Naval Historical Center home page Colloquium on Contemporary History Project

THE POLARIS
A REVOLUTIONARY MISSILE SYSTEM AND CONCEPT

by

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Perspective

The U.S. Polaris submarine-launched ballistic missile was not the world's first sea-based strategic missile system. In September 1955, the Soviet Union launched an SS-1B Scud-A ballistic missile from a surfaced submarine.[1] This launching occurred almost four years before the first U.S. submarine launching of a Polaris ballistic missile. Still, in several respects, the U.S. Polaris was a revolutionary weapons system.

The concept of employing sea-based ballistic missiles to attack an enemy's homeland appears to have been originated by the Germans during World War II. The Germans planned to employ a V-2 missile encased in a towing/launch canister that would be towed submerged behind a submarine to within firing range of the United States. The German submarine-towed V-2 concept did not become operational. While components and plans did fall into Soviet hands at the end of the war, the Soviets did not pursue this concept. However, employing German technology and technicians, the Soviet Union did begin the development of both submarine-launched guided (cruise) and ballistic missiles in the late 1940s.[2] Both types of submarine weapon were put in service in the late 1950s, with the first submarine (surface) launch of a modified Army ballistic missile taking place in September 1955. The world's first operational, submarine-launched ballistic missile was the SS-N-4 (Soviet R-13), a surface-launched, 350-nautical-mile ballistic missile carrying a nuclear warhead. When it became operational in 1959, it was the world's first submarine-launched ballistic missile (SLBM) system.

But the U.S. Polaris SLBM-which went to sea a year later-was a more advanced and truly revolutionary weapon system. By "revolutionary" I mean a weapon system that 1) makes a significant technical advance in a given area or; 2) has a major impact in combat or on defense policy. In my opinion, the Polaris SLBM did both.

The revolution was in three areas: submarine platform; missile; operational concept

The Polaris Decision

The effort that led to the Polaris SLBM was initiated in the aftermath of the Soviet detonation of a hydrogen (thermonuclear) device in August 1954 and the "Big Four" summit meeting in Geneva in September 1955. As a result of feared Soviet advances in strategic missiles, the Eisenhower administration ordered the Navy to join the Army in development of an intermediate range ballistic missile (IRBM) that could be launched from surface ships.[3]

The Navy objected strenuously to the joint program because the Army was developing the liquid-propelled Jupiter missile. The Navy considered liquid propellants too dangerous to handle at sea and the 60-foot missile too difficult to install in ships.[4]

In addition, there was general opposition to ballistic missiles at sea within the Navy, from the "cultural" viewpoint, on two issues. First, from the late 1940s on, the Bureau of Aeronautics and the

Bureau of Ordnance were separately developing guided (cruise) missiles that could be launched from submarines against land targets; neither bureau wished to divert scarce resources to the development of a new ballistic missile program. Second, the Navy had lost the B-36 bomber versus carrier controversy to the Air Force in the late 1940s. That loss had cost the Navy prestige, plus the cancelled construction of the first postwar aircraft carrier. As a result, the Navy's leadership wanted to avoid another inter-service battle, this time over strategic missiles. Indeed, Admiral Robert B. Carney, Chief of Naval Operations from 1953 to 1955, restricted the Navy from advocating the development of sea-based ballistic missiles.

There was a third issue, which while not "cultural" to the Navy, was very real. This was the fear of having to pay for a new system out of the regular Navy budget.[5]

The opposition to developing a sea-based ballistic missile force changed with the appointment of Admiral Arleigh A. Burke as Chief of Naval Operations in August 1955. According to the admiral's biographer, "Burke's most significant initiative during his first term [1955-1957] was his sponsorship, in the face of considerable opposition, of a high-priority program to develop a naval intermediate-range ballistic missile."[6]

Fearing that the project would be given low priority within the Navy and doomed to failure if left to the existing Navy bureaucracy, Admiral Burke established a Special Projects Office (SPO). He wanted the SPO to be a "vertical" organization, separate from the existing technical bureaus, that would direct the sea-based missile project. Heretofore, all major naval technical developments, as well as production, had been directed by the technical bureaus, which had been organized in a horizontal structure since 1842. In these moves, he was strongly supported by the Secretary of the Navy, Charles S. Thomas.

