a vital gateway for importing key resources that cannot be transported via land routes, as well as for the export of Polish goods. This aligns with Poland's efforts to establish one of the most capable armed forces within the North Atlantic Treaty Organization, particularly in the land domain, to strengthen deterrence against any potential attack on Polish territory. As NATO Secretary General Mark Rutte emphasized during his visit to Warsaw on November 13, 2024, Poland has emerged not only as a key player on NATO's eastern flank but also as a major security provider for the Alliance, thanks to its significant contributions to collective defense.[2] The procurement of advanced submarines, capable of striking deep into enemy territory, along with the acquisition of other surface combatants, could significantly enhance Poland's ability to defend its strategic interests and support other nations in the region with limited naval capabilities, particularly the Baltic states, which face a much greater risk of potential attack than most allied nations on NATO's eastern flank. This would further strengthen Warsaw's position as a linchpin of the Alliance. Gen. Wiesław Kukuła, Chief of the General Staff of the Polish Armed Forces, recently underscored the importance of strengthening the Polish Navy. He reaffirmed Poland's commitment to enhancing its naval capabilities, identifying the ORKA submarine program as one of the military's highest priorities. According to Gen. Kukuła, modernizing the Navy and acquiring

ORP Orzeł during OSTROBOK 21 exercises

Author:
st. chor. sztab. mar.
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3 Flotylla Okrętów

new submarines is particularly critical for Poland's security. He also emphasized that such capabilities cannot be substituted by other systems, such as Poland's Naval Strike Missiles or underwater drone systems.[3]

Nonetheless, Polish officials will undoubtedly face significant challenges in selecting future submarines, given the complexity of these vessels and the wide range of tasks they must undertake. It is also worth noting that recent technological advancements, including new weapon systems and other technical breakthroughs over the past few years, have led to the development of highly capable submarine designs, which can often be tailored to meet the specific requirements of the customer. As part of the ORKA program, Poland's future submarine fleet is expected to feature numerous capabilities based on the requirements presented in Table 1.[4]

The new Polish submarines are expected to incorporate additional capabilities beyond those previously mentioned. However, it is important to recognize that technical and tactical requirements are among numerous factors requiring careful consideration when evaluating potential contenders for the ORKA program. As highlighted in the earlier paper, *Silent Guardians: Part 1*, the procurement of new submarines should prioritize solutions that ensure

TABLE 1 Key requirements of ORKA submarine program

Endurance	The potential ability to operate for at least 30 days without resurfacing
Depth capability	The capacity to remain submerged at depths exceeding 200 meters
Combat effectiveness	The ability to engage enemy surface combatants and submarines using torpedoes and submarine-launched missiles
Land-attack capability	The ability to strike land-based targets located deep within enemy territory
Anti-aircraft Capability	The ability to engage rotary-wing aircraft and fixed-wing maritime patrol aircraft
Countermeasure systems	The ability to effectively counter enemy torpedoes
Special operations support	The ability to conduct and support special operations missions
Mine warfare	The ability to perform tasks related to mine deployment and clearance
Unmanned systems integration	The capacity to carry and deploy unmanned underwater vehicles (UUVs)
Advanced propulsion	A propulsion system that allows the vessel to remain submerged for extended periods

the continuity of Poland's submarine warfare capabilities, particularly in personnel training. **This highlights the importance of the delivery timeline, as well as any interim or bridging solutions proposed by the future ORKA submarine manufacturer, which should be among the primary considerations for Polish decision-makers.** Consequently, this paper will also examine the development status and key aspects of the operational capabilities of each submarine type to assess potential risks associated with acquiring designs that have yet to be introduced into active service. The analysis of potential development-related challenges will also consider the integration of additional systems, such as land-attack missiles, unmanned underwater vehicles (UUVs), and advanced propulsion systems. While these features have been proposed by all potential contenders in the ORKA program, some of the aforementioned systems have not yet been implemented in operational submarines.

This paper aims to summarize the latest trends and developments in submarine design, highlighting their relevance to the Navy's requirements for its future submarine fleet. The authors subsequently examine potential contenders in the ORKA program, representing seven shipbuilding companies from five countries, as outlined in Table 2. Given the scope of this material, the economic and industrial implications of collaboration with these entities fall outside the scope of this analysis.

This paper focuses exclusively on the ORKA program; therefore, midget submarines are not included in the overview of available submarine designs. The so-called mini-ORKA submarines require further research and dedicated analysis.

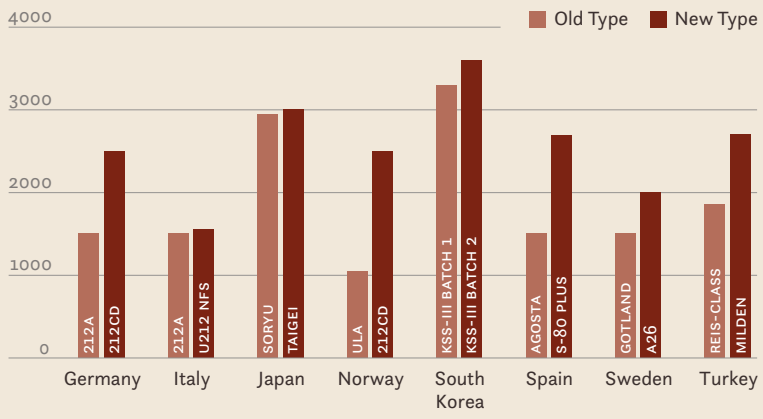
TABLE 2 Potential contenders in the ORKA submarine program

COUNTRY	MANUFACTURER	SUBMARINE CLASS
Sweden	SAAB	A26 / Blekinge
South Korea	Hanwha Ocean	KSS-III Batch 2
	HD Hyundai Heavy Industries	KSS-III PL
		HDS-2300
France	Naval Group	Scorpène
Spain	Navantia	S-80 Plus
Germany	ThyssenKrupp Marine Systems	Type 212 CD
Italy	Fincantieri	U212 NFS

2 Latest Trends and Developments in Submarine Designs

Modern conventional diesel-electric submarines have evolved from their traditional roles in anti-ship and anti-submarine warfare into fully multirole vessels that feature air-independent propulsion (AIP) systems, lithium-ion batteries, advanced sonar technologies, sophisticated weapon systems, and unmanned underwater vehicles (UUVs). This combination of capabilities enables them to perform a wide range missions and functions, including land-attack operations, as well as reconnaissance, and surveillance tasks. These enhancements, combined with larger dimensions and increased displacement, enable the latest submarine designs to achieve extended endurance and operate effectively across tactical, operational, and even strategic levels. This is particularly evident in advanced designs that support submarine-launched cruise missiles with ranges exceeding 1,000 kilometers, enabling strikes on land targets deep within enemy territory. In the past, the aforementioned capabilities used to be available only to very large nuclear-powered submarines, however, the technological advancements in the recent years have allowed for construction of much smaller conventional submarines capable of carrying out all kinds of tasks. Although relatively small submarines equipped with air-independent propulsion (AIP) systems and anechoic tiling are exceptionally difficult to detect, they face significant challenges due to their compact dimensions. These limitations include reduced sensor range and precision, restricted availability of dedicated modules (e.g., for special operations), and limited payload capacity for torpedoes and missiles.[5] Therefore, modern conventional submarine designs are becoming larger, more complex, and fully capable of performing a wide range of missions. This trend toward acquiring larger, more versatile conventional submarines is particularly evident among NATO member states, which aim to enhance their naval capabilities – a development depicted in Graphic 1. Furthermore, the multirole characteristics of such vessels are more pronounced than ever thanks to recent developments in the field of propulsion, armaments, and unmanned underwater vehicles. Manufacturers of diesel-electric submarines employ various technologies to enhance the stealth characteristics of their vessels. These include the use of anechoic coatings, non-magnetic metals in hull construction, and advanced propulsion systems designed to minimize acoustic and thermal signatures.

GRAPHIC 1 Size Comparison of Modern Conventional Submarines Acquired by Selected Countries



Swedish Södermanland-class submarine with the Stirling engine AIP

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2.1 Air-independent Propulsion and Lithium-ion Batteries

A submarine's ability to remain submerged for extended periods is a key factor in determining its overall capabilities. While the most powerful naval forces in the world – such as the U.S. Navy, the Royal Navy, the Russian Navy, and the People's Liberation Army Navy – operate exclusively nuclear-powered submarines or a combination of nuclear-powered and conventional submarine fleets, most countries rely on diesel-electric submarines equipped with air-independent propulsion (AIP) modules or advanced batteries to support prolonged underwater operations. This reliance arises from the high costs and significant technological challenges associated with building nuclear-powered submarines, as well as political factors that restrict access to such technologies. Currently, only six countries possess nuclear-powered submarines: China, France, India, Russia, the United Kingdom, and the United States. Meanwhile, Brazil and Australia are set to join this group as non-nuclear states that will acquire nuclear-powered submarine capabilities in the 2030s and 2040s, respectively. Additionally, North Korea is reportedly seeking to acquire such capabilities in the near future.[6]

Undoubtedly, nuclear reactors provide submarines with capabilities unmatched by diesel-electric vessels, including virtually unlimited underwater endurance. However, the efficiency of modern AIP systems currently in use can significantly extend the endurance of conventional submarines, enhancing their survivability in highly contested environments. Although the overall tactical and technical advantages of nuclear-powered submarines over their conventional counterparts are undeniable, some analysts argue that the U.S. Navy should consider acquiring AIP-equipped submarines given their greater cost-efficiency regarding both construction and maintenance and the ability to complement vessels with nuclear propulsion.[7] With the shift from blue-water to littoral operations following the end of the Cold War and the Anti-Access / Area Denial (AA/AD) capabilities of conventional submarines,[8] AIP-equipped submarines have emerged as the weapon of choice for countries with vital maritime interests, such as Japan, South Korea, Germany, and Sweden. Even nuclear powers like the People's Republic of China[9] and Russia continue to build diesel-electric vessels, developing advanced variants of the renowned Kilo-class submarines, which are capable of deploying anti-ship missiles and submarine-launched cruise missiles. These examples demonstrate that conventional submarines, particularly those equipped with AIP systems, remain a crucial component of any capable naval force.

