

SUBMARINES

WEAPONS OF CHOICE IN FUTURE WARFARE



EXECUTIVE SUMMARY

The cover of the ninth and last edition of "Soviet Military Power," published by the U.S. Department of Defense in 1990, featured a picture of a Delta IV ballistic missile submarine. This formidable weapon system epitomized the profound nature of the Soviet threat to the American homeland. Throughout the Cold War, the United States relied on a fleet of attack submarines to track, and if necessary destroy, these Soviet behemoths. With superbly trained and dedicated crews, this U.S. fleet was also charged with protecting surface combatants and naval convoys from Soviet attack submarines. In 1990, the United States had 100 submarines available for these anti-submarine warfare (ASW) missions.

Because of the overwhelming importance of ASW, nuclear attack submarines (referred to in naval nomenclature as SSNs – SS for submarine, N for nuclear-powered) were associated with a relatively narrow role in the ongoing drama of the Soviet-American competition. Consequently, they were often viewed as a quintessential "Cold War weapon." When the Soviet Union collapsed, some considered the SSN an anachronism.

Ironically, the contrary has proven true. U.S. military planners and joint force commanders are more aware than ever of the unique attributes of submarines that make them extraordinarily useful tools. It is a fleet that can operate in hostile shallow waters and influence events onshore because it can strike land targets quickly, conduct secret reconnaissance over extended periods and covertly deliver special operations forces.

In an even more dramatic reversal of Cold War roles, four Ohio-class ballistic missile submarines – U.S. counterparts of the Delta IVs – are being relieved of their strategic payload and are being refitted for conventional missions. Designated as SSGNs, these four submarines will have some of the same missions as SSNs, but with a much larger payload.

As the United States enters the twenty-first century and the era of global terrorism, the American submarine fleet continues to represent a capability far above and beyond that of any other country. But this advantage cannot continue to be taken for granted. Today's attack submarine fleet is barely half the size it was in 1990, and consists entirely of platforms initially designed for the Cold War environment. While these facts do not constrain the operational value of the fleet in any significant way today, the continuing evolution of the threat against the American homeland and U.S. interests abroad demand that the country continues to invest in and deploy advanced submarine technology optimized for the new environment. With adequate funding, robust training and innovative operational thinking, the submarine fleet will continue to be the Navy's "crown jewel" well into the future.

The initial draft of this report was written by Myra S. McKittrick. All members of the Naval Strike Forum had an opportunity to review and modify the final report.

Submarines: Weapons of Choice in Future Warfare

The 1980's goal of a 600-ship Navy included 100 attack submarines. This goal was met in 1988 and sustained for several years. But with the end of the Cold War, the SSN force objective was rapidly reduced in a series of studies between 1991 and 1993. These numbers reflected the significantly reduced role envisioned for America's non-strategic submarine fleet. As the number of active submarines declined, so also did procurement of new boats. The last Los Angeles-class (SSN-688) was funded in fiscal year 1990. Its successor program, the Seawolf (SSN-21), was terminated in 1992, although three boats eventually were appropriated by Congress.

By the end of the 1990's military planners were beginning to have second thoughts about these reduced force levels, particularly in light of peacetime operational requirements. A 1999 study by the Joint Chiefs of Staff (JCS) set the parameters around which current planning still revolves. The JCS study asked regional commanders-in-chiefs to estimate future submarine requirements based on their own projections of the regional threat. The results forecasted a substantial increase in demand for intelligence, surveillance and reconnaissance (known as ISR) that could be provided only by submarines. They also projected a need for a much greater forward presence in the Asia-Pacific region, especially in the latter years with the increased prospects for the emergence of a peer military competitor. The study determined that these peacetime missions of submarines justify a larger SSN force structure of 68 boats. However, taking into consideration resource constraints, the JCS finally concluded that the number for war-fighting requirements (55) is an acceptable floor for the fleet at least until 2015. By 2025 the recommended goal increases to 76 (with a floor of 62) SSNs to take into account evolving threats.

Attack Submarine Force Goals

Reagan-Era 1980s	Base Force 1991	JCS Study 1992	Bottom-Up Review 1994	QDR 1997	JCS Study 1999	QDR 2001
100	80	51	45	50	55 (68)	55

Defense Capabilities for the New Strategic Environment

The 2001 Quadrennial Defense Review (QDR) established a framework for adapting the U.S. defense posture to a security environment primarily characterized by uncertainty, even as key U.S. interests endure. While general trends in the future military threat are certainly identifiable, the fluid nature of the political environment makes it impossible to predict where or when armed conflict might actually loom. Shifting alliances, maturation or deterioration of long-standing regimes, and

the cyclical power of terrorist groups render traditional threat-based planning unsatisfactory for purposes of calculating future military needs. Instead, the QDR embraced “capabilities-based planning”, a concept that focuses on achieving key military goals regardless of the specific circumstances. In the future, the United States must deploy forces capable of adapting to and initiating surprise, operating covertly, and both employing and countering asymmetric warfare. Such forces must be available at all times in distant regions in sufficient quantities to swiftly defeat any adversary, with modest or no reinforcement; or, if that is not possible, to quickly pave the way for follow-on forces.²