Equally important was the selection of the first director of the new organization. Burke appointed to the billet Rear Admiral William F. Raborn, a naval aviation officer with considerable experience in guided missiles. Because of Raborn's importance to the Polaris project, I feel it vital to cite Admiral Burke's criteria for the attributes needed by an officer selected to head this controversial and difficult, but essential project. According to Burke:

I realized that he didn't have to be a technical man. He had to be able to know what technical men were talking about. He had to get a lot of different kinds of people to work. I wanted a man who could get along with aviators because this [program] was going to kick hell out of aviators. They were going to oppose it to beat the devil because it would take away, if it were completely successful in the long run, their strategic delivery capability.

It would be bad to have a submariner, in that because it first was a surface ship [weapon]; submariners were a pretty close group and they would have wanted to do things pretty much as submariners had already done . . . besides they were opposed to ballistic missiles.[7]

Burke also had problems with surface officers, because "they didn't know much about missiles or strategic [matters]." Regardless, the admiral later made it clear to the author of this paper that he had selected-and fully supported-an officer whom he believed had the qualifications to direct the project primarily on the basis of his individual qualifications and with minimal concern for his membership in one of the Navy's "unions." Burke's support included telling Raborn that if he kept the numbers small, he could call on the best people in the Navy for his project staff; and that any time that it looked like the project's goals could not be accomplished, Raborn could recommend to Burke that the project be scrapped.

On 8 November 1955, the Secretary of Defense established a joint Army-Navy IRBM program. The sea-based Jupiter program, given top national priority along with the Air Force Atlas ICBM and the Army Jupiter programs, progressed rapidly. The Navy anticipated deploying Jupiter IRBMs to sea on board converted merchant ships; three missiles per ship.[8] During 1956 a schedule was developed to put the first IRBM-armed merchant ships at sea in 1959. Some studies also addressed the feasibility of submarines launching the Jupiter IRBM from the surface.

The Navy still had severe misgivings about the use of highly volatile liquid propellants aboard ship and studies were initiated into solid-propellant missiles. However, solid propellants had a low specific impulse, a major shortcoming. The biggest boost for solid propellants came in mid-1956 when scientists found it feasible to miniaturize thermonuclear warheads. Dr. Edward Teller is said to have suggested in the summer of 1956 that a 400-pound warhead could provide the explosive force of a 5,000-pound one.[9] In September, the Atomic Energy Commission estimated that a small nuclear warhead would be available by 1965, and perhaps by 1963.

This development, along with the development of higher specific impulse solid-fuel propellants, permitted; 1) a break away from the Army's Jupiter program in December 1956; 2) formal initiation of the Polaris SLBM program with a solid-propellant missile, and; 3) a shift from surface ships to submarines as launch platforms.

On 8 February 1957, Chief of Naval Operations Burke issued the requirement that a 1,500-nautical-mile missile launched from a submarine be operational by 1965. A range of 1,500 nautical miles was stipulated because that would permit a submarine in the Norwegian Sea to target the Soviet capital of Moscow-1,100 nautical miles inland.

The February 1957 schedule that set the 1965 goal was soon followed by a series of revisions and accelerations in the Polaris program. On 4 October 1957, the Soviets orbited Sputnik, the world's first artificial satellite; on 23 October the Secretary of the Navy proposed acceleration of the Polaris program to provide a 1,200-nautical-mile missile by December 1959, three SLBM submarines by mid-1962, and a 1,500-nautical-mile missile by mid-1963. A month later, the program was further accelerated to provide the 1,200-nautical-mile missile by October 1960. In December 1957, the Navy drew up a plan to provide the first submarine by December 1959 and the second vessel by March 1960.

To enable production of these vessels in so short a time, on the last day of 1957 the Navy ordered the reconfiguration as ballistic missile submarines of a recently begun nuclear-propelled, torpedo-attack submarine and a second, not-yet-started unit. The design for the attack craft was revised to lengthen the hull by 130 feet in order to permit the installation of special navigation, missile control, and other mission support equipment as well as 16 launch tubes for the Polaris missiles.

