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# China Maritime Report No. 30: A Brief Technical History of PLAN Nuclear Submarines

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## Summary

After nearly 50 years since the first Type 091 SSN was commissioned, China is finally on the verge of producing world-class nuclear-powered submarines. This report argues that the propulsion, quieting, sensors, and weapons capabilities of the Type 095 SSGN could approach Russia's Improved Akula I class SSN. The Type 095 will likely be equipped with a pump jet propulsor, a free-floating horizontal raft, a hybrid propulsion system, and 12-18 vertical launch system tubes able to accommodate anti-ship and land-attack cruise missiles. China's newest SSBN, the Type 096, will likewise see significant improvements over its predecessor, with the potential to compare favorably to Russia's *Dolgorukiy* class SSBN in the areas of propulsion, sensors, and weapons, but more like the Improved Akula I in terms of quieting. If this analysis is correct, the introduction of the Type 095 and Type 096 would have profound implications for U.S. undersea security.

## Introduction

It has been some 55 years since the People's Republic of China (PRC) began building its first nuclear-powered submarine, and the journey has been anything but smooth sailing. China began its nuclear submarine program in July 1958 when Mao Zedong and the Central Military Commission (CMC) authorized the "09 Project." Mao seemed to appreciate the enormity of the challenge, as China possessed neither the intellectual or industrial capability necessary, and he was persistent in asking the Soviet Union for assistance. Finally, in October 1959, after being rebuffed numerous times, Mao issued the decree that China would proceed on a path of self-reliance in the development of nuclear submarines.[1]

For the next five years, progress was slow, caused by the severe lack of nuclear expertise and the political and economic chaos from Mao's Great Leap Forward. The submarine program was also competing for the same talent and funding needed for the development of atomic weaponry, and it soon became apparent that the two projects could not be pursued simultaneously. Thus, in March 1963 the submarine program was postponed and only a small cadre of engineers continued doing technical exploration on nuclear propulsion.[2] In other words, it was a research project tasked with gathering every scrap of information on how other countries used nuclear propulsion in ships and submarines. After China successfully detonated its first atomic bomb on 16 October 1964, the CMC revisited the nuclear submarine program and authorized its restart in March 1965.[3] The research project ended, and the submarine design process began in earnest.

## First Generation: Type 091 [Han] SSN and 092 [Xia] SSBN

China's ultimate goal was to build a nuclear-powered ballistic missile submarine (SSBN), but the prospect of developing an extraordinarily complex submarine platform simultaneously with a radically new ballistic missile system was cause for concern. The compromise solution adopted had the missile program proceed independently, while the marine engineers concentrated on designing an anti-submarine torpedo nuclear submarine (SSN) first.[4] When the missile system was deemed ready,

[1] John Wilson Lewis and Xue Litai, *China's Strategic Sea Power: The Politics of Force Modernization in the Nuclear Age* (Stanford, CA: Stanford University Press, 1994), p. 6.

[2] *China Today: Defence Science and Technology, Volume 1* (Beijing: National Defence Industry Press, 1993), p. 314.

[3]当代中国的船舶工业 [*Shipbuilding Industry in Contemporary China*] (Hong Kong: Contemporary China Publishing House, 1992), p. 165.

[4] 杨连新 [Yang Lianxin], 见证中国核潜艇 [*Witnessing Chinese Nuclear Submarines*] (Beijing: China Ocean Press, 2013), p. 124.

a carrier submarine using common equipment developed for the torpedo submarine could then be built.[5]

As the tactical technical requirements for the new submarine were finalized, awareness grew of just how daunting this project was. For example, the desired 9-meter pressure hull diameter was nearly twice as large as the Type 033 Romeo, and yet, the hull had to support the same maximum operating depth of 300 meters.[6] The torpedo deep-water launching system had to be able to fire torpedoes down to that maximum operating depth—far deeper than the 80-meter limit of the Type 033.[7] In addition, numerous supporting systems to enable long voyages would have to be developed from scratch. But it was developing the propulsion plant, especially the reactor, that proved the greatest challenge.