The development of fully operational air-independent propulsion (AIP) systems for submarines dates back to the 1930s, when German scientist Hellmuth Walter engineered a hydrogen peroxide-based turbine, which was implemented in the experimental V80 submarine. The successful trials of this prototype vessel in 1940 prompted the Kriegsmarine to adopt the Walter system in the Type XVIIB coastal submarines, which had a displacement of approximately 300 tons.[10] Following Germany's defeat in World War 2, the United States, Great Britain, and the Soviet Union explored similar systems for their vessels based on German WW2-designs. Nonetheless, these attempts were largely unsuccessful and resulted in the British and Soviet decisions to concentrate on nuclear propulsion instead. The United States, meanwhile, pursued experiments with AIP systems, resulting in the construction of the X-1 midget submarine in the mid-1950s.[11] This vessel was launched three years before the commissioning of USS *Nautilus*, the world's first nuclear-powered submarine.[12] The technology that eventually replaced all conventional submarines in the U.S. Navy.

Nonetheless, work on air-independent propulsion (AIP) systems for submarines continued throughout the second half of the 20th century, resulting in the development of some solutions that remain operational today. These include the French closed-cycle steam turbine MESMA (Module d'Énergie Sous-Marin Autonome) system, a Stirling engine-based AIP system developed in Sweden for the Gotland-class submarines in the 1990s,[13] and fuel cells, first introduced by the German Navy in 1989.[14] Additionally, advancements in lithium-ion battery technology represent a significant breakthrough in submarine propulsion. While this technology does not qualify as an air-independent propulsion system, it effectively enhances the capabilities of diesel-electric submarines, including those already equipped with AIP systems.[15] Lithium-ion batteries were recently incorporated into two newly constructed Sōryū-class vessels by Mitsubishi Heavy Industries and Kawasaki Shipbuilding Corporation for the Japanese Navy. This new design replaced the Stirling engine-based AIP system used in earlier models of the same class.[16] The same approach has been adopted for the latest Taigei-class submarines,[17] the lead ship of which was commissioned in 2022.[18] Similarly, the latest South Korean KSS-III submarines, designated as the Batch 2 and currently under construction by Hanwha Ocean, will be equipped with lithium-ion batteries in combination with fuel cells.[19] Main characteristics of the available AIP systems were summarized in Table 3.

The first of the aforementioned systems, MESMA, has been installed on at least one out of three Agosta 90B/Khalid-class submarines for the Pakistani Navy. Although the Naval Group initially proposed equipping Scorpène-class submarines with this AIP system, recent reports suggest the French manufacturer has opted for more advanced alternatives. Consequently, Scorpène

TABLE 3 General characteristics of AIP systems[101]

	TYPE OF AIP SYSTEMS		
	Mesma	Stirling Engine	Fuel Cells
Advantages	• High Output Power	• Mature Technology • Simple Maintenance • Low Life-cycle Cost	• Very Quiet • Low Operating Temperatures • Highly Efficient • Relatively Mature Technology • Does not Emit Exhaust Gases • Its Performance Can be Significantly Enhanced by the Integration of Lithium-ion Batteries
Disadvantages	• High Oxygen Consumption • High Fuel Consumption • Relatively Low Efficiency • Exhaust Gases Management Method • Limited Diving Depth	• Relatively Large Size • Limited Diving Depth • Exhaust Gases Management Method	• Relatively Heavy System • Requires Special Refuelling Infrastructure

Saab-Kockums submarine shipyard
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Evolved Full Lithium-ion Battery submarines will be fitted with lithium-ion batteries and will not include an AIP system, similar to the Scorpène submarines planned to be built at the PT PAL shipyard for the Indonesian Navy.[20]

On the other hand, Sweden's efforts to develop a Stirling engine-based AIP can be considered successful, as the technology has been applied to several vessels, including the Swedish Södermanland and Gotland-class submarines, as well as the Blekinge-class submarines currently under construction for the Swedish Navy. Additionally, the Stirling-cycle engine has been installed on 10 Japanese Sōryū-class vessels and two Archer-class submarines of the Republic of Singapore Navy.[21]

The Stirling engine-based AIP system is characterized by a relatively lower energy conversion efficiency compared to fuel cells, with an efficiency of approximately 40%, compared to nearly 80% for fuel cells. However, it offers a higher efficiency than the MESMA system (25%). The Stirling engine is simpler and more cost-effective to operate, as it does not require specialized maintenance infrastructure. This system enables a quick renewal of operational readiness, with replenishment of stocks taking only a few hours, even at sea. Stirling engines also allow for a maximum underwater speed of about 20 knots. While the system has low acoustic and thermal signatures, it still falls behind fuel cells in this regard due to the mechanical parts involved. A notable drawback is the need to release exhaust gases into the sea after dissolving them in seawater.[22]

In recent years, the fuel cells-based technology has become an indisputable leader as far as the AIP systems for submarines are concerned. This technology is also applied in most types of vessels that could potentially become Poland's future ORKA submarine. Among the most notable examples of submarines with this technology that have been introduced into service to date are, among others, 10 Type 212A vessels built for the Germany and Italian Navies,[23] four Type 218SG (Invincible class) submarines of the Singaporean Navy,[24] nine KSS-II (Sohn Wonyil class, built in cooperation with the German shipbuilding company HDW based on the Type 214 design) and three KSS-III Batch 1 submarines of the Republic of Korea (ROK) Navy (Dosan Ahn Changho class, developed by South Korean shipbuilding company Hanwha Ocean),[25] as well as future German and Norwegian Type 212CD submarines. Fuel cells, which rely on the electrochemical conversion of an oxidant and fuel – typically hydrogen – to produce electricity, offer significant advantages over other AIP systems. This is primarily due to the absence of moving parts, which greatly reduces the submarine's acoustic signature and enhances its stealth capabilities. Additionally, the closed-cycle design eliminates the need to discharge exhaust gases into the sea, further reducing the risk of detection. These characteristics make fuel cells an attractive option for potential customers, particularly for vessels that require extended, undetected underwater operations.[26] The primary limitation of fuel cell technology is its reliance on specialized refueling and storage infrastructure. Navantia has proposed an alternative approach to address this challenge, implementing it on the S-80 Plus submarines. The Spanish submarine program, initiated in 2003, has faced numerous obstacles and delays over the years. However, in October 2024, Navantia announced the commencement of a new AIP system installation on the *Cosme García* (S-83), the third S-80 Plus submarine.[27] This marks a significant milestone for the Spanish manufacturer, as neither the lead ship of the class nor the second vessel currently under construction has been equipped with the AIP system. The Spanish AIP system, branded by Navantia as BEST (Bio-Ethanol Stealth Technology) and the third-generation AIP, is fundamentally based on fuel cells. Unlike German or South Korean designs, which store

hydrogen onboard, the Spanish design incorporates a bioethanol processing system that converts bioethanol into hydrogen to power the fuel cells, when necessary.[28] Plans are underway to retrofit the first two vessels of the class with the Spanish AIP module in the future. The Spanish solution represents an innovative approach to AIP design and could significantly enhance the safety of submarine operations. However, it is important to note that, as of December 2024, no operational submarine has been equipped with this system. Moreover, available data indicates that the process of converting bioethanol into hydrogen requires relatively large quantities of both fuel and water.[29] Given the limited information about the system's performance, further in-depth research is recommended to fully assess the capabilities of this AIP technology.

Last but not least, recent advancements in lithium-ion battery technology have positioned it as the most promising alternative to traditional AIP systems, or as an efficient complement to such systems. As mentioned earlier, the potential of this technology has been recognized by both producers and customers, leading some submarine manufacturers to abandon the implementation of AIP systems on their vessels. For example, this concept has been implemented in the most advanced diesel-electric submarines of the Taigei class built for the Japanese Navy.[30] The same approach has also been proposed by the French Naval Group with the latest variant of the Scorpène Evolved submarine. These examples illustrate that lithium-ion battery technology has not only overcome major technical challenges but has also reached a level of maturity that ensures its full efficiency, safety, and reliability. These advancements correspond to an extended operational range and cruising speed, lower maintenance costs, and a more compact design in comparison with lead-acid batteries implemented in the previous generation of submarines.[31] Furthermore, lithium-ion batteries can be integrated with an AIP system, such as fuel cells, combining the best of both worlds. The South Korean KSS-III Batch 2 exemplifies this innovative approach to submarine design as the second operational submarine type in the world to be integrated with this technology.

In this context, it is important to note that the batteries used in submarines can be based on various technologies and raw materials. These encompass previously mentioned lead-acid batteries common in the previous generation of diesel-electric submarines and nuclear-powered vessels,[32] as well as several types of lithium-ion batteries, including lithium iron phosphate (LFP) and nickel manganese cobalt (NMC) batteries. The lead-acid batteries are technologically inferior to lithium-based systems due to their limited lifespan and the number of charging cycles, among others.[33] For instance, the latest German and South Korean submarine designs, including the 212CD and the KSS-III Batch 2, utilize more advanced lithium-based batteries, while the Spanish S-80 Plus submarines[34] and the KSS-III Batch 1 are still equipped with the older-generation lead-acid batteries.[35]

2.2 Armament

Modern conventional submarines are best understood as versatile, multirole vessels due to the range of advanced technologies that can be incorporated into their designs. These include an extensive variety of weapon systems, such as traditional torpedoes, mines, anti-ship missiles, and, more recently, submarine-launched cruise missiles (SLCMs). While SLCMs were once considered exclusive to larger nuclear-powered submarines, a number of nations, such as Pakistan, Russia, and South Korea, among others, have deployed conventional submarines equipped with SLCMs. Additionally, SLCMs are now increasingly sought after by nations procuring diesel-electric submarines, including Brazil, Italy, the Netherlands, Spain, Turkey, and Spain. A detailed overview of various submarine classes and their respective customers is provided in Table 4.

The primary limitation of conventional submarines in carrying diverse weapon systems is their size. However, as illustrated in Graphic 1, the dimensions and displacements of diesel-electric submarines have grown over the past decade. Several countries, including Russia, the People's Republic of China, Japan, South

TABLE 4 Procurement of conventional submarines with land attack capabilities by selected countries

Country	Class	Commentary
Germany	212CD	IDAS (Interactive Defense and Attack System) – anti-air system with limited anti-ship and land attack capabilities (still under development)
Italy	U212 NFS	Integration with submarine-launched cruise missiles (reportedly under development)
Netherlands	Orka class	Based on Suffren-class nuclear-powered submarines. The Orka class is expected to be integrated with Tomahawk missiles.[102]
Norway	212CD	IDAS (Interactive Defense and Attack System) – anti-air system with limited anti-ship and land attack capabilities (under development)
Spain	S-80 Plus	• Can be integrated with Tomahawk cruise missiles • Currently researching the possibility for integration with the Naval Strike Missile (NSM-SL)
South Korea	KSS-III Batch 1	• Reportedly integrated with South Korean submarine-launched cruise missiles (SLCM) • Integrated with South Korean submarine-launched ballistic missiles (SLBM) • Equipped with 6× VLS (each cell carrying 1 SLBM)
	KSS-III Batch 2	• Reportedly integrated with South Korean submarine-launched cruise missiles (SLCM) • Integrated with South Korean submarine-launched ballistic missiles (SLBM) • Equipped with 10× VLS (each cell carrying 1 SLBM)
Sweden	A26 Blekinge	• Offer VLS module optimized to deploy Tomahawk cruise missiles, with capacity for 18 missiles. • Potential integration with Naval Strike Missile (under development, the NSM is already utilized by the Swedish Navy)

Korea, and Australia, have deployed conventional submarines with displacements of approximately 3,000 tons or more.[36] A similar trend has been seen among NATO member states such as Germany, the Netherlands, Norway, Spain, and Turkey. This increase in size is essential for accommodating a significant payload of torpedoes and various missile types, including submarine-launched cruise missiles and anti-ship missiles. Additionally, the larger size, coupled with advanced air-independent propulsion systems, enables modern submarines to conduct blue-water operations, as demonstrated by South Korea's KSS-III submarines. These design advancements allow relatively large diesel-electric submarines to achieve capabilities comparable to smaller nuclear-powered vessels in terms of armament.