These are ambitious goals, even for a global superpower. They are made even more challenging by the continuing spread of technology to potential adversaries. An unfriendly nation or terrorist organization does not have to be able to counter U.S. military power directly to hamper or even halt the employment of American force. By using or threatening weapons of mass destruction, attacking overseas airfields and ports with ballistic and cruise missiles, laying minefields in shallow water or on land, operating diesel submarines, or launching anti-ship cruise missiles and advanced surface-to-air missiles against battle groups and bombers, future adversaries may create a “sanctuary” for themselves by denying access to U.S. forces.

Against such asymmetric future threats, capabilities-based planning demands that the U.S. conceive and nurture a force with its own asymmetric ability to counter such anti-access and area-denial strategies. Among other things, this force must have “robust capabilities to conduct persistent surveillance, precision-strike and maneuver”³ within the areas the adversary seeks to deny. Many, if not most, of the area-denial and anti-access activities will take place in coastal regions, in the hostile “littoral” area of relatively shallow water and the first few miles of land. They pose a particular problem for the U.S. Navy in its role as a key enabler of follow-on joint forces.

*If the Navy cannot clear the way,
sealift and other forces cannot follow.*

Congressional Budget Office, March 2002⁴

Unique Advantages of Submarines

This discussion of the evolving threat environment makes clear the challenges facing force planners and future operational commanders. The QDR’s analysis puts a premium on capabilities such as deception, surprise, persistence, adaptability and precision fire power, to meet these challenges. Each capability is inherent in the modern U.S. nuclear submarine.

The most obvious characteristic of a nuclear submarine is its stealth. While stealth is a characteristic of many of America's most modern weapon systems, only submarines are difficult to detect in all environments, by all types of sensors, when they are submerged. This makes them the ultimate covert platform.

The stealth of nuclear submarines provides the opportunity to conduct missions that are never revealed, or to provide strategic, operational or tactical surprise in both peacetime and wartime. Nuclear submarines can remain on station, hidden and carrying out their mission 24 hours a day, seven days a week, for months. This characteristic of persistent stealth is of great value in meeting key military goals reaffirmed in the QDR.

Defend the Homeland

In the Global War on Terror, submarines have a day-to-day mission to clandestinely collect intelligence. The submarine's own sensors, and its special operations delivery capability (much enhanced with deployment of the SSGNs and Virginia class, as discussed below), allow it to observe without being observed. Unlike satellites with their predictable overhead paths, submarines can be anywhere in the hostile littoral at any time. Using the same capabilities, submarines can engage in covert information operations by transmitting data to a target audience and monitoring the response. In the last several years, technology has made rapid progress in submarine communications with high data rate antennas, allowing real-time transfer of this intelligence data via manned or unmanned aircraft or satellites to users at the highest levels.



One of the most difficult challenges of Homeland Security is the protection of ports. The United States receives 5,400 ships a year with international cargo and crews, creating an enormous monitoring task. While much effort is being devoted to enhancing security at the ports themselves, there are obvious advantages to monitoring and even interdicting suspicious shipments long before they reach American waters. Again, because of their covert nature, submarines could potentially be used to monitor ships in foreign ports and track them even in territorial waters.

The most widely reported use of submarines in the war on terror already has been displayed in Operation Enduring Freedom as the United States worked to eliminate the terrorist base of operations in Afghanistan. In the future, terrorist targets, including mobile command centers and weapons stores, could be identified by covert submarines and special forces working in tandem, and then promptly destroyed by the submarine's precision strike capability.

Deter Aggression and Coercion Forward

Deterrence is often thought to be best served by the presence of highly visible military forces. But the best movie directors have long known that the greatest suspense is created when an audience cannot see what it fears. In the prelude to any conflict, a potential adversary knows that America may well have a virtually undetectable submarine lurking off its shores, ready to make the opening moves in a counter or pre-emptive attack.

Because it is capable of total surprise in an initial strike, today's submarines armed with Tomahawk cruise missiles can attack sensitive and strategically important mobile or movable targets, such as command and control and stockpiles of weapons of mass destruction. They can also serve as key enablers of follow-on air forces by attacking surface-to-air missile sites and other defenses. In a very short time, a covert submarine attack can substantially degrade an adversary's ability to mount a defense. This capability against time-sensitive targets could be enhanced by the deployment of tactical, semi-ballistic missiles on nuclear submarines. In addition to the surprise factor of launch from a submarine, this type of weapon (discussed in more detail below) has the speed to reach a target several hundred miles inland in a matter of minutes.