Given that submarine nuclear power plant information was a closely guarded secret in the Soviet Union and the West, Chinese engineers had to make do with open-source data. This limited them to information on civilian nuclear-powered merchant ship designs, such as the *Otto Hahn* (West Germany), *Savannah* (U.S.), the Soviet icebreaker *Lenin* (Figure 1), and possibly *Mutsu* (Japan). After much debate, the designers selected a loop type pressurized water reactor, similar to that on *Savannah*, *Lenin*, and *Mutsu*.[8]

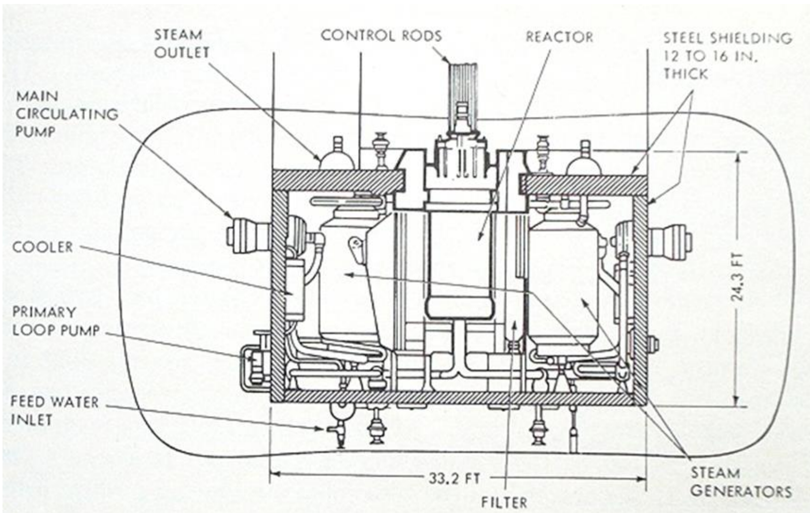


Figure 1. OK-150 loop type reactor on the Soviet icebreaker *Lenin*. Note that the width and height of the reactor complex is about 10 meters x 10 meters if the control rod height is included.

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[5] Ibid., p. 125.

[6] Lewis and Xue, *China's Strategic Sea Power*, p. 115.

[7] Ю.В. Апальков, [Yu.V. Apalkov], Подводные Лодки Том 1 Часть 2: Многоцелевые ПЛ и ПЛ Спецназначения [Submarines Volume 1 Part 2: Multipurpose Submarines and Special Purpose Submarines] (St. Petersburg: Gallery Print, 2003), p. 57.

[8] Lewis and Xue suggest that the decision on the reactor type was based on the relative political standing of the two institutes involved; however, the decision to go with a loop type reactor was likely based more on pragmatism than politics. The reactor plant for *Otto Hahn* was an integrated design that produced steam from tube bundles or cassettes located inside the reactor vessel. This was a far more complex reactor setup than a loop-based design that uses external steam generators. In addition, loop-based reactors were adopted by the U.S., Japan, and the USSR, and that would strongly influence the decision. The greater complexity of an integrated reactor, while theoretically superior, came with a much higher risk of failure and the decision to go the simpler route was a prudent one. Lewis and Xue, *China's Strategic Sea Power*, pp. 30-31.

With the reactor type formally approved in July 1965, China proceeded to simultaneously design and build both the land-based prototype and the first Type 091 submarine.[9] This was a calculated risk, but one that was deemed necessary to regain some of the time lost due to the earlier program deferment. The Type 091 design work proceeded very quickly, with the technical design finalized in 1967 and all detailed construction drawings completed in early 1969.[10] Construction began on the lead boat in November 1968, and the submarine was launched in December 1970.[11] After many years of sea trials, China's first nuclear submarine was commissioned on 1 August 1974.[12] The second unit was commissioned some six years later, on 30 December 1980—a victim of the political turmoil associated with the Cultural Revolution.[13]

The first two Type 091 submarines were widely touted as triumphs for the fledgling Chinese nuclear submarine program. And indeed, their production were noteworthy accomplishments, but both submarines suffered from severe mechanical problems. Significant corrosion issues purportedly caused leaks from the steam generators, main coolant piping valves, and reactor coolant pumps that, somehow, allowed radioactive primary coolant to find its way to theoretically sealed off secondary drains in the engineering spaces.[14] There were also claims of high radiation levels that adversely affected the crews. In addition, there were issues of poor-quality machinery components in the main propulsion system, to include defective pumps, condensers, and the reduction gear.[15] In short, the entire main propulsion system had significant reliability problems.