Given that the capability to launch cruise missiles is among the key requirements of the Polish ORKA program – and that this technology remains relatively novel in the context of Western diesel-electric submarines – it requires special attention. Such technology is already operational in the Russian Navy, where various Kilo-class submarines are equipped with Kalibr-family cruise missiles. Similarly, the People's Liberation Army Navy deploys YJ-18B submarine-launched cruise missiles[37] on nearly 40 Song- and Yuan-class vessels. Furthermore, the South Korean KSS-II and KSS-III submarines have reportedly been integrated with indigenously developed SLCMs.[38] Regarding the Polish ORKA program, first, and possibly the most important matter, is the selection of the design along with the integration of a specific cruise missile. As of 2024, there are three major contenders as far as the SLCM for the ORKA is concerned:

1. American BGM-109 Tomahawk,
2. French Missile de Croisière Naval (MCN/MDCN),[39] and potentially
3. South Korean Haeseong-III manufactured by LIG Nex1.[40]

The BGM-109 Tomahawk is a versatile and precise cruise missile, renowned for its operational success since the 1991 Gulf War. Its submarine-launched variant (UGM-109) includes the advanced Block IV (TLAM-E) iteration, equipped with features such as in-flight target reprogramming, loitering, and two-way satellite communication. Key upgrades include enhanced navigation, real-time imagery transmission, and a reliable Williams F415-WR-400 engine for extended range and precision. The missile is launched using specialized capsules, capable of evading obstacles with ultra-low flight altitudes.[41]

The Missile de Croisière Naval (MDCN) is a modern French naval cruise missile derived from the SCALP EG/Storm Shadow air-launched system. It was developed under a 2006 contract and tested in 2011, with integration into FREMM frigates and Barracuda-class submarines. Redesigned for submarine and vertical launches, the missile features a cylindrical fuselage, Microturbo TR50 engine, and advanced guidance combining GPS, TERPROM, and thermal imaging for precise targeting. With a lighter 300 kg warhead and a range exceeding 1,000 km, the MDCN offers a strategic capability for naval platforms.[42]

USS Annapolis launching a Tomahawk Land Attack Missile

Author: MC1 (SW/AW/SCW) Ronald Gutridge, US Navy

The Haeseong is a family of surface-ship- and submarine-launched cruise missiles developed as part of the South Korean cruise missile program, which began in the 1990s. The submarine-launched variant of this missile, known as Haeseong-III, has been operational since the 2010s. To date, the Haeseong missiles have been integrated with several South Korean submarines, including KSS-II and KSS-III diesel-electric submarines. Although little is known about the missile's technical specifications, some sources suggest that its range is approximately 1,500 km.[43]

Beyond the technical specifications of these three cruise missiles, a crucial consideration is whether the acquisition of submarine-launched cruise missiles can be included in the contract for constructing new submarines for the Polish Navy or if a separate agreement with external suppliers will be required. The former option seems viable only for South Korean and French submarines, as shipbuilding companies from these two countries have integrated domestically developed SLCMs into their designs and conducted thorough testing. Conversely, all other available submarine types would require Poland to procure the BGM-109 Tomahawk from the United States through the Foreign Military Sales (FMS) procedure. This procurement approach may involve additional costs, technological and development risks, and potential delivery delays.

Another important consideration regarding cruise missiles is the method of their deployment and launch, which can involve traditional torpedo tubes or the integration of a Vertical Launch System (VLS). Although the integration of VLS was not specified in the publicly available requirements for the ORKA submarines, the potential to acquire such capabilities should be thoroughly examined. According to information provided by potential contenders in the program, the integration of a VLS system is included as an option in the proposal by Sweden's SAAB. However, it is important to note that the first Blekinge-class submarine is still under construction, and the Swedish variant will not feature this capability. Consequently, this solution may entail several technological and procedural challenges, particularly as SAAB does not currently offer submarine-launched cruise missiles (SLCMs) in its portfolio.

In recent years, one of the most significant advancements in diesel-electric submarine armament has been the integration of ballistic missiles with conventional warheads into South Korea's KSS-III submarines. In September 2021, the South Korean Ministry of National Defense announced that the first KSS-III submarine (*Dosan An Chang-ho*) had successfully hit a target with a submarine-launched ballistic missile (SLBM).[44] This accomplishment is particularly noteworthy because both the Hyunmoo SLBM and the Vertical Launch System (VLS) were developed domestically by South Korean industry. It positions Seoul among a select group of several nations with such capabilities and highlights a strategic advantage for South Korea's shipbuilding sector, which relies on in-house development

of submarine-launched land-attack missiles – unlike many other submarine manufacturers that depend on external suppliers.

One of the final and perhaps most contentious weapon-related requirements in the ORKA program is the submarine's ability to engage enemy helicopters and fixed-wing maritime patrol aircraft. The justification for acquiring submarine-launched anti-aircraft missiles remains unclear, given that submarines are designed for stealth to avoid or significantly reduce the risk of detection by enemy anti-submarine warfare (ASW) systems, including specialized helicopters. While the concept of submarine-launched anti-aircraft missiles is not new – efforts to integrate such systems date back to the Cold War – successful operational implementation has yet to be achieved. A potential development direction involves adapting existing anti-aircraft missiles, such as the AIM-9X, for launch from submarines via torpedo tubes or vertical launch systems (VLS) using specialized canisters. This approach has reportedly been tested by the U.S. Navy. Another approach has been applied in the ongoing development of the IDAS (Interactive Defense and Attack System for Submarines) missile, which is reportedly based on the IRIS-T missile design. The IDAS missile, unlike the aforementioned anti-aircraft systems, is directly launched from submarine's torpedo tubes without the use of specialized canisters, from a submerged position. A key distinction between conventional anti-aircraft missiles and the IDAS system is the use of optical fiber cables, which are required to maintain communication with the operator for missile guidance, as well as the IDAS's subsonic speed.[45] The ability of submarines to defend themselves against ASW helicopters could have been particularly valuable for earlier generations of diesel-electric submarines. These vessels, lacking an AIP system or equipped with outdated AIP technology, were forced to surface more frequently to recharge their batteries, increasing their vulnerability. In such scenarios, a submarine-launched anti-aircraft missile could serve as a critical last line of defense, to be employed only when no other options are viable. However, a significant consideration is the limited space onboard and the limited number of such missiles a submarine can carry. Since Poland's next-generation submarines are expected to also launch cruise missiles – and a VLS is not among the specified requirements – the integration of dedicated anti-aircraft missiles could reduce other capabilities, such as the capacity for carrying anti-ship weapons. Therefore, the feasibility of acquiring such missiles requires careful examination. Modern AIP systems, advanced stealth designs, and the risks associated with launching anti-aircraft missiles – including the potential compromise of the submarine's location and the possibility of failed interceptions against ASW helicopters equipped with electronic countermeasures – must all be thoroughly evaluated.

2.3 Unmanned Underwater Vehicles

The concept of equipping submarines with unmanned underwater vehicles (UUVs) is relatively new and its operational application is yet to materialize. The unmanned underwater systems have been adopted on various types of surface combatants; in Poland, for example, the Kormoran 2-class (proj. 258) minehunters are equipped with several types of such systems, which are specialized in supporting these vessels in mine warfare missions.[46] However, the application of unmanned vehicles in the context of submarines is more challenging given that it requires not only integration of submarines' systems with UUVs but also physical means of transporting and launching UUVs from a submerged vessel. At the conceptual level, UUVs could be launched from torpedo tubes, but their recovery and operations are a more complex issue. In July 2024, the U.S. Navy announced that a torpedo-tube launch-and-recovery (TTL&R) uncrewed underwater vehicle (UUV) capability would be integrated into an operational Virginia-class submarine *USS Delaware* for the very first time. The development of such capabilities is also included in the Pillar 2 of the trilateral partnership between Australia, the United Kingdom, and the United States (AUKUS).[47]

UUVs can potentially perform a plethora of functions in support of submarine operations

Rendering of a Saab submarine with an Autonomous Underwater Vehicle
Copyright Saab AB

such as mine hunting, underwater explosive ordnance disposal (EOD), reconnaissance missions, and undersea mapping.[48] A key capability provided by drones is their ability to operate in areas, which are difficult or impossible for submarines to access, such as shallow waters or locations near critical maritime infrastructure. The potential advantage of the drones could also be the speed with which they can be deployed, making them an effective tool against time-sensitive threats, including acts of sabotage or hostile reconnaissance.[49] At the same time, the utilization of drones to carry out such tasks would free up the mothership to pursue other objectives. While the extent of operations that can be conducted or supported by UUVs is extensive, and has its rightful place as part of the maritime domain, their deployment by submarines is a complicated matter. A key consideration has to be made regarding UUV deployment and recovery which, while difficult, is not impossible as L3Harris demonstrated with "a fully autonomous launch and recovery of an AUV from an underway submarine".[50] Despite that however, such systems are incredibly complex and their development and implementation is still underway, which could potentially complicate or postpone the delivery of the primary product, that is the submarines themselves.

An additional consideration that has to be made when discussing UUVs and their deployment from submarines is their potential effect on the mother vessel's stealth capabilities. While deployment of the underwater drones might not be as problematic, the potential for tracking an operating UUV back to the submarine that deployed it might increase their discoverability. As a yet unproven (in actual operations) technology the actual effects of UUV deployment and recovery on the stealth characteristics of submarines is not certain.

