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A paper submitted to the Faculty of the Joint Advanced Warfighting School in partial satisfaction of the requirements of a Master of Science Degree in Joint Campaign Planning Strategy. The contents of this paper reflect my own personal views and are not necessarily endorsed by the Joint Forces Staff College or the Department of Defense.

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Abstract

Throughout history, offensive and defensive weapons development continues to oscillate in a balance of power struggle. The submarine has been a naval weapon of significant consequence and one that changed the character of naval battle. The revolutionary invention of the nuclear-powered submarine not only made it a more lethal platform but one that is extremely versatile and multi-mission capable. It remained relevant to wars of modern day while other naval platforms like the battleship became obsolete. Platforms that replaced them like the aircraft carrier and the nuclear-powered submarine theoretically are in danger of a similar life cycle and run the risk of obsolescence if mitigations are not considered and implemented effectively. Given the promise of new technology and possible lapses in nuclear-powered submarine advantages, it too may become obsolete and further research into its operational value is needed. Analysis of the manned nuclear-powered submarine against competing technologies like Unmanned Underwater Vehicles (UUVs), Unmanned Aerial Vehicles (UAVs) including space-based assets, Air Independent Propulsion (AIP) and Artificial Intelligence (AI) and compared to their mission roles, including emerging high-risk theaters of the Pacific and the Arctic, highlights the nuclear-powered submarine's irreplaceable benefits. With modifications to technology and tactical/strategic employment of the platform, nuclear submarines will carry significant capabilities to fulfill a multi-mission role and prove to remain indispensable.

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Chapter 1: Introduction

Ingenuity on the battlefield has as much of a place as superior numbers, military might, morale and will soldier's will to fight. Revolutionary changes in warfare often occurred simultaneous to inventions that sought to counter offensive capabilities. Such a revolution occurred with the invention of the ironclad in response to incendiary long-range artillery in which a weaker side invented as means to create asymmetric advantage to counter overwhelming force. The Turtle submarine of the American Revolutionary War shows how using adaptive technology can create advantages and break the established norms of naval warfare of the time. The modern nuclear submarine emerged from an era where airpower, radar and sonar technology crippled the conventional attack submarines' (SSK) stealth characteristics. The natural progression, an adapt or die evolutionary requirement, in naval warfare; saw the submarine evolve multiple times in its lifespan and remain a relevant weapon through each era to the present. The world is approaching another period of revolution when the future of the submarine is to adapt or to drift into obsolescence.

There is a growing opinion that the oceans are becoming sensor rich.[1] With cheaper autonomous vehicles becoming available, a swarm of robots can make searching and detecting a submarine easier to do. That's the argument of a 2016 report by a British think tank, which contends that the growing numbers and sophistication of drones are depriving submarines of their stealth.[2] A briefing paper for Britain's Parliament

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[1] Michael Peck, *Navy Nightmare: Meet the 1 Thing That Could Make Submarines Obsolete*, (The National Interest: September 26, 2019). https://nationalinterest.org/blog/buzz/navy-nightmare-meet-1-thing-could-make-submarines-obsolete-83486

[2] Michael Peck, *Navy Nightmare*, September 26, 2019.

presented this position in consideration of whether to modernize or abandon the UK's ballistic missile submarines. The hypothesis essentially outlines the resulting conclusion on the question of who is the winner in an arms race of the small, cheap but numerous drones that can be employed in swarms to that of an expensive platform whose capabilities rely on not being detected. A number of emerging technologies such as Unmanned Underwater Vehicles (UUVs), Unmanned Arial Vehicles (UAVs), space systems, Air Independent Propulsion (AIP) and Artificial Intelligence (AI) are expanding and showing promise in playing a big role on the battlefield of tomorrow. These innovations degrade key submarine advantages and are making the proposition of the expensive nuclear-powered submarines becoming a technology of the past, and ineffective for the battlefield of the future. If these technologies go unchecked without implementing effective counter strategies and technologies, the submarine will become the hunted, as the German U-boat found itself to be in World War 2. With proper mitigations, nuclear submarines will remain viable well into the 21st century and in fact grow in significance because they carry significant capabilities that will fill a strategic and tactical role. Given the likelihood of increased offensive missile technology and increased vulnerability for surface combatants, submarines not only fill valuable roles but preserve an important operational advantage.

Submarines are vulnerable to various factors including technologies that create a difficult operating environment for submarines in the near future. Before illustrating the significance of these new developments, it will be first important to establish the context of submarine warfare in history and understand where it fits in naval warfare. Throughout history, offensive and defensive weapons continue to oscillate in a struggle for balance of

power. Using historical analysis, the research discusses the significance of naval power on the world stage, where the submarine played a part and changed the game. The role of the submarine changed through world wars to modern day and while some naval platforms became obsolete, like the ship of the line, the battleship, and potentially the aircraft carrier, the submarine adapted. However, now the nuclear submarine is experiencing another major transition in naval warfare and will need to adapt to remain relevant in this natural cycle. In addition to historical examples the analysis will refer to works by prominent historians and scholars such as A.T. Mahan, Sir Julian Corbett, J.F.C. Fuller, B.H. Liddell Hart, Robert Kaplan and others in order to answer the questions: Why is naval power and undersea dominance important to security, and why does the nuclear submarine remain a weapon of strategic importance?

Review of the theories behind emerging technologies and risks they present to the nuclear submarine. Developments in UUVs, UAVs, space-based assets, AI and information processing critical dangers. The technologies that threaten to nullify the stealth capabilities of the submarine, making it much easier to locate and target. Not only is it important to look at singular possible threat technologies, it is important to identify the critical ones where in concert as a system of systems, they achieve something new altogether. The combination of capabilities, when employed together, creates tactical changes and limitation effects which could add significant risk for viability of the submarine in general, not just nuclear-powered submarines. Locating a submarine at sea is an investigation that involves various stages of focus. The initial stage of establishing a general area of uncertainty (AOU) is as much art as science. The investigator is piecing together snippets of information from a multitude of sources to build the initial cues and

establish a confident AOU which could be pursued by localized search. This initial stage of AOU development is where a network of technologies mentioned above can make localizing a submarine quicker and easier. Anticipating this development and considering mitigations such as counter-autonomous-vehicle offensive weapons, next generation stealth technology and multiplication of force capabilities will ensure the emerging threats do not defeat the nuclear submarine. For the submarine to lose its tactical advantages would be an incredible blow to national security because it would limit the reach and effectiveness of the platform and detract from the overall strategic leverage U.S. naval force provides today. After investing billions of dollars of national funds into the nuclear submarine platform, the U.S. cannot afford to let it become obsolete. Proactive pursuit to develop tactics and technology to frustrate detection technology is critical to the future of the submarine as an effective lethal weapon and worth the expense.

A compare contrast analysis shows there is no true substitute to the nuclear-powered platform and in-fact more nations are planning to grow and develop the ships. However, reasonable consideration should be given to cheaper alternative options such as conventional and AIP submarines. Some mission areas have alternatives to the nuclear submarine and there are smaller nations making significant advances in submarine technology.[3] Interest in submarine acquisition is growing around the world. In one big way it is a status symbol as much as a military capability. Non-submarine nations like Thailand, the Philippines and Taiwan are seeking to develop a capable submarine force.

[3] Augusto Conte-Rios and Juan-Diego Pelegrin-Garcia, "A Revolution In Submarine Propulsion," *U.S. Naval Institute, Proceedings* Vol. 146/10/1412: October 2020. https://www.usni.org/magazines/proceedings/2020/october/revolution-submarine-propulsion

Japan is an example of a large submarine fleet operator that is a leader in conventional AIP submarine technology. There are advantages and specific tasking for such platforms however, after a through compare contrast analysis it will become evident that there is not true substitute to the nuclear-powered platform and in-fact more nations are looking to develop and obtain these ships. Some established conventional submarine operators in the Indo-Pacific like South Korea and others are looking to upgrade and are considering obtaining nuclear powered submarines. India being one of the newer operators is growing its small two nuclear submarine force and illustrating the fact that substitutes for the nuclear platform are still lacking and a submarine (nuclear-powered) (SSN) creates more options opening up the field for new possibilities.

Strategists or statesmen that think in three-dimensional warfare and in global terms can save their countries from being outmaneuvered on distant flanks of the global battlefield.[4] SSNs create depth and breadth of mobility and capabilities which speak to the "…essence of warfare, no region of the globe is too distant to be without strategic significance, too remote to be neglected in the calculation of power politics."[5] A gap analysis of the nuclear submarine mission roles on the modern and future battlefield presented in this paper will demonstrate the longevity we anticipate to witness well into the end of this century. The enduring nuclear strategic deterrent tasking as well as operations in remote and hard to reach areas of the globe far from support facilities require a reliable, abundant and self-contained energy source such as the naval nuclear reactor. Because of the vast distances and long deployment periods there is still no viable

[4] Nicholas J. Spykman, *America's Strategy in World Politics: The United States and the Balance of Power* (New York Harcourt, Brace, 1942), p. 165.

[5] Nicholas J. Spykman, Ibid., p. 165.

substitute for a power supply. However, for these mission sets to be adeptly covered into the future, there are technologies and mitigations that will be required in communication, stealth, self-defense capabilities and flexibility of offensive weapons for the submarine fleet. Technologies like deployable and retrievable UUVs, UAVs, submarine-fired lasers, anti-ship missiles as well as coordinated fleet operations will be needed for this next contest. Chapter 8 highlights the possible mitigations to losing the strategic and tactical advantage. IT also analyzes the technologies necessary to ensure the longevity and viability of the nuclear-powered submarines though the next cycle of competition.

The frontier of the next conflict will be challenging. It is likely to be fought in the Pacific and in regions far north as well as under the Arctic ice. "The Arctic, especially if it warms, will give new meaning to sea power... in future decades" and in combination with airpower the "…increased use of polar routes will bring the United States, Russia and China in an ever-tighter embrace."[6] As geography becomes more accessible it is likely to become more crucial.[7] Russia is investing in a fleet of nuclear ice breakers attempting to open norther trade routes and access to energy. They are establishing permanent basing far north with a specialized military branch consisting of Arctic mechanized infantry units. China is making a statement that they are an Arctic nation. Nuclear submarines are the only reliable platform able to operate in the vastness of the Arctic Ocean, including under the ice, and therefore will be a significant factor in influencing which world power leads the new frontier at the top of the world. A.T. Mahan held the navy in very high regard and not only deemed it more important than land power

[6] Robert Kaplan, *Revenge of Geography: What the Map Tells Us about Coming Conflicts and the Battle against Fate* (New York, NY: Random House, 2013), 101.

[7] Albert Wohlstetter, *Illusions of Distance* (Foreign Affairs, New York, January 1968).

but also less threatening to national stability as it had limits on projecting coercive power inland. "[The Navy] keeps open the communication between its own ports; it obstructs those of the enemy; but it sweeps the sea for the service of the land, it controls the desert that man may live and thrive on the habitable globe."[8] The major economic and strategic theater of the Pacific must be discussed in order to envision how submarines may influence whether there will be a war or peace. A case study analysis of the defense of Taiwan problem and the role the submarine may play will demonstrate the need for such a platform not only in the present but future conflict in the theater. Discussion on specific issues of the Pacific and the Arctic area will ground all of the discussed features in a case example of where the nuclear-powered submarine is needed and how it will help fulfill strategic goals.

Finally, the closing summary covers the risks, mitigations, and reinforce the vision of the next few decades in submarine warfare. Without a viable submarine force that can travel far, remain on station for long periods of time undetected and strike decisively at sea-borne and land targets alike, the United States will not be able to project its global power. In order to do so the silent service must maintain its stealth and agility to change. Operating alone, independent, with exceptional skill and confidence, and comfortable with the constant danger is what made the submarine force successful thus far. Even in the absence of an enemy, the submarine crew remains keenly alert living inside a complex machine and operating dangerous systems in an unforgiving harsh dynamic environment where mistakes have grave consequences. This fact, the tradition

[8] Alfred T. Mahan, *The Influence of Sea Power Upon History* (New York: Dover Publications, Inc.: 1987) [Reprint of 1894 Little, Brown edition], p. 329.

of the warrior spirit, and the necessity for cerebral technical professional excellence are assets and power in themselves. This in concert with technology will continue to give the U.S. nuclear submarine force an edge and provide the ability to meet the challenges of demanding and dangerous theaters of conflict around the planet. Undoubtedly the United States submarine warfighter will remain at the sharp tip of the spear well into the latter half of the 21st century.

Chapter 2: The Historical Context

From the Greco-Persian War at Thermopylae through the events of the Peloponnesian War and destruction of the Athenian navy, war between Rome and Carthage, Napoleon's Trafalgar, the British Empire and the American Revolution, Barbary Pirates to World War I and ending in modern day conflict, naval forces had indisputable significance on global warfare and commerce. The invention of the submarine introduced a new layer of warfare at sea similar to how aircraft influenced terrestrial battle. Submarines transformed an open two-dimensional plane into a battlefield with a third unseen and difficult to reach ecosphere. The advent of the aircraft carrier extended the reach of aircraft and added yet a fourth dimension to war at sea, making it more dynamic and unpredictable.

The Great War saw the first extensive use of the submarine in warfare. Britain blockades German access to the Baltic Sea for most of World War I. Britain, having a larger surface fleet, and Germanys' inability to achieve a decisive victory at sea despite tactical success at the Battle of Jutland, lead to Germany's decision to overcome the disadvantages by employing the submarine. Through the strategy of unrestricted submarine warfare, Germany sought to sink merchant shipping that supplied Britain and create a blockade of their own. The German innovation resulted in great success and over 1 million shipping tons were sunk.[1] If it were not for the Kaiser rescinding his order permitting unrestricted submarine warfare due to the threat from the United States to

[1] William Kelleher Storey, *The First World War: A Concise Global History, 2d ed*, (New York: Rowman and Littlefield, 2014), 77-79.

enter the war, submarine warfare may have decisively choked off supply to the British Isles.

World War II demonstrated that the submarine menace of World War I, destructive as it was in the beginning of the war with significant success and famously alarmed Winston Churchill. Churchill was quoted as saying, "—the only thing that ever really frightened [him] during the war was the U-boat peril."[2] The U-boat was not invincible. The ultimate failure of the U-boat campaign was due to the development of tactics, radar and sonar technology, airpower and SIGINT that limited the submarine and countered its advantages leading to neutralization.[3] Admiral Doenitz planned to deploy a new Walter type submarine designed to reverse the grim situation for the Germans. The large submarine could remain underwater for long periods of time running on a new perhydrol fuel maintaining high speeds while submerged but the war ended prior to implementation.[4]

In an effort to improve submarine lethality, submarine technology post-war advanced to maximize stealth and independence of operations. Introduction of the nuclear-powered submarine capabilities relegated conventional boats to costal and local operations. The submarine as it made some advances also lost some capabilities such as attacking smaller targets. The deck gun to eliminate small surface vessels and the anti-aircraft guns to defeat airborne threats disappeared. In the era of a multitude of technologies, submarines must not lose the flexibility naval platforms need to possess.

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[2] Winston S. Churchill, *The Second World War: Their Finest Hour* (London: Cassell, 1949), 528-29.

[3] Clay Blair, *Hitler's U-Boat War: The Hunters 1939-1942*. (Random House: New York, 1996), 128-129.

[4] Michael J. Lyons, *World War II: A Short History, 5th ed.* (New York: Routledge, 2010), 217-219.

Warships need to be able to not only combat peer adversaries but also handle asymmetric engagements. The case of the German battleship Bismarck shows how technological design often leads to technological tradeoffs that prove costly when not fully understood in the operational environment.

The modern and state of the art Bismarkt had anti-aircraft sights geared towards aiming at fast-moving targets. When the slow-flying attacking Swordfish bi-planes made their approach towards the battleship, none were hit, and they were able to successfully launch a torpedo attack that crippled the Bismarck, allowing the Royal Navy to sink it. The competition between offensive and defensive capabilities is an ongoing process. The submarine platform must continually make adjustment to the environment in a development cycle of offensive and defensive capabilities in order not be rendered obsolete as was the case with previous historical examples.

Tactics of naval warfare are changing and the submarine is partially responsible. There are inherent differences between land and sea warfare and Sir Julian Corbett asserts that these differences are far-reaching. The ability to take the fleet out of combat by safely harboring in port or close to home shore prevents the stronger enemy from holding a decisive battle. Corbett describes this dilemma as embarrassing because when the enemy withdraws from the sea, in order to reach them, assistance of the army is required and the services dislike requiring support from other services .[5] The defensive attitude that employed retreat and sporadic counter strike tactics frustrated the dominant

[5] Julian S. Corbett, *Some Principles of Maritime Strategy* (New York: Dover Publications, 2004) [Reprint of 1911 Longmans, Green edition], 104-106.

sea powers of the last centuries and rendered decisive victory out of reach. The technique prevailed for many centuries.

Until World War II adversaries attempted to force the enemy from safe harbor to sea for a decisive battle. This began to change as technology evolved. The allies repeated attacks on the German battleship Tirpitz (Bismarck Class) while harbored in a Norwegian port using strategic bombers and midget submarines marked a major shift in tactics. The Tirpitz was ultimately destroyed inside the port. In modern warfare with long range precision missiles, a vessel in-port is a fantastic static target and defenseless in many ways. The ships are not typically operationally manned and defensive systems are not ready. It is vulnerable to attack from sea or air. However, an approaching surface ship or aircraft can be detected and countered by supporting forces before an attack occurs. A nuclear-powered submarine with missiles and torpedoes possesses the ability to position undetected within range that can hold ships in-port at risk and strip them of the safe harbor. The tactic is a new development for naval warfare and explains why the Chinese People's Liberation Army (PLA) is building underground tunnels for their vessels. The tunnels will protect their ships from attack while in harbor. Contrary to traditional understanding of naval warfare, it can be reasoned that there is now more safety at sea while underway with ready weapon systems, and a moving ship presents a harder target. The modern submarine creates a dilemma. If the enemy navy decides to put out to sea, a nuclear submarine can intercept and attack the surface action group (SAG) as it leaves home port or shadow the SAG until a time of a commanders choosing, maintaining tactical control and holding it at risk.