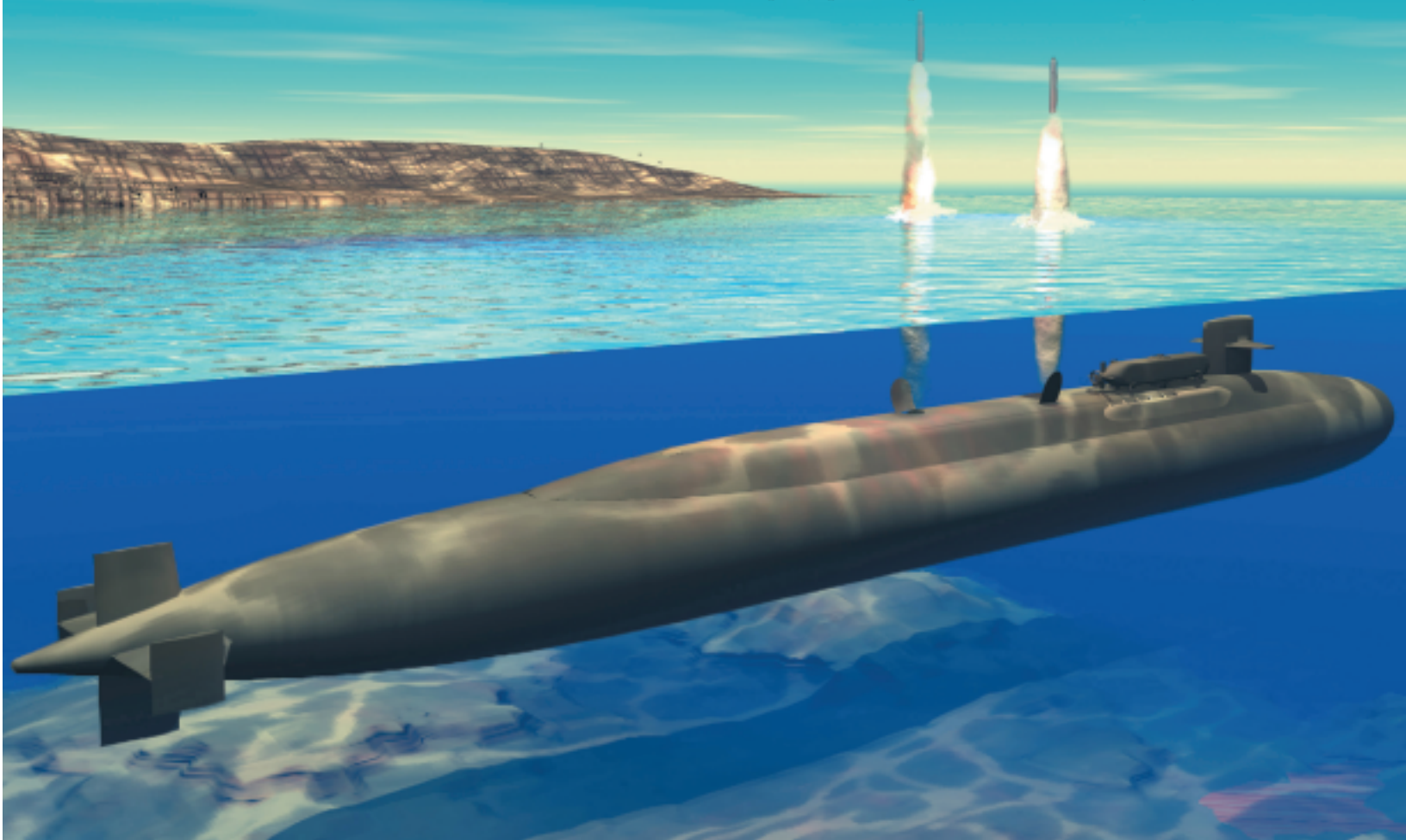
Although strike options such as these momentarily reveal a submarine's presence, other initial enabling missions allow a submarine to remain covert and conduct operations during the pre-hostilities phase of conflict, potentially deterring further action. These missions are particularly important in littoral environments. They include tracking adversary submarines and mapping mine fields.

Swiftly Defeat Aggression

Once a decision is made to go to war, submarines can engage in the type of clandestine early attacks needed by follow-on forces such as discussed above. They protect surface ships by neutralizing underwater threats like enemy submarines and mines, and by targeting enemy surface vessels with heavyweight torpedoes. Perhaps just as important, they serve as a base for special operations forces tasked with generating targeting data, seeking weapons of mass destruction and/or gathering intelligence on ground forces.