3 Overview of the Potential Contenders in the ORKA Program

3.1 A26 – SAAB

The A26 Blekinge class of submarines is primed to be the pinnacle of Sweden's extensive shipbuilding expertise. While still under construction, and the lead ship of the class the HSWMS Blekinge only set to set sail in 2027, its history can be traced to the 1990s and Sweden's pursuit of a new submarine class to enhance its maritime posture. The initial need for a new submarine for Sweden, which already operated the Västergötland class and was introducing the new Gotland class, withered out due to a decrease of potential security threats and the end of the Cold War. The project resurfaced in the 2000s with the growing perception of the Västergötland as an aging platform that needed to be replaced. The initial plans focused on joint projects with other nordic states, primarily Norway and Denmark; however, the idea failed due to partner withdrawals and a series of disagreements between Stockholm and ThyssenKrupp, which at that point owned Kockums representing the Swedish industry in the joint venture. As the joint project failed the Swedish Defence Materiel Administration (Försvarets materielverk, FMV) decided to recover their intellectual property they invested in with Kockums. However, due to inconsistencies in the agreements between FMV and ThyssenKrupp, the transfer was cancelled.[51] Kockums and its technological solutions found their way back after the purchase of the company to Saab in the aftermath of the agreement discussions with FMV. The project was then relaunched again in its final form as the A26.

The A26 is offered by Saab in several different versions: the Pelagic, Oceanic, and Oceanic Extended Range. The major difference between the three versions is size:

1. **Pelagic** with a length of 50 m and a surfaced displacement of 1,000 tons;
2. **Oceanic** (the standard version also called the *Blekinge class*) with 65 m of length and surface displacement of roughly 2,000 tons;
3. **Oceanic Extended Range** with 3,000 ton displacement and a comparably extended length over the Oceanic.

What makes the A26 design unique, and what actually allows the three different types above to be considered a single design, is the modularity of the vessels. Each ship is constructed as a series of connected modules (up to 9 modules) allowing Kockums shipyard to achieve great flexibility and optimization of the design in accordance with customer needs.

The customizability of the design can already be seen in the differences between the Swedish variant of the A26 (Blekinge class) and the proposed offers for export customers like Poland. The greatest observation to be made here is the inclusion of a VLS module in the Polish

offer, with the capability to hold as much as 18 Tomahawk cruise missiles. This change is a significant upgrade of the *Blekinge* submarine ordered by Sweden, which is armed with both heavy 533 mm and light 400 mm torpedoes, and mines but it is not equipped with a VLS module. It is possible that in the future the A26 will also be optimized to use Naval Strike Missiles, which are already utilized by the Swedish Navy. However with no ships in class operational as of December 2024, it is difficult to determine the actual armament capabilities, especially in the case of the VLS and the potential difficulties with the acquisition of the appropriate munition, in this case Tomahawks, which are not produced by the supplier and would require additional government-to-government agreements with the United States to be secured.

The A26 can utilize its modular design to be adapted to a plethora of missions, beyond the traditional role of conventional submarines as hunter-killers. One such adaptation is the Multi-Mission Portal (MMP). Installed between the torpedo tubes in the front section of the vessel, this 1,5 meter-wide and 6 meter-long cylindrical dock can allow the A26 to conduct a number of missions.[52] The dock can be utilized to launch and recover Unmanned Underwater Vehicles or deploy special forces with sizable equipment.

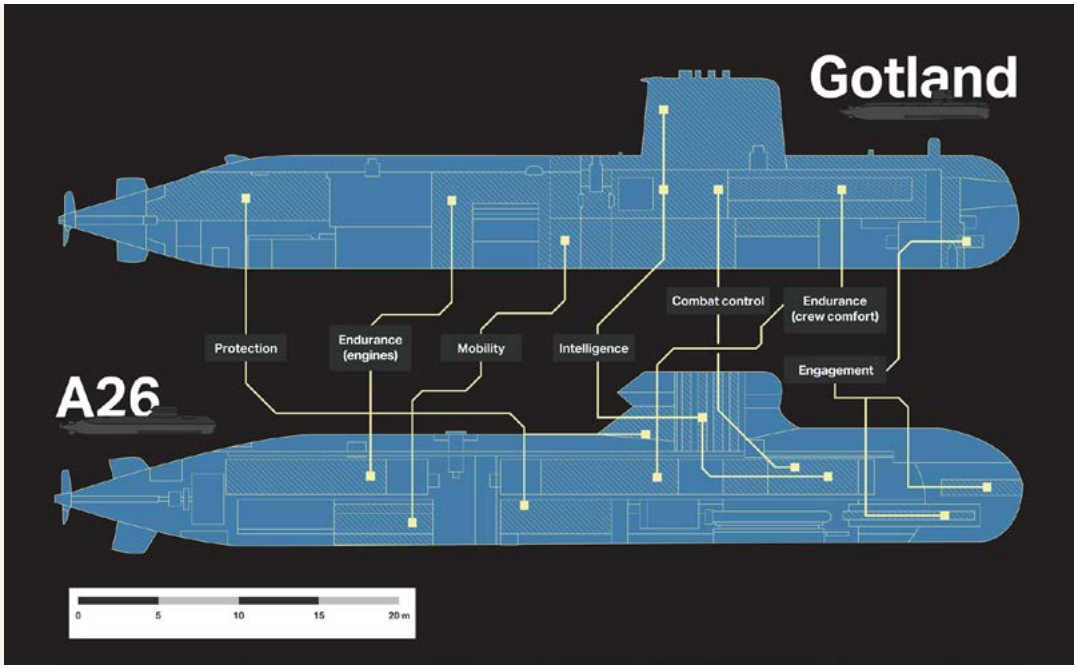
Rendering of the A26-class submarine
Copyright Saab AB

The MMP can also be reportedly utilized to deploy weapons that could not be deployed from the vessel's 533 mm torpedo tubes.

The A26, however, offers much more beyond the capabilities of its armament. The first technical solution garnering attention is the AIP system based on a Stirling engine. In this case, as opposed to the proposed VLS module, the AIP module has already been tested and proven in Kockums' previous designs, such as the Gotland-class submarines that were fitted with Stirling engines running on diesel fuel and liquid oxygen mix to power the vessels underwater, or the refitted Västergötland-class, now upgraded to the Södermanland-class standard. The technical solutions applied to the upgraded Gotland-class and Södermanland-class are reportedly the solutions that will be found in the new A26s.[53]

Another consideration is the GHOST (Genuine Holistic Stealth) system, which is supposed to make the new vessels very hard to detect, considering even the running mechanical components of the Stirling engine, which has already been optimized to produce as little noise as possible. Among others the system utilizes rubber mounts to reduce the sound produced by onboard equipment, as well specialized frames with "acoustic damping plates" decreasing the vessels sound signature.[54] Additionally, the submarine's architecture is designed to reduce noise production – with the hull shape and fin design lowering sounds resulting from water flow along the vessel's exterior. While the technology utilized in the A26 is yet to be tested on board a fully operational vessel, outside Kockums shipyards, it is vital to underline the company's previous achievements in terms of stealth technology. The Saab-produced Gotland-class submarines have already enjoyed high praise on the basis of its operational capabilities, especially stealth, and according to available sources the new GHOST system exceeds those achievements.[55]

A significant advantage of the A26 for Poland is the established cooperation between Poland and Sweden, both in terms of previous military-industrial projects, but also the new strategic partnership agreement. This agreement prioritizes cooperation in securing the Baltic Sea against foreign threats, and aims to pursue



Infographic Overview of the A26 and Gotland class Submarines
Copyright Saab AB

TABLE 5 Specifications of A26 submarine (oceanic variant)

Country of Origin	Sweden
Main Producer	SAAB
Displacement	2,000 tons
Length	65 m
Beam	6.4 m
Height	n.d.
Complement	18–26 (capacity for additional 11 personnel)
Submerged Endurance	Reportedly 18 days
Total Operational Endurance	18–45 days[103]
Max operating depth	n.d.
Propulsion System	• Diesel-electric • Stirling engine-based AIP system with a GHOST system (Genuine HOlistic STealth)
Armament	• Heavy 533 mm torpedoes • Light 400 mm torpedoes • Up to 18 SLCM in the VLS (3 cells, 6 missiles each) • More than 15 torpedoes/missiles in storage
Current Users	-
Future Users*	Sweden
Number Produced to Date	0
On Order	2 (under construction)
VLS	YES (potential integration in the future; Swedish Navy vessels will not feature the VLS)
Cruise Missiles	YES (potential integration of UGM-109 Tomahawk)**
Ballistic Missiles	NO

* Based on contracts signed to date
** Requires an additional contract with the United States through FMS

joint policy implementation and advocacy within the EU, as well as "develop strategic, long-term and mutually beneficial Polish-Swedish defense industrial cooperation in the air, land, space and maritime domains, and explore mutual investment opportunities."[56] Industrial and military cooperation between Poland and Sweden has been made quite evident in the last few years, with the acquisition of two used Saab 340 AEW early warning aircraft, the procurement of over 6,000 Carl Gustav recoilless rifles,[57] and the procurement of Delfin-class SIGINT vessels which are being built in the Polish Remontowa Shipbuilding shipyard.[58] As such both SAAB and Sweden suggest exchanging knowledge and experience and jointly develop technologies with Poland.[59] This could point to the possibility that the Polish shipbuilding industry could benefit from the agreement on the procurement of the submarines from SAAB. On the other hand, it is noteworthy that the construction of the Blekinge-class submarines for the Swedish Navy has seen significant delays and based on the available information the delivery of the first two submarines of the class will take place in 2027 and 2028, respectively. The future of the program remains uncertain given that Sweden could potentially opt for a completely new design to replace older-generation submarines in their fleet.[60]

3.2 KSS-III & HDS-2300

3.2.1 KSS-III Batch 2 – Hanwha Ocean

The KSS-III Batch 2 development program exemplifies South Korea's determination and commitment to advancing its capabilities in constructing conventional submarines equipped with sophisticated AIP systems and formidable armament. The KSS program, aimed at establishing indigenous submarine-building capabilities, traces its origins to the 1980s, when Seoul acquired a license to domestically produce Type 209 submarines with technical assistance from the German shipbuilding company Howaldtswerke-Deutsche Werft (HDW). This partnership provided South Korea with the necessary knowledge and technologies to initiate local production.[61] While the first KSS-I vessel (Jang Bogo class) was constructed in Germany, the remaining eight vessels were constructed in Daewoo Shipbuilding & Marine Engineering's (now Hanwha Ocean's) Geoje shipyard, marking significant progress in the country's shipbuilding industry. This progress eventually facilitated the export of three Nagapasa-class submarines to Indonesia in the late 2010s. The third vessel of the class, a modified Type 209/1200 submarine, was assembled at Indonesia's PT PAL shipyard in Surabaya with support from the South Korean industry and was delivered to the Indonesian Navy in 2021.[62] Over the course of the KSS program, South Korean-built Type 209 submarines were significantly enhanced with domestically developed technologies, including advanced sonars, combat management systems, and weaponry.