The concept of the vastness of the sea and its safety as a defense also changed after World War II. It was the case that a fleet can slip away and remain unlocated by the enemy as was the case with the Japanese fleet that sailed to conduct a surprise attack on Pearl Harbor in 1941. A fleet has many more options for maneuver than on land where geography dictates limits in direction of movements and therefore makes things more predictable. At sea the liability of missing the enemy is much greater. Finding and engaging the enemy was a difficult task.[6]

Today, however, locating enemy surface ships is much more achievable. In fact, with satellite, radar, aircraft and commercial vessels, a surface fleet is not that difficult to locate. The sea is a vast unobstructed plain without mountains, valleys or forests to obscure movement, especially for a large fleet. To regain the characteristics and advantages of open ocean naval warfare, large warships with firepower and speed have to submerge beneath the waves. A large nuclear submarine with bigger payloads than before can disappear beneath the surface and reappear at a time of its choosing, seizing the advantages for itself by exacerbating the difficulties for the adversary of a vast ocean.

A modern nuclear submarine enables hitting while guarding, the inevitable consequence of duality in war that Liddell Hart described when he wrote of the basis of strategy. To achieve effective concentration for decisive action the enemy has to be adequately dispersed. "For if the enemy is certain as to your point of aim he has the best possible chance of guarding himself—and blunting you weapon."[7] The submarine forces dispersion and dislocates the enemy by flexible maneuver that keeps the enemy at a

[6]Corbett, *Some Principles of Maritime Strategy*, 107-108.
[7]B. H. Liddell Hart, *Strategy*, 2d rev. ed. (New York: Meridian, 1991), 329.

perceived disadvantage. An enemy that is distracted and in fear of being trapped is deprived of the freedom of action. The SSN is a weapon that can create these effects by shifting from operating undetected and dispersed to overt action and concentration. Most importantly it forces the opponent on defense and deprives fit of freedom of action physically and psychologically. Also significant is the fact that a submarine fleet at sea is safer from attack than a surface fleet at sea or in port. The dilemma of choosing weather to keep your force at sea or in port is somewhat moot with respect to the nuclear submarine. It is a great platform to hide at sea or worst case in a tunnel in port. In the vastness of the ocean, you can maintain your submarine forces both ready for action and safe from preemptive attack. The mere existence of a fleet that is safe from attack and maintains offensive capability is of great strategic value. This is the idea of a "fleet in being" that originated in 1690 during a conflict with the French where the British in alliance with the Dutch found themselves at a disadvantage in home waters.[8] Having a force that can give battle but more importantly holds the enemy at risk and attack when necessary showed that an inferior fleet when employed to frustrate an enemy's plans and rob them of a decisive victory while sapping them of resources and advantage can achieve strategic aims. From this standpoint a nuclear platform with a routine high operational tempo creates a continuous "fleet in being" at sea. Typically, U.S. submarines operate for 6 months forward about every other year. This means there could be a dozen or more submarines on mission around the world. That's hundreds of torpedoes and tomahawk missiles safe from enemy attack and close to the enemy for a strike. In a period of heightened tensions this number can be greatly increased and provide a strong

[8]Corbett, *Some Principles of Maritime Strategy*, 144-156.

survivable “fleet in being” while remaining less provocative than an overt SAG presence. There is a case for the modern nuclear-powered submarine to be the bedrock of a future navy, but once again technologies taking shape today are threatening to put the submarine on its heels. The next few chapters discuss these threats and necessary adjustments required for the platform to remain relevant.

Chapter 3: Technology Threats

Unmanned Underwater Vehicle (UUV) Capabilities

Developments in the UUV sector have been very innovative from an engineering standpoint as well as consequential to the submarine in particular. The growing number of UUVs in the ocean and their onboard sensor capabilities pose a risk to the submarine in losing its stealth but they also provide opportunities in using UUVs as counter measures and mission enhancers.

Many U.S. firms are now building experimental models and developing operational units for the military. BAE has been expanding its manufacturing capacity for UUVs by acquiring smaller companies like Riptide Autonomous Systems and building production facilities. These BAE UUVs are small and portable vehicles ranging in size from twenty-five pounds at 4.875-inch-diameter to 240-pound, 9.375-inch-diameter. Not only are these vehicles small but they are capable of extreme depths and lowest power usage rates in the industry. Energy being one of the most limiting factors to UUV implementation means those that can pack more power and exhibit most efficiency will have a broader range of capability and see a bigger rate of employment. These vehicles have been demonstrated in conducting signal intelligence collection of radio transmissions and transmitting this data acoustically to a surface vessel.[1] Development and incorporation of these vehicles into submarine operations means that a nuclear-powered ship can carry a large inventory and deploy them in mass for various mission types that include: intelligence collection, seafloor surveillance, mine countermeasures,

[1] Various, *BAE Systems Expanding Riptide UUV Manufacturing Capacity*, (Legal Monitor Worldwide, SyndiGate Media Inc.: May 2020).

harbor penetration/defense, decoy and deception, and many other roles. The Navy is growing its interest in UUVs with major tech companies taking part. General Dynamics Mission Systems' the Bluefin Robotics line of UUVs, is operating medium size vehicles for multi-mission applications. Utilizing machine-learning algorithms via onboard automated target recognition (ATR) software, UUVs can autonomously analyze data and send updates on potential targets to operators acoustically while submerged or via satellite when on the surface.[2]

Developing standards for command and control like the U.S. Navy's Unmanned Maritime Autonomy Architecture (UMAA) will allow various types of UUV units to swiftly interface with one another and integrate mission-vital sensors across platforms. With standardization, concepts like the Defense Advanced Research Projects Agency's (DARPA) Mosaic Warfare could broadly expand the reach and function of UUVs as detection platforms that are able to convey pertinent mission information to commanders, other manned units, and networks of UUVs to achieve greater effects. Under the Naval Sea Systems Unmanned Maritime Systems (PMS-406) office, Boeing is developing future systems as well. The submarine Navy is interested in small- and large-delivery UUVs (LDUUVs) due to the payload capacity benefits.[3] PMS-406 program manager Capt. Small said, "The real purpose of that vehicle is that we're pretty sure we're going to always want a large-payload, large-endurance UUV capability that can be deployed from a submarine." Being able to carry, deploy and recover UUVs from a submarine is challenging and will require a lot of work in order to achieve operational efficiency. Not

[2] Michael Guay,, and Gordon Clark, "UUVs on the Frontier: Augmenting Naval Operations in the New Decade," *Sea Technology*, 61 no. 6: June 2020), 23–26.

[3] Daniel P. Taylor, *CHARTING COURSE ON UUVs.* (Sea Power 62, no. 8: October 2019), pp 29–31.

all UUVs are designed to be host surface ship or submarine deployable. One of the largest of these vehicles is the Orca. It is an extra-large UUV which completed first phase of design contract with Boeing for five units. This UUV is very similar in shape to a manned submarine minus the sail and is designed for long range and long endurance operations that are independent of a host ship. A fairly new Navy squadron, the Unmanned Undersea Vehicle Squadron One (UUVRON-1) has been established to organize and manage these and other like machines. As the number of units and complexity grows, it is likely the Navy will have many new UUV squadrons to provide logistics and operational support for these vehicles.

Figure 1: Boeing's Echo Voyager, a precursor to the Orca extra-large UUV. Source: Daniel P. Taylor, CHARTING COURSE ON UUVs. (Sea Power 62, no. 8: October 2019).

In 2020, Iran conducted a ceremony to launch over 100 new boats, which included a vessel with no sail, which suggests it is uncrewed, comparable to the Boeing Orca XLUUV. Based on initial evidence it may lack sophistication but presents Iran's

interest and implied threat potentially intended to give the U.S. Navy pause.[4] Russia maintains high capacity for technological prowess and has developed an autonomous nuclear propulsion, 10-20 megaton nuclear warhead torpedo named Status-6 Kanyon or "Posideon." It is a very large 6.5 ft. diameter, self-operating, AI enhanced torpedo that can operate 7 months without maintenance with a twenty-year operating life. The weapon can be deployed from a mothership such as the Ocsar II Belgorod which can carry six of these weapons.[5] This weapon can loiter in distant areas off enemy shores or in deep waters of the oceans awaiting instructions and then return to home waters for recovery months later. Another interesting UUV is the Harpsicochord-2P-PM or "Klavesin". It is an autonomous side scan sonar UUV that can deploy from a mothership and return to it after mission is complete. Other systems address power requirements of underwater systems like the "Shelf". It is a self-contained undersea portable reactor that can power underwater hydroacoustic arrays and potentially do more things like recharge UUVs.

China is not lagging behind. The HSU-001 UUV recently on display during a parade is indicative of large UUV technology being pursued by major military powers.[6] The HSU-001 is similar in size to Boeing's Orca and is likely to be designed for long endurance missions with potential to carry an offensive pay load capability. There are larger platforms like the 150-foot unnamed sail-less submarine that was launched by the PRC Navy. The lack of the sail suggests that it is an uncrewed vessel because a crewed submarine requires a raised superstructure like the traditional sail for access of personnel

[4] Various. *Iran's UUV to add new dimension to its warfare capability*. (Forbes. *Tehran Times* [Tehran, Iran]: 30 May 2020).

[5] Various. *"Russian Defense Ministry says work on oceanic system equipped with Poseidon nuclear submarine drones currently at final stage."* (Russia & CIS General Newswire, 26 July 2020).

[6] Joseph Trevithick, *Four Of The Biggest Revelations From China's Massive 70th Anniversary Military Parade,* (TheDrive: October 2019).

while at sea and manning the sail while on the surface. If so, it would make this the largest UUV in the world.[7] It is likely to be a testing and training platform

Figure 2a: Left: HSU-001 on display at the PRC 70th anniversary military parade. Source: Joseph Trevithick, "Four Of The Biggest Revelations From China's Massive 70th Anniversary Military Parade," TheDrive, October 2019.
Figure 2b: Right: The launch ceremony of the so-called 'sail-less' submarine in October 2018. The name or purpose of this submarine has not been revealed. Source: H.I. Sutton, "The Chinese Navy's New Mystery Submarine," Forbes, October 2019.

for attack submarines and other surface and air assets.

UUVs allow for loiter capabilities and multiplication of force if operating in a swarm. The hardware is an important aspect but autonomous systems require the electronic brains to run them. The degree of coordination necessary for swarms to function is highly complex. Indicators suggest that Chinese scientists are working hard on this subject and are possibly achieving results. In a 2020 paper published by Chinese scientists titled "A Behavior-Driven Coordination Control Framework for Target Hunting by UUV Intelligent Swarm," the authors claim to have achieved significant improvement and efficiency with coordination control of unmanned underwater vehicle intelligent swarms (UISs) by implementing dual-switching from global to local control in their

[7] H.I. Sutton. *The Chinese Navy's New Mystery Submarine.* (Forbes: October 2019).

simulation trials.[8] Incorporating global-control to search for targets and local-control for tracking and capture, resolves behavior conflicts and constraint differences to improve UIS target hunting with great performance of efficiency in an unknown and uncertain environment. Technologies to improve self-organization and fault-tolerance are key features that will make it possible to capitalize on mass of UUV swarms and make UISs effective at pursuing missions at sea. UUV decision making is of extreme importance. This is a limited interaction environment that requires accurate target recognition and cooperation of vehicles. Vision systems are being improved with intelligent recognition methods like the kernel two-dimensional nonnegative matrix factorization (K2DNMF) which can potentially enhance underwater target recognition facility of the UUVs vision system.[9] Multi vehicle cooperation depends on innovative dynamic maneuver decision-making algorithms being developed that are based on the combination of game theory[10] and intuitionistic fuzzy sets. [11]

The underwater environment, with its difficulty in communications, environment noise and uncertainties, presents varied degrees of data accuracy and therefore requires techniques like intuitionistic fuzzy sets, to assign membership values to questionable

[8] Liang, H., Y. Fu, F. Kang, J. Gao, and N. Qiang. "A Behavior-Driven Coordination Control Framework for Target Hunting by UUV Intelligent Swarm," *(*IEEE Access, Access, IEEE 8: January 1, 2020).

[9] Xu, Jian, et al. *Kernel two-dimensional nonnegative matrix factorization: a new method to target detection for UUV vision system.* (Complexity, vol. 2020: January 2020).

[10] "**Game theory**, branch of applied mathematics that provides tools for analyzing situations in which parties, called players, make decisions that are interdependent. This interdependence causes each player to consider the other player's possible decisions, or strategies, in formulating strategy. A solution to a game describes the optimal decisions of the players, who may have similar, opposed, or mixed interests, and the outcomes that may result from these decisions." Steven J. Brams and Morton D. Davis, *Game theory*, (Encyclopædia Britannica: August 2020). https://www.britannica.com/science/game-theory

[11] "**Fuzzy set** is a mathematical model of vague qualitative or quantitative data, frequently generated by means of the natural language. The model is based on the generalization of the classical concepts of set and its characteristic function" Milan Mares, "Fuzzy Sets," *Scholarpedia*, 1(10)2031: 2006. http://www.scholarpedia.org/article/Fuzzy_sets

inputs and solve the major problems of making decisions at sea.[12] Multi-vehicle maneuver is difficult to achieve and requires various approaches such as Particle Swarm Optimization[13] and Nash Equilibrium[14] Theory, to determine the optimal maneuver strategy. Development and testing of these new brains and systems in such a difficult environment will be challenging. Like a submarine that is at times information and sensor data deprived, the UUV will find itself alone and unafraid with a set of circumstances and a mission set where the utility of its decision-making process will require high degree of autonomous operation. Many autonomous decision-making methods are being developed. One such method is based on a dynamic influence diagram (DID) and expected utility theory for reasoning, prediction, judgment, and plan selection uses a model with decision-making nodes and expected utility nodes used in the process of its project selection. The UUV, based on the threat assessment results, will determine the utility of each decision-making plan using the decision-making nodes and infer maximum expected utility to select an optimal autonomous decision-making plan. With a dynamic and unpredictable environment, methods like DID will have to be extremely sophisticated.[15] A system that reveals itself or self-destructs more often than not, will not

[12] Liu, Lu, Lichuan Zhang, Shuo Zhang, and Sheng Cao. "Multi-UUV Cooperative Dynamic Maneuver Decision-Making Algorithm Using Intuitionistic Fuzzy Game Theory," *Complexity*, 2020.

[13] "**Particle swarm optimization (PSO)** is a population-based stochastic approach for solving continuous and discrete optimization problems. In particle swarm optimization, simple software agents, called *particles*, move in the search space of an optimization problem. The position of a particle represents a candidate solution to the optimization problem at hand. Each particle searches for better positions in the search space by changing its velocity according to rules originally inspired by behavioral models of bird flocking. Particle swarm optimization belongs to the class of swarm intelligence techniques that are used to solve optimization problems." Marco Dorigo et al., "Particle Swarm Optimization," *Scholarpedia*, 3(11):1486: 2008. http://www.scholarpedia.org/article/Particle_swarm_optimization

[14] "**Nash equilibrium** is a concept within game theory where the optimal outcome of a game is where there is no incentive to deviate from their initial strategy." James Chen, "Nash Equilibrium," (www.investopedia.com: Feb 2020)

[15] Yao, Hongfei, Hongjian Wang, and Ying Wang. *UUV Autonomous Decision-Making Method Based on Dynamic Influence Diagram.* (Complexity: 2020).

be effective or efficient and therefore, it is likely that autonomous operation advances will be most innovative in the world of UUVs, where like in the submarine force self-reliance and operating in uncertainty is paramount.

The commercial unmanned underwater vehicle market was worth USD 2.69 Billion in 2017 and it is projected to almost double by 2022 to USD 5.20 Billion. This increase in large part is driven by offshore drilling and security concerns but the defense sector is continuing to surge demand in the sensors segment and is projected to witness the highest growth, due to bigger use of sensors in military application of scanning, detecting, mapping, and remote sensing.[16] These system from small to large have the potential to consistently patrol coastal waterways and open oceans looking for submarines. Once detected they can communicate with one another as well as central coordination stations to call in further assets to the swarm in order to verify detection and box in the submarine unveiling its stealthy cloak. For the submarine to remain viable, they will have to develop tactics and methods to counter the UUVs. Incorporating UUV technology into submarine operations to generate defensive capabilities in the form of decoy and false contact generation thereby distancing the manned ship from danger and frustrating the swarm contact confirmation will give the initiative back to the submarine on the future battlefield.

Unmanned Aerial Vehicles (UAV) and Space

There are a number of new systems being developed in the field of air and space. Since World War II, the biggest threat to a submarine came from the air. The advantages

[16] *"Unmanned Underwater Vehicles (UUV) Market Worth 5.20 Billion USD by 2022."* (M2 Presswire: 2020). Accessed on 3 Oct, 2020. https://link.gale.com/apps/doc/A632330408/ITOF?u=wash60683&sid=ITOF&xid=d4b3cb46.

of air and space platforms are mobility, range, communications but mainly visibility based on the height of eye. Increased numbers of satellites and air vehicles puts more eyes in the sky that can potentially detect a submarine. Flying machines from small to large are providing more persistent sensor coverage from the skies. They can be low altitude, small, short duration mission or high-altitude pseudo-satellite (HAPS) with a 262-foot wingspan like the solar powered Sunglider which flies at an altitude of 65,000 feet on months-long continuous missions without a need to land.[17] These platforms allow detection of the submarine on or near the surface in more ways than only visually. The periscope above water presents an opportunity to be detected by radar or heat signature. The wake of the periscope which develops due to the movement of the submarine can also be distinguishable. At night the movement of the submarine through biologics such as plankton creates bio luminescence and the path of the sub literally lights up and can clearly be detected from above. This is similar to seeing the contrail of an aircraft flying at high altitude. Even if the submarine is not raising any masts, aerial systems can see the silhouette of the submarine near the surface. This is largely dependent on sea conditions, water clarity and lighting. This is why it is preferred to limit and minimize the number of times a submarine needs to come to the surface or periscope depth but even at depth the submarine might not be hidden. Specialized sensors can peek deeper beneath the surface and, by using certain frequencies of light, penetrate into the depths. Light scatters very quickly in water but green and blue light can travel further. In 2018 Chinese scientists said that they are developing laser equipped satellites that are geared towards detection of submarines and the wake they create. According to the South China Morning Post,

[17] "AEROVIRONMENT SUCCESSFULLY COMPLETES SUNGLIDER SOLAR HAPS STRATOSPHERIC TEST FLIGHT," *ENP Newswire*: October 8, 2020.

researchers at the Shanghai Institute of Optics and Fine Mechanics say they have tested lasers and very sensitive detectors that can detect objects more than 160 meters (525 feet) beneath the surface and require just a few photons for detection.[18] Limitations on this device will be power as powerful lasers require lots of power that satellites typically do not have. Detecting the wake of a submarine with light will be extremely hard as there is quite a bit of noise and activity in the ocean and although pursuit of wake detection is not a new idea, there is no reliable evidence available that it has been done effectively in practice. With respect to detecting the submarine itself, there is the problem of a "big ocean small target" theory and the question of how reflective a target is.