Given the highest national and Navy priorities, the first Polaris submarine, the USS *George Washington*, was rushed to completion. The submarine fired the first submarine-launched Polaris missile on 9 June 1959. The submarine departed on her first strategic missile patrol on 15 November 1960. The vessel was armed with 16 Polaris A-1 missiles, each possessing a range of 1,200 nautical miles and carrying a warhead of almost one megaton (MT). The *George Washington* was at sea on that initial patrol for 67 consecutive days. The ship set an underwater endurance record by remaining submerged for 66 days and 10 hours.

On 30 December 1960, before the *George Washington* returned to port, the second Polaris submarine, the *Patrick Henry*, sailed on her first deterrent patrol. By 1967, 41 Polaris submarines carrying a total of 656 missiles had gone to sea.[10]

The Submarine

The world's first SLBM submarines were the Soviet Zulu-class, diesel-electric-propelled vessels armed with two SS-N-4 missiles. These undersea craft, converted to the SLBM role in 1958-1959, were followed by the new-construction Hotel (nuclear) and Golf (diesel) classes, each of which carried three missiles. The first missiles, armed with a one-MT warhead, had a range of approximately 350 nautical miles. Significantly, the submarine had to surface to launch the SS-N-4 missiles.

In contrast, the U.S. Polaris submarines each carried 16 missiles. Further, the U.S. missiles could be launched while the submarine remained fully submerged and were believed to be more accurate than the Soviet weapons.[11]

Like the missiles, the fire control and navigation systems for the Polaris submarines were developed at an accelerated rate. Precise navigation was essential, given the range of the missile and the need for the submarine to remain submerged. In this era before the development of navigation satellites, the Ships Inertial Navigation System (SINS) developed for the Polaris program was also a remarkable technological achievement. Another major accomplishment was the development of a life support system that generated oxygen and water for 150 to 160 crewmen during a 60- to 70-day submerged cruise.

In summary, at the time of their construction, the Polaris SLBM submarines were the largest, most complex, and most heavily armed submarines yet constructed by any nation.[12] Spokesmen for the Polaris program were fond of noting that a single Polaris submarine could deliver more explosive force than all of the world's bomber aircraft had in World War II. The construction of Polaris submarines, with 12 vessels completed in 1963 alone, was truly remarkable.

The Missile

The principal criterion for judging a warship or any military platform should be its weapons payload. Here the Polaris submarine was truly revolutionary. As noted above, the initial Soviet SLBM submarines each carried two or three missiles. The decision was made early in the program to arm the Polaris submarine with a large number of missiles-ultimately 16. Some participants of the project argued that putting "so many eggs in one basket" would put a large number of missiles at risk if the enemy located and sank one of the Polaris boats. But, most officials believed that the enemy would be hard-pressed to find the normally submerged submarines, so putting that many weapons in one hull was cost-effective and strategically sound.[13] When one considers that the Polaris submarine hull was a modified attack submarine hull, the Navy's ability to put 16 missiles in one unit was a major feat in ship design.

The Polaris missiles were the world's first long-range missiles propelled with solid fuel. The Army's Jupiter IRBM used a liquid propellant and was considerably larger than the initial Polaris SLBM:

	Jupiter IRBM	Polaris A-1
Weight	108,500 lbs	28,800 lbs
Length	60 ft	28 ft
Diameter	105 in	54 in

Range	1,500 nm	1,200 nm

The development of solid-propellant propulsion permitted a remarkable reduction in missile size. Another achievement was the development of a system that could eject the missile from a submerged submarine's launch tube, propel it to the surface (for its rocket engine to ignite the weapon had to be above the surface), and enable the submarine to adjust to the sudden massive loss of weight. One drawback of the Polaris missile, however, was its limited range, which severely restricted the ocean operating area of the SLBM submarines if they were to target Moscow and other locations in the interior of the Soviet Union.

The 1,200-nautical-mile A-1 missile was considered an interim weapon from the outset of the solid-propellant program. Longer-range versions were already in development. The A-1's shorter range was accepted to compress the deployment schedule. The A-1 went on patrol in the *George Washington* in November 1960. The 1,500-nautical-mile A-2 missile went on patrol in June 1962 in the USS *Ethan Allen*, and the 2,500-nautical-mile A-3 in the USS *Daniel Webster* in September 1964. All three versions of the Polaris had approximately the same dimensions (see Appendix A).