South Korea simultaneously advanced its submarine fleet by adopting the Type 214 design from Germany's ThyssenKrupp Marine Systems in the early 2000s, leading to the deployment of the first KSS-II (Sohn Won Il class) submarine in 2007. Altogether, South Korea has constructed nine submarines based on the Type 214 design, featuring a significantly higher rate of indigenization compared to their predecessors. During the 2010s, the KSS-II submarines were reportedly equipped with domestically developed cruise missiles.[63] This program subsequently paved the way for the fully domestic development of the KSS-III, the most advanced submarine ever built by South Korea and one of the world's most capable AIP-powered vessels to date. South Korea's Hanwha Ocean, a leading shipbuilding company involved in Seoul's submarine programs, currently has the capacity to construct two submarines in parallel at its shipyards.[64] With ongoing investment projects, this capability is projected to expand to five vessels by 2029.[65]

The development of the KSS-III submarine program coincided with South Korea's rapid industrial expansion into global markets, a shift that elevated the nation's economy into the ranks of the largest and most advanced in the world. This rapid economic and industrial growth broadened Seoul's strategic interests beyond the Korean Peninsula, prompting the Navy to focus on capabilities for blue-water operations. The necessity of a robust naval force was further emphasized by the militarization of neighboring

ROKS Dosan Ahn Changho, the first KSS-III class submarine.
Author: ROK Ministry of National Defense

countries, including North Korea's missile programs and its submarine fleet equipped with submarine-launched ballistic missiles (SLBMs), as well as the rapid expansion of the People's Liberation Army Navy's capabilities.[66] These geopolitical pressures influenced the design of the new South Korean vessels, resulting in a much larger size, formidable armament – including submarine-launched ballistic missiles – and a remarkably high degree of indigenization, currently estimated at approximately 80 percent.[67] The design of the KSS-III also reflects the strategic role these submarines are expected to play within South Korea's Three-Axis System, which encompasses:[68]

1. **Kill Chain**, a preemptive strike capability aimed at neutralizing North Korea's ballistic missiles or other nuclear weapon carriers if such weapons are deployed and ready for launch.
2. **Korea Air and Missile Defense (KAMD)**, a defensive system designed to detect and intercept incoming missiles.
3. **Korea Massive Punishment and Retaliation (KMPR)**, a strategic capability to deliver retaliatory strikes against North Korea following a nuclear or conventional attack on the Republic of Korea.

Given Seoul's emphasis on developing submarines equipped with SLBMs and SLCMs, the KSS-III submarines offer a much broader range of capabilities than the hunter-killer missions typically associated with diesel-electric vessels. It is reasonable to assume that their advanced weapon systems could be utilized in both preemptive and retaliatory scenarios, thereby greatly enhancing the deterrence posture of the Republic of Korea Armed Forces.

The future KSS-III fleet is planned to consist of nine submarines, built in three batches of three vessels each.[69] By late 2024, all three KSS-III Batch 1 vessels were commissioned by the Republic of Korea Navy.[70] The first vessel of the Batch 2 is scheduled to be launched in mid-2025.[71] The third and final model is expected to be handed over to the ROK Navy by 2031.[72] Selected specifications of Hanwha Ocean's proposal for the ORKA program, the KSS-III Batch 2 submarine – the most advanced variant of its class – are presented in the table 6.

The design of the KSS-III Batch 2 submarine represents a significant evolution over the Batch 1 vessels in terms of dimensions, displacement, and weapon capacity. The hull has been extended by 5.8 meters, enabling the integration of an additional four VLS cells – bringing the total to 10 – and enlarged flank array sonars. Batch 2 submarines are also equipped with modern lithium-ion NMC batteries, which replace the older-generation lead-acid batteries used in the Batch 1 submarines. The propulsion system has been substantially enhanced, featuring an expanded capacity for the fuel cell-based AIP system and three MTU 12V 4000 U83n diesel engines. These advancements significantly improve the KSS-III's overall capabilities, particularly its endurance. The Batch 2 vessels can remain submerged for over three weeks, and can operate at sea continuously for more than 50 days. The adoption of advanced lithium-ion

TABLE 6 Specifications of KSS-III (Batch 2)

Country of Origin	South Korea
Main Producer	Hanwha Ocean
Displacement	3,600 tons
Length	89 m
Beam	9.6 m
Height	14.7 m
Complement	33 (Up to 50 including Special Operations Forces)
Submerged Endurance	Over 21 days
Total Operational Endurance	50 days
Max operating depth	500 m
Propulsion System	• Diesel Engine • Lithium-ion Batteries • AIP: PEM Fuel Cells
Armament	• 6×533 mm ATP torpedo tubes • K761 Tiger Shark, Haeseong-line SLCM), Submarine Launched Mobile Mine (SLMM), • 10×VLS (Hyunmoo-line SLBM) • Up to 20 torpedoes/missiles • 10 SLBM (VLS) in storage
Current Users	South Korea
Future Users*	South Korea
Number Produced to Date (Commissioned)	3
Number on Order	3 (under construction) (+3, Planned Batch 3)
VLS	YES 10 cells
Cruise Missiles	YES Haeseong-line SLCM
Ballistic Missiles	YES Hyunmoo-line SLBM

* Based on contracts signed to date

batteries has doubled the maximum number of charging cycles from 2,000 to 4,000. Additionally, the maximum distance the KSS-III can travel on battery power has increased by 200 percent at maximum speed and by 60 percent at cruising speed.[73] This enhanced performance is supported by a specialized lithium-ion battery safety system, ensuring secure and reliable submarine operations. With the stealthy characteristics of its fuel cells and the implementation of highly efficient NMC lithium-ion batteries, the KSS-III AIP system ranks among the most advanced on the market. It offers exceptional reliability, safety, and quiet operation. These attributes, combined with anechoic tiles, sound-insulating foam, and elastic mounts, further enhance the submarine's stealth capabilities, substantially reducing the risk of detection by enemy forces.

The boats are equipped with numerous sensors, including seven active and passive sonars produced by LIG Nex1, including a new conformal sonar located in the submarine's bow, an additional mine-detection sonar manufactured by Thales, as well as Safran's Series 30 Attack Optronic Mast (AOM) and the Search Optronic Mast (SOM) installed on the submarine's sail. The data from the KSS-III Batch 2 sensors is integrated and processed by the Naval Shield ICMS (Integrated Combat Management System), a proven technology successfully implemented across dozens of South Korean ships of various types and classes, as well as vessels operated by the Royal Malaysian Navy[74] and the Philippine Navy.[75] The system has been developed by Hanwha Systems and has undergone incremental upgrades tailored to the specific requirements of the ROK Navy. This adaptability represents a significant advantage for the KSS-III Batch 2 submarines, particularly when considering future modernization programs.

The KSS-III Batch 2 is the most advanced submarine design proposed under the ORKA program in terms of integrated weapons systems. In addition to standard submarine armaments such as torpedoes and naval mines, the Batch 2 possesses deep-strike capabilities using both cruise and ballistic missiles. While cruise missiles are launched through the submarine's torpedo tubes, the SLBM is integrated with the indigenously developed VLS system. Most importantly, it is the only submarine offered in the ORKA program with these advanced systems already tested and operationally deployed. Furthermore, these missiles are produced domestically by the South Korean industry, which means that Poland could potentially acquire such weapons alongside the submarines. This capability positions the KSS-III Batch 2 favorably against its competitors, particularly since only the French proposal includes cruise missiles. The integration of the VLS with SLBM capability aboard a conventional submarine marks a significant technological breakthrough for South Korea, as no Western diesel-electric submarine has yet been equipped with this technology. The differences between the KSS-III Batch 1 and Batch 2 were presented in Table 7.

TABLE 7 Comparison of KSS-III Batch 1 and Batch 2 submarines

Platform	KSS-III Batch 1	KSS-III Batch 2
Length	83 m	89 m
Displacement	3,300 tons	3,600 tons
Endurance	Less than 21 days (submerged)	Over 21 days (submerged)
Sonar	8 Sonars (Cylindrical Bow Sonar)	8 Sonars (Conformal Bow Sonar)
Max. Storage of Weapons	26 (including 6 VLS)	30 (including 10 VLS)
Propulsion System	Lead-Acid Battery + AIP	Lithium-Ion Battery + AIP 1× Auxiliary Bow Thrust

Based on Hanwha Ocean's plans, the South Korean shipbuilding company could deliver the first submarine within six years of contract signing, with the second and third vessels following at yearly intervals. This timeline suggests that if the contract is signed in 2025, the first KSS-III Batch 2 submarine could be delivered to the Polish Navy by 2031, the second by 2032 or 2033, and the final vessel by 2034. Given Hanwha Ocean's extensive experience, proven track record of timely deliveries, and the fact that these submarines are based on operational designs requiring minimal modifications, the risks associated with technological challenges or delays appear minimal compared to other options. Competing proposals may necessitate significant design adjustments, the integration of additional systems, and the acquisition of weapon systems from external suppliers, which could introduce further complexity and risk.

While industrial cooperation is outside the scope of this analysis, it is worth noting that Hanwha Ocean is actively exploring partnerships

with Polish defense companies as well as academic institutions and research and development centers. Additionally, Poland maintains a well-established partnership with another Hanwha Group member, Hanwha Aerospace (formerly Hanwha Techwin). This collaboration facilitated the technology transfer for manufacturing the K9 chassis to the Polish state-owned defense contractor HSW, enabling the development of the Krab self-propelled howitzer (SPH). Following Russia's invasion of Ukraine, the Polish Ministry of National Defense has also procured other systems from Hanwha, including K9 SPHs and K239 multiple rocket launchers for the Polish Land Forces. These acquisitions involved several Polish defense companies, such as WB Group, and allowed for the integration of Polish technologies into South Korean weapon systems. Although these contracts are unrelated to the ORKA program, the proven track record of effective cooperation and prompt deliveries is a key factor that should not be overlooked.

3.2.2 KSS-III PL & HDS-2300 – HD Hyundai Heavy Industries

KSS-III PL

One of the two submarine types proposed by the second South Korean shipbuilding company, HD Hyundai Heavy Industries, is the KSS-III PL, a modified version of the KSS-III submarine. As both types originate from the South Korean KSS-III program, their development and role in South Korea's defense and deterrence policy are discussed in Chapter 3.2.1.