In an attempt to correct these deficiencies, project managers enacted greater quality control procedures and the second set of Type 091 submarines was lengthened by eight meters. The extra length provided additional room for crew habitability, greater space for maintenance, and badly needed improvements to nuclear safety.[16] During the development of the Type 092 ballistic missile submarine, it was found that that the original reactor plant could handle a 20 percent increase in power to 58 MW (thermal) along with an increase in the main engines output.[17] This reactor was also fitted into the last three Type 091 submarines. There were still concerns about the reliability of the propulsion plant, however, and the first deep dive to 300 meters was made by Han hull 404 (fourth in the class) in April 1988, fourteen years after hull 401 had been commissioned.[18]

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[9] Contrary to many open-source references, the reactor for the Type 091 was not a copy of the OK-150 on the *Lenin* class icebreaker with a rated power of 90 MW (thermal). The OK-150 was physically too large to fit in a 9-meter diameter pressure hull. What China adopted was a loop type reactor of which the OK-150 is but an example. The loop reactor plant design that bears the closest resemblance to the Chinese Type 091 reactor plant is the one on the Japanese cargo ship *Mutsu*. Lewis and Xue provide a more reasonable 48 MW (thermal) power rating for the Type 091. Ibid., p. 46.

[10] 当代中国的核工业 [*Nuclear Industry in Contemporary China*] (Hong Kong: Contemporary China Publishing House, 2009), p. 238.

[11] 刘华清谈中国核潜艇 ["Liu Huaqing Talks About Chinese Nuclear Submarines"], 舰船知识 [*Naval and Merchant Ships*] 11, no. 3 (March 2005), p. 11.

[12] Ibid.

[13] Type 091 (09I) Han class Attack Submarine – SSN, https://www.seaforces.org/marint/China-Navy-PLAN/Submarines/Type-091-Han-class.htm

[14] Lewis and Xue, *China's Strategic Sea Power*, pp. 109-110.

[15] Ibid.

[16] Yang Lianxin, *Witnessing Chinese Nuclear Submarines*, p. 117.

[17] Lewis and Xue, *China's Strategic Sea Power*, p. 115.

[18] *China Today: Defence Science and Technology, Volume 1*, pp. 335-336.

From a late 1970s warfighting perspective, the Type 091 attack submarines were slow, had limited sensor capability, and were acoustically quite loud—similar to Soviet Type 1 nuclear submarines of the Hotel, Echo, and November classes.[19] Despite being labeled anti-submarine submarines, the Type 091s had, at best, a self-defense anti-submarine capability and would largely assume an anti-surface role. For many years, however, these submarines were essentially “toothless” as they lacked a torpedo to fire.[20]

The priority requirement to shoot torpedoes at deep depths drove the adoption of a hydraulic positive ejection system rather than the direct application of compressed air to expel a weapon. The new ejection system appears to have required Chinese engineers to install shorter torpedo tubes on the Type 091 submarines, precluding the use of Yu-1 and Yu-4 series torpedoes, which were 7.5 meters and 7.7 meters long respectively.[21] Development of the Yu-3 took far longer than anticipated, as the final design was not approved until 1984 and the first deep-water test firings did not occur until May 1988.[22] By 1989, Chinese nuclear submarines finally began receiving warshot torpedoes—23 years after the start of the Yu-3 torpedo program and 15 years after the first Type 091 was commissioned.[23]

Modernization appears to have been largely limited to hulls 403-405, with new sonar systems, to include a flank array and passive ranging arrays, updates to the fire control, Yu-3BG and possibly Yu-6 torpedoes, and the YJ-82 anti-ship cruise missile.[24] There is also photographic evidence that these submarines received anechoic coating and a seven-bladed screw.[25] The basic physical characteristics of the Type 091 submarines are listed below.

Table 1. Type 091 [Han] SSN Characteristics

| Characteristics | Hulls 401, 402 | Hulls 403, 404, 405 |
|---|---|---|
| Length: | 98 m | 106 m |
| Beam: | 10.6 m | 10.6 m |
| Surf Displacement: | 4,000 tons | 4,500 tons |
| Subm Displacement: | 5,100 tons | 5,600 tons |
| Reactor: | 1 x 48 MW | 1 x 58 MW |
| Propulsion: | 12,000 HP | 14,400 HP |
| Max Speed: | 24 knots | 25 knots |
| Acoustic Signature: | Loud | Loud |

[19] In the Office of Naval Intelligence *Worldwide Submarine Challenges* 1996 document, the Type 091 [Han] class is depicted as being just a little noisier than a Project 671 [Victor I] SSN (p. 11). This is consistent with Soviet first-generation nuclear submarines. See *Worldwide Submarine Challenges 1996* (U.S. Navy, Office of Naval Intelligence), p.11.