Thus, within a period of four years, the missile range was increased by a factor of two. A penetration aids re-entry package was developed for the A-3, but it was not deployed. Instead, the A-3 was fitted with a three-warhead, Multiple Reentry Vehicle (MRV) payload that would "shotgun" the three, relatively small warheads, onto a single target. This was the only U.S. strategic missile deployed with MRV warheads, which compensated for the limited accuracy of the missile to increase its effectiveness against "soft" targets. All 41 submarines were eventually refitted to carry the A-3 missile.[14]

Missile and warhead development continued, and in March 1971 the USS *James Madison* departed on patrol with 16 Poseidon C-3 missiles. While a "conversion" of the submarine was required to embark this weapon, the changes required were relatively few. 31 submarines were eventually converted to this configuration.

The Poseidon was the world's first operational strategic missile with Multiple Independently targeted Reentry Vehicles (MIRV). Up to 14 warheads could be fitted, albeit at the reduction of range, on the A-3 missile. The MIRV program-later adopted for the Minuteman III and subsequent ICBMs and SLBMs-was deployed primarily to overcome expected Soviet anti-ballistic missile (ABM) systems. Normally, the Poseidon-nee-Polaris submarines would deploy with 10-warhead missiles. The Poseidon SLBMs also reportedly approached the accuracy of land-based ICBMs.

A final version of the Polaris/Poseidon was the so-called EXPO missile (Extended-range Poseidon), that entered advanced development in the early 1970s. This missile was soon renamed the Trident I (C-4). 12 of the original 41 Polaris submarines were converted to carry this weapon.[15]

Accordingly, the Polaris SLBM, carried in large numbers by the U.S. submarine fleet, was one of the most flexible weapons in America's strategic arsenal.

The Operational Concept

Early in the development of the Polaris system, the decision was made to operate the submarines with two complete crews (each of about 160 men), enabling the vessels to remain on patrol for long periods of time. This concept was labeled "Blue" and "Gold." Routinely, the Blue crew took the submarine to sea for a 60-day patrol. When the vessel returned to port, both Blue and Gold crews would spend about 15 days replenishing supplies and readying the boat for patrol. Then, the Gold crew would take the submarine to sea for another 60-day patrol.

Crews operating submarines based in Holy Loch, Scotland, and Rota, Spain, were normally rotated by air to and from their bases in the United States.

The crew ashore would have about 45 days for leave and training (on simulators). This Blue-Gold crew concept worked well for the 41 Polaris/Poseidon submarines. At any given time, more than half of the SLBM force was at sea and operational. From a mathematical standpoint, the at-sea time should have been approximately 4:1; however, the submarines were periodically required to spend longer periods in port for overhauls, missile tests, etc.

The Schedule

The Polaris project was undertaken on several premises: that smaller warheads could in fact be developed and produced and that solid-propellant propulsion would work. The development time of the Polaris SLBM *system*-that is the actual submarines, missiles, navigation gear, life-support systems, training devices, and a multitude of other components-was truly remarkable. This feat has probably not been equaled since with any U.S. weapon system of similar complexity.

To insure that all of the pieces "fit together," on schedule, Rear Admiral Raborn adopted the then-innovative PERT scheduling system. A historian of the Polaris program has observed that, "the Special Projects Office has gained an international reputation for the innovativeness and effectiveness of the management control system it has employed."[16]

As the Polaris system was developed, compromises were made in the schedule to bring systems on-line earlier. In late 1957, the Navy plan called for six Polaris submarines to be at sea by 1965. The *George Washington* put to sea in late 1960. By mid-1962, six Polaris submarines were operational (the *Ethan Allen* carried the A-2 missile) and by 1967, the entire fleet of 41 Polaris submarines strengthened America's nuclear deterrent force. Polaris spokesmen frequently declared that Polaris was "on target, on schedule."

From the outset, the growth potential of the Polaris system-especially missile ranges, payloads, and accuracy-was recognized, planned for, and carried out. In this context too, the Polaris SLBM could be labeled as a revolutionary system.