The KSS-III PL, also branded as the HDS-3300, is reportedly based on the design of the KSS-III Batch 1 submarines. As such, its general specifications, including displacement and dimensions, are consistent with those of the Republic of Korea Navy's submarines. This likely indicates that certain limitations of the base variant, such as less advanced sensors, and a lower-capacity AIP system, are carried over from Batch 1. However, other features, such as the combat management system, are expected to align more closely with the capabilities of the Batch 2 submarines.

HD Hyundai Heavy Industries has introduced some significant modifications to the KSS-III PL. Notable upgrades include the replacement of traditional lead-acid batteries with modern lithium-ion batteries, although the air-independent propulsion (AIP) system remains based on the Batch 1 design. Despite its relatively large dimensions, the Polish variant will not be equipped with the K-VLS system and, consequently, will lack the ability to carry submarine-launched ballistic missiles. While the inclusion of vertical launch systems (VLS) was not specified in the Polish requirements for the ORKA program, their absence means that all weapon systems must be launched via torpedo tubes. This limitation reduces the maximum number of weapons the submarine can carry. Nonetheless, such a solution has been offered by most companies, with Hanwha Ocean and SAAB being the only companies including the VLS capability in their proposals. In place of the VLS, HD Hyundai Heavy Industries proposes utilizing the space to install a specialized module for deploying unmanned underwater vehicles (UUVs) or carrying special forces equipment. This alternative reflects a strategic decision to

TABLE 8 Specifications of KSS-III (PL)

Country of Origin	South Korea
Main Producer	HD Hyundai Heavy Industries
Displacement	3,300 tons
Length	83 m
Beam	9.6 m
Height	14.7 m
Complement	35 (+15 for Special Operations Forces)
Submerged Endurance	n.d.
Total Operational Endurance	50 days
Max operating depth	500 m
Propulsion System	• Diesel-electric • Lithium-ion Batteries • AIP: Fuel Cells
Armament	• 6 × 533 mm ATP torpedo tubes Babcock International WHLS (K761 Tiger Shark, SLCM) • Submarine Launched Mobile Mine (SLMM) • Up to 20 torpedoes/missiles • 6 SLBM (VLS) in storage
Current Users	South Korea
Future Users*	South Korea
Number Produced to Date	3 (2 units KSS-III Batch 1 produced by Hanwha Ocean; 1 unit produced by HD Hyundai Heavy Industries)
Number on Order	0
VLS	NO
Cruise Missiles	YES
Ballistic Missiles	NO

*Based on contracts signed to date

ROKS Shin Chae-ho, the latest KSS-III Batch I submarine

Author: Defense Acquisition Program Administration

prioritize mission versatility over ballistic missile capability in meeting Poland's operational needs.[76] A possible configuration of the KSS-III PL submarines is presented in the table below.

The KSS-III PL is a project of a relatively large and capable submarine, derived from the same design as the KSS-III Batch 1 submarines developed by Hanwha Ocean. It is worth noting that both KSS-III Batch 1 and Batch 2 rank among the largest diesel-electric submarines with air-independent propulsion (AIP) systems in the world. The KSS-III Batch 2 is a heavily armed submarine designed for extended endurance and capable of conducting blue-water operations, while the KSS-III PL prioritizes versatility and may offer additional capabilities, such as deploying unmanned underwater vehicles (UUVs). However, as discussed in Chapter 2, the integration of UUVs with submarines remains a significant challenge. Although many manufacturers are engaged in research and development in this area, the technology has yet to be fully operationalized. A notable trade-off of the KSS-III PL, despite its considerable size, is the absence of the VLS, which could significantly enhance Poland's deterrence and land-attack capabilities at the strategic level. This is particularly relevant when considering the possibility of acquiring KSS-III submarines equipped with ballistic or cruise missiles.

HDS-2300

The second submarine project offered by HD Hyundai Heavy Industries is more compact than the other two designs. According to the South Korean manufacturer, the smaller size of the HDS-2300, combined with other features, makes it well-suited to the specific operational needs of the Polish Navy in the Baltic Sea. Details about the project remain limited, as HD Hyundai Heavy Industries has marketed the HDS-2300 as a joint research and development initiative between Polish and South Korean industries. Leveraging its extensive experience, HD Hyundai Heavy Industries has incorporated lessons learned from the KSS-II (Type 214) and KSS-III programs, both of which the company was instrumental in either designing or producing. The HDS-2300 is expected to feature an air-independent propulsion (AIP) system based on fuel cells, as well as advanced lithium-ion batteries, though the technical specifications of these systems have not been disclosed. According to HD HHI, the first vessel of this class could be delivered within 72 to 80 months of contract signing, making it one of the fastest delivery timelines available to Poland. Moreover, the construction costs of these submarines are reportedly much lower than those of their larger counterparts. However, it is important to note that the HDS-2300 remains a conceptual design and is not based on a proven, operational platform like the KSS-III submarines.[77] Moreover, based on the available information, the South Korean Navy has no plans to incorporate vessels of this class into its submarine fleet. As a result, the Polish Navy would be the first operator of these submarines. The characteristics of these vessels, based on the information released by the producer, were presented in the Table below.

HD Hyundai Heavy Industries does not have an established track record of cooperation with the Polish defense and shipbuilding sectors. However, it is noteworthy that the company recently signed a memorandum of understanding (MoU) with the Polish private firm Remontowa Shipbuilding.[78] While HD HHI has yet to develop long-term partnerships within Poland's defense and shipbuilding industries, it possesses significant experience in technology transfers, which could serve as a foundation for future collaboration. This expertise was demonstrated in its collaborations with the Philippine Navy and local industry following Manila's acquisition of two HDF-2600 multi-role frigates, two HDC-3100 frigates, and six HDP-2200-class maritime patrol ships.[79] Given the limited information available about the systems that could potentially be integrated into the Polish HDS-2300, the viability of acquiring these submarines requires further investigation. The concept's primary advantage may lie in the potential for industrial cooperation with HD HHI rather than the submarine's inherent capabilities.

TABLE 9 Specifications of HDS-2300

Country of Origin	South Korea
Main Producer	HD Hyundai Heavy Industries
Displacement	2,300 tons
Length	73 m
Beam	Approx. 8 m
Height	14.4 m
Complement	35 (+15 Special Operations Forces)
Total Operational Endurance	50 days[104]
Max Operating Depth	250 m[105]
Propulsion System	• Diesel Electric • Lithium-ion Batteries • AIP: Fuel Cells
Armament	• 6 torpedo launchers capable of launching anti-ship missiles and SLCM • Up to 20 torpedoes/missile in storage
Current Users	-
Future Users*	-
Number Produced to Date (in Service)	0
Number on Order	0
VLS	NO
Cruise Missiles	YES
Ballistic Missiles	NO

*Based on contracts signed to date

3.3 Scorpène – Naval Group

The Scorpène-class submarines, developed by the French DCNS (now Naval Group), were designed exclusively for export. Countries such as Chile, Malaysia, India, and Brazil have acquired these submarines, with some opting for domestic construction in collaboration with French partners. One of Naval Group's recent export achievements is Indonesia's decision to procure Scorpène Evolved Full LiB submarines. The design combines modern features with proven reliability, though most buyers have chosen the base version without air-independent propulsion systems. Indonesia, for example, selected vessels equipped with diesel-electric propulsion and lithium-ion batteries. Previously, Naval Group offered the Scorpène-class with three propulsion options: MESMA (a steam-based AIP system), second-generation fuel cells (FC2G), and lithium-ion batteries. While MESMA supports two weeks of submerged operation, it is slower and consumes more oxygen. Fuel cells enable up to three weeks underwater, whereas lithium-ion batteries provide endurance for about one week.[80] Due to limited demand for Naval Group's AIP systems, the French producer is likely to offer lithium-ion batteries without the AIP. This approach was promoted by Naval Group at MSPO 2024.[81] The specifications of the Scorpène Evolved submarines are outlined in the table below.

Naval Group has incorporated noise-reduction technologies such as rubber tiles on the pressure hull to enhance stealth capabilities. The Scorpène-class submarines are versatile, compact, and capable of continuously operating at sea for up to 70 days. Highly automated systems allow for efficient operation with a small crew, accommodating 25 personnel and six additional Special Forces operators. This makes them an

INS Kalvari, a Scorpene class submarine of the Indian Navy
Author: Indian Navy

TABLE 10 Specifications of Scorpene Evolved

Country of Origin	France
Main Producer	Naval Group
Displacement	2,000 t
Length	76–78 m
Beam	6.2 m
Height	n.d.
Complement	31 (+6 SOF)
Submerged Endurance	Over 12 days[106]
Total Operational Endurance	Approx. 80 days[107]
Max operating depth	Over 300 m
Propulsion System	• Diesel-electric • Lithium-ion Batteries Optional: • FC2G (Fuel Cell 2nd Generation) AIP[108]
Armament	• 6×533 mm torpedo tubes • MdCN/NCM • Up to 18 torpedoes/missiles in storage
Current Users	• Chile • Malaysia • India • Brazil
Future Users*	Indonesia (Scorpene Evolved)
Number Produced to Date	13
Number on Order	3 (including 2 Scorpene Evolved)
VLS	NO
Cruise Missiles	YES (Expected integration of MdCN/NSM)
Ballistic Missiles	NO

*Based on contracts signed to date

appealing option for navies seeking advanced diesel-electric submarines with modern weapon systems. Scorpène submarines come with six torpedo tubes for torpedoes and anti-ship missiles, with future compatibility for MdCN cruise missiles. However, their armament capacity is limited to 18 weapons, as they lack the flexibility of additional missile sections seen in other designs, particularly those featuring the VLS system. The French Naval Group offers integration of cruise missiles like the MdCN/NSM, which provide land-attack capabilities with a range of over 1,000 kilometers. This makes them an appealing option for navies seeking advanced diesel-electric submarines with modern weapon systems. Nevertheless, it is important to note that, as of late 2024, no vessel of this class has been deployed with MdCN cruise missiles. On the other hand, the MdCN missiles were successfully integrated and tested with the French Suffren class nuclear-powered submarines.[82]

The option to acquire submarines equipped with cruise missiles gives the French proposal a significant advantage over competitors proposing integration with UGM-109 Tomahawk cruise missiles. Choosing the Tomahawk would necessitate Poland obtaining these weapon systems separately through a Foreign Military Sales (FMS) contract with the United States, adding complexity to the procurement process.