By assuring freedom of the seas, the submarine fleet can solve a major portion of the access-denial problem. “In short,” summarized the Congressional Budget Office, “if naval forces as a whole represent the vanguard of U.S. military power – preparing the path and securing the beachheads for much larger ground and air forces in areas where they do not have access to land bases – then submarines may be key to clearing the way for other naval forces that are more vulnerable to an enemy’s access-denial strategy.”⁵

The value of submarines in the early phases of conflict has been demonstrated in recent operations, especially in Operation Iraqi Freedom. During this war the U.S. had 12 attack submarines in-theater, joined by two British submarines. Of the 800 Tomahawk missiles that were fired, about a third of them came from these 14 boats. In this rapidly paced operation where the targeting



process was compressed to hours – and in some cases minutes – submarines participated as a full partner networked with the National Command Authority. And, although not much information has been made public, special operations forces were highly effective in Iraq. This “marriage of the two premier stealth forces in the nation, special operations forces and the submarine force”⁶ has created a capability that will be substantially enhanced with deployment of both the Virginia class SSN and the SSGN.

The Future Submarine Force

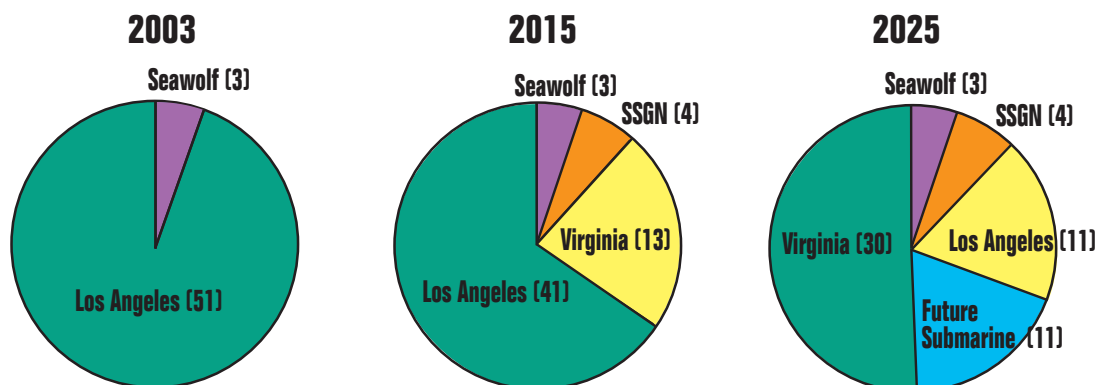
The Current Shipbuilding Program

With the fiscal year 2004 budget, the Department of Defense proposed a plan for submarines that would acquire one new Virginia-class SSN a year in 2004, 2005 and 2006. These SSNs will join the five already approved and under construction, and with the 22 planned for the years beyond fiscal 2006, will be part of an overall inventory of 30 Virginia-class boats.

The plan also funds the conversion of one strategic SSBN to the SSGN configuration in 2004, and another in 2005, added to two earlier conversions funded in fiscal year 2003.

With this fiscal 2004 plan, the Defense Department also proposed a long-term program of shipbuilding that would increase the Virginia-class procurement to two SSNs a year in 2007, 2008 and 2009. This increase in the procurement rate was intended to support a fleet objective of 55 attack submarines, consistent with the 2001 QDR as discussed above. As this chart shows, through 2015 this objective will continue to be met based primarily on refueled Los Angeles-class submarines as the new Virginia-class slowly enters the inventory.