Impact of Combat (Deterrent) Capability and Defense Policy

U.S. leaders began development of the Polaris SLBM system in the 1950s because they feared the Soviet Union was already ahead in a race to develop missile and satellite systems that would threaten America's very survival. By the mid-1960s, and the deployment of the lethal Polaris SLBM and land-based Minuteman ICBM systems, the feared "missile gap" with the USSR had evaporated. Indeed, until the 1970s the United States held a clear advantage in these systems.

The Polaris program produced a large number of missiles capable of striking the Soviet Union in a relatively short period of time. The Air Force's Minuteman program produced 1,000 solid-propellant, silo-deployed ICBMs by 1967. That same year, the Soviets began to deploy their SS-9 intercontinental ballistic missile, long an enigma to U.S. intelligence. The SS-9 was the world's largest missile at the time and its Mod 4 carried three MRV warheads. In the 1970s, many American analysts concluded that the SS-9's three large warheads were designed to eliminate the Minuteman missiles, which were deployed in groups of three in a pattern similar to the footprint of the SS-9 warheads. Clearly, the SS-9s and later weapons seriously threatened America's fixed, land-based strategic missiles.

The Polaris submarines, however, were at the time *entirely* invulnerable to Soviet countermeasures. To deal with the Polaris, the Soviets initiated several major antisubmarine warfare programs, but not until the late 1970s did these efforts pose a significant threat to the SLBM force. In 1978, the Secretary of Defense could still state, unequivocally, that "The critical role of the SLBM force, as the most survivable element in the current TRIAD of strategic forces, both now and in the foreseeable future, is well established."[17]

Because of this survivability, according to Secretary Brown, "the SLBM force contributes to crisis stability. The existence of a survivable, at-sea ballistic missile force decreases the Soviet incentives to procure additional counterforce weapons and to plan attacks on United States soil since such attacks would not eliminate our ability to retaliate."[18] Not said, but certainly obvious, the limited accuracy of the Polaris vis-a-vis the land-based ICBMs meant that the submarine missile could not be used as a first-strike or counterforce weapon; it was truly a retaliatory, countervalue weapon.

When the Soviet Union put great emphasis on antisubmarine warfare, experts within and outside of the U.S. defense establishment questioned the survivability of U.S. strategic missile submarines in a major conflict with the Soviets. Still, in survivability comparisons between SLBM submarines and land-based bombers or ICBMs, the former invariably fared best. In February 1994, Secretary of Defense Frank Carlucci stated, "Our fleet of 28 Poseidon and eight Trident ballistic missile submarines . . . provide us with our most survivable strategic nuclear capability."[19]

Lessons Learned

The Polaris SLBM was a revolutionary weapon system. First, Polaris incorporated major technical advances with respect to submarines and missiles. Also significant was the almost unprecedented growth potential of the system; essentially the same submarine types carried each new generation of missile-from Polaris A-1 to the A-2, A-3, Poseidon, and Trident I missiles[20] Second, the Polaris SLBM provided a highly survivable strategic system, which has had a major impact on U.S. defense policy.

Related to the above, the Polaris system was developed and deployed efficiently and in a short period of time.

If one looks at the subsequent Trident SLBM system, the concept was approved for development in the early 1970s. The first submarine was completed only in November 1981-ten years later.[21] Moreover, the Trident was far less innovative than the Polaris-most elements of the Trident system were improvements of previous SLBM components.

The longer gestation period was probably caused by: 1) a less efficient Department of Defense and Navy bureaucracy; 2) the lack of the highest national priorities for SLBM development and; 3) the involvement of the controlling Admiral Hyman G. Rickover, head of the Navy's nuclear propulsion program, in the Trident effort (he had been excluded from the Polaris project).