The difficulty with locating a submarine this way is significant. There are big challenges, one of which is the need to cover a lot of ocean and without other cueing this is a lengthy task. Even if the area can be limited to a small portion of the ocean to find the submarines' slender thin and rounded profile from the top is a challenge due to a narrow surface area for reflection. Additionally, the submarine is black and already absorbs energy with its hull. To even further reduce the submarines reflection coefficient and counter this detection from above technology there are fairly simple remedies that can be implemented at very low comparative cost in the form of specialized paint to be applied to the top area of the submarine and help scatter and absorb any reflections back to space. NASA engineers have developed a material that absorbs more than 99 percent of the ultraviolet, visible, infrared, and far-infrared light that hits it. The team of engineers at

18 Michael Peck, *China is Trying Really, Really Hard to Detect U.S. Submarines*, (The National Interest: December 2020).

NASA's Goddard Space Flight Center in Greenbelt, Md., reported their findings almost a decade ago at the SPIE Optics and Photonics conference.[19] The team produced nanotech-based coating consisting of a thin layer of multi-walled carbon nanotubes. These tiny hollow tubes made of pure carbon about 10,000 times thinner than a strand of human hair are able to absorb 98 - 99.5 percent of light depending on wavelength. Other researchers are reporting approaching 100 percent absorption levels mainly in the ultraviolet and visible range. Many other labs have made developments in vertically aligned nanotube arrays (VANTA) and produced products such as "VantaBlack" (Figure 3), a trademarked name by Surrey NanoSystems Limited, one of the darkest materials known, which absorbs 99.965 percent of visible light.[20]

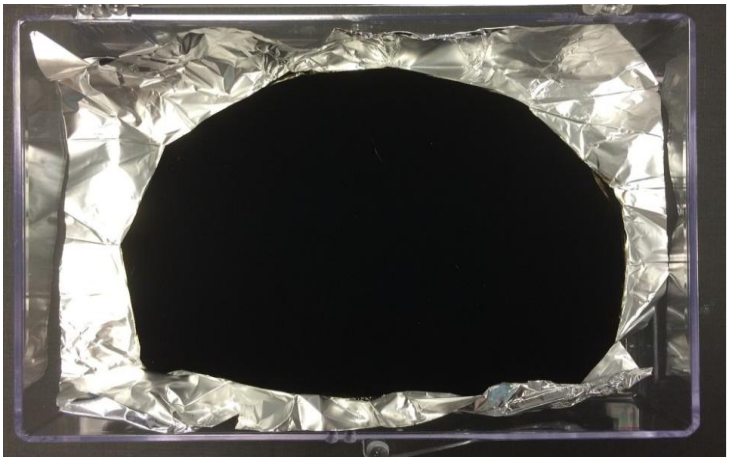

Figure 2: "Vantablack" on equally crinkled tinfoil Open Source: Free Image VantaBlack Image. https://en.wikipedia.org/wiki/Vantablack#/media/File:Vantablack_01.JPG.

It can be reasoned that application of this and similar materials in creative camouflage patterns can potentially make the submarine invisible to energy sensors from above. Kinetic and electromagnetic energy-absorbing coatings for sound, radar and light

[19] Lory Keesey and Ed Campion, "NASA Develops Super-Black Material That Absorbs Light Across Multiple Wavelength Bands," *NASA*, Goddard Release No. 11-070: Nov 2011.

[20] Surrey NanoSystems. https://www.surreynanosystems.com

have seen a dramatic improvement with the rise of nano-tech. With further development and a decade of study already behind us it is reasonable to say that the counter-detection technologies are not too far behind detection sensor research and will continue to compete.

Another creative detection system being mounted on aerial vehicles is magnetic anomaly detectors (MAD). In the past, to achieve a high degree of sensitivity these detectors required sophisticated hardware often using very low temperatures approaching absolute zero, lasers and significant power. A team in Wuhan reports to have developed bean-sized highly sensitive detectors. If these devices can be made operational, they would not need large aircraft to implement and can be installed not just on aircraft but on smaller aerial vehicles like UAVs.[21] These MAD devices have been around since World War 2 but had limited range. They are able to detect the magnetic field disturbances or anomalies in the Earth's magnetic field caused by ferromagnetic materials such as large metal objects like submarines. The new superconducting quantum interference devices (SQUID) are a lot more sensitive but have until now been limited to laboratories. They have not been implemented due to limited practical field application as they are quickly overwhelmed by background noise out in the real world. Environmental effects like solar storms and minute changes in Earth's magnetic field can significantly affect the detectors. The new magnetometer, built by Shanghai Institute of Microsystem and Information Technology, uses an array of SQUID detectors in an effort to filter through the noise and achieve a more consistent detection. It could potentially increase detection range of the magnetic signature from a few hundred

[21] Michael Peck, *China is Trying Really, Really Hard to Detect U.S. Submarines*, (The National Interest: December 2020).

meters to 6 km or greater.[22] This would be a significant improvement. In 2019, U.S. military researchers asked the defense industry to develop a small 36-pound UAV equipped with a MAD that can deploy from the U.S. Navy P-8A Poseidon maritime patrol aircraft (MPRA) sonobuoy launcher to detect submarines.[23] Submarines do have countermeasures to this. There are magnetic health checks for all submarines and special degaussing systems and ranges designed to treat the submarine and reduce its signature. However, after these checks and corrections the metal tends to lose the magnetic stealth capability and requires periodic attention. Solving the magnetometer background noise is not simple and Cathy Foley at CSIRO, the Australian government research agency, feels there are several difficulties with turning a SQUID into a sub-hunter. Although no one has solved these problems yet, the Chinese rate of progress means they may well be first to do so. Scientific and engineering efforts to lower submarine magnetic signature and confuse the sensors with other active devices will be needed to counter this technology but the submarine can use UAVs to its advantage as well. The Navy conducted a successful demonstration of the submarine-launched Blackwing™ UAV to link with a swarm of UUVs via a secure digital datalink called DDLTM and communicate with the submarine combat control system. These types of UUVs are key to submarines ability to work in an Anti-Access/Area Denial (A2/AD) environment.[24] They can serve as a communications relay between geographically separated allied manned and unmanned air and sea assets or provide intelligence gathering and targeting data. Potentially, submarine

[22] David Hambling, "China's quantum submarine detector could seal South China Sea," *New Scientist*, Technology: August 2017.

[23] John Keller, "Industry to Develop Magnetic Anomaly Detector (MAD)-Equipped UAV for Anti-Submarine Warfare (ASW)," *Military & Aerospace Electronics*, 30, no. 8: August 2019): 30.

[24] "United States Navy Demonstrates Cross-Domain Communications, Command and Control via AeroVironment Blackwing Submarine-Launched UAV," *ENP Newswire*, September 9, 2016.

launched UAVs may be modified from a support and enabling role to an offensive weapon, giving the submarine the reach into the air domain.

There is a lot of activity in the sea and one of the best counter detection features is the busyness of the oceans. Large merchants and small fishing vessels all put out wakes and magnetic signatures. Picking out a submarine will not be easy in this environment. A submarine that can lower its own signature and possesses UUVs that can serve as louder shinier decoys when necessary will be better prepared for the operational environment of the future. A more daunting problem will arise when adversaries can integrate sensor data with information and the cyber domain powered by AI to resolve locating tasks on a large scale.

Artificial Intelligence (AI)

All this aerial and sea hardware technology is capable but they all still require a brain to operate. A system of systems integrated by AI at a level where inputs from all sensors of raw detection from radar, UUV, UAV, Space and traditional naval platforms, in conjunction with unconventional commercial sources of information to include social media which have not been previously integrated, can create a new level of detection that has not been seen before. The human operator is important in decision making and does well with cognitive analysis but reaches the limit of efficiency when processing large volumes of information. Automation is appropriate in specific, detailed or repetitive tasking. Machines have extreme focus, perfect objective recall (memory), endurance, strength, speed and are good at tedious work. As long as processing power supports, they can handle analyzing large volumes of data. Giving autonomous vehicles

the most capable brain system will allow the robot and the network of robots to reach the most potential on the battlefield.

Nine companies have been awarded over $400 million to develop an AI powered unmanned aircraft named Skyborg. AeroVironment, BAE Systems Controls, Blue Force Technologies, Fregata Systems, Lockheed Martin, Wichita State University, Autonodyne, NextGen Aeronautic and Sierra Technical Services are working to develop the AI system that will operate the aircraft and team up with a human pilot on the battlefield by 2026.[25] The Skyborg Vanguard Program will integrate UAV technology with manned-unmanned teaming. This will allow for airborne combat mass, support rapid, informed decisions, situational awareness and survivability as UAVs will be able to handle missions that are too dangerous for manned aircraft. This and three other U.S. Air Force's Vanguard programs will be a game-changing transformation to air operations of the future. With a range of battle field contributions ranging from simple play-book algorithms to advanced team decision making, and on-ramp opportunities for further AI technology, this effort will provide a foundation for a family of layered, autonomous, and open-architecture unmanned aerial systems. This trend is not limited to the Air Force alone but extends across the Department of Defense.

Defense Secretary Dr. Mark T. Esper delivered a speech and identified one aspect of great power competition at the virtual Joint Artificial Intelligence Center symposium, and that is the race to develop artificial intelligence. There are opinions in government that AI is going to transform the future. Former Secretary of Defense, Mark Esper, stated that:

[25] *"USAF Awards $400M-Worth Contracts to Develop AI-Powered Skyborg Drone."* (Legal Monitor Worldwide, 1 Oct. 2020).

> History informs us that those who are first to harness once-in-a-generation technologies often have a decisive advantage on the battlefield for years to come. I experienced this firsthand during Operation Desert Storm, when the United States' military's smart bombs, stealth aircraft and satellite-enabled GPS helped decimate Iraqi forces and their Soviet equipment, [but] unlike advanced munitions or next generation platforms, artificial intelligence is in a league of its own, with the potential to transform nearly every aspect of the battlefield, from the back office to the front lines. [26]

It is therefore of highest importance that the U.S. take the lead and not lose ground in this field as the nation cannot afford to let authoritarian powers use this technology to break and reshape international rules to their nefarious ways. World leaders all around the globe are not losing sight of this. Russian President Vladimir Putin said the nation that leads in AI will be the "ruler of the world".[27] Major powers like Russia and China are investing in AI in an effort to influence world events to come. The PRC is developing autonomous drones with stealth technology that can deliver lethal strike capability and advanced surveillance systems powered by AI. They are preparing to pitch low-cost, long-range autonomous vehicles and cyber systems to counter America's conventional power and export this technology to other authoritarian nations. "As we speak, the PRC is deploying — and honing — its AI surveillance apparatus to support . . . targeted repression," Esper stated. The implications of AI technology are far reaching and multi domain.

To illustrate the power and potential impact of AI consider how fragments of seemingly unrelated data can be put together to develop an operationally relevant product. A group of 150 sailors stop using their cellphone data at the same time and a few of them start again months later on a different continent. The social media snippets begin

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[26] *"Esper Says Artificial Intelligence Will Change the Battlefield."* (US Official News: September 14, 2020). Accessed 7 Oct, 2020. https://link.gale.com/apps/doc/A635514079/STND?u=wash60683&sid=STND&xid=19fcbe13.

[27] *"Esper Says Artificial Intelligence Will Change the Battlefield."* (US Official News: September 14, 2020).

to form a picture of personalities and views. Spending habits and family links provide additional layers. Fairly soon a picture develops where an adversary can form a plan plan to press on sensitive factors of that crew or undermine some weaknesses to affect the units' operational readiness. Combined with increasing number of surveillance equipment around the world and billions of data points created by the Internet of Things, they can be used by nefarious actors to undermine confidence in the combat fighting team. China is actively occupying private lives and invading every aspect of its citizens' activities like purchases, travel, text messages, internet searches and other doings.[28] Unfettered by privacy laws or ethics this exposes the populace to control and conditioning by confining dissent in real time and with AI deleting nonconformists from social life at the press of a button. When everything is being done online with electronic banking and cell phone in a cashless society, disconnecting people from participation in the social system becomes extremely easy. Establishing behaviors that build resilience of sailors to information warfare through cyber and other means is not only a good habit, but a must for operational security. Some service members maybe more susceptible to coercion from external forces than others.[29]

It was at first intuitive to think that the internet's ease of accessibility to information was going to drop the curtain on the walls that authoritarians have built, but

[28] *"Esper Says Artificial Intelligence Will Change the Battlefield."* (US Official News: September 14, 2020).

[29] Human Rights Watch asserts that social scoring is emblematic of a system of predictive policing, whereby monitoring an individual's social interactions, use of social media, and physical movement enables the state to make real-time assessments of their perceived "threat" to it at any time. This enables the capacity to literally eliminate the ability for people to use electronics our society relies on today for modern life and place dissenters in a sort of purgatory unable to find good employment, exchange money, make purchases etc.- the dystopian future of science fiction coming to life. "China: Big Data Fuels Crackdown in Minority Region," *Human Rights Watch* Feb. 26, 2018. Michael Clarke, "China's Application of the 'Three Warfares' in the South China Sea and Xinjiang" *ORBIS*: Spring 2019, 201.

as time goes on, people are beginning to realize that the technology more and more people rely on can be manipulated with greater ease by the day. AI is making this easier and faster to do. The technology of seeming freedom is in real danger of being controlled by digital authoritarianism in harmful ways. The future military arena however will certainly use AI on both sides of the battlefield. It is still difficult to imagine the implications but one can get an idea if you consider how Facebook, Google and Amazon push products to the customer based on secondary and tertiary data gathered from seemingly disjointed sources. In a similar fashion a system that can lasso information on the family of the crew of the submarine, maintenance information, parts shipping, inspection team schedules and movements, port visits etc. will be able to build increasingly accurate movement and timing predictions of the submarine whereabouts and thereby help locate the submarine in real time and either prosecute or avoid it.

AI technology will be incorporated into most combat systems out of necessity to maintain parity and stay ahead of the potential foe. As the U.S. develops AI it will do this within the framework of maintaining core values and protecting the U.S. Constitution.[30] At least for now most Americans treasure individual liberty, human rights, democracy and the rule of law. Utility of machines with the engine of AI might intoxicate and blind civilizations to the dangers as we go further. It will be impossible to let go of them and humans run the risk of becoming beholden to their usefulness. Hopefully military leaders will not lose sight of the importance that the human factor holds in decisions of war. Humans are better at flexibility, empathy, trust, and acceptance. It would be hard to say that these qualities have no place in warfare and therefore should be dispensed with.

[30] *"Esper Says Artificial Intelligence Will Change the Battlefield."* (US Official News: September 14, 2020).

Civilized nations expect and take pride in ethical and moral behavior of their soldiers on the battlefield. As in daily life which is full of ambiguity, war presents many unforeseen vague situations requiring application of humanity. Will nations build AI machines in their own image, based on unique national identity qualities and values? One can argue that machines with empathy will be less effective on the battlefield and therefore people will draw a distinction between appropriate machine and human behavior as something separate. Some nations may choose not to abandon their value system and design machines in their own image, making them inherently more vulnerable or less effective by doing so. While others will prioritize lethality over all else in order to win. What this means is that risk of detection will grow as well as the uncertainty of outcome once a submarine is detected. This is to say that autonomous systems may increasingly act aggressively on initial stages of detection in order to protect themselves from destruction. Most already consider a drone being shot down as a low-level evet when compared to a manned aircraft and this trend will likely continue. The danger is that in a robot-on-robot engagement a manned submarine may get involved and therefore considerations need to be made for more defensive capabilities as well as increased survivability of manned submarines.

This is truly uncharted territory. One can't say for sure where this world of AI integration will lead. Today's Great Power Competition seems to demand a concerted and dedicated effort into developing the most capable AI systems available for the defense industry. It is unclear where this AI arms race will lead. Humans struggle with the imprecise world of decision making based on empathy, ethics, and morals. As such there may be an attempt to teach machines to do this as well. It may not be possible for

machines to be taught these things if we ourselves have difficulty in this area. Conversely, humans might convince themselves one day that machines are better at ethical and moral decision making and give them the reins. Some nations may forgo even considering or worrying about ethics and morals when giving killing power to a machine. It is evident that the pragmatic choice, for now, is to continue the effort in development of most capable AI systems while factoring in participation of the human in the decision chain. Limit giving lethal power over to the machines to the most extent possible and lead the machines to the nations' purpose while resisting letting the machine lead the action. With computing power increasing so rapidly, a submarine control room has been filled with more and more sensors and sources of information for the team to process. At times the data flow is overwhelming to the point where less is more. But in a world of increased complexity and activity the warfighter must keep up to stay competitive on the battle field and so addition of AI assisted data processing that incorporates mission goals is a must. Having capable AI will become even more critical when human submariners begin to face fully autonomous UUVs armed with torpedoes, there will be even less room for consideration than exists now and he who draws second will surely be at a disadvantage.

Chapter 4: Tactical Threats in Combination of UUV, UAV, AI and Space

It is not surprising that emerging technologies are threatening to make the oceans transparent. There has been considerable effort in this field for many decades and for good reason. A submarine that is unlocated is dangerous. The desire by less capable nations to neutralize the threat is strong but so far most of these futuristic endeavors remain science projects. No single one has been effective and, in all cases, they are cost prohibitive. However, in this current generation of systems it is beginning to appear that these very interesting but limited capability systems if employed together and integrated with AI can start to generate measurable benefits in submarine detection and tracking. One such example can be seen in the Republic of Singapore Navy (RSN). Singapore Defense Minister Ng Eng Hen made public plans for the RSN to replace its missile corvettes with a multi-role combat vessel (MRCV) that would carry unmanned air, surface and subsurface vehicles.[1] MRCVs will start being delivered in 2025 and have a modular package designed to extend the ships reach and provide flexibility. There will be unique challenges in the employment of each vehicle that will have to be worked out but the benefits of a scaled down joint operation system on a tactical level made available to every captain is extremely alluring. Not only does this add to both the defensive and offensive capabilities of each ship but overall grows the sensor pool making the seas a sensor rich environment and in turn functions as a deterrent.