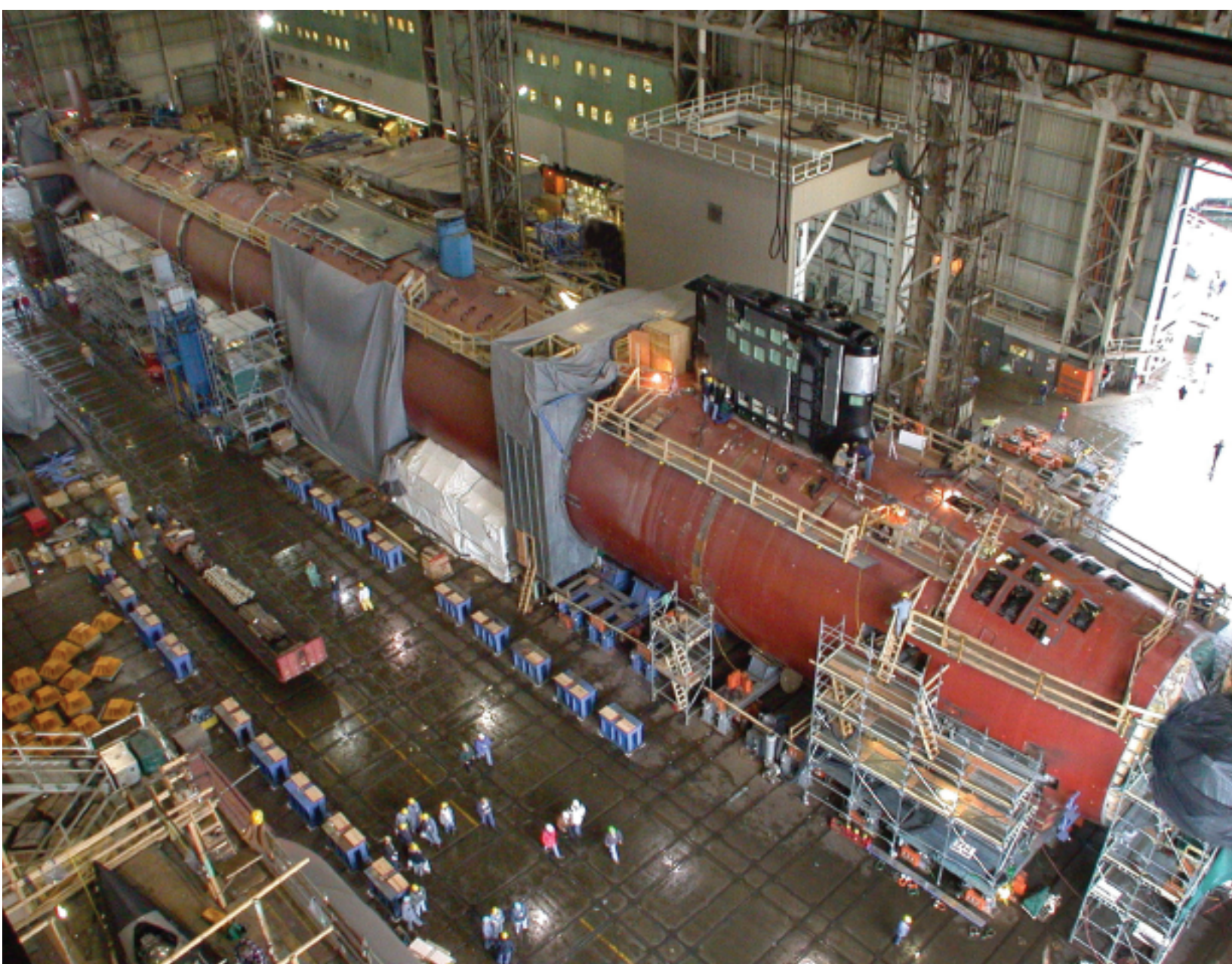
Composition of the Non-Strategic Submarine Force
Under Current Force Planning



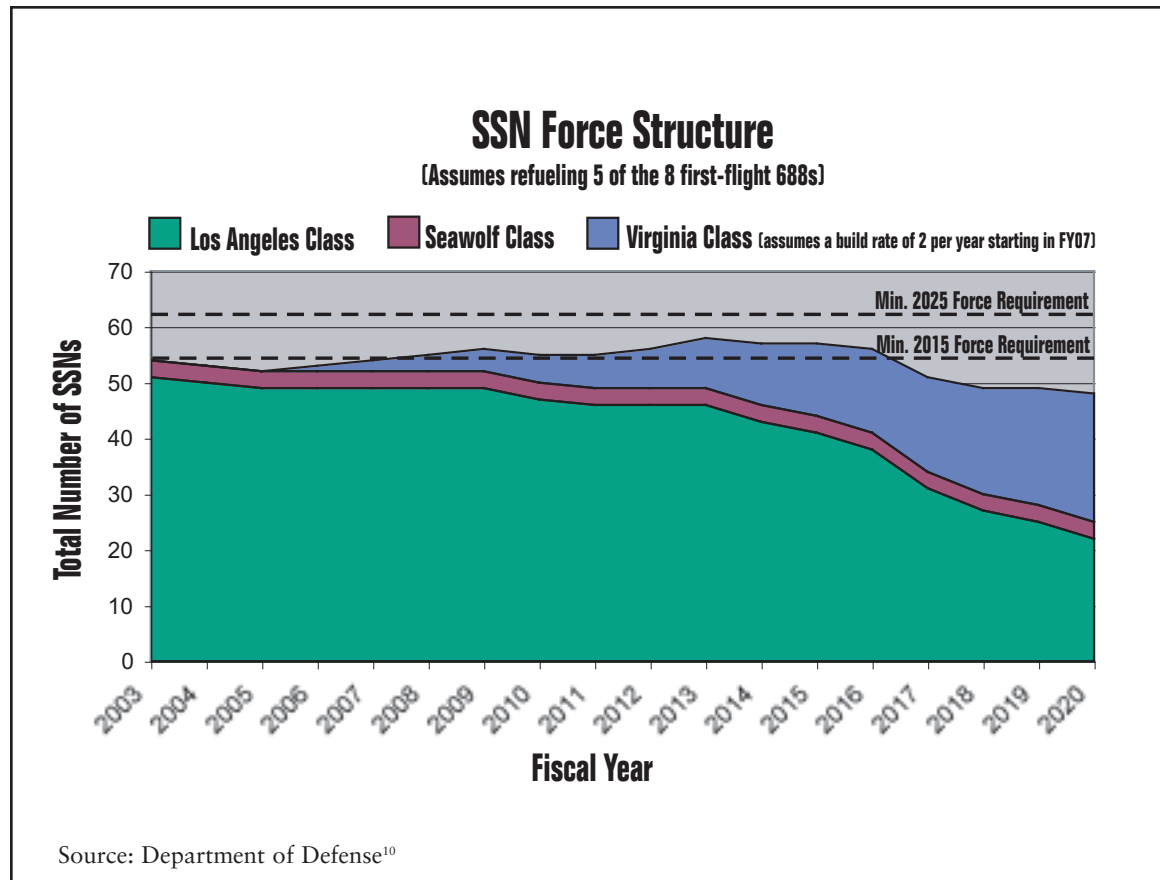
Source: Department of Defense⁷; Congressional Budget Office, March 2002

