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CMSI Translations #23: The Elusive "Deep-Sea Beast": Analysis of the Performance of the Main Equipment of the U.S. Navy Virginia-Class Nuclear Attack Submarine

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翻译

TRANSLATIONS

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The Elusive "Deep-Sea Beast": Analysis of the Performance of the Main Equipment of the U.S. Navy Virginia-Class Nuclear Attack Submarine[1]

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In the vast expanse of the blue ocean, the U.S. Navy's Virginia-class nuclear attack submarine, with its exceptional performance and advanced technology, has become the backbone of the U.S. Navy's undersea force in the 21st century. As one of America's most modern nuclear attack submarines, the Virginia-class leads the global development of nuclear submarine technology with its multifunctional and multi-purpose design, exceptional stealth, and powerful combat capabilities.

Basic Overview

In August 2003, the first Virginia-class attack nuclear submarine of the U.S. Navy, the USS *Virginia*, held a launching and naming ceremony. In June 2004, it was officially delivered to the U.S. Navy and successfully completed sea trials. In October of the same year, it was officially commissioned in Norfolk. According to the U.S. Navy's shipbuilding plan, the construction and delivery of Virginia-class nuclear submarines will continue until at least 2043, with a total of 48

[1] 王向向 [Wang Xiangxiang], 潜行无踪的"深海猛兽" ["The Elusive 'Deep-Sea Beast': Analysis of the Performance of the Main Equipment of the U.S. Navy Virginia-Class Nuclear Attack Submarine"], 当代海军 [*Navy Today*], no. 5 (May 2025), pp. 74-77.
Translator's Note: *Navy Today* is an official magazine of the People's Liberation Army Navy (PLAN).

to 50 boats to be built. Production is divided into seven batches, and continuous improvements are being made. Currently, three batches have been delivered, with the fourth batch under construction. The Virginia-class nuclear attack submarine USS *Iowa*, which was launched and commissioned on April 5, 2025, is the sixth submarine of Block IV and the 24th submarine of this class.

The U.S. Navy's Virginia-class attack nuclear submarine is 114.8 meters long (accounting for payload modules: 140.5 meters) and 10.36 meters wide, with a displacement of nearly 7,900t (accounting for payload modules: 10,364t); its maximum speed is 28 knots on the surface and 34 knots underwater; its diving depth is 244 meters, with a maximum of 500 meters.

Key Technologies

Modular design The interior of the U.S. Navy's Virginia-class nuclear attack submarine utilizes a functional modular design, including the sonar system at the submarine's bow, the combat command system and weaponry in the command-and-control compartment, and other components. Each compartment is independently constructed according to its functional requirements. Thanks to its open structural design,

----------p. 75 begins----------

Figure 1: U.S. Navy Virginia-class nuclear attack submarine cruise missile launch tube.

this type of nuclear submarine achieves plug-and-play functionality for all its systems. The sonar system was the first to utilize this technology, and other electronic weapon and equipment systems have also largely adopted this functionality. Over time, based on future operational needs and technological developments, the U.S. Navy will utilize modular technology to quickly and easily replace modules in various functional compartments during the construction of new Virginia-class nuclear attack submarines or during overhauls. The Navy will also be able to promptly install the latest functional modules, enabling plug-and-play integration. This will allow submarines of different types and uses to be derived from the standard model Virginia-

class nuclear attack submarine, enabling it to keep pace with advanced technologies and maintain its leading edge.

Power System The U.S. Navy's Virginia-class nuclear attack submarines are equipped with an S9G pressurized water reactor, which uses a more economical and efficient steam generator. A single nuclear fuel load can last the entire service life of the Virginia-class nuclear attack submarine (30-33 years).

Weapon Systems The U.S. Navy's Virginia-class nuclear attack submarine is capable of striking targets deep inland. Behind the submarine's spherical sonar, it is equipped with 12 vertical cruise missile launch tubes, each capable of vertically storing and launching seven cruise missiles. The submarine possesses a total of 84 Tomahawk land-attack cruise missiles with a range of 2,500 kilometers.