[1] Aqil Haziq Mahmud, "Submarine hunter, recon leader: What a naval mothership and its unmanned systems can do," *Channel News Asia CAN*, Singapore: May 19 2019.

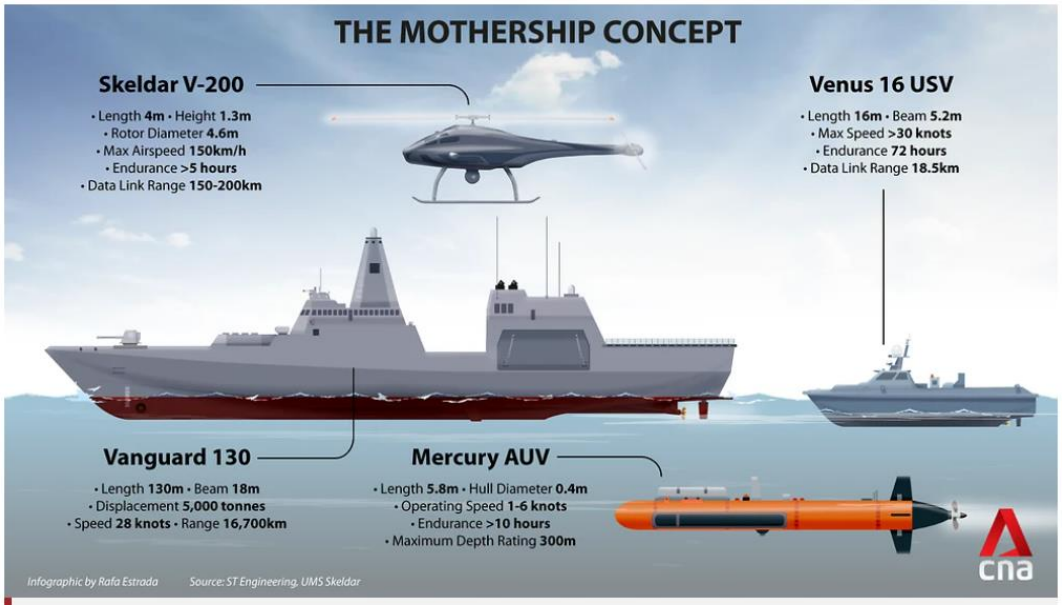


Figure 3: The Mothership Concept Source: Aqil Haziq Mahmud, "Submarine hunter, recon leader: What a naval mothership and its unmanned systems can do," Channel News Asia CAN, Singapore: May 19 2019.

US partners and adversaries are not only designing specific weapon platforms but are developing sophisticated sensors and networks of systems. Putting together laser satellites, SQUIDs, UUVs, UAVs, RAP arrays, AI and unmanned surface patrolling vessels into an active defense system is underway. Technologies of AI, space-based lasers, magnetometers, big data, quantum computing are cited as techniques that might make oceans transparent.[2] These systems are not likely to be concentrated and consistent enough to threaten the strategic deterrent submarine on patrol in open ocean but are a concern for the SSN on mission in more restricted and focused areas. China has been working on upgrading their ASW capabilities into the "Underwater Great Wall".[3] This is an attempt to frustrate forward operating U.S. and partner submarines with a thread of

[2] Brixley-Williams, S., and C. Naughton, "Impact of Emerging Technologies on the Future of SSBNs", *Basic*, 2016. http://www.basicint.org/publications/sebastian-brixey-williamsproject-leader/2016/report-impact-emergingtechnologies

[3] David Hambling, "China's quantum submarine detector could seal South China Sea*," New Scientist*, Technology: August 2017.

submerged sensors, buoys and drone submarines that is thought to be close to completion. It's just part of a wider effort to neutralize the submarine threat and countering these efforts starts with discussion and establishing priorities.

The recently released December 2020 Navy, Marine Corps and Coast Guard Tri-Service Strategy highlights very poignantly emerging threats and concerns.[4] AI, Autonomy, additive manufacturing, quantum computing, and new communications and energy technologies could each, individually, generate enormous disruptive change. In combination, the effects of these technologies, and others, will be multiplicative and unpredictable. Militaries that effectively integrate them will undoubtedly gain significant warfighting advantages. These pursuits "seek to shift the burden of escalation by reinforcing annexed territory with long-range precision-strike weapons and make a military response to an invasion seem disproportionately costly."[5] That is why a forward present submarine force that is able in a timely manner to thwart or lessen the aggression's effect is ever more important. "Unchecked, these trends will leave the Naval Service unprepared to ensure advantage at sea and protect national interests within the next decade."[6] The strategy calls for combat credible forces. This means it is not purely the number of forces that will be required to counter adversaries but the credible threat those numbers pose. Therefore, there is a need for platforms that display active operation forward while exhibiting lethality of their capacity. A balance of showing submarines in

[4] Office of the Chief of Naval Operations, *Advantage at Sea Prevailing with Integrated All-Domain Naval Power, An integrated U.S. Navy, U.S. Marine Corps, and U.S. Coast Guard strategy*, (DCNO for Warfighting Development (OPNAV N7): December 2020).

[5] Office of the CNO, *Advantage at Sea*, 5.

[6] Office of the CNO, *Advantage at Sea*, 5.

number operating in contested areas but not being able to be successfully tracked, directly communicates that credible display of combat ready forces.

The United States military is recognizing the need to plan for gaining tactical and strategic advantages in the realm of autonomous vehicles and robotic warfare. CAPT Wayne P. Hughes Jr., USN (ret), Dean Emeritus, Naval Post-Graduate School believes that it is not a matter of choice but that it is an inevitable future and the military needs to embrace the change to stay in the game. In 2016 the Vice Chairman of the Joint Chiefs of Staff issued a Joint Concepts for Robotic and Autonomous (JCRAS) systems publication.[7] The fact of the matter is that advances in Robotic and Autonomous Systems (RAS) technologies can be a threat to the submarine but also give the Joint Force a tremendous opportunity to preserve operational advantage in a future where the opponents are becoming more capable and sophisticated. Similarly, to the post war years of change that occurred with innovations brought about by both World Wars, the emerging technology if skillfully adapted has a significant influence to the future effectiveness of U.S. Joint Forces. The JCRAS is a vision to guide the needed development. This will be a lengthy process to likely take a decade or more. Choosing to do it is the first step but the military will have to be creative and innovative. The goal of this effort is to employ the Joint Force with integrated Human-RAS teams in various combinations to expand the Joint Force's field of options by 2035. The end state is when each service and echelon is interconnected to a degree where individual highly capable RAS units and functions are coordinating and collaborating across domains and services to achieve greater combined effects and capabilities. Submarines manned with humans

[7] Chairman of the Joint Chiefs of Staff, *Joint Concept for Robotic and Autonomous Systems (JCRAS*). (Washington, D.C. October 19, 2016).

would be enhanced by RAS systems to complete complex missions and those systems would in turn be focused and engaged for maximum tactical and strategic results by human inputs. Responsibility and accountability will remain a human endeavor leveraging technology and autonomy as an enabling capability. Increased activity, information, sensor inputs and speeds of action require this integration and those that can do this well will be most successful and able to maintain competitive advantage in all domains.

> Use of directed energy, hypersonic or even cyberspace weapons may produce nearly instantaneous effects on their targets, striking without warning and with devastating impact. Adversaries may use similar technology, not only to destroy, but to disrupt command, control, communications, and computer systems while robot swarms overwhelm Joint Force defenses. The battlespace confusion caused by strategic disruption may have a stronger operational effect than a straight-forward destruction of assets. An adversary who can integrate these capabilities with advanced battle management artificial intelligence could put the entire Joint Force at significant disadvantage in terms of speed and reaction time.[8]

Our current Joint Force capability is based on expensive, sophisticated and small units which are not able to generate forces as quickly as needed. RAS systems provide the potential to quickly generate large quantities of inexpensive units and generate mass. There is also a significant capability and enhancement of cooperative behavior where machines become more capable as a group and network thereby enhancing Joint Force capabilities.[9] Additionally, this supports dispersal of forces and provide survivability from mass localized attack as well as create a layered force able to support one another in depth of defense.

[8] CJCS, JCRAS, Ibid.

[9] In August 2015, the Naval Postgraduate School's Advanced Robotic Systems Engineering Laboratory (ARSENL) successfully demonstrated the ability of two operators to control 50 RAS performing cooperative behaviors and exchanging information.

Integration and coordination will require getting used to operating not only with the hardware discussed here but getting proficient at working with other service branches. It appears that one of the closest relationships that of the Navy and the Marine Corps is going to get closer. The USMC already has logistical support experience working unmanned vehicles and is a logical operator for joint submarine-autonomous vehicle maneuvers. Operating unmanned or even autonomous platforms in forward positions, especially in a contested environment will in some way require forward presence. The undersea fight will be critical against a near-peer adversary. Creating a solid contact detection network is key to winning. Losing advantage is this domain could have existential consequences. To stay ahead one will need to stay forward. The Marine Corps' expeditionary advanced base operations (EABO) is a concept that is designed to integrate cross-domain ASW and enable the joint force to sustain or widen its advantage. This is a theater-level campaign support of sustained actions for undersea advantage.[10] Employment of UUVs, UAVs, RAS from Marine expeditionary advanced bases (EABs) will offer forward logistics and support for the sensor fleet and create strike capabilities for the ASW mission. There is a natural partnership that just makes sense in creating this interoperability specifically between the Marine and Submarine force. This is supported in general terms by the 2020 Tri-Service Strategy and in specific terms by senior USMC leadership. Going forward ahead of the fight is the key. At the 2019 Naval Institute/AFCEA WEST Conference Commandant General Robert Neller said, "We're going to have to fight to get to the fight," and, "I think we're going to need more submarines". The current Commandant General Berger in his November 2020

[10] David Berger, General U.S. Marine Corps, "Marines Will Help Fight Submarines" (U.S. Naval Institute *Proceedings* Vol. 146/11/1,413: November 2020).

Proceedings article said he is willing to take it even further.[11] He indicated his support for EBAO in support of ASW in the Greenland–Iceland–United Kingdom gap and the First Island Chain in the western Pacific. The U.S. will need to fight for sea control which has been taken for granted in the past. Fighting in contested areas will require penetration platforms like nuclear submarines but to be effective they will need help from integrated autonomous and remotely operated systems.

For a majority of its lifespan the submarine had operated alone and unafraid. Now with growing capabilities of competitors in weaponry and communications there is a need to integrate and synergize submarine strengths into joint operation in order to maximize the ability to exert maritime dominance. The growing gap in numbers of ships and the closing gap in parity means the services will need to work together in a greater Joint Force effort than ever before to support each other and cover gaps. This means that to counter the growing network of detection methods the submarine needs to be efficiently joined into an allied network designed to counter it. Creating a multilayered, robust contact detection and prosecution network is going to require developing close joint operations mechanisms with cross-service partners and likely assets like Marine boots close to the ground with EABs. Adversaries have closed the gap in precision long range weaponry; the U.S. must maintain advantage in the undersea domain which is also now narrowing. With EABOs scouting and as importantly counter-scouting the battle domain, they will complement the attack submarine and limit where the enemy submarines can act without impunity. Rapidly sensing and acting on that information offensively in

[11] David Berger, Ibid.

coordination with other ASW units will ensure that U.S. limited ship numbers maintain at an advantage in the maritime domain.

Chapter 5: Conventional/Air Independent Propulsion (AIP) vs Nuclear-powered Submarine

Conventional submarines of World War II became obsolete for many reasons but one of the most important was lack of submerged endurance. The diesel engine requires air to function and battery capacity significantly limits time a conventional submarine can remain submerged. However, given these limitations the conventional submarine did not disappear. It remains the most prevalent submarine platform in the world. One reason for this is that there is a significant and prohibitive cost of entry to nuclear-powered submarines for most smaller nations which also requires a highly technical and capable support structure to maintain. Another reason is that the conventional submarine has made improvements over time in AIP technologies and allowed the conventional submarine to increase its endurance to remain submerged. The conventional submarine suits most nation well because they do not employ the submarine for distant offensive operations that require speed and long endurance. The nations using submarines near their borders focus on coastal and trade route defense close to their home shores and therefore cheaper conventional submarines enhanced with AIP technology suit them well. There are many interesting developments in this area.

The conventional submarine using various designs of AIP technology has significantly improved its endurance. Submerged operations of 2 to 3 weeks and in rare cases as many as 5 weeks have been reported by designers in leading technology nations such as Germany, Sweden, France, India, Russia, China and Japan. Submarines utilizing fuel cells (which are very quiet), closed-cycle turbines (which are powerful) or the Stirling engines (which are efficient in cold waters), can operate submerged and recharge batteries of the submarine without the need to snorkel. The ability to recharge batteries

eliminates the need for the boat to come up to periscope depth to run the loud diesel and in turn maximizes its stealth. These methods do have disadvantages. For one they rely on stored capacity of specialized fuels which are limited. India's indigenously made AIP fuel-cell for the Kalvari-Class submarines can extend its submerged mode of operation by two weeks but relies on a limited resource of oxygen and hydrogen.[1] Closed-cycle turbines and Stirling engines require ethanol or similar fuels and oxygen. These fuels are often very flammable and explosive. Accidents have occurred and submarines have been lost. Fueling and storing is a hazard. South Korea and other nations are looking at high-power density batteries as alternatives. Japan is shifting from using Stirling engines to lithium-ion batteries in their eleventh boat of the Soryu-Class AIP submarine.[2] Due to higher storage capacity when compared to traditionally used lead-acid batteries, they pack more power for the same size. Although a higher fire hazard, having more battery storage effectively renders other AIP systems unnecessary if endurance can be matched. But this technology is still in development and holds risks. "The optimal operating temperature for lithium-ion batteries is between 59ºF and 95ºF. An unexpected impact, a poor manufacturing process, an external-internal short circuit, or overly hot surroundings can cause the battery temperature to rise."[3] A modern submarine is well insulated in part due to necessary sound silencing technology. Air-conditioning and water cooling of high heat systems is therefore required. In the absence of adequate cooling the temperature on the submarine rises quickly especially in warmer waters. If battery temperatures rise

[1] Shubam Sharma, *Explained: Air Independent Propulsion System*, (DefenseXP India Defense Network: August 30, 2020). https://www.defencexp.com/explained-air-independent-propulsion-system

[2] Mariska Buitendijk, "Japanese Submarines Exchange Stirling Engines For Lithium-Ion Batteries," *SWZ Magazine*, December 31, 2019, https://www.swzmaritime.nl/news/2019/12/31/japanese-submarines-exchange-stirling-engines-for-lithium-ion-batteries/?gdpr=deny

[3] Conte-Rios and Pelegrin-Garcia, "A Revolution In Submarine Propulsion,"

above around 212ºF some components of the battery become unstable and start to react, releasing extra heat. This can cause an effect referred to as thermal runaway and in turn cause fire or explosion. Therefore, this battery technology requires further development for reliable submarine use. Even with improvements in AIP, fueling the submarine periodically is still required. Hydrogen and oxygen fueling is dangerous and requires specialized equipment. This means that it is not cheap. Secure and available basing for refueling is required. There can't be certainty in a wartime environment that this will be possible in forward contested regions, restricting freedom of operations and making the submarine vulnerable. Nuclear powered ships have no limitations in this area and therefore hold a significant advantage in endurance but also speed and sustained speed.

The nuclear submarine surpasses any AIP boat in submerged endurance but there is also a factor to consider of speed and sustained speed endurance. Even if an AIP boat can remain submerged for longer periods of time, it can only do so at low speeds of about 5 knots. A conventional submarine even with AIP will drain its batteries in a matter of a couple of hours at any speed higher than 20 knots and will need to travel slowly for a long time to recharge its battery capacity level. Nuclear submarines can sustain very high speeds essentially indefinitely with few limitations. Being able to sprint at any point for any period of time is an incredible advantage when fighting a highly mobile war against multiple threats. With a war where there are potentially many hostile torpedoes being shot frequently from all directions, a submarine that can outrun them repeatedly and reposition for counter attacks will ultimately have the stamina to endure the fight and win. A submarine captain with operational flexibility that allow him to avoid evolutions (snorkeling, ventilating etc.) which compromise stealth or maneuver, is the one who is

truly able to exercise tactical control, freedom of action and self-reliance at sea. Evidence of this is USS Newport News' recently completed deployment in the U.S. 5th Fleet area of operations which included a period of 137 continuous days at sea.[4] "The reactor underpins the submarines' self-sufficiency—allowing them to deploy quickly across the globe and remain on station almost indefinitely with minimal support."[5] This kind of global reach is very attractive to commanders and nations that seek to possess an asymmetric advantage at sea.

More countries are looking to acquire nuclear submarines. Status of possessing a submarine operating navy is one reason but the capability it brings is primary. India is one of the newest nations to acquire nuclear submarines with aid from Russia geared towards projecting its naval power further to sea and countering the growing PRC threats in the Indian Ocean. Iran, after fielding its newest indigenously built Fateh conventional submarine has voiced intent to develop a nuclear-powered submarine. The commander of the Iranian Navy said that developing nuclear submarines is on the agenda. Rear Admiral Khanzadi said that, "it's a kind of [neglect] if the Islamic Republic does not think about using nuclear propulsion in submarines . . . this domestic capability exists in the Defense Ministry regarding the production of submarines bigger than Fateh and certainly, the developing of submarine propulsion is on the agenda of the Navy."[6] The justification for this is rooted in maintaining effective deterrence. South Korea, facing the rising threat of

[4] Arianna Herriott, "USS Newport News returns to Naval Station Norfolk after deployment," *3WTKR*, Military News: July 2020. https://www.wtkr.com/news/military/uss-newport-news-returns-to-naval-station-norfolk

[5] Daryl Caudle, Vice Admiral U.S. Navy, "Sustaining the Submarine Force's Competitive Edge," *U.S. Naval Institute, Proceedings*, Vol. 146/10/1412: October 2020. https://www.usni.org/magazines/proceedings/2020/october/sustaining-submarine-forces-competitive-edge

[6] *"Developing nuclear submarine on agenda of Iran's Navy"* (Mehr News Agency: 16 Apr. 2020).