Historian Harvey Sapolsky concluded that the "programmatic success" of the Polaris program was due to "a convergence with technological opportunity and a widely accepted policy need. Next there must be committed to the project people who are extraordinarily skillful in the art of bureaucratic politics."[22]

Rickover did not impede the development of Polaris because Admiral Raborn kept tight control of his project and because Chief of Naval Operations Admiral Burke directed that the new submarines would not employ a new nuclear power plant but instead use the existing S5W. Raborn and the other flag officers in the Polaris project feared that Rickover's participation "would lead to domination of the new project" by his office.[23] Consequently, as Atomic Energy Commission historians Richard Hewlett and Francis Duncan have revealed, "under written orders from Admiral Burke [Raborn and other admirals] excluded Rickover from all the preliminary studies."[24]

There were other reasons for the development of Polaris. In 1974 Secretary of Defense James Schlesinger asked the military services to detail why the buildup in strategic arms had occurred. The result was a comprehensive analysis entitled "History of the Strategic Arms Competition, U.S.-U.S.S.R., 1945-1972." I had the privilege of heading the Navy's study team that investigated the U.S. and Soviet strategic missile submarine and U.S. carrier strike programs. The overall report concluded that U.S. strategic weapons were developed because of 1) the Soviet threat; 2) technological opportunities; and 3) interservice rivalry.

As Sapolsky has observed, the Polaris SLBM system was developed to fill a "need"-i.e., to counter the Soviet threat-and technological opportunity. Hewlett and Duncan add another reason; interservice competition for resources and missions. Fearing that the Air Force's Thor missile would be operational by 1960, with a subsequent reduction in defense funding, Admiral Burke "was now [1957] hoping the Navy could catch up with Thor by having the first Polaris submarine ready by late 1959 or early 1960."[25]

A decade after the start of the Polaris program, the Navy began Poseidon, the fourth generation of U.S. SLBMs. The Poseidon differed from the previous versions of the Polaris in that it provided the United States with its first MIRV system on a strategic missile (the Minuteman III became operational in December 1971 with a three-MIRV system). A review of the contemporary literature suggests that American leaders pushed the MIRV Poseidon because they were concerned about the need to overcome postulated Soviet ballistic missile defenses. However, one is left with the feeling that this concern was premature when considering then-available intelligence. In my opinion, the move to Poseidon was driven more by political factors than military requirements (i.e., President Johnson wished to make a statement in the strategic weapons area).

The Navy also sought the weapon in the context of interservice strategic rivalry with the Air Force. But that subject should probably be explored in another paper, at another conference.

Appendix A

U.S. Submarine-Launched Ballistic Missiles				
(deployed 1960-1971)				
	Polaris A-1	Polaris A-2	Polaris A-3	Poseidon C-3
IOC	1960	1962	1964	1971
Weight	2,800 lbs	32,500 lbs	35,700 lbs	65,000 lbs
Length	28 1/2ft	31 ft	321/3 ft	34 ft

Diameter	54 in	54 in	54 in	74 in
Range	1,200 nm	1,500 nm	2,500 nm	2,500 nm*
Warheads	1 RV	1 RV	3 MRV	14 MIRV
*With reduced payload				

Glossary

ABM	Anti-Ballistic Missile
AEC	Atomic Energy Commission
CEP	Circular Error of Probability
CNO	Chief of Naval Operations
FBM	Fleet Ballistic Missile
ICBM	Intercontinental Ballistic Missile
IOC	Initial Operational Capability
MIRV	Multiple Independently targeted Re-entry Vehicle
MRV	Multiple Re-entry Vehicle
MT	Megaton
NM	Nautical Mile
PERT	Program Evaluation and Review Technique
RV	Re-entry Vehicle
SINS	Ships Inertial Navigation System
SLBM	Submarine-Launched Ballistic Missile
SPO	Special Projects Office
SSBN	fleet ballistic missile submarine (nuclear-propulsion)

ENDNOTES

[1] All Soviet missile and ship designations used in this paper are NATO-U.S. designations. The Soviet designation for this missile is R-11FM.

[2] The U.S. Navy similarly initiated the development of guided missiles (but not ballistic missiles, although an experimental launching from an aircraft carrier was conducted). The U.S. cruise missile program, which included several technology approaches, evolved into the Regulus submarine/ship-launched weapon that was operational in the U.S. fleet from 1955 to 1964.

[3] Naval versions of the IRBM were designated Fleet Ballistic Missile (FBM), a designation used for the first two decades of the Polaris program; FBM has since given way to the designation SLBM, which is used throughout this paper for the purpose of consistency.