Around 2015, however, these older boats will begin reaching the end of their 33-year service life at the rate of 2.7 each year. In order to maintain the QDR force objective of 55 SSNs by 2025, the Navy must buy three submarines per year for much of the next decade. And, to meet the minimum JCS goal of 62 SSNs by 2025, it must begin buying three per year in 2008. According to the most recent Congressional Budget Office analysis, the Navy would have to more than double its current submarine budget to meet the JCS goal. Even meeting the more conservative QDR goal of 55 represents the “greatest procurement challenge facing the U.S. Navy.”⁸

With its final approval of the 2004 Defense Appropriation, the U.S. Congress further complicated this picture by refusing to approve the plan to increase submarine procurement to two per year in 2006 and 2007.⁹



The table below shows the picture of a rapidly aging submarine fleet that must be replaced equally rapidly by a new generation of boats in order to sustain force structure goals. It also displays clearly the implications of failing to meet the “procurement challenge” of funding more than the two submarines per year in the Future Year Defense Plan.



How the SSGNs will factor into this SSN force goal remains an open question. The conversion program was not yet in place and thus not directly addressed by either the 1999 JCS study or the 2001 QDR. However, even including the four converted submarines in the SSN force number would delay by only two years the requirement to procure three boats annually.

The year 2025 – indeed the year 2015 – seems far away now, and the necessity of deciding on a force for that time frame perhaps doubtful. But again in their uniqueness submarines stand apart, requiring more time to manufacture than almost any other weapon system.¹¹ Starting with two years for advance procurement of long-lead time materials, largely for the nuclear reactor, and adding six years for actual construction, it takes eight years to add a new submarine to the fleet. Careful advance planning therefore is crucial to ensuring continuing American dominance of the undersea environment and its ability to affect operations ashore from under the sea.

Programs and Technology

The force numbers are half of the equation – simply reflecting the logistics of having a platform in place when you need it. The other half reflects the capabilities behind each platform, and here America is fortunate to be on the verge of realizing the benefits of years of research and development in the areas of submarine design and manufacturing, sensor and communications technology and operational innovation.

The three Seawolf-class SSNs were designed to be significantly more capable in anti-submarine warfare than their predecessor Los Angeles class, as befitting their Cold War orientation. The final boat of this class, the U.S.S. *Jimmy Carter*, will be delivered in 2004 with modifications to directly address today's requirements for tactical surveillance, mine warfare and special operations. The other two platform components of the future non-strategic submarine force structure are exciting for different reasons – the Virginia-class because it is the first submarine to be designed with littoral warfare in mind, and the SSGN because of the opportunities presented by its enormous payload volume. Additionally, recent work in the areas of sensors, payloads and communications will lend even greater capability in the future to these platforms.



Virginia Class Attack Submarine. The Virginia program emerged in the early 1990's out of the Navy's re-examination of the submarine mission after the collapse of the Soviet Union and termination of the Seawolf program. It is different from every other submarine in the world because it is designed to be dominant in both the open ocean and in shallow (littoral) waters. It will have a number of improved sensors mounted on its bow, hull and sail, as well as towed sensors, which will allow it to detect large objects such as quiet diesel electric submarines, and smaller objects including mines. In another "first," the Virginia will not have a traditional periscope. Instead, two photonic masts mounted on the exterior will provide digital images, including color and infrared, directly onto screens in the central command station.

From the beginning the Virginia has been envisioned as a special operations platform. The design includes a special chamber that can house up to nine special operations personnel. With a lock-in and lock-out capability, the chamber allows people to both come and go while the submarine is submerged. If more people are needed to augment the Special Forces team, the Virginia's torpedo room can be reconfigured for more people and less weapons. Alternatively, the torpedo room can be reconfigured to accommodate other weapons or sensor payloads. All Virginia-class SSNs will be able to transport a dry deck shelter for special operations' mini-sub, including the new Advanced SEAL Delivery System, discussed below.

The first four Virginia-class submarines – commissioned in 2006 through 2009 – will include all these capabilities. Future Virginia-class SSNs will boast even more improvements, with several significant enhancements now in development. Using a modular approach and emphasis on commercial components, the engineers have crafted a submarine design that could accept such major design changes as an advanced new reactor to fuel ever-growing energy demands, and an integrated all-electric drive propulsion system.