[20] Lewis and Xue, *China's Strategic Sea Power*, p. 110.

[21] Ibid., p. 67.

[22] *China Today: Defence Science and Technology, Volume 2* (Beijing: National Defence Industry Press, 1993), p. 703.

[23] *Shipbuilding Industry in Contemporary China*, p. 502.

[24] 091 型核潜艇 [Type 091 Submarine], https://baike.so.com/doc/958441-1013101.html

[25] The one photograph that best shows these features is no longer active, but was located at: http://www.nipic.com/show/10142989.html

The Type 092 has often been described as a 091 with a missile section, and this rough assessment is largely accurate. The biggest structural difference between the two classes is the missile compartment that likely had an increased pressure hull diameter of 10 meters.[26] As noted above, both the reactor and main propulsion turbines were redesigned with an increased power capacity, shared with the later Type 091 SSNs, but otherwise the non-missile related systems on the Xia SSBN were very similar to those on the Han SSNs. The biggest challenge for the submarine designers, however, was the missile ejection system. Not only did the engineers have to figure out how to get a 14+ metric ton missile out of the submarine safely without damaging it, but they also had to meet the strict environmental requirements for solid-rocket motors while the missile sat in the tube as well as design a compensation system to handle the rapid weight difference between a tube full of missile vice a tube full of water.

For the ejection system itself, the designers looked at a compressed air concept, a gas-steam generator, and a "cool" gas system based on a launch assist device (LAD). Contrary to earlier Western analyses, the LAD option was not adopted. Photographic evidence makes it very clear that the gas-steam generator was developed and tested both on land and on the Type 031 Golf SSB.[27] A gas-steam generator concept uses a small solid rocket motor to instantly flash distilled water into superheated steam; and the combination of the steam and the rocket motor exhaust gases pushes a missile out of the tube at considerable speed. This approach is identical to that used on U.S. Navy SSBNs since the fielding of the Polaris A-1 missile.

The Type 092 was laid down in September 1971, nine months after the first Type 091 SSN was launched. Construction proceeded very slowly, with the shipyard and component manufacturers experiencing delays from the chaos generated by the Cultural Revolution. The submarine was finally launched in April 1981 and commissioned in August 1983.[28] Only one Type 092 was ever built.

The JL-1 missile's development was also sluggish, both for technical and political reasons. The decision to produce a medium-range, submarine-to-surface missile was approved in March 1967, but the first at-sea test shot from a submerged submarine (Type 031 Golf) did not occur until 12 October 1982.[29] In September 1985, the Type 092 SSBN conducted its first submerged test firings. All three missiles failed in flight, but the missiles had successfully been launched and safely cleared the submarine.[30] It would be another three years before China's first SSBN would launch two missiles that successfully flew down range.[31]

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[26] Lewis and Xue, *China's Strategic Sea Power*, p. 115.

[27] Lewis and Xue argue that the Chinese adopted the LAD concept as it would allow them to use the Soviet method of launching with the submarine remaining underway at 2-4 knots. The U.S. Navy approach had the submarine come dead-in-the-water and hover at a prescribed launch depth. The problem with this assessment is that at this point in time Soviet SSBNs used only liquid-fueled missiles that could be launched directly from a flooded tube as the rocket engine thrust could be throttled; something that cannot be done with a solid-rocket motor. Lewis and Xue, *China's Strategic Sea Power*, p. 71. A photograph of a Chinese gas-steam generator ejection system was found in a limited distribution book, *The Road to China's Nuclear Submarines, Volume 4,* 2015, p. 127.

[28] *China Today: Defence Science and Technology, Volume 1*, p. 321.

[29] Lewis and Xue, *China's Strategic Sea Power*, p. 73.

[30] *China Today: Defence Science and Technology, Volume 1*, p. 351.

[31] Ibid.