[4] Soviet submarines have used primarily liquid propellants in their SLBMs.

[5] While initially additional funds were provided to the Navy for SLBM development, by 1959 the Navy was forced to cancel development of the Regulus II land-attack cruise missile and the P6M Seamaster flying-boat bomber, and delay construction of an aircraft carrier to help pay for the Polaris project. At the time all three of these programs were viewed by the Navy as strategic strike weapons.

[6] David A. Rosenberg, "Arleigh Albert Burke," in Robert William Love, *The Chiefs of Naval Operations* (Annapolis: Naval Institute Press), p. 277. Admiral Burke served an unprecedented six years as CNO, from 1955 to 1961.

[7] Norman Polmar and Thomas B. Allen, *Rickover: Controversy and Genius* (New York: Simon & Schuster, 1981), p. 539. Interview by authors with Admiral Burke.

[8] There appears to have been some "magic" in the number three. The first Soviet purpose-built SLBM submarines of the Hotel and Golf classes each could carry three missiles.

[9] Lieutenant Millard A. Cosby, USNR, "Polaris-Deep Deterrent," Unpublished Paper, p. 7. Hewlett and Duncan cite a Polaris warhead weight of 600 pounds (compared to a Jupiter warhead of 1,600 pounds with a similar explosive yield); p. 309.

[10] The Polaris program of the early 1960s provided for 45 submarines (i.e., five nine-boat squadrons) carrying 720 missiles. Secretary of Defense Robert S. McNamara reduced the program by four boats (64 missiles). The Navy then formed only four ballistic missile submarine squadrons.

[11] While the Polaris Circular Error of Probability (CEP) is classified, a declassified Secretary of the Navy memorandum of 30 January 1958 credited the Polaris A-1 (1,200 NM) with a CEP of three to four miles and the A-2 (1,500 NM) with a CEP of two miles.

[12] At the time the U.S. nuclear-propelled, radar-picket submarine TRITON was larger in dimensions but had less displacement because of her hull configuration (less total volume that the Polaris submarines); the TRITON was an unsuccessful, one-of-a-kind submarine.

	Length	Beam	Surface Displ	Submerged Displ
TRITON	447 1/2 ft	37 ft	5,950 tons	7,780 tons
G.W.	381 2/3 ft	33 ft	5,900 tons	6,700 tons

[13] In the early 1960s the U.S. Air Force put forward a plan for 3,000 Minuteman missiles, although that program was cut to 1,000 by Secretary of Defense McNamara.

[14] The Polaris A-3 is also carried by the four British SLBM submarines, although those missiles are fitted with a British-developed warhead.

[15] The subsequent Trident II (D-5) submarine-launched missile now in development, scheduled to become operational late in 1999, reportedly will have an accuracy *exceeding* that of land-based ICBMs.

[16] Harvey M. Sapolsky, *The Polaris System Development* (Cambridge: Harvard University Press, 1971), p. 94.

[17] Harold Brown, "Department of Defense Annual Report, Fiscal Year 1979, of 2 Feb 1978, p. 110.

[18] Ibid.

[19] Frank C. Carlucci, "Annual Report to the Congress, Fiscal Year 1989, Feb 1988, p. 234. Technically he was in error as 12 of the 28 Poseidon submarines as well as the eight Trident submarines (*Ohio* class) carried the Trident I (C-4) missile.

[20] There were in fact three distinct classes of Polaris submarines:

5 SSBN-598 *George Washington* class

5 SSBN-608 *Ethan Allen* class

31 SSBN-616 *Lafayette* class

There were significant improvements in each succeeding class, with the *Lafayette* having two subtypes (based primarily on engineering changes). However, all three classes had the same basic configuration, the same S5W reactor plant, and carried 16 missiles.

[21] The original Trident submarine construction program called for 1-3-3-3 submarines to be authorized in successive years (i.e., ten to be approved in a four-year period); in reality they have been authorized at the rate of one per year.

[22] Sapolsky, p. 253.

[23] Ibid., p. 309.

[24] Ibid., p. 308.

[25] Hewlett and Duncan, p. 314.

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Source: http://www.history.navy.mil/colloquia/cch9d.html