DPRK submarine launched ballistic missile capabilities, has expressed a strong interest in acquiring a fleet of nuclear-powered attack submarines as well.[7] Australia's defense experts have been discussing leasing or buying nuclear submarines from the U.S. for years. Ross Babbage, one of Australia's best defense experts said:

> I remain strongly of the view that the best submarines for Australia for the coming 40 years would be 10-12 leased or bought Virginia or Astute class boats. The Virginia class boats, in particular, are well sorted and reliable, they have low risk, they have known costs, they never need to be refueled and they could be acquired with associated training programs and system upgrade pathways… However, all other things being equal, if the U.S. government were open to the idea, it would seem more sensible for Australia to opt for the Virginia Class. Australian boats of this class would be operating in very close cooperation with U.S. boats in Pacific and Indian Ocean waters. There are likely to be substantial advantages flowing to both countries from joint basing, logistic support, training and many other aspects.[8]

Based on high costs of Australia's current conventional Collins class submarine and large distances to patrol much like the U.S., it makes sense to invest in a more expensive but more appropriate platform for the job. Regional common interests of allied nations in the Indo-Pacific make a case for strategic benefits nuclear submarine forces would present for stability and prosperity. Shared interests in national security against military aggression, deterrent and defense against potential aggressors like North Korea and China may fuel collaboration. Collective interests in preserving the economic growth and prosperity depends on open seas. Freedom of the seas, law, order and the peaceful resolution of international disputes maybe guaranteed by an effective allied nuclear

[7] The Moon administration has emphasized repeatedly that South Korea "needs nuclear submarines in this era." South Korea has mentioned its desire for this asset several times in high-level talks with the United States, has commissioned a civilian study of the feasibility and desirability of the project, and has developed a military task force to consider the development of a ROK SSN. Jun Ji-hy, "South Korea Moving to Build Nuclear-Powered Submarines," *Korea Times*: 20 September 2017. http://www.koreatimes.co.kr/

[8] Harry Kazianis, "CHINA AND RUSSIA'S WORST NIGHTMARE: AMERICA STARTS SELLING NUCLEAR SUBMARINES." *States News Service*: 9 Nov. 2019.

submarine force in the theater.[9] With its reach of lethal strike and survivability, the nuclear platform gives the operating nation projection of power on a different order. To compete, diesel submarines are looking more like nuclear boats' sleek hydrodynamic hulls deigned for submerged operations, with X-shaped rudders and impeller propulsion. These and silencing technology, modern sonar, fire-control systems and other innovations are increasing the costs.

From time to time the topic of acquiring diesel-electric submarines for the U.S. navy comes up. Every time this is based on realization that the U.S. is behind in unit numbers and because nuclear boats cost billions. There is a reasonable argument that cheaper diesels would allow for more submarines on the same budget. However, every time this argument gets evaluated the conclusion seems to be very similar. The mission set required by the U.S. navy and reality of geography does not support conventional submarines. Further, the actual savings do not tell the whole story and would not substitute for losses in capability. A German 212 Type diesel boat costs USD $623 Million. Compared to U.S. Virginia class that costs USD $2.7 Billion these savings seem significant. However, the comparison is made between significantly different capabilities. For one, if a mission requires a submarine to transit 4,000 nm from Pearl Harbor to the Western Pacific, a nuclear ship will do this in 6 days while the 212 Type will need three weeks. There are many other apples to oranges comparisons that should not be made but what should be compared are more similar platforms. To consider a closer competitor with advanced modern capabilities and propulsion like the Australian acquisition program for 12 units of the French built Shortfin Barracuda Block 1A submarines for

[9] Yu, Jihoon, and Erik French. *Should the United States Support a Republic of Korea Nuclear Submarine Program?* (Naval War College Review, no. 1 2020): p 84.

USD $38 Billion, it will become apparent that at USD $3 Billion per boat the case for a modern conventional submarine being cheaper than a nuclear ship becomes weak.[10] Modern submarines whether nuclear or not cost significant investments. If it is any consolation to the promoters of a cheaper conventional submarine navy, they should take some comfort in the rise of autonomous vehicles. In a sense, adoption of large UUVs and their incorporations into forward operations is giving the U.S. conventional submarine capabilities without creating a manned submarine force and doing it at a much cheaper cost than manned conventional boats. It is also a more efficient use of conventional propulsion because a large amount of energy is directed towards maintaining life support systems and pushing all that extra weight that goes into a manned submarine. With an unmanned non-nuclear system, limits of the conventional submarine are significantly reduced due to the reduced burden of power consumption due to size and human load. Expanding the UUV program instead of substituting for nuclear submarines with conventional platforms is really the force multiplier at reduced cost the navy needs to pursue in future force planning.

Conventional submarines have a place on the battlefield and will continue to be important. Their capacity to ambush transiting targets and defend local waters is substantial. AIP boats' advantage in coastal protection remains intact and U.S. allies possessing this capability contributes to deterring aggressors and combined defense of allied nations. The U.S. however, based on geography and mission requirements, will

[10] Cameron Aljilani, (Cmdr), *U.S. Diesel Boats? Never Again!* (Undersea Warfare Magazine: Winter 2018). p.7.

continue to remain focused on nuclear power with desirably a robust UUV program to support forward operations.

Chapter 6: Nuclear-powered Submarine Mission Roles

Most commonly nuclear submarines are associated with strategic nuclear deterrence. The reason for this is survivability of the nuclear powered and nuclear armed ballistic missile submarine (SSBN) platform. Arguably the reason total war is not likely between the great powers is due to the balance that is provided by nuclear weapons and assurance of mutual destruction. This is only possible due to assurance of a survivable second-strike option in case of surprise attack. When nuclear weapons were first developed and the delivery method remained via heavy bomber only, the prospect of total destruction by the enemy was low. It would take time to deliver the weapon and this meant an air defensive and counter attack could be mustered in time. With the ballistic missile quick and total destruction became possible. In turn this meant that to deter the enemy you would have to protect and hide your arsenal so that the enemy could not neutralize it in a preemptive strike. Missile silos and mobile platforms do present some protection but have drawbacks. The best option to date has been the submarine launched deterrent "which provides the only survivable leg of the nation's strategic deterrent triad and carries approximately 70 percent of the nation's accountable nuclear warheads."[1] As long as it can remain hidden the SSBN will continue to be the best nuclear deterrent.

The Ohio-class Trident ballistic nuclear missile submarine (SSBN) program initiated by Admiral Zumwalt in the seventies has been the centerpiece of the nuclear triad, but the 14 boats' service life is coming to an end and already has been extended well past what was originally planned. Their replacements, the new Columbia-class subs,

[1] Caudle, "Sustaining the Submarine Force's Competitive Edge."

are under development and planned for 12 units to be constructed. This new SSBN is expected to cost about $128 billion to develop.[2] In a world where advances in sensing technology may be making submarines easier to detect and harder to hide, a valid question is being raised. Critics ask whether these investments make sense for the future of strategic deterrence. The answer to this question is that it depends. It depends on which countries' SSBNs is being considered and where they are patrolling. Technology and geography or rather bathymetry matter quite a lot.

The technology of the Ohio class submarine made it the stealthiest platforms developed. This didn't happen by chance. In the early days of the cold war the Sound Surveillance System (SOSUS) system of underwater hydrophones allowed the U.S. to detect Soviet submarines by listening to the narrow-band, low frequency machinery tonals emitted by those submarines. As a matter of fact, this system also detected U.S. submarines on patrol including the George Washington class ballistic submarine which was the deterrent platform of the day. Based on the lessons learned of submarine acoustics the U.S. was able to develop the stealthy Ohio class which took silencing technology to the next level.[3] This effort did not stop with design but continued with a submarine sound trial program that evaluated silencing characteristics of all operational submarines with detailed assessments conducted on specialized dynamic and static ranges. Having this sound silencing experience and determination to make improvements upon it, the U.S. stands to make the stealthiest submarine yet. The Columbia class will

[2]Owen R. Cote Jr., "Invisible nuclear-armed submarines, or transparent oceans? Are ballistic missile submarines still the best deterrent for the United States?" *Bulletin of the Atomic Scientists*, 75:1, 30-35: 2019.

[3] Cote Jr, "Invisible nuclear-armed submarines, or transparent oceans?"

continue this trend and likely be the quietest platform in the sea. But will it still be detectable? This is where geography comes into play.

The bathymetry in the Pacific and Atlantic is such that it favors the U.S. in setting up listening arrays that can monitor very large areas of the deep oceans. Low frequency propagated sound waves require deep water for the sound channel to exist and the sensors require specific locations to catch them. These favorable conditions exist close enough to U.S. and its allies' coasts where setting up the large arrays and infrastructure cabling to shore processing facilities is possible. Specifically, a closely located continental shelf with a steep drop off into a basin creates these favorable conditions. This bathymetry is available on both U.S. coasts but most world adversaries do not have as adequate ability to create these networks and would have to set them up far from their shores in distant locations. It also means that these networks would be in shallow water near allied shores and not easy to defend in peace time. Additionally, when a U.S. SSNB is on patrol, its missile range allows for freedom of maneuver just about anywhere in the Pacific from Seattle to New Zealand. Conversely and adversary's SSBN would have to enter deeper waters past the first or even second island chain[4] to cover its targeting objectives and into the view of U.S. systems. Otherwise, their SSBNs remain confined to the costal seas where the range is distant and detection is easiest with multi domain capabilities. To put it simply, when the adversary SSBN goes on patrol it is restricted and prone to array tracking whereas a U.S. SSBN has freedom of maneuver and little opponent sensor array

[4] First island chain refers to the chain of island from the Japanese home islands through the Ryukyu Islands, Taiwan, and the Philippine archipelago enclosing the East Asian coastline. The second island chain is further east and refers to the island chain formed by the Ogasawara and Volcano Islands of Japan running south through the United States territory islands of Marianas including Guam.

threats. So at least for the foreseeable future the U.S. SSBN will remain practical and capable.

The fast attack nuclear submarine has a much wider range of mission sets. To name a few: Anti-Submarine Warfare (ASW), Anti-Surface warfare (ASUW), Land Strike, Special Operations Forces support and Intelligence Surveillance and Reconnaissance (ISR). In all these missions the submarine is operating aggressively forward and likely to be in shallow and constrained areas of operation. This is where smaller and shorter-range arrays (smaller than SOSUS) will start to present a challenge. These are designed to detect contacts of ranges of only a few miles. These arrays referred to as Reliable Acoustic Path (RAP) arrays are also bottom-mounted.[5] They are typically set up in thousands of nodes in deep water looking upwards. This type allows for very reliable detection with little interference but is limited to small areas of the ocean. Although it doesn't provide oceanwide coverage it does allow monitoring of choke points where a U.S. SSN would likely pass through. Similar linear fixed acoustic arrays are set up by the adversary at approaches to their naval bases. This allows for monitoring of approaching threats - a sentry on a castle wall of sorts, minding the security of the keep or a port in this case. Cueing from RAP and linear SOSUS-like arrays is valuable and use of them will undoubtedly continue but as submarines get quieter and develop UUV capabilities to counter the arrays their utility may be limited. What is more likely is that acoustic arrays will not be a stand-alone system but contribute as one of many inputs into the AI controlled detection network that pieces the puzzle from scraps and bits of data. Although the environment will likely be more difficult to operate in for the fast boat it

[5] A. Baggeroer, and B. Elliott, *Distributed Remote Sensing For Naval Undersea Warfare* (Washington, DC:Naval Studies Board: 2007).

doesn't mean that these difficulties outweigh advantages. The fast boat's sheer size allows for mission flexibility and addition of equipment and people. The speed and endurance eliminate boundaries for the operational artist,[6] and give them significant capability. What needs to improve in the future are availability of onboard UUV/UAV capabilities and offensive anti-air and small craft weapons. As surface fleet energy directed weapons and jammers develop, the force will need to look at arming submarines with similar systems. The fact that energy is a limiting factor for a lot of these weapons creates an opportunity for a nuclear-powered ship such at the SSN to harness this onboard resource and make the SSN even deadlier. This will expand mission roles and provide capability to destroy line of sight targets such as drones, small boats and potentially missiles, adding to defensive capabilities submarines already provide to the aircraft carrier and the surface fleet. To expand over-horizon targeting capability and coordination of defense with surface assets will require new integration with other platforms and services.

The need for modernization has not been lost on the Services. Both, the Navy and the Air Force realize that ships and aircraft will require updating but just updating major platforms will not be sufficient. China's A2/AD capabilities produce difficulties for the Air Force and the Navy, for which they have had no prepared answers. In the Western Pacific survivability of land-based air forces as well as military satellites are in question. China's progressively improving and formidable integrated air defenses may be difficult

[6] An operational artist is a planner who applies the principles of operational art as described by the Joint Planning doctrine: "Operational art is the cognitive approach by commanders and staffs—supported by their skill, knowledge, experience, creativity, and judgment—to develop strategies, campaigns, and operations to organize and employ military forces by integrating ends, ways, means, and evaluating risks." JCS Joint Publication 5-0, *Joint Planning*, 1 December 2020.

to suppress. The Navy is concerned with survivability of the carrier strike group and other surface combatants. Wargame simulations on the eastern flank of the North Atlantic Treaty Organization (NATO) treaty area produce lack of encouraging results. While analysis indicates new lines of effort and operational concepts needed to counter the threat, actual implementation is slow to materialize as it often comes with a cost of reducing existing planned programs.[7]

One of the biggest issues faced today is the proliferation of long range, fast and accurate anti-ship missiles. These hypersonic and ballistic missiles have made the surface ship more vulnerable than before. The aircraft carrier requires a lot of dedicated defense forces. The submarine to a degree remains unaffected as long as it remains at sea and at depth. So at least operationally the missile advances are not as dramatic with respect to offensive capability versus submarines. Developments in counter missile technology are moving forward with rail gun and laser systems, but are lagging. It appears that the future is trending away from large surface ships to a future of smaller ships in larger number with autonomous defensive and offensive units able to disperse the force and fight the missiles in aggregate. A submarine is naturally able to avoid the growing danger posed by long range standoff weaponry by simply submerging and escaping the threat of a missile altogether. This development is turning into a case of conventional deterrence. Very similar idea to the familiar nuclear deterrence concept most agree has worked so far. In order to create stability, it is important to lower the dangers posed for the U.S. military of a prolonged high-intensity war and to make this emphasis known to all adversaries. If the force is designed to withstand initial stages of a conflict sufficiently to

[7] Ochmanek, David. "Improving Force Development Within the U.S. Department of Defense: Diagnosis and Potential Prescriptions," *RAND Corporation*, July 2018.

endure, the U.S. is less likely to strike first or shy from retaliation. Otherwise, there might be an implied predisposition to strike opponents' "A2AD capabilities before they could be used against U.S. forces and thereby increase the risk that those capabilities would be used before, they were themselves struck. In parallel with measures to prevent crises from becoming violent and violence from becoming severe, the United States should try to reduce the impact of Chinese A2AD by investing in more-survivable weapons platforms and in its own A2AD capabilities: missiles, submarines, drones and drone-launching platforms, cyber, and anti-satellite (ASAT)."[8] Lowering the confidence for the adversary of victory and inserting uncertainty, would increase the chances for stability and deterrence. Although this may not guarantee dominance, having the right array of forces to prevent major unrecoverable losses in the initial stages of conflict and avoid significant financial cost would potentially avoid a larger conflict from occurring. This brings a necessary discussion of where U.S. fleet numbers are going and what will be the balance of forces in the future U.S. Navy.

The Navy is gearing up to change the balance of combat forces in the fleet. The CNO has issued the new "Report to Congress on the Annual Long-Range Plan for Construction of Naval Vessels" in December 2020 from which a number of conclusions can be made on the future makeup of the fleet.[9] Two main takeaways from the report are that the number of unmanned naval systems is increasing dramatically and the number of nuclear-powered attack submarines will eventually lead to be the most dominant platform

[8] David C. Gompert, Astrid Stuth Cevallos, Cristina L. Garafola, "War with China Thinking Through the Unthinkable," *RAND Corporation*, Santa Monica, Calif.: 2016, 11.

[9] Office of the Secretary of Defense, *Report to Congress on the Annual Long-Range Plan for Construction of Naval Vessels* (CNO, Deputy Chief of Naval Operations, Warfighting Requirements and Capabilities - OPNAV N9: December 9, 2020).

by number. Total new construction funding is seeing an increase in the next 5 years. This is not surprising. What is interesting is that the make-up of the future force is tending to smaller platforms. Full funding requirements for three carriers, CVN 80/CVN 81 and advanced procurement for a CVN in FY2026 remain while the department recognizes the need for continued exploration of carrier evolution and expects to conduct an analysis of alternatives within the Future Years Defense Program (FYDP).

The carrier as it stands today faces significant risks. The growing vulnerability to long range missiles and inability to effectively counter swarm tactics, limits its military value as a deterrent and presents a liability whether at sea or in port for repairs. No doubt that it has been a symbol of American power and a go-to tool for many U.S. Presidents in conflicts of the past. Washington has long viewed aircraft carriers as the crown jewel of American naval power and it has been difficult to break from this position. Dr. Thomas X. Hammes, a retired Marine Corps colonel and a Distinguished Research Fellow at the National Defense University's Institute for National Strategic Studies, outlined his innovative and surely controversial, proposal.[10] His idea is to shift the focus of the U.S. Navy from its aircraft carriers to a large armada of missile-armed merchant ships that can be made lower profile, cheaper, expendable, tougher, able to absorb more damage, and overall better equipped to handle the challenges of modern naval warfare. While it is understandable to squint at such ideas, with hypersonic and ballistic “carrier killer” missiles being fielded, there is some reason to consider alternatives. As long as it cannot be guaranteed with reasonable assurance that the carrier will be protected from overwhelming missile and swarm drone attack (sea or air), the USD $20 billion

[10] *NAVY NIGHTMARE: AMERICA'S CARRIERS ARE IN TROUBLE IN THE NEXT GREAT WAR.* (States News Service: July 16, 2019).

investment (with airwing embarked and 4000 sailors) is too expensive to put under serious risk and alternatives are needed. Aircraft carriers possess tremendous qualities and capabilities but the pause and slight reduction to 10 units in the build plan is understandable, while the fleet considers defensive measures and potential restructuring to alternative platforms (like the SSN) that will be non-carrier centric.