SSGN. This designation has been given to the four Ohio-class ballistic missile submarines that are being converted to fire only non-nuclear missiles. These four boats were made available by a 1994 review of U.S. nuclear posture that determined 14, rather than 18, SSBN's were sufficient for strategic nuclear targeting. Instead of retiring the extra four boats, as originally had been planned, the United States will convert them for other missions.

The first step of conversion involves removing the 24 ballistic missiles from their tubes in the middle section of the submarine. The huge space left behind – the tubes are contained in an area equal to the size of about four four-bedroom colonial houses – will be used to launch cruise missiles and both launch and recover special operations forces. The SSGN will carry 154 cruise missiles (compared to 38 weapons on the Virginia-class)¹² and at least 66 SEALs and their equipment. Two of the former

missile tubes will be reconfigured to hold special forces undersea vehicles and large-diameter lock-in/lock-out chambers for access outside the submarine.

The tremendous carrying capacity of the SSGN presents many opportunities for future enhancements to the land attack, intelligence gathering and special operations missions of submarines. Ideas under consideration include unmanned air and sea vehicles launched from the SSGN to deliver supplies or gather information; long-range non-nuclear ballistic missiles for global strike; and a laboratory for analyzing samples for evidence of weapons of mass destruction.

Advanced SEAL Delivery System. The ASDS is a key program in the potentially transforming partnership between special operations forces and submarines. It is one of the Special Operations Command's top priority programs, and addresses the greatest weaknesses of earlier versions of swimmer delivery vehicles that included extremely austere conditions for the swimmers who get wet inside the vessel. Within the ASDS, divers can stay warm, dry and at atmospheric pressure until it is time



to leave the vehicle and swim. This advantage expands the scope of potential missions to include those with long transit times and in very deep and/or cold water.

In development since the early 1990's, the ASDS program has experienced challenges but is now on track with delivery of the first craft in June 2003. The ASDS is more than 65-feet long, is battery operated and has a range of 125 miles. It is designed to carry special operations forces from the submarine to an offshore location where they can exit and swim to shore, later returning to the ASDS for the trip back to the mother submarine. The Navy plans to buy a total of six of these vehicles, but the second one will not enter service until 2009. It can be carried by specially modified SSNs, by the Virginia-class or by the SSGN's.

Sensors and Payloads

The 1998 Defense Science Board Study on the Submarine of the Future recommended a collaboration between the Navy and the Defense Advanced Research Projects Agency (DARPA) to look beyond the focus of traditional submarine research and development to emphasize sensors, associated vehicles and other interfaces with the water. Out of this recommendation DARPA's Advanced Sensors and Payloads program was born. This two-year program coincided with the decision to convert the four older SSBNs. Between these two initiatives, a variety of new options have emerged to enhance submarine operations of the future. Some of these options can be netted together to provide entirely new levels of situational awareness and operational effectiveness.

Unmanned Undersea Vehicles (UUVs). Concepts for UUVs span the range of imagination. Both the Navy and industry have used UUVs – primarily vehicles connected to a manned platform via a tether – for years. The emphasis has been on communications and reconnaissance. More recently, research and development has expanded to include mine hunting capabilities, advanced intelligence gathering, high speed data transmission and logistics support.

In the recent “Giant Shadow” experiment with the SSBN U.S.S. *Florida*, the U.S. Navy demonstrated several of these missions using a large, autonomous UUV called the *Seahorse*. More than 28 feet long and three feet wide, this experimental vehicle was launched from the SSBN and went on to both detect mines and ferry supplies between the *Florida* and special operations forces ashore.

The *Seahorse* plotted a course through a simulated minefield using forward searching sonars. A smaller UUV, about the size of a torpedo employing similar technology is currently being deployed to the attack submarine fleet. The Long-Term Mine Reconnaissance System (LMRS) has a forward and side searching sonar that scans both the bottom and the water ahead. The information can be relayed back to the submarine through a radio-frequency link or stored aboard the UUV.

With the information provided by mine-plotting UUVs, submarines as well as surface ships can plot a course to avoid mines. Submarines once again provide the ideal platform for such an activity where secrecy is desired. Covertly deployed special forces or small UUVs could silently de-activate mines and maintain operational surprise for early-entry forces. Taken together, these technologies allow the preparation of safe transit routes for American vessels without the potential adversary ever being aware of the activity.

A derivative of the LMRS called the “mission-reconfigurable unmanned undersea vehicle,” or MRUUV, is being designed to exploit this underwater capability for missions beyond mine-hunting. By changing the sensor packages on the MRUUV, the vehicle can be adapted to best support the overall mission of the submarine carrying it. The MRUUV will be capable of clandestine intelligence gathering, surveillance and reconnaissance. The first MRUUV will be operational in fiscal year



2007. An even larger vehicle, two to four times larger than the MRUUV could be deployed by 2010. This vehicle would dock to a SSN, or could be carried inside a SSGN missile tube. Possible missions include launching UAVs and smaller UUVs.