In addition, four 533mm torpedo tubes are mounted on either side of the hull forward of the conning tower, aft of the vertical missile launch tubes. These can launch MK48 torpedoes, Harpoon anti-ship missiles, and newer mines such as the MK67/Mk60 Predator mines. The MK48 torpedo has a warhead weighing 267kg and an operational depth of 900 meters, and it can be guided both actively and passively, with a maximum range of 50km and a maximum speed of 55 knots. The torpedo tubes are equipped with a turbo-pressure system, eliminating the need for water injection before launch.

Figure 2: U.S. Special Forces Transport Vehicle (ASDS).

----------p. 76 begins----------

The US Navy's Virginia-class nuclear attack submarines are capable of launching and recovering autonomous underwater vehicles (AUVs). These vehicles are equipped with submarine-compatible acoustic and non-acoustic sensors, radio frequency and video signal sensors, and target recognition and classification equipment. They can perform surveillance, reconnaissance, and anti-submarine warfare missions in waters far from the submarine. Furthermore, these nuclear submarines can launch remotely-controlled reconnaissance drones, which can conduct

reconnaissance of land targets and transmit the results in real time to the submarine, enabling the latter to carry out precision strikes against land targets.

Of particular note is the US Navy's Virginia-class nuclear attack submarine's ability to deploy and recover special operations carriers (such as the Advanced Seal Delivery System (ASDS)), with onboard docking ports. These carriers can accommodate 6-10 special operations personnel and the equipment they need to carry out special missions. These personnel can simultaneously disembark from the submarine to conduct missions such as rescue, search, sabotage, intelligence gathering, and directing airstrikes. Upon completing their mission, they can return to the submarine in a discreet carrier.

Not only that, in 2004, the Virginia-class nuclear attack submarine was equipped with a new type of unmanned underwater vehicle, i.e., the "Long-Range Mine Reconnaissance System", which uses torpedo tubes to launch and recover two 6-meter-long unmanned underwater vehicles, a mine with an arm length of 18 meters, a blasting remote-controlled robot, and corresponding supporting equipment.

Submarine Electrical Systems The Virginia-class nuclear attack submarine's mast system highlights its stealth, situational awareness, and multi-mission capabilities. This mast system includes the non-penetrating electro-optical and infrared mast (the AN/BVS-1) (which integrates sensors such as a low-light television camera, optical camera, infrared camera, and laser rangefinder; it can directly transmit high-definition images to multiple console screens using fiber-optic sensors for collaborative analysis by commanders, helmsmen, and other personnel); a communications mast (which enables high-speed data link communication with satellites, control platforms, or surface ships, and an extremely low-frequency receiving antenna, allowing the submarine to maintain contact even at maximum dive depth); an electronic reconnaissance mast (which detects enemy radar and radio signals, automatically compares captured signals with known signal characteristics in a database, and covers the mast surface with radar-absorbing material for stealth); and a navigation mast (which includes GPS antennas and weather sensors).

The C4ISR automated command and control system is the core of the US Navy's Virginia-class nuclear attack submarine's operational capabilities. It integrates seven functional modules: command and control, communications, computing, intelligence, surveillance, and reconnaissance, achieving fully automated battlefield dynamic perception, decision support, and weapons control. The AN/BYG-1 tactical control system, the core of C4ISR, integrates target tracking, fire control decision-making, and weapon launch functions, supporting multi-sensor data fusion. Through a large touchscreen and open configuration diagram, commanders can view real-time information from multiple sources, including sonar, electro-optical sensors, and radar, allowing them to formulate combat plans quickly. The control system is touch-sensitive, using a two- or four-button joystick system similar to those used in electronic toys to control the submarine's navigation. Computer control technology continuously tracks and determines changes in underwater depth and acceleration, automatically compensating for them and

ensuring smooth underwater high-speed navigation. A switch button quickly switches between automatic and manual control modes. If the automatic mode fails, the system can be switched back to manual mode.