Attack submarine construction for 10 Block V *Virginia* class submarines is unchanged while Block VI is increasing to a 12 ship multi-year procurement. The major goal is to increase shipyard capacity for three submarines per year production capacity. $1.7B was added FY2022-24 for shipyard facilitation to enable increased production of SSNs. The DDG program continues with a two ship per year pace and the FFG increases production to three ships in FY2023 and to four ships by FY2025. While procurement of the new *Columbia* class SSBN is the top priority with significant funding, the numbers (Table 1) show that the two submarine programs demand the most funding and the SSN procurement is number one by a large margin. The DDG and FFG program are next in size and even combined don't surpass the SSN program funding.

Table 1: FYDP funding for Ship Building and Conversion Navy (SCN)

	FY22		FY23		FY24		FY25		FY26		FYDP	
Ship Type (TY$M)	**$**	**Qty**	**$**	**Qty**	**$**	**Qty**	**$**	**Qty**	**$**	**Qty**	**$**	**Qty**
CVN[1]	2,398		1,949		1,722		2,944		2,987		11,999	
DDG 51[2]	3,676	2	4,589	2	4,137	2	3,948	2	4,277	2	20,627	10
FFG 62[3]	1,212	1	3,293	3	3,094	3	4,227	4	4,388	4	16,214	15
SSN 774	6,618	2	7,749	2	10,026	2	11,689	3	9,823	3	45,905	12
SSBN 826[4]	4,726		5,198		5,406	1	6,789		8,209	1	30,328	2
LPD Flt II[5]	41		1,787	1			1,625	1			3,453	2
LHA(R)[5]	2,109	1	1,784								3,893	1
LAW	156	1	150	1	300	2	450	3	450	3	1,506	10
T-AO 205	809	1	1,347	2	1,283	2	1,308	2	1,335	2	6,082	9
NGLS			150	1	150	1	300	2	300	2	900	6
T-EPF	540	2	270	1	270	1	270	1	270	1	1,620	6
T-ATS 6	81	1	80	1							161	2
T-AGOS (X)[6]	437	1	410	1	418	1	398	1	407	1	2,070	5
AS (X)[6]					1,151	1			1,151	1	2,302	2
Total New Construction[7]	**22,803**	**12**	**28,756**	**15**	**27,957**	**16**	**33,948**	**19**	**33,597**	**20**	**147,060**	**82**

Source: Office of the Secretary of Defense, "Report to Congress on the Annual Long Range Plan for Construction of Naval Vessels." CNO, Deputy Chief of Naval Operations, Warfighting Requirements and Capabilities - OPNAV N9: December 9, 2020.

This makes sense as the SSN fleet ages and faces retirement. The decommissioning rate of attack submarines is going to hit a critical high with 2 submarines decommissioning on average per year and some years going as high as 4 to 5 boats leaving the force. (Table 2) Establishing an industrial capacity for three ships a year is critical for sustainability.

Table 2: Battle Force Retirement Plan

Fiscal Year	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
Aircraft Carrier				-1		-1					-1					-1			-1		-1				-1		-1			
Large Surface Combatant	-6	-2	-2		-1	-3	-2	-1	-3	-5	-3	-3	-4	-3	-2		-2	-4	-4	-3	-5	-3	-4	-3	-2	-2	-3	-2	-2	-2
Small Surface Combatant			-4			-4													-1	-3	-3	-5	-3	-3	-4	-4	-3	-2		
Attack Submarines	-2		-4	-2	-3	-1	-2		-3	-1	-1	-3	-1	-1		-1	-5	-1	-2	-3		-2	-1	-1	-1	-1	-1	-1	-2	-2
Cruise Missile Submarines					-2	-1	-1																							
Ballistic Missile Submarines						-1	-1		-1		-1	-1	-1	-1	-1	-1	-1	-2	-1	-1										
Amphibious Warfare Ships	-1	-4	-3	-1	-1		-1	-1					-1			-1			-1		-1			-2	-4	-4	-4	-3	-2	-2
Combat Logistics Force		-2		-1	-1	-2	-1	-1	-2	-1	-1		-1	-1	-1	-1	-1								-1	-5	-4	-5	-3	-4
Support Vessels	-1	-2	-1		-1	-1	-1	-2	-2	-1		-2	-2	-1	-2	-1	-1	-3	-2		-1	-1		-2	-1	-1	-1	-1		
Total Naval Force Retirements	-10	-10	-14	-5	-9	-14	-9	-5	-11	-8	-7	-9	-10	-7	-6	-6	-10	-10	-12	-10	-11	-11	-8	-11	-14	-17	-17	-14	-9	-10

Source: Office of the Secretary of Defense, "Report to Congress on the Annual Long Range Plan for Construction of Naval Vessels." CNO, Deputy Chief of Naval Operations, Warfighting Requirements and Capabilities - OPNAV N9: December 9, 2020.

Projecting naval force numbers into the 2050s the U.S. leadership anticipate the SSN decommissioning rate versus production to stabilize by 2028 and begin to slowly increase over the next twenty years. Growing from fifty-three submarines in 2028 to eighty by 2051. (Table 3) Aircraft carriers will maintain at ten units while other large surface combatant numbers reduce. Small surface combatants and logistics support vessels will be doubling in size and overall manned combatants will reach a 405-ship fleet by midcentury. The trend is toward smaller, mobile and survivable platforms.

Table 3: Battle Force Inventory

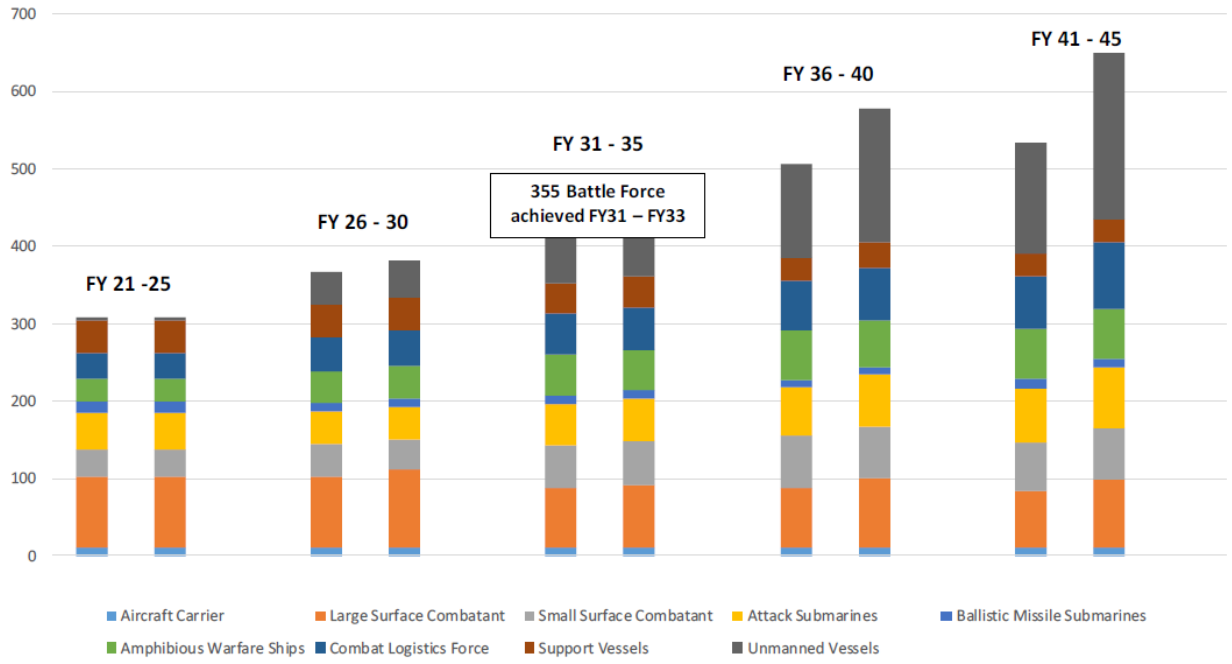
Fiscal Year	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
Aircraft Carrier	11	11	12	11	11	10	11	11	11	11	11	11	11	11	11	11	11	11	10	11	10	10	10	11	10	10	9	10	10	10
Large Surface Combatant	91	92	92	95	96	97	100	101	100	97	94	92	88	86	85	87	86	83	80	78	75	75	73	74	74	74	74	74	74	74
Small Surface Combatant	34	37	35	35	36	34	36	39	42	45	49	53	55	58	62	64	67	69	71	69	69	66	66	66	65	63	63	63	66	68
Attack Submarines	52	54	53	52	50	53	53	55	54	56	58	57	58	61	63	64	62	62	64	64	67	68	70	72	74	75	77	79	79	80
SSGN / Large Payload Submarine	4	4	4	4	2	1																						1	1	1
Ballistic Missile Submarines	14	14	14	14	14	13	13	13	12	13	13	13	13	13	13	13	13	12	12	12	12	12	12	12	12	12	12	12	12	12
Amphibious Warfare Ships	31	28	26	27	29	32	35	37	40	42	44	47	48	52	55	57	61	62	63	64	64	64	64	66	65	63	61	62	62	62
Combat Logistics Force	31	31	32	32	32	35	37	39	40	43	45	48	50	52	54	56	58	61	62	63	65	66	66	69	70	69	69	68	69	69
Support Vessels	37	39	41	45	46	47	48	49	48	49	49	47	45	44	42	41	40	38	36	37	36	35	35	33	32	31	30	29	29	29
Total Naval Force Inventory	305	310	309	315	316	322	333	344	347	356	363	368	368	377	385	393	398	398	398	398	398	396	396	403	402	397	395	398	402	405

Source: Office of the Secretary of Defense, "Report to Congress on the Annual Long Range Plan for Construction of Naval Vessels." CNO, Deputy Chief of Naval Operations, Warfighting Requirements and Capabilities - OPNAV N9: December 9, 2020.

As a key priority the ship building plan focuses on maintaining the undersea advantage. Most survivable strike platforms, SSNs and SSBNs are key to both deterrence and winning great power conflict.[11] Additionally, the transition towards light aircraft carriers (CVL) indicates the desire for a smaller profile platform that presents not only a smaller target tactically but strategically as well. A potential loss of a capital ship would be detrimental to the overall health of the political effort. As we approach mid-century the number of unmanned vessels will approach matching the number of manned ships. (Table 4) This is the second most significant take away and a radical change to what the future of the navy will look like. During the next critical

[11] SecDef, *Report to Congress on the Annual Long-Range Plan for Construction of Naval Vessels,* Ibid, p.10.

Table 4: Range of Naval Force Inventory by Ship Category



Source: Office of the Secretary of Defense, "Report to Congress on the Annual Long Range Plan for Construction of Naval Vessels." CNO, Deputy Chief of Naval Operations, Warfighting Requirements and Capabilities - OPNAV N9: December 9, 2020.

five years, we will begin to see some unmanned platforms come online. As the Navy reaches Battle Force 355 goals by the end of the decade, we should see close to 100 unmanned ships join the fleet and operate alongside manned vessels. (Table 6) By 2051 there will be a near one-to-one ratio of manned and unmanned units totaling close to 800 vessels in the U.S. Navy. These units will allow for distributed operations and provide offensive and defensive fires capacity to the fleet at an affordable cost. Large Unmanned Surface Vessels (LUSVs) are initially envisioned to operate as adjunct fires magazines with larger manned multi-mission platforms to minimize technical risk and maximize survivability. Medium Unmanned Surface Vessels (MUSVs) show promise as low-cost forward sensors and C2 nodes. While XLUUVs, a modular design UUV, will support the undersea mission and provide the capability to deliver multiple payloads at extended ranges.

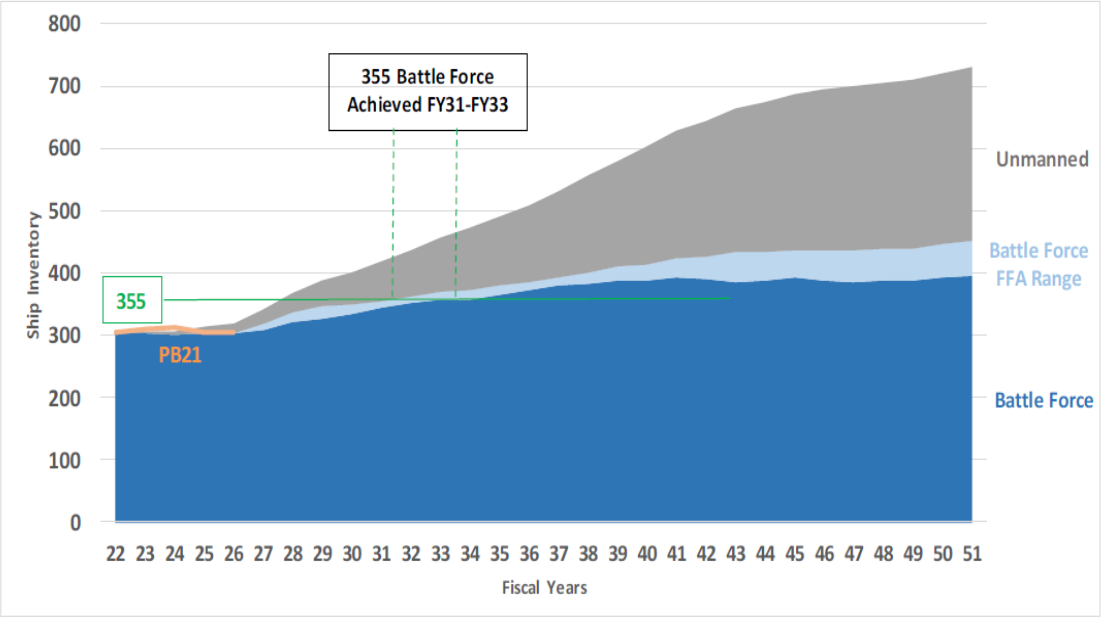
As these technologies mature and increase interoperability with manned ships, we will see budgets further allocated to them. Managing and operating all these platforms will require a lot of resources and support facilities not currently available but anticipated to be a cost saving solution needed in order to maintain a balance of force numbers with adversaries. When compared to manned ships they will be significantly cheaper to build. (Table 5) Projected unmanned platforms for the next five years will cost only $0.19 Billion per unit while manned ships (Table 1) on average will be eight times more expensive. Operating remote and autonomous ships will be less expensive as well. A large portion of the ship and its systems is dedicated towards habitability and life support for the crew. Of course, the fleet cannot do away completely with manned ships and the comparison is not an apples-to-apples comparison. Both will be required for future effective naval operations.

Table 5: FYDP funding for Unmanned Platforms

	FY22		FY23		FY24		FY25		FY26		FYDP	
Ship Type (TYSM)	**$**	**Qty**	**$**	**Qty**	**$**	**Qty**	**$**	**Qty**	**$**	**Qty**	**$**	**Qty**
LUSV[1]	232		445	1	837	3	854	4	868	4	3,236	12
MUSV[2]	26		47	1	44		45		46		208	1
XLUUV[3]					227	2	215	2	453	4	895	8
Total New Construction[6]	**258**	**0**	**492**	**2**	**1,108**	**5**	**1,114**	**6**	**1,367**	**8**	**4,339**	**21**

Source: Office of the Secretary of Defense, "Report to Congress on the Annual Long Range Plan for Construction of Naval Vessels." CNO, Deputy Chief of Naval Operations, Warfighting Requirements and Capabilities - OPNAV N9: December 9, 2020.

Table 6: Naval Force Inventory Ranges



Source: Office of the Secretary of Defense, "Report to Congress on the Annual Long Range Plan for Construction of Naval Vessels." CNO, Deputy Chief of Naval Operations, Warfighting Requirements and Capabilities - OPNAV N9: December 9, 2020.

A ship or a submarine with a human crew ensures that there is a decision maker always present in a forward position. The communication environment may be limited and AI autonomous vehicles will make a decision without the human in the chain. This will always be a risk for regrettable outcomes. A submarine platform can provide this human presence close to the fight and include a decision maker in a dynamic environment. The 2016 RAND report previously cited postulates that U.S. submarine forces would be "largely invulnerable to poor and quickly depleted Chinese ASW capability" [while] "older [Chinese] submarines [would be] vulnerable to U.S. ASW. A few advanced ones [would] survive and threaten U.S. surface forces."[12] Reliable area access of forces in a

[12] Gompert, Cevallos and Garafola, "War with China Thinking Through the Unthinkable,", 36.

potential conflict is reason enough to ensure the Navy maintains a strong capability in the undersea domain. As interoperability with unmanned systems increases, it will be as important to have reliable and survivable command and control of them at all times. A manned submarine would make a logical choice for providing layer of redundancy and depth to the command a control needs of this future force.

Chapter 7: Pacific and Arctic Theater Risks

The Pacific and Arctic theater has been identified as one of primary focus for the Navy, Marines and Coast Guard in the December 2020 Tri-Service strategy.[1] Specifically, priority of competition with the Peoples Republic of China (PRC) is clearly stated. The PRC has increased its number of ships three-fold in the last 20 years and the number is projected to continue to grow (Table 7). China is eyeing the Arctic as they build icebreakers to bolster their fleet. This rapid growth is enabled by economic capacity and a robust shipbuilding infrastructure. There are multiple shipyards that surpass those in the United States in size and throughput. Additionally, surplus PRC industrial capacity, and additional commercial shipyards, could in short order be turned toward military production and repair, further increasing China's ability to generate new naval platforms.[2] "The expansion and modernization of China's submarine and surface warship fleets were among the reasons the Pentagon put "great power competition" at the heart of its national defense strategy after 15 years of focusing on the fight against Islamist militants. China has demonstrated it has the capability to build warships at an impressive rate, with Beijing unencumbered by financial or political obstacles of the sort faced by U.S. administrations.

After taking office in 2012, President Xi outlined a deep-sea ambition for the country's naval force and urged the People's Liberation Army (PLA) Navy to develop a

[1] Office of the Chief of Naval Operations, Advantage at Sea Prevailing with Integrated All-Domain Naval Power, An integrated U.S. Navy, U.S. Marine Corps, and U.S. Coast Guard strategy. (DCNO for Warfighting Development (OPNAV N7); December 2020).