Anti-Submarine Warfare. Already a top priority for the U.S. Navy, the ASW mission will only increase in importance as modern diesel-electric submarine technology continues to proliferate. Today 12 countries other than the United States produce submarines. Most of these are U.S. allies, but many export their products to third parties. About 40 countries operate a total of 300 submarines worldwide. The capabilities of these forces vary a great deal, but several represent current and growing challenges for the United States, especially when operated in the complex environment of the littorals where interferences such as currents and shipping undermine acoustic signal processing.

The Littoral ASW (LASW) program within the Office of Naval Research serves as a focus for the Science and Technology efforts to counter these evolving threats to American power projection from the sea. The program is developing technologies to better locate, characterize and neutralize diesel electric submarines as well as other enemy capabilities such as UUVs. While SSNs are just one of the ASW platforms in the U.S. arsenal (others include surface ships and aircraft), once again their covert nature allows only submarines to perform the ASW mission at all times and under all circumstances.

Weapons. Building on the success of the Army Tactical Missile System (ATAMS), the Navy has put together an Advanced Concept Technology Demonstration designed to test naval adaptations of this system. A submarine launched version, planned for deployment later in the decade, will have the ability to carry a penetrating warhead for use against hard and deeply buried targets such as underground storage or command and control bunkers, or area munitions for softer, mobile targets.

A key advantage of the semi-ballistic missile system is its speed once launched. With advanced targeting technologies, an ATACMS-type missile can reach a target up to 250 miles inland within 10 minutes. In the case of targets like mobile missile launchers, which may be active – and thus observable – for only a short while, time is of the essence.

Networking. The stealth, endurance, firepower and special operations capabilities of the newest American submarines are truly remarkable. However, their full contribution to joint operations in both peacetime and in conflict cannot be realized without effective communication links. In this new era of rapid decision-making based on real-time intelligence and targeting “chat rooms,” the Silent Service must be an integral part of the force network.

The Navy's Forcenet initiative intends to join together all naval sensors, platforms, command and control and data bases in an overarching information network to support joint operations. Submarines must, and can, be a part of this naval-wide network. The new high data rate antennas used by U.S. submarines during Operation Iraqi Freedom proved that submarines can be on the net, sending and receiving large amounts of information in real-time. The Giant Shadow exercise with the *Florida* networked a P-3 aircraft, acting as a surrogate Global Hawk UAV, small UAVs like the Scan Eagle and the Seahorse UUV, allowing Navy special operations forces operating from the submarine to successfully complete their mock mission to destroy weapons of mass destruction.

Weapons of Choice

The future threat environment facing the United States is murky at best. It is clear the global war on terrorism will continue for some time, and regional conflicts or imminent threats will emerge. What isn't clear is where or when these things will happen. Keeping their consequences as far from the U.S. homeland as possible will be a key objective. In this environment, forward deployed forces with the stealth, persistence and capability inherent in submarines are destined to prove essential. Whether defending the homeland, deterring aggression overseas, or participating decisively in combat, submarines will continue to be a weapon of choice. Decades of commitment and investment have given America an overwhelming advantage in submarine technology, and continuing commitment and investment will ensure that advantage extends for decades.



¹ In its 1998 report on the “Submarine of the Future,” the Defense Science Board called SSNs a “key and enduring element of the current and future naval force - a crown jewel in America’s arsenal.”

² See, for example, the discussion on pages 13-14 and 25 of the *QDR Report*, Department of Defense, September 30, 2001.

³ Department of Defense, *QDR Report*, September 30, 2001; page 31.

⁴ Congressional Budget Office, *Increasing the Mission Capability of the Attack Submarine Force*, March 2002, p. 7.

⁵ *Ibid.*

⁶ Rear Admiral Paul F. Sullivan, Director of Naval Submarine Warfare Division; *Sea Power*, July 2003.

⁷ Office of the Secretary of Defense, *Report on Nuclear-Powered Submarine Force Structure: Supporting the National Military Strategy Through 2020*, August 2002.

⁸ Congressional Budget Office, *The Long-Term Implications of Current Defense Plans*, January 2003, pp. 59-61.

⁹ In language accompanying the Defense Appropriations Bill, legislators suggested it was too early in the program to commit to a ramp-up in production in a particular year. Final action on the Bill occurred September 23, 2003.

¹⁰ Office of the Secretary of Defense.

¹¹ A nuclear-powered aircraft carrier takes longer.

¹² Submarines fired 270 Tomahawk cruise missiles during Operation Iraqi Freedom, about one-third of the total. The 38 weapons on the Virginia-class include a combination of torpedoes and cruise missiles.

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1600 Wilson Boulevard • Suite 900 • Arlington, Virginia 22209
tel 703.522.5828 • fax 703.522.5837
www.lexingtoninstitute.org • mail@lexingtoninstitute.org

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