While the design promoted by Naval Group has some interesting solutions, the lack of progress in terms of further development and the completion of outstanding agreements can be an unfortunate signal for potential buyers. Since the September 2024 meeting between Indonesia and France discussing cooperation on the new submarines, which did not disclose any information on delivery timelines, there has been no reported progress on the construction or development of the new vessels designated for the Indonesian navy.[83] One of the key priorities of the Polish Navy is the rapid reconstitution of its submarine capabilities so that the existing know-how and operational capabilities of Polish submarine crews and technical personnel are maintained – swift acquisition of new vessels is of key importance. Additionally, it is in vital interest to Poland to continue operating its submarines well into the future with possibilities for adaptation in accordance with new and emerging threats – which might be problematic when faced with delays in development.

3.4 S-80 Plus – Navantia

The S-80 Plus diesel-electric submarine is the brainchild of the Spanish Navantia, a state-owned company controlled by the Sociedad Estatal de Participaciones Industriales (SEPI) under the Spanish Ministry of Finance. The new ships are set to replace the aging, and mostly decommissioned, the S-70 class that formerly composed the Spanish submarine fleet. Out of the four S-70s only one remains in active service, and has only recently been joined by the first S-80 Plus submarine *Isaac Peral*, which entered into service in late 2023. Despite the fact that the first S-80 has only recently been commissioned, its history stretches all the way back to the 1980s and the French shipbuilding industry. The first designs of the S-80 have been the work of the DCNI (Direction des Constructions Navales International), the predecessor of the Naval Group, in a bid to produce a design capable of replacing the aging fleet of S-60 *Daphné*-class diesel submarines. The design however did not find purchase and funding for the project from the French government was stopped. The unfinished project was picked up by the Spanish Empresa Nacional Bazán, which sought to produce a worthy replacement to the *Delfin* class (Spanish designation of the Daphné class) in service with the Spanish Navy.

S-80 Plus Submarine
Author: A_Guy_Named_Nyal, flickr.com/people/189326381@N08

The new S-80 Plus builds on the initial French designs, however the solutions implemented make it a truly Spanish innovation. The most unique and arguably advanced technology crafted by Spanish engineers is the ship's propulsion system based on fuel cells. The BEST (Bio-Ethanol Stealth Technology) AIP system is a one of a kind design utilising bioethanol where other fuel cells-based AIP systems use hydrogen. Bioethanol stored on board is used to produce hydrogen, using a specialised hydrogen generator. This solution has been implemented for several reasons – firstly, according to Navantia, bioethanol is much safer to store on board submarines when compared to hydrogen in its pure form. Secondly, the utilization of this system allows the S-80 Plus to operate underwater for periods of time two to three times as long as other designs, at least according to Navantia.[84] On the other hand, the production of hydrogen from bioethanol also generates other gases, primarily carbon dioxide, which is problematic in the enclosed environment of a submarine. The solution to this was the implementation of a specialised scrubbers which dissolve the unwanted gasses in sea water on board the vessel and only then release it out of the ship. This allows potentially harmful gasses to be vented without jeopardizing the ship's stealthy signature with escaping gasses. While this solution looks very promising on paper it is important to consider several factors. Firstly, no vessel has been fitted with this system yet, the first two ships of the class, including the already commissioned *Isaac Peral*, do not have this system installed and will only be upgraded to have it later on.[85] Secondly, the system requires additional systems to be operational – mainly the hydrogen generator and the scrubber-venting systems to vent out harmful gasses. This points to not only increased complexity of the entire system, which could lead to longer production timelines, but also greater chances for technical issues. These considerations require further research, however the chances for it are so far limited due to lack of actually existing vessels fitted with the systems.

The armament of the S-80 Plus is very similar to other diesel-electric submarines, though original concepts were quite different. Initial

TABLE 11 Specifications of S-80 Plus

Country of Origin	Spain
Main Producer	Navantia
Displacement	2,695 tons
Length	81 m
Beam	7.3
Height	11.6 m
Complement	32 (+8 Special Operations Forces)
Submerged Endurance	Approx. 21 days[109]
Total Operational Endurance	50 days
Max operating depth	>300 m[110]
Propulsion System	• Diesel-electric • Lead-acid Batteries • AIP: BEST (Bio-Ethanol Stealth Technology) Fuel Cell-based system
Armament	• 6× torpedo launching tubes[111] • 12 stowages for extra armament • DM2A4 Heavyweight Torpedo • Sub-Harpoon Missile • Fitted for Tomahawk Missile • Spanish Navy Mine • Up to 18 torpedoes/missile in storage
Current Users	Spain
Future Users*	Spain
Number Produced to Date	1
Number on Order	3 (under construction)
VLS	NO
Cruise Missiles	YES (Potential integration of UGM-109 Tomahawk)**
Ballistic Missiles	NO

* Based on contracts signed to date
** Requires an additional contract with the United States through FMS

plans for the new generation submarines was the focus on anti-submarine operations and defensive measures. The change came on in 2003 with the publication of the new Strategic Defence Review (*Revisión Estratégica de la Defensa*) which postulated for a switch in submarine warfare, prioritising the ability to project power in "littoral and coastal waters, reaching all the way into the interior as well", signifying the need for submarines to possess land-attack capabilities.[86] These perceptions shaped the final shape of the S-80 Plus class which has been designed to be capable of utilizing both standard 533 mm DM2A4 heavy torpedoes, but also Harpoon anti-ship missiles, and can be optimised to utilise Tomahawk cruise missiles for use against land targets. Furthermore, under a programme led by the Spanish Navy, Navantia is currently researching further capacity for improved equipment and arsenal for the S-80, primarily the Naval Strike Missile-SL (NSM-SL) as a joint project with the Norwegian Kongsberg, as well as capabilities to utilize various unmanned underwater vehicles.[87] Nonetheless, the integration of the NSM-SL missile remains in the initial stage of development, as of January 2025. In its current configuration the S-80s are capable of combating enemy submarines, surface ships, and land targets. Without an installed VLS all armaments are launched via torpedo tubes, with total payload capacity of 18, with 6 armaments at the ready in the launching tubes and an extra 12 stowage spaces.

212A class submarine during exercise Arctic Dolphin

Author:
Tom Kistenmacher.
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3.5 Type 212

3.5.1 Type 212CD – ThyssenKrupp Marine Systems

Type 212CD submarine is the result of a cooperation between Germany and Norway aimed to provide both countries with the most capable vessels fitted with the most recent and advanced technology. In comparison to other European solutions discussed in this paper the history of the 212CD is much more recent, starting with the increasing need to replace the aging Ula-class submarines of the Royal Norwegian Navy. Oslo has been searching for an appropriate partner to engage in a joint project to produce a new submarine, one of the obvious directions was Germany, due to a strong shipbuilding industry and an established history of submarine production and cooperation with Norway. German shipbuilding and technological companies had manufactured all of Norway's retired Kobben class submarines in Rheinstahl Nordseewerke shipyard in Emden, and contributed in a joint project to produce the aging Ula-class vessels. The cooperation between Norway and Germany was established in 2017, with the German ThyssenKrupp Marine Systems (TKMS) chosen as the primary contractor for the production of new vessels. The first contract for the new submarines, designated 212CD (CD for Common Design), was signed in 2021 and established the production of 6 vessels in total, with two designated for the German Navy and the rest for the Royal Norwegian Navy. An additional contract for a further four submarines for the German Navy was signed in December 2024.[88] Production capabilities and further development of the 212CD as well as its potential successors seem almost a given due to the extensive investment of the TKMS into its shipyard in Kiel, where it built a brand new production hall worth 250 million euro.[89] With over 300 workers on one shift, the new facility is one of the most advanced of its kind. Despite that, however, it is worth noting that the production queue for the near future is filled with the shipyard processing German and Norwegian orders until early-to-mid 2030s.

It is vital to note that as part of the agreement, fostering greater industrial and defence cooperation between Berlin and Oslo, all of the newly produced submarines will be garrisoned together in the Haakonsvern base in southern Norway, the current home of the *Ula* vessels, with new infrastructure to be built to accommodate German troops and provide the proper facilities for the 212CDs. The Haakonsvern base will also serve as the primary maintenance shipyard to support 212CD submarines' operations.[90]

While the new 212CD design is based on the German made 212A-class, and will without a doubt

utilize a number of solutions implemented in the older design, it will be an entirely new class of submarines. Already as per the available information, it can be seen that the new vessels will be an extensive upgrade to the capabilities of both the German and Norwegian navies and their capabilities to protect those states interests and security. Firstly, it is worth noting that the 212CDs are much larger than the 212As, with an increase in displacement from roughly 1,500 to 2,500 tons, length from around 56 to 73 m, beam from 6.8 to 10 m, and will feature an extended endurance compared with the older type. The hull itself has been designed in the form of a diamond to increase the vessel's stealth capabilities and decrease the chances of being discovered by active sonars. The new larger submarines will also feature an improved propulsion system based on an Air Independent Propulsion system produced by HDW/Siemens utilizing Polymer Electrolyte Membrane Fuel Cells. When installed on the 212A, the AIP system allowed the vessel to traverse continuously underwater for roughly two weeks.[91] The introduction of the lithium-ion batteries, a significant improvement on the lead-acid batteries installed on the 212As, would allow for longer underwater operations, possibly over three weeks.

TABLE 12 Specifications of Type 212CD

Country of Origin	Germany
Main Producer	TKMS
Displacement	2,500 tons
Length	73 m
Beam	10 m
Height	13 m (beam + sail/fin)
Crew	28 capacity for SOF
Submerged Endurance	Extended endurance over the 212A, possibly over 21 days
Total Operational Endurance	n.d.
Max operating depth	n.d.
Propulsion System	• Diesel-electric • Lithium-ion Batteries • AIP: Fuel Cells[112]
Armament	• Reportedly 8× 533 mm torpedo tubes*** for DM2A4 heavy torpedoes;[113] • new Common Heavyweight Torpedo reportedly under development (joint development program of Norway and Germany), • IDAS missiles • Reportedly up to 14 torpedoes/missiles in storage***[114]
Current Users	-
Future Users*	Germany Norway
Number Produced to Date	0
Number on Order	10 (Germany 2 + 4,[115] Norway 4)
VLS	NO
Cruise Missiles	YES (Potential integration of UGM-109 Tomahawk)**
Ballistic Missiles	NO

* Based on contracts signed to date
** Requires an additional contract with the United States through FMS
*** No official data available, other sources indicate that the 212CD will only feature four torpedo tubes and 12 weapons in storage

The Type 212CD submarines will enjoy greater capabilities in terms of the actual munitions used compared with the previous generation. The 212CD is expected to be integrated with both DM2A4 and new Common Heavyweight Torpedoes that is reportedly under development,[92] but much more importantly it will also be capable of being customized to utilize Harpoon anti-ship missiles, Tomahawk cruise` missiles,[93] and the Naval Strike Missile,[94] although such arrangements are yet to materialize. Such customizability would be very beneficial for potential customers and their specific needs. The most impressive upgrade, however, is the Interactive Defense and Attack System (IDAS) which would allow the submarine to engage both land and aerial targets, like for example hostile ASW helicopters, while submerged.[95] While the 212CD has not yet been completed, the IDAS has already gone through testing on a 212A submarine. While impressive the wide ranging munition capabilities of the 212CD might prove to be potentially problematic such as having to sign additional agreements to ensure the needed weapon system deliveries, like for example with the Tomahawk cruise missiles. Furthermore, the long production schedules would only allow potentially interested parties to examine a fully functional vessel and therefore its capability as a platform for the naval forces in 2029.