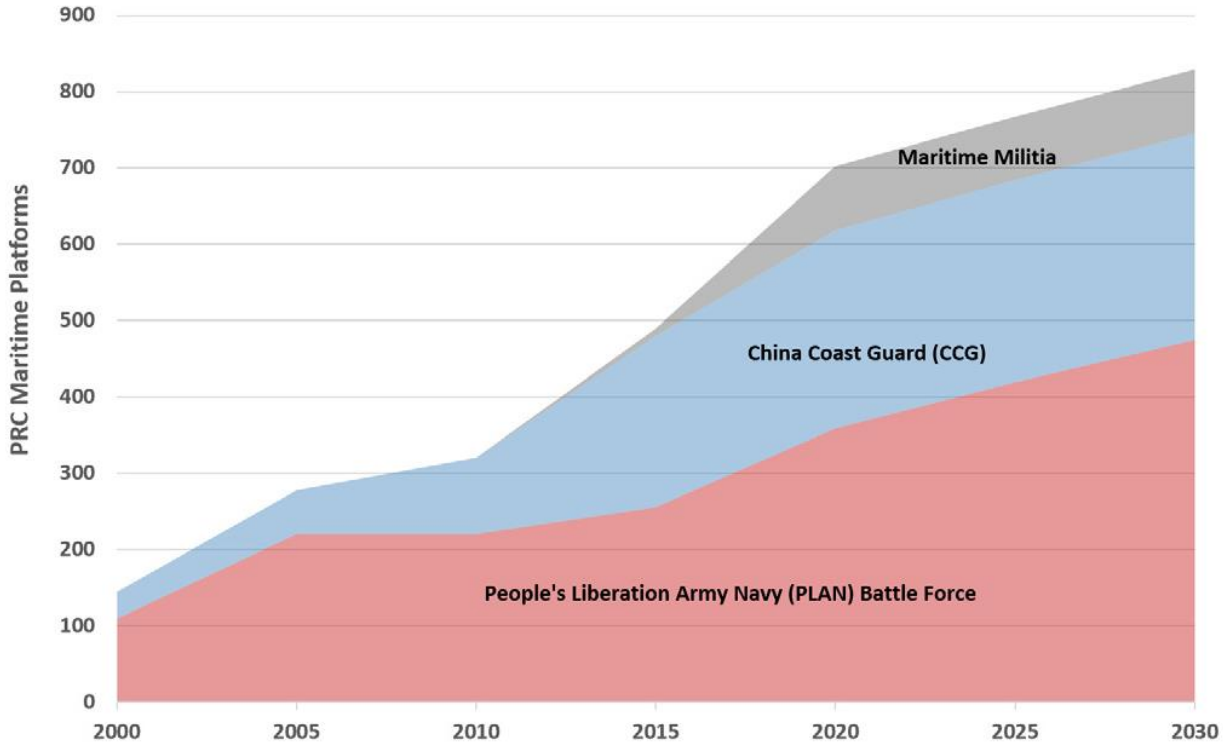
[2] Office of the Chief of Naval Operations, *Advantage at Sea Prevailing with Integrated All-Domain Naval Power, An integrated U.S. Navy, U.S. Marine Corps, and U.S. Coast Guard strategy*. (DCNO for Warfighting Development (OPNAV N7): December 2020).

"world-class" service capable of rivalling the US."[3] Submarines comprise a large part of the Chinese naval force. 12 nuclear submarines have been built in the last 15 years with projections of doubling the SSBN fleet in this decade. PLA Navy (PLAN) also maintains a sizable conventional submarine fleet. "The PLAN will likely maintain between 65 and 70 submarines through the 2020s, replacing older units with more capable units on a near one-to-one basis. China continues to increase its inventory of conventional submarines capable of firing advanced anti-ship cruise missiles (ASCMs). Since the mid-1990s, the PLAN has purchased 12 Russian-built Kilo class SS units, eight of which are capable of launching ASCMs. During these years, China's shipyards have delivered 13 Song class SS units (Type 039) and 17 Yuan class diesel-electric air-independent-powered attack submarine (SSP) (Type 039A/B). The PRC is expected to produce a total of 25 or more Yuan class submarines by 2025."[4] Today the PLA fleet stands at approximately 700 units and is projected to grow to over 800 by the end of this decade. While the U.S. stands at 300 ships currently with a modest growth rate over this decade to a battle force of 355 ships. The significant number mismatch is further exacerbated by the reality of geography and concentration of forces.

[3] *"Beijing ready to deploy its improved nuclear armed submarines."* (The Times, Global Issues, London, England: May 01, 2020). p. 28.

[4] OFFICE OF THE SECRETARY OF DEFENSE, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China* (DOD: August 21, 2020).

Table 7: Growth of China's maritime forces since 2000



Source: Office of the Secretary of Defense, Annual Report to Congress: Military and Security Developments Involving the People's Republic of China, DOD: August 21, 2020.

The geography of the United States requires a two ocean Navy — a Pacific and an Atlantic Fleet. This, together with the vast distance between the oceans means that the U.S. requires two capable fleets, one on each coast, because timely support from one coast to another presents a challenge in time and distance. Both routes, North through the Arctic and south through the Panama Canal, have problems: Ice in the Arctic, and a choke point in Panama. Both options even if feasible are long voyages. To address this problem of inability to quickly combine forces and without drastically growing the size of the two fleets the U.S. needs to increase forward basing and forward presence of the two fleets around the globe. Instead of thinking to combine across Panama or the Arctic we look to combine in the other direction. By moving units East in the Atlantic and West

in the Pacific the Navy can shorten the response time in combining forces if needed. Having forces operate forward and dispersed helps to solve the problem of rapid increasing of forces but also gives the dispersion of forces in day-to-day operations in support of Joint Force efforts.

The Tri-Service strategy concepts of Distributed Maritime Operations, Littoral Operations in a Contested Environment, and Expeditionary Advanced Base Operations to support Joint Force Commander objectives are designed to provide increased response and effectiveness. The Joint Warfighting Concept requires integration and flexible forces. Large battle fleet formations are likely to be rare. Instead, agile, mobile, distributed units will integrate, synchronize and will mass the effects of joint, sea-based, and land-based kinetic and non-kinetic fires.[5] Forward based nuclear submarines allow for continual forward presence and to be the initial force in the theater. They can be the first responders or provide intelligence gathering to shape the response to follow. A submarine platform in a covert posture and with ability to vary mission roles can connect and integrate platforms, weapons, systems, and sensors increasing battlespace awareness. The idea is to control the sea continually and deny free access to the adversary by holding them at risk. Containing the enemy fleet to areas that prevent freedom of operation through control of choke points or preferably force them to remain in port, allows for more effective air and land targeting. Distributed forces and maneuvering across all domains allow one to exploit uncertainty and achieve surprise. The submarine can fulfill this role well but to cover all the strategic areas in number, forward basing is lacking and will require more submarine tender support than currently exists. This forward basing

[5]CNO, OPNAV N7, Ibid, p 13.

will solidify U.S. response capability in strategically important areas such as the straits of Malacca, Luzon and Taiwan.

The PRC holds its Taiwan territorial claims to be very close to their fundamental views on territorial integrity. Additionally, proximity of any democratic government is a direct threat to its regime. Consequently, their commitment to gaining Taiwan and ending democracy will be very strong. Western belief that China would eventually turn to a democratic society over time, as Taiwan has, is now a distant proposition. It is the belief of the Chinese Communist Party elite that China's greatness lay in its Confucian authoritarian hierarchical state historically, and currently complemented by the imagery of the Communist Party into a combined contemporary Chinese consciousness, and thus has no reason to seek any alternative system. The renaissance of China rests in the unique national political Chinese forms which are embedded with historical authoritarian hierarchical continuity comfortably complemented by neo-Confucianism and accompaniment of a modern socialist communist state and hence views the future global political and economic conduct to reside with its indigenous political forms. In other words, democracy was never needed throughout Chinas history, its current rise, and therefore it will not be needed in the future.[6] Democratic Taiwan is a threat politically but it also holds a strategic value.

The beginning of the US-Japan Pacific war in 1941 was marked with the attack in Southeast Asia on the Philippines and Dutch East Indies that came from Taiwan, or as it was known then, Formosa. This was a staging point for Japan's forces and a central focal point for the U.S. in considerations of its strategic objectives. In the Korean War 10 years

[6] Kevin Rudd, Former Prime minister of Australia, (Watson Institute, April 2018). Access via: https://www.youtube.com/watch?v=ObOo9tb6TBk

later, president Truman highlighted the significance of its strategic value and felt that the "occupation of Formosa by Communist forces would be a direct threat to the security of the Pacific area and to the United States forces performing their lawful and necessary functions in that area."[7] This makes sense. This a large island that is centrally located in the so called first island chain. It provides both a gateway to the South China Sea from the Pacific and lies in the path of trade routes for shipping to Korea and Japan to the north, and South-east Asian countries to the south, as well as the Middle East and Europe via Singapore. The island lies 100 miles east of China's mainland, 200 miles from the Philippines, 700 miles from Japan, and 900 miles from Vietnam. Whomever controls this strategic asset can both launch action from this central location and provide general area defense. If China were to control Taiwan it could assert more claim to the whole of the South China Sea nine-dash line as territorial waters with all of the gas and oil deposits as well as control shipping and apply pressure at will on neighbors that rely on freedom of the seas in the region. Basing of aircraft and missile systems would give those weapon platforms a longer effective range into the Pacific. Establishing submarine operations from Taiwan would allow the PRC quick access to deep water and entry into open ocean for both conventional and nuclear submarines avoiding long transits on the surface and trawler congested shallows. Taiwan also has an economic interest. It produces a large number of advanced microprocessors and high-tech computer chips. It has a large educated population with many established industries in chemical, textile, food, petroleum, machinery, steel, consumer products and pharmaceutical sectors. Not least significant is that Taiwan is also a promoter of a western style of administration and has a

[7] President Harry S. Truman

democratically elected government. Having observed the failure of the "one country, two systems" policy China had with Hong Kong, all major Taiwanese political parties rejected being ruled by the autocratic PRC and the possibility of this arrangement.[8]

President Barack Obama declared a *pivot to Asia* in 2011 and stated before the Australian parliament a U.S. commitment to securing democracy in the region. The Taiwan Relations Act declared that any effort other than peaceful determination of Taiwan's future would constitute "a threat to the peace and security of the Western Pacific area and of grave concern to the United States."[9] The December Tri-Service strategy singles out the PRC as the primary challenger. It is very likely in this context that the U.S. would come to the defense of Taiwan. Failure to stand by Taiwan would mean lack of will or capability and diminish U.S. standing in the region and around the globe.[10] Due to the PRC's large long range missile capability, a surface fleet would be vulnerable. To ensure a PRC landing force has little chance of success, a large portion of it would have to be neutralized via missiles and torpedoes. The best platform to deliver this ordinance would be the stealthy and survivable submarine. The PRC's aggressive behavior has fueled defensive trends and somewhat of a conventional submarine arms race in the Pacific. (Table 8) There are established submarine operating nations like India

[8] Yew Lun Tian and Yimou Lee, China drops word 'peaceful' in latest push for Taiwan 'reunification', (Reuters: May 2020).

[9] Taiwan Relations Act (Public Law 96-8, 22 U.S.C. 3301 et seq.) January 1, 1979.

[10] Joseph Bosco, Cross-Strait Relations: Strategic significance of Taiwan (University of Nottingham Taiwan Studies Programme), 26 Feb 2018. Access on https://taiwaninsight.org/2018/02/26/cross-strait-relations-the-strategic-importance-of-taiwan.

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and newcomers like the Philippines that are planning to acquire more submarines in the near future.

Table 8: Planned and Recently Completed SSK Acquisitions in the Indo-Pacific

Planned and Recently Completed SSK Acquisitions in the Indo-Pacific	
India	24
Taiwan	8
Australia	6
Vietnam	6
Indonesia	5
Thailand	3
Singapore	2
Bangladesh	2
Philippines	2

Sources: Groll and De Luce, "China Is Fueling a Submarine Arms Race"; "Thailand Approves $393-Mln Purchase of Chinese Submarines," Reuters,24 April 2017, in.reuters.com/; Ridzwan Rahmat,"TKMS Begins Work on Singapore's Third and Fourth Type 218SG Submarines," Jane's 360, 16 January 2018, www.janes.com/; Marhalim Abas,"Fighters, Submarines on Philippines Shopping List," Aerospace Daily & Defense Report, 22 June 2018, viationweek.com/; "Bangladesh's First 2 Submarines Commissioned," Daily Star, 12 March 2017, www.thedailystar.net/; Franz-Stefan Gady, "Taiwan's Indigenous Submarine to Be Based on European Design," The Diplomat, 26 September2018, thediplomat.com/.)[11]

More nations are looking for costal defensive naval capabilities such as those provided by a patrolling submarine. Since exact timing of an attack would be difficult to determine, the ability to produce a continuous defensive submarine presence allows a safety buffer and a deterrence. Alternatively, to a locally-sourced conventional submarine, a nuclear submarine and autonomous vehicle fleet would provide endurance and flexibility in response. It will be able to stay on station for long periods of time and

[11] Yu, Jihoon, and Erik French. *Should the United States Support a Republic of Korea Nuclear Submarine Program?* (Naval War College Review, no. 1 2020): p 90.

patrol the areas of approach. Coordinating detection and counter-action using line of sight communications with teams of UUV and UAV would provide an always ready force.

The PRCs commitment to reunification has always been strong as it has considered Taiwan a rebel province. Use of force has not been ruled out in an effort to retake it. Most recently in May 2020 Chinese Premier Li Keqiang left out the word "peaceful" in his state-of-the-nation work report at the start of the annual meeting of China's parliament.[12] Chinas strong political stance and Navy buildup with a goal to be on parity and surpass the U.S. by 2035, presents a "wicked problem"[13]. Regardless of what the U.S. does, China will continue to move towards regaining Taiwan as long as the CCP deems it to be central to the One China Policy and they see tangible strategic benefit to controlling the island. Control of the South China Sea and beyond is of great importance for the PRC as it depends on oil from the Middle East, Africa, Southwest Asia, and, increasingly, Russia. Most of this oil arrives by ship, although pipelines are being built west and north as part of the Belt and Road initiative. The desire to control flow of energy and trade is directly linked to maintaining legitimacy through economic prosperity.

> Absent a healthy economy, a large part of the legitimacy of the rulers in Beijing vanishes. A navy ensures the safety of secure sea lines of communication (SLOCs) and also provides a fallback position for Chinese rulers as defenders of the nation if the economy falters. Navies are flexible tools. Besides protecting SLOCs, they can project power, deny other navies access to vital areas, and interrupt communications—for example, those between the United States and its treaty allies in the West Pacific: Australia, New Zealand, Japan, the Philippines, Thailand, and South Korea. Again, the issue of the legitimacy of China's rulers surfaces. As nationalism, encouraged by the Chinese Communist Party (CCP),

12 Yew Lun Tian and Yimou Lee, *China drops word 'peaceful' in latest push for Taiwan 'reunification'*, (Reuters: May 2020).

13 The term "wicked problem" was introduced by design theorists Horst Rittel and Melvin Webber in 1973. It refers to a problem that is difficult to solve or resists a solution due to contradicting, incomplete, changing or inconsistent information such as in situations typical to the complexities of social policy.

> grows, the ability to prevail in such disputes as raised by China's territorial claims in the South and East China Seas supports the CCP's legitimacy. The Party's unchallenged and supreme rule subsumes all else in the calculations of China's rulers. A powerful navy can hope to keep SLOCs open and oil and exports flowing. It is an important element in asserting territorial and mineral rights in nearby international waters. The ability of the People's Liberation Army Navy (PLAN) to project power would be key if Beijing decides to slice communications between the United States and its West Pacific allies. Freedom of the seas and national independence is in the interest of the US and its allies in the Indo-Pacific. More importantly, adhering to commitments and coming to the defense of those under threat from coercive and nefarious forces is living up to American values. China's intimidation of its neighbors, all of whom rely significantly on the South China Sea for commercial enterprise, raises questions about the commitment of the United States to remain an effective alliance partner and a defender of international oceanic space. A strong actively patrolling submarine force would assure US partners of the ability to respond quickly and decisively if the need arises. Additionally, as air superiority would serve to support success on land, possessing undersea superiority would place doubt in US adversaries' plans who seek to control the region and its weaker neighbors. If the United States is found lacking, friends and allies will rearrange their defenses and alliances.[14]

This would likely cause instability and unforeseen crises that could have been avoided through display of dependable consistency and resolve.

To the North the picture is also starting to look complicated. Observing the increased Arctic exploits of Russia and the interest being shown by the PRC calling itself an 'near Arctic State', it is reasonable to expect more activity and operations in the area. President Xi Jinping announced in 2014 that he wants China to become a "polar great power".[15] When comparing fleets, the differences are large. Russia possesses 40 icebreakers with a number of them nuclear and half a dozen more nuclear ships under construction. The PRC has two icebreakers and plans for more including a nuclear variant. At present the U.S. lacks numbers in the icebreaker fleet although efforts are

[14] Seth Cropsey, *Seablindness : How Political Neglect Is Choking American Seapower and What to Do About It*, (New York, Encounter Books: 2017).

[15] Jeremy Luedi, "Are China's Arctic ambitions a threat to Canada?" *True North Far East:* May 2020.

being made to increase from two to six.[16] There is no call for a rapid buildup as there is no consensus that lack of icebreakers results directly in a strategic lag from a military standpoint. A military ship moving behind a slow icebreaker would not necessarily present a difficult target. This data is more illustrative of level of interest in engagement in the Arctic region and does require thought and attention. It may be indicative of not only economic pursuits but a PRC desire to operate strategic ballistic missile submarines like Russia has done in the past. While things remain unclear and are yet to come into focus, the U.S. can potentially rely on additional capacity of icebreakers that allies such as Canada, Japan and Norway have in inventory. From a military standpoint nuclear powered submarines in the Arctic operating under the ice would be the preferred platform for ensuring a strategic balance is maintained. This area of operations is not well suited for a conventional or AIP system submarine as being trapped under the ice without the ability to surface would be disastrous. The U.S. has been operating submarines in the Arctic for a long time and continues to have expertise and ability to operate under the ice. In order to maintain situational awareness of other nations' exploits in the Arctic as well as secure lines of approach from the northern latitudes, the U.S. needs capable ships with reach and endurance. Combination of manned and autonomous systems will be required to support the intensification of action. Continuing this effort will be important as the ice recedes and activity increases in the Arctic.