AN/BSY-3 combat system This combat system enables multi-mission operations and represents the highest level of information and intelligence collection capabilities in U.S. Navy submarines. It highly integrates a sensor fusion module (sonar system and non-penetrating electro-optical mast), weapon control and fire control systems, and C4ISR systems. Together with command, communications, navigation, and electronic warfare systems, it forms a distributed data processing network, supporting cross-domain collaboration with aircraft carrier strike groups, drones, and satellites.

Figure 3: Internal information and intelligent equipment of the U.S. Navy's Virginia-class nuclear attack submarine

----------p. 77 begins----------

Eavesdropper transceiver system.[2] As one of the core components of this type of nuclear submarine's electronic warfare and intelligence gathering capabilities, the Eavesdropper transceiver system is primarily used for highly sensitive electronic signal interception (capable of detecting signals that satellites cannot intercept), covert communications, and weapon control. It greatly enhances battlefield awareness and tactical advantage in complex electromagnetic environments. The intercepted data can be directly fed into the AN/BYG-1 tactical control system to generate a comprehensive tactical situation map.

[2] **Translator's Note:** The original Chinese article has the word "Eavesdropper" in English.

Underwater Acoustic System The US Navy's Virginia-class nuclear attack submarines are equipped with the latest AN/BQQ-10 integrated sonar system. Moreover, there are active and passive sonar arrays on the bow, side-mounted wide-aperture passive ranging sonars, CHIN high-frequency active sonars located forward of the conning tower and below the bow, TB16 and TB29 (A) towed sonar arrays, and WLY-1 reconnaissance sonars. This multi-band sonar system provides 360-degree underwater situational awareness information, with data directly fed into the C4ISR system for target classification and threat assessment.

Stealth Technology The Virginia-class nuclear attack submarine inherits and surpasses the ultra-high stealth technology of the US Navy's Seawolf-class nuclear attack submarine. Its main engine compartment modular design utilizes raft-type shock absorption, significantly reducing onboard noise. Specifically, the hull exterior utilizes integrally cast polyurethane anechoic tiles, the hull shape is designed to minimize the impact of water flow noise, and the main engine utilizes elastic shock-absorbing bases and a new pump-jet propulsion system. Furthermore, 600 noise and vibration detectors are located throughout the submarine to monitor vibrations at all times, immediately addressing any anomalies and minimizing overall noise. Furthermore, this type of nuclear submarine utilizes demagnetization technology to reduce the probability of triggering induction mines and enhance its stealthiness.

Figure 4: Schematic diagram of pump-jet propulsion and equipment of the U.S. Navy Virginia-class nuclear attack submarine.

It is worth mentioning that, starting from the fifth Virginia-class nuclear attack submarine, a low-drag "advanced conning tower" has been adopted, which greatly improves the submarine's stealth in shallow waters. The increased space inside the tower can accommodate more detection equipment.

Shortcomings

There were quality control issues. After the U.S. Navy's Virginia-class nuclear attack submarine, the USS *Minnesota*, completed sea trials, some of the pipes in its propulsion system failed to meet quality standards, making them difficult to connect to the system. Similar failures due to inferior pipes have occurred on at least three of these submarines, forcing the U.S. Navy to conduct costly unplanned overhauls.

Frequent occurrence of wear and tear on parts and a shortage of replacement parts. Since 2013, the U.S. Navy's Virginia-class nuclear attack submarines have experienced frequent parts replacements. While this may seem normal, the frequent replacements and premature wear and tear will reduce their planned 33-year service life by at least 10 years. To a certain extent, this also exposes the U.S. Navy's underinvestment in supply chains and shipyard infrastructure, resulting in poor parts quality and insufficient replacement parts production.

In short, the Virginia-class nuclear attack submarine, a steel behemoth with unparalleled power in the ocean depths, has established the U.S. Navy's dominance in undersea warfare. However, in the turbulent waters of international politics, it has inevitably become a pawn in power struggles. Its technological advancements and operational prowess cannot fully offset the inherent risks and uncertainties. The future fate of the Virginia-class nuclear attack submarine remains to be seen.