Submarine of the 212A class, the primogenitor of the Italian 212NFS
Author: Björn Wilke.
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3.5.2 U212 NFS – Fincantieri

The U212 NFS (Near Future Submarine) is the Italian evolutionary variant of the German 212A submarines, or rather the Italian version the U-212A Todaro class submarines. The main reason for the procurement of new submarines for the Italian Navy was the pressing need to replace the remaining four ageing, already upgraded, Sauro-class submarines. The *Documento Programmatico Pluriennale Della Difesa* for the years 2020–2022 released by the Italian Ministry of Defence outlined the need to acquire four new submarines to maintain a fleet of eight vessels (including four Todaro ships), that could protect Italian maritime interests.[96] The 2023–2025 edition of the Italian MOD's publication has further highlighted the need for a capable submarine fleet to protect Italian and NATO interests in the Mediterranean, highlighting the need to secure key trade routes, and protect against increasing Russian influence in the region.[97]

The new U212 NFS are supposed to be developed on the basis of the experience gained by the Italian industry with the U212A, providing new technological solutions that have been produced by the mobilised Italian industry, R&D and academia. The NFS will be slightly larger than its progenitor, with an extended pressure hull and increased displacement. The size increase will enable the installation of a more extensive CIC (Combat Information Center) with additional consoles, and a "new generation combat system with Leonardo-developed command management system and weapon control."[98] Fincantieri's design also boasts new lithium-ion batteries, a significant improvement over the lead ones installed on the Todaro class, which in combination with the increased fuel capacity, and hydrogen storage greatly increases the vessel's endurance.[99] The submarine will also be equipped with additional systems that enhance its capabilities in tropical environments, such as the Indian Ocean.

In terms of armament the NFS will be equipped with six 533 mm torpedo tubes, which will deploy Leonardo's Black Shark Advanced torpedoes. The vessel and its weapon systems are also customized to deploy cruise missiles with deep strike capabilities. However, there is only limited information on the type of the missiles that are to be integrated with the vessel or their actual capabilities as their implementation and utilization are still being evaluated by the Italian Ministry of Defence.[100] The vessel can be also fitted with a transport container, developed by CABI Cattaneo, which can act as a base for an UUVs, which can further enhance the submarines' capabilities by operating in difficult environments or enhancing the vessel's reconnaissance abilities.

The Italian design is quite noticeably an innovative solution, and one that is different from its

TABLE 13 Specifications of U212 NFS[116]

Country of Origin	Italy
Main Producer	Navantia
Displacement	1,550 tons
Length	58,3 m
Beam	7 m
Height	n.d.
Complement	29
Submerged Endurance	n.d.
Total Operational Endurance	n.d.
Max operating depth	n.d.
Propulsion System	• Diesel-electric • Lithium-Ion batteries • AIP: Reportedly Fuel Cells
Armament	• Leonardo Black Shark Advanced heavyweight torpedo (533 mm) • Reportedly cruise missile-capable[117] • No data regarding weapons in storage
Current Users	
Future Users*	Italy
Number of Vessels Produced to Date	0
Number on Order	4
VLS	NO
Cruise Missiles	YES (Potential integration of UGM-109 Tomahawk**)
Ballistic Missiles	NO

* Based on contracts signed to date
** Requires an additional contract with the United States through FMS

competitors. The smaller size of the vessel, in comparison to other new designs like the TKMS 212CD, is an interesting approach but one that casts doubt on the vessel's equipment capacity, like the amount of stored torpedoes, the range of its potential operational capabilities or the possibilities for future development and adaptation to emerging threats. What can be also noticed is the fact that these vessels will likely require additional approval from TKMS prior to procurement, making the acquisition process even more complicated in the eyes of potential buyers.

4 Conclusion

In the past decade, submarine design has undergone significant technological advancements, particularly in the integration of air-independent propulsion (AIP) systems and improvements in stealth capabilities. AIP technologies, such as fuel cell-based systems combined with lithium-ion batteries, have enabled submarines to operate without surfacing for extended periods, enhancing their survivability and operational effectiveness. Additionally, submarines have become more adaptable to evolving defense needs, with the ability to integrate advanced systems such as cruise missiles, unmanned underwater vehicles (UUVs), and vertical launching systems (VLS). These improvements are crucial for Poland's ORKA program, as they would enable the Polish Navy to project power far beyond the Baltic Sea, ensuring Poland's deterrence capabilities and strategic flexibility over the next 30 to 40 years.

Looking ahead, Poland's future submarines should prioritize capabilities for strategic land strikes, particularly through the integration of submarine-launched cruise missiles with ranges exceeding 1,000 km. This would significantly enhance the Navy's ability to defend Poland's strategic interests and provide the Armed Forces with the ability to strike key targets deep within enemy territory. The deployment of advanced multirole submarines equipped with powerful weapon systems and sensors will be a key component of Poland's multi-domain operational capabilities. These new vessels will also enhance interoperability among different branches of the Armed Forces. ORKA submarines, in particular, will not only elevate the Navy's overall effectiveness but also enhance the deterrence and defense posture of the Polish Armed Forces as a whole. The adoption of larger submarines, with increased payload capacity and operational flexibility, is also recommended, as they offer superior endurance, the potential for future upgrades, and the ability to integrate a broader range of weapon systems, including UUVs and support for special operations.

Poland's ORKA Program must evaluate several submarine options, each with distinct strengths and weaknesses. Proven designs, such as the French Scorpene and the South Korean KSS-III, offer reliable, modern platforms equipped with advanced AIP systems. Additionally, their integration with long-range cruise missiles is likely to be less complex compared to other designs that would require the integration of UGM-109 Tomahawk missiles, a process that necessitates separate government-to-government agreements with the United States.

In conclusion, Poland should prioritize larger, modern, and adaptable submarine designs capable of meeting both current and future defense needs. Submarines with advanced AIP systems and the capacity to integrate submarine-launched cruise missiles, would greatly enhance the strategic capabilities of the Polish Navy. While acquiring proven designs offers reduced risks, Poland must ensure that any chosen design can accommodate future upgrades and integration with cutting-edge technologies, including UUVs. The ORKA program should focus on securing platforms that not only bolster Poland's regional defense but also enhance its deterrence capabilities through the ability to conduct strategic strikes and operate beyond the Baltic Sea.

5 Recommendations

1. Poland should prioritize acquiring a submarine design that will significantly enhance the capabilities of its Navy and Armed Forces as a whole over the next 30 or 40 years. Acquiring more advanced submarines equipped with submarine-launched cruise missiles with ranges exceeding 1,000 km could bolster Poland's power projection, strengthen the Navy's ability to defend the country's maritime interests, and provide the Armed Forces with strategic capabilities, including the potential to strike key targets deep within enemy territory.

2. One key consideration is whether to acquire a proven yet modern submarine design or opt for a completely new design. It is essential to carefully evaluate the advantages and drawbacks of these two approaches. Choosing a proven submarine design could potentially lead to a faster delivery timeline and mitigate the risks typically associated with the development process of submarines, which often arise during the construction of complex naval vessels such as conventional submarines equipped with AIP systems. However, the selected design must be modern, adaptable for future upgrades, and capable of integrating new technologies to address evolving challenges.

3. It is also important to consider the delivery timeline, as the Polish submarine fleet currently consists of a single forty-year-old vessel that urgently needs replacement. Therefore, the procurement process should prioritize, among others, the producer's capability to deliver new submarines in a timely manner. Furthermore, the Polish Navy will require an interim or bridging solution to address gaps in Poland's defensive capabilities, resulting from future retirement of the ORP *Orzeł*. These considerations should be among the top priorities for Polish decision-makers in the ORKA program.

4. Despite the unique characteristics of the Baltic Sea, it is important to emphasize that a vessel's larger size, including its overall dimensions and displacement, offers several significant advantages. These include extended submerged endurance and the ability to operate continuously at sea, the capacity to integrate a vertical launching system (VLS), and an increased payload of weapons such as torpedoes, missiles, and mines. Additionally, larger submarines provide the flexibility to incorporate and store advanced systems in the future, such as unmanned underwater vehicles (UUVs), and support special operations. This larger size is especially crucial for submarines designed to conduct strategic strikes on land targets, as they must carry a diverse array of weapon systems to ensure both self-defense and offensive capabilities when necessary.

5. Given the range of technological options available on the market for air-independent propulsion (AIP) systems, most manufacturers appear to favor the integration of fuel cells in their designs. Currently, the only shipbuilding company likely to offer an alternative to fuel cells is SAAB, which employs a Stirling engine-based system in its submarines. In contrast, the French company Naval Group seems to have completely abandoned

the integration of AIP systems in its latest designs. Additionally, it is worth noting that fuel cell integration can be complemented by the installation of lithium-ion batteries, which further enhance a submarine's ability to operate covertly.

6. It is crucial to pay close attention to a producer's ability to integrate specific systems and to carefully evaluate the risks associated with their installation, particularly if the technologies in question are not yet fully mature or have not previously been integrated with the submarine type in question. This consideration is especially critical in the context of cruise missiles, as some manufacturers propose future integration of such weapon systems through external partners. In the case of Poland's future ORKA submarines, the integration of UGM-109 Tomahawk missiles would likely be required. These missiles would need to be procured through additional government-to-government contracts with the United States.

7. Unmanned Underwater Vehicles (UUVs) can effectively support submarine operations and enhance their capabilities. However, as a still developing technology, undoubtedly with significant potential, they should not be treated as a priority. With that in mind it would be prudent to consider submarine designs with the future potential for integration with drone technology as it fully develops, thus minimizing risks resulting from integrating this technology prematurely.

8. The new submarines should allow Poland and its Navy to operate not only within the boundaries of the Baltic Sea but also beyond it, as part of NATO operations as well as a critical tool of force projection. Such capabilities would further increase Polish deterrence capabilities and protect Polish interests worldwide.

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