It is clear that the future in the Pacific and Arctic region will require the use of capable nuclear powered submarine platforms. Quick response time to strategic choke

[16] Paul C. Avey, "The Icebreaker Gap Doesn't Mean America Is Losing in The Arctic," *War on The Rocks:* November 2019.

points and deterrence by a credible fighting force that can deliver lethal overwhelming fire will help offset the losing numbers game.

Chapter 8: Risk Mitigation: Required Submarine Technology and Tactics Improvements

The submarine in large degree can be compared to a sniper moving through the jungle that sometimes is dense and loud or very quiet and sparse. The sea environment is extremely varied and dynamic. Hearing in this underwater jungle is seeing. The reality of sound behavior in the ocean is extremely complex as it bends and bounces due to temperature, pressure, salinity, thermal layer combinations, currents, bottom composition and bathymetry. Detecting your target first and developing a firing solution is the first and foremost advantage in this fight. Continuing to develop sonar systems with improved ocean environment models and AI-assisted fire control systems will keep the onboard hardware on the right slope, but there is more. A sniper that is assisted with cueing and targeting data from remote sources becomes that much more effective. Developing this capability of receiving locating data while submerged from external sources while completely stealthy is the sixth sense integration that will allow the hunting submarine to begin the engagement well beyond onboard sensor range. A robust system of undersea sensors and subsurface communication portals will help maintain communication with the hunting submarine while avoiding traditional near-surface modes of communications.

Additionaly, these are deployable and retrieavable UUVs carried by the submarine will

Figure 4: Maritime Surveillance Systems and Integrated Systems Source: UWCT Office Enabling Strategic Innovation for the Undersea Force. Accessed on April 11, 2021, https://www.navsea.navy.mil/Portals/103/Documents/USWCTO/CTO_FactSheet.pdf?ver=2016-11-01-133919-130.

extend the horizon for the submarine in various ways. By deploying the UUVs in a specific geometry dictated by tactical picture, the UUVs can serve as tripwires or lookouts. They can enter contested or congested areas and record contact patterns and provide this information to the submarine. They can be the active sonar platform, allowing the manned submarine to remain in passive receive mode or act as an SSN clone and decoy. UUVs can be deployed on counter detection mission with the goal of locating and defeating adversarial undersea hydrophone networks. The applications are numerous and increasingly important to maintaining undersea dominance. Nuclear submarines maybe gaining even more capabilities that are offensive weapons.

One of the biggest detection threats to a submarine comes from the air in the form of aircraft. Modern submarines have no air attack capabilities while submerged and could do little with small arms fire while surfaced. For the most part submarines have lost air warfare capabilities since World War II, although a few subsurface-to-air missile technologies have been designed in the past. There are some instances where having an

offensive capability to defeat drones or helicopters would be advantageous. A destroyer typically carries one or two helicopters and if the right circumstances presented themselves where a submarine could eliminate the destroyers' helicopter, that warship may recklessly rush to the location of the crash and present itself an easy target for the submarine or, to the contrary, withdraw from the area due to losing a significant ASW asset. The submarine may either score an easy victory or not even have to engage the ship directly. Either way this would present tactical options to the submarine commander not available in the past. Although no program of record has been reported to exist, there have been reports from technology magazines[1] and media that the U.S. Navy is investigating the idea of putting laser systems (Figure 6) onboard the Virginia class attack submarines. There is speculation as to the purpose and potential targets as well as technological feasibility, but development of such a system would add yet another impressive capability to the SSN arsenal.[2]

[1]David Hambling, "The Navy Is Arming Nuclear Subs With Lasers. No One Knows Why," *Popular Mechanics Magazine*: February 04, 2020. https://www.popularmechanics.com/military/navy-ships/a30647372/laser-nuclear-subs/

[2] H. I. Sutton, *The Navy Is Arming Attack Submarines With High Energy Lasers,* (Forbes: February 09, 2020). https://www.forbes.com/sites/hisutton/2020/02/09/the-navy-will-arm-attack-submarines-with-high-energy-lasers/?sh=53c018fa3779

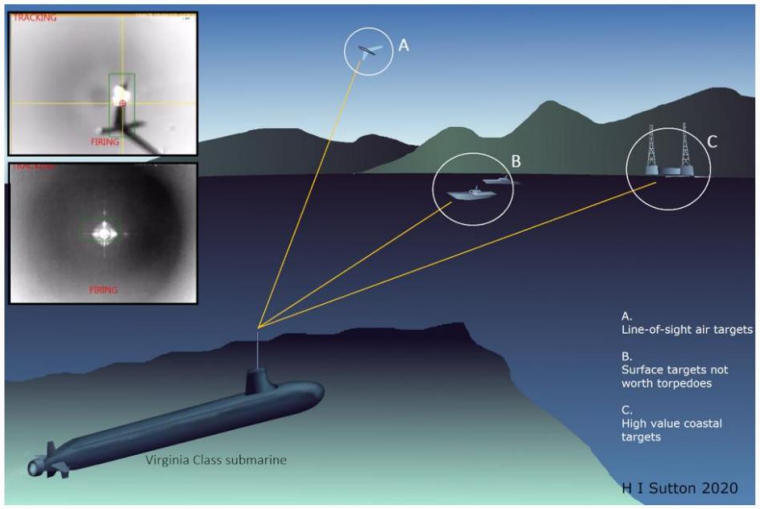

Figure 5: The U.S. Navy project will fit high energy lasers (HEL) onto a mast of the Virginia Class attack submarine. This could be used to engage a range of targets, provided that there is a direct line of sight. Inserts from U.S. Navy laser tests. Source: H. I. Sutton, "The Navy Is Arming Submarines With High Energy Lasers," Forbes, February 09, 2020.

It is a difficult engineering task to make this technology practical. Fitting all the associated equipment onboard, routing the beam through a mast, make it dependable in dynamic seas and environmental conditions will be challenging. However, the benefits may be worth it. The nuclear reactor with a proper generator will be able to supply large amount of energy and therefore the laser will be powerful and provide a higher fire rate. The submarine can use it to attack air targets of opportunity and pose a known risk to the adversary which is a tactical advantage in itself. Also, this weapon can be used for force protection. A submarine on the surface has limited defense capabilities and is most vulnerable to small boat and drone attack when coming in and out of ports. If submarines are to operate more frequently in forward locations, they are likely to see more foreign ports as well. Having a powerful defense against surprise attack from small craft, means the submarine can buy sufficient time to prepare the boat for dive and slip away into the depths. As the U.S. pursues the concept of distributed forces, this will contribute to

submarines' capability of independent operations in distant locations and require less reliance on other forces.

To support distributed forces concept and continued forward presence, it is necessary to increase the number of submarines in theater by moving their basing and operations more forward. There are limits to current basing and creative ideas are needed. Setting up permanent submarine bases in foreign countries is potentially too aggressive and provides security concerns. One way to improve flexibility is to increase the number of submarine tenders. Currently two operating platforms allow for some flexibility but nowhere near what is required to fulfill the vision. Nuclear ships require specialized support and there is little substitute for a submarine tender other than home port. Although nuclear power does allow for rapid positioning, the distances are still too large for adequate surge response time. A fleet of submarine tenders in forward non-traditional locations such as the Philippines, Malaysia and Indonesia will directly reflect in more submarine density and operational time on station. It also allows for less complicated logistics of relocating the support ship to different ports and minimizes overhead with establishing permanent basing arrangements domestically and internationally. Additionally, setting up a submarine support facility is likely to be a politically sensitive issue but a submarine tender mooring would be an easier proposition and a much more realistic task to achieve politically. Widened support structure is one aspect but effective ships with trained and skilled warfighter on them is indispensable.

In an effort to maximize the weapon the crew is trained extensively. Tactical considerations are constantly revised and questioned in the submarine training centers on a daily basis. In general terms, the approach to developing tactics stems from maximizing

advantages of the available hardware versus countering capabilities of the opponents and minimizing their perceived advantages. If the U.S. were to think strategically when anticipating what conditions are needed to ensure achieving a tactical edge in the future, the country needs to develop systems that are resilient and agile to fit unforeseen conditions. "New manufacturing technologies, inexpensive improved computer processors, and local industrial tooling will make assembly of sophisticated weapons and connected devices relatively inexpensive and easy to conceal. Advancements in commercial technology will substantially increase the range, precision, persistence, and lethality of potential adversary weapons systems and erode the current U.S. military advantages of networked precision strike, stealth, and surveillance capabilities."[3] The fleet cannot give up critical things like speed, endurance, redundancy, capacity, survivability and maintainability. These are the core attributes that ensure the platform can meet the requirements of tomorrow's tactics. Targeting and localization is becoming easier. In the current period of fourth generation warfare large mass of military power may be a disadvantage while smaller units that are maneuverable and agile provide the advantage needed in the modern style of warfare.[4] The nuclear submarine can disperse and regroup rapidly when required making it a flexible platform that is needed in the fourth-generation warfare. The nuclear submarine is not a weapon of massing in a war of attrition, it is a stealthy and mobile sniper. Every enemy ship does not need to be sunk in a battle. The object is to sink just enough to force the enemy to reconsider their plans and,

[3] Paul Scharre, *Robots on the Battlefield: Part I: Range Persistence and Daring,* (Washington D.C.: Center for a New American Security, May, 2014), p.7.

[4] Tom Lansford and Jack Covarrubias, "The Limits of Military Power: The United States in Iraq," in Tom Lansford, ed., *America's War on Terror, 2d rev. ed.* (Farnham, Surrey: Ashgate Publishing, Limited, 2009), 6.

most importantly, the submarine needs to survive in order to carry out another attack. A resilient and unrelenting group of hunters that can act alone with decisive results, or combine forces in a concentrated effort of a wolfpack for decisive outcomes, requires trained and ready crews.

Undersea warrior development is a leadership challenge. Culture of the warrior ethos has to be singularly important, as is the technical expertise. This requires study of history and practical experience. At the start of the submarine war in the Pacific during World War 2, American submarines did not see much success. Even though there was a culture of learning, exercises induced conservative tactics and risk avoidance. There were no night attacks or coordinated attack group (CAG) (equivalent of German wolf pack) tactics as it was deemed too dangerous. The submarine world was at odds with what the Navy would eventually need in the Pacific.[5] As one Sailor-scholar observed:

> Submarines were to be confined to service as scouts and "ambushers." They were placed under restrictive operating conditions when exercising with surface ships. [this] led to the erosion of tactical expertise and the "calculated recklessness" needed in a successful submarine commander. In its place emerged a pandemic of excessive cautiousness, which spread from the operational realm into the psychology of the submarine community.[6]

Aggressive pursuit of objectives balanced with calculated risk and improved CAG tactics eventually shifted the culture and U.S. submarines, only comprising 2 percent of the navy, ultimately sank 54.6 percent of Japanese shipping totaling 1,392 ships.[7] Most of the success came in late 1943 through to 1945 after the submarine force adjusted tactics and

[5] F.G. Hoffman, "The American Wolf Packs A Case Study in Wartime Adaptation," *National Defense University*: JFQ 80, 1st Quarter 2016, 133.

[6] Craig C. Felker, "Testing American Sea Power: U.S. Navy Strategic Exercises, 1923–1940" *College Station*: Texas A&M University Press, 2007, 62.

[7] William P. Gruner Jr., *U.S. Pacific Submarines in World War II* (Maritime Park Association: 2016-2018).

fixed torpedo issues plaguing the early years of the war.[8] Boldness and aggressiveness of submarine skippers did the rest. This quality of "organizational learning dominance" was as critical as the foresight in the interwar period.[9] In order to meet future demands effectively, the ability of the joint force to rapidly create new knowledge and disseminate changes in tactics, doctrine, and hardware will certainly be part of the formula for success.

The combination of technologies, tactics and warrior ethos are pieces of the puzzle in the science of war. They all have to be managed and the effects on the warrior have to be anticipated and accounted for. As described by J.F.C Fuller in "The Foundations in the Science of War," conditions of the next war must be foreseen. Forecasting the next war will affect training in peace time and when war does break out those tactics are likely to change. It is also fairly self-evident that there is a tendency towards improvement in weapon design. What is not as obvious but exists nonetheless is the psychological effect on the warfighter. Standoff weapons have created a detached relationship to the task of eliminating your enemy. War in an evolution of civilization which discovers its tendencies through its course. Fuller described some of the changes:

> but, unless the psychology of war has been carefully studied, there is a distinct difficulty to forecast the moral conditions, new weapons, etc., will give rise to on the battlefield. Thus, for instance, a tank can undoubtedly assist an infantryman to capture a machine-gun, but will this increase the courage of the infantryman? Not necessarily; for, in place of stimulating his courage, the fact that the tank is invulnerable to machine-gun fire will throw him back on his reason and imagination, and he will say: "-This machine is quite capable of dealing with the machine-gun; why should I risk, therefore, my life by following it closely? I will wait until the tank has destroyed the enemy, and then I will advance and occupy the position." This is common sense, and we must understand such conditions as these, for otherwise we may, during peace-time, when the instincts are not

[8] F.G. Hoffman, "The American Wolf Packs A Case Study in Wartime Adaptation," 137.

[9] R. Evan Ellis, "Organizational Learning Dominance," *Comparative Strategy*, 18 no. 2 (Summer 1999), 191–202. DOI: 10.1080/01495939908403173

> aroused (because of the absence of danger), determine on tactics which demand close co-operation between tanks and infantry, and then, during wartime, we may discover that the infantry will not closely co-operate, and our tactics break down, because they- are not harmonized with the moral conditions created by the tank in this special case - the infantry attack.[10]

This is to say that the conditions created on the training battlefield are different from those of reality. Additionally, advances of robots and autonomous underwater and aerial vehicles combined with AI decision making and providing recommendations will have their effect on the warrior. "When Navy and Department of Defense leaders speak of the submarine force's competitive advantage, they also warn that it cannot be taken for granted."[11] We cannot be certain what the future will look like but we must be aware that there will be an effect and it will require anticipation, mitigation and leadership.

[10] J.F.C. Fuller, *The Foundations of the Science of War* (Ft. Leavenworth, KS: U.S. Army Command and General Staff College Press, 1998), 186.

[11] Caudle, "Sustaining the Submarine Force's Competitive Edge."

Conclusion

There is no question that the submarine of the last century transformed naval warfare into a multidimensional battle and became a fearsome weapon. There are unknowns to whether this platform will become obsolete as others have over the course of military technology lifecycle. It is possible that it will if the fleet does not tailor the role, technology, and approach to its employment. In the coming age of increased ability to detect the submarine, where detection is becoming easier to accomplish, the submarine will be forced to hide deeper and further.

To stay relevant on the battle-field the submarine needs to maintain its edge by maintaining its stealth. That is the key ingredient in the secret sauce that encapsulates the platform and makes it an attractive asset in any naval force portfolio. Without stealth the wolf is not so dangerous and loses not only strike power but psychological advantage over the enemy of creating uncertainty. Uncertainty is an extremely powerful tool for a military strategist. An adversary that is unsure is an adversary that could be prevented from making a decision. Indecision is undoubtedly a useful way to disarm as well as open the enemy to making mistakes which lead to losses. Because the enemy fears the risk of a loss, the 'decidophobia' can debilitate action and force the foe into re-action.[1] This is where the submarine threat proves so instrumental and why great efforts are made to neutralize it.

The great speed at which UUV, UAV, space tech and AI is developing forces the question whether these technologies are getting ahead of stealth capabilities of the

[1] Walter Kaufmann, *Without Guilt and Justice*, (1973).

nuclear submarine. The competences of these technologies to detect and track the submarine in concert is growing. The cost of entry into the realm of autonomous vehicles is becoming cheaper and more accessible. This means smaller nations using this technology may be able to reduce or neutralize the submarine threat off their shores. If the veil that keeps the submarine hidden is lifted, the submarine will lose the advantage. The technology that threatens the nuclear platform does even more damage to diesel and AIP variants. The fact that a conventional submarine travels at very low speeds often less than 5 knots, allows UUV to trail it and hand off shepherding the submarine to other units once located. As the number and capability of autonomous vehicles and networks grows, the non-nuclear boats will be further relegated to local operations and home waters defense, making successful prospect of remote operations less appealing. It is true that the cost to build non-nuclear-powered ships is lower, but as the AIP systems become more complex the cost is still significant and much more than a conventional diesel. Even though an AIP submarine can at times act like a nuclear-powered ship for a few hours, the drawback is required recovery time and at the end of the day it still has a limited supply of fuel making it a constant calculation of tradeoffs for the commander and never a true substitute for the freedom of operation a nuclear-powered boat brings.

For the U.S. Navy's submarine fleet to continue to hold the advantage, the goal must be to develop offensive counter-autonomous vehicle weaponry to defeat individual units in the field as well as generate network deniability capabilities to break command and control and communication channels. But most importantly, the key lies in creating systems and mode of operation that inserts a degree of uncertainty in the positive detect

and confirmation of contact of these systems. Creating false detects and overwhelming the system with false positives renders the detection system useless.

A nuclear platform holds advantages over other naval platforms in many areas. Specifically, in space and time. The nuclear powerplant allows for sustained speed of maneuver in order to exit a threat area quickly cover vast distances if needed and reposition to confuse detection. The reactor gives endurance by allowing the commander flexibility in choosing when to act without constraints. The boat can loiter in its most stealthy posture for extensive periods until the time is right for action. The commander has great flexibility to be creative. Lastly the size of the ship with a nuclear powerplant gives builders and scientists room for more systems and weapons of the future. It's a platform with less restrictions in the realm of what is possible. This means the same boat of 20 years ago can have a new lease on life as Los-Angeles class submarines have experienced transformation over the decades. This will be the winning angle: giving the nuclear submarine systems and technology that can multiply its presence. An inventory of UAVs and UUVs that can be deployed and recovered with a nuclear platform that can covertly enter an area, deploy UUVs, and return days later to recover them or act in concert to attack and confuse the enemy will turn one nuclear submarine into a squadron. This would be very similar to how an aircraft carrier gains its strength from the inventory of aircraft it carries. The foremost characteristic of a nuclear-powered submarine is that it is an offensive weapon designed to operate far from home shores and in the midst of an enemy's waters. It is a front-line global reach capability that any nation seeking to control the destiny of its endeavors will need to develop but likely only few will be able to master.

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