The Type 092 suffered from the same warfighting ailments as the Type 091s: she was slow, just as loud acoustically, and, until 1989, without a self-defense capability.[32] Rumors of the submarine's propulsion plant being unreliable, coupled with infrequent deployments, and none out of area, suggest the Type 092 was not a true operational naval asset.[33] In support of this theory, none of the unclassified documents published by agencies in the U.S. Intelligence Community have assessed the JL-1 as being deployed operationally. At best, the operational status of the Type 092 submarine and the JL-1 was considered questionable.[34] The basic characteristics of the Type 092 submarine are provided below.

Table 2. Type 092 [Xia] SSBN Characteristics

| Characteristics | Hull 406 |
|---|---|
| Length: | 120 m |
| Beam: | 11 m |
| Surf Displacement: | 6,530 tons |
| Subm Displacement: | 8,325 tons |
| Reactor: | 1 x 58 MW |
| Propulsion: | 14,400 HP |
| Max Speed: | 22 knots |
| Acoustic Signature: | Loud |

## Second Generation: Type 093/093A/093B [Shang I/Shang II/Shang III] SSN and Type 094 [Jin] SSBN

The historical record available in the English language on Chinese second-generation nuclear submarines is sparse to say the least. But what little is known indicates that future nuclear submarine development was not held in high regard. When Deng Xiaoping initiated his Four Modernizations in 1978, nuclear-powered submarines were not a priority for the military modernization aspect.[35] A declassified Central Intelligence Agency (CIA) report from 1984 echoes this sentiment. The report cites Chinese sources indicating that the limited military capability of the early nuclear submarines was not worth their very high cost and construction would halt after the submarines on the construction ways were completed.[36] Given Deng's disinterest, the Type 093 and 094 would languish until the late-1980s, when preliminary design work slowly started to pick back up. But, it would take

[32] In 2009, ONI depicted the Type 092 [Xia] as noisy as the Type 091 [Han]. See *A Modern Navy with Chinese* Characteristics (U.S. Navy, Office of Naval Intelligence, July 2009), p. 22.

[33] Bernard D. Cole, *China's Quest for Great Power*, (Annapolis, Md: Naval Institute Press, 2016), p. 62.

[34] The National Air and Space Intelligence Center has published several versions of its Ballistic and Cruise Missile Reports over the years. The last edition with an entry for the CSS-NX-3/JL-1 was in 2013, where the report continued to describe the missile as "Not yet deployed." In the Department of Defense Annual Report to Congress, Military and Security Developments Involving the People's Republic of China, 2008–2011, the operational status of the Xia class SSBN and JL-1 SLBM "remain questionable."

[35] Lewis and Xue, *China's Strategic Sea Power*, p. 121.

[36] *China Rethinks Its Nuclear Submarine Program*, EA84-10224C (Central Intelligence Agency, December 1984), p. 1. CIA-RDP85T00310R000300090003-2, Declassified on 2010/01/04.

the rise of Jiang Zemin to General Secretary of the Chinese Communist Party before an emphasis on new nuclear submarines was officially reinstated in 1994.[37]

Despite the formal suspension of future submarine design work, there was a sustained, low-level effort within the PLAN to continue studying and refining design options as well as keeping track of foreign advancements.[38] From the evaluation of the first-generation submarines, three key performance issues were repeatedly raised as requiring increased attention: reliable propulsion plants that would deliver higher speeds and lower radiated noise levels.[39] Improvements in sensors and weapons were not disregarded, but these could be more readily developed in support of new conventional submarines that, at the time, were more popular. By 1987, Chinese engineers were looking at a more reliable and powerful loop type reactor for the Type 094, and probably the Type 093 as well.[40] But it was the CIA that first raised the question as to whether the Chinese would decide to go to two reactors to attain higher speed; even though this option might require a sacrifice in noise levels.[41] The U.S. Navy's Office of Naval Intelligence (ONI) would appear to provide an answer to this question in the *Worldwide Submarine Challenges 1997* document that contained artists' depictions of both the Type 093 (Figure 2) and Type 094 with two reactors.[42] The graphics were likely inspired by satellite imagery of structural hull components, as the lead Type 093 is reported to have been laid down in December 1998 and thus long lead items were probably visible at the Huludao-based Bohai Shipbuilding Heavy Industry Company's shipyard in 1996-97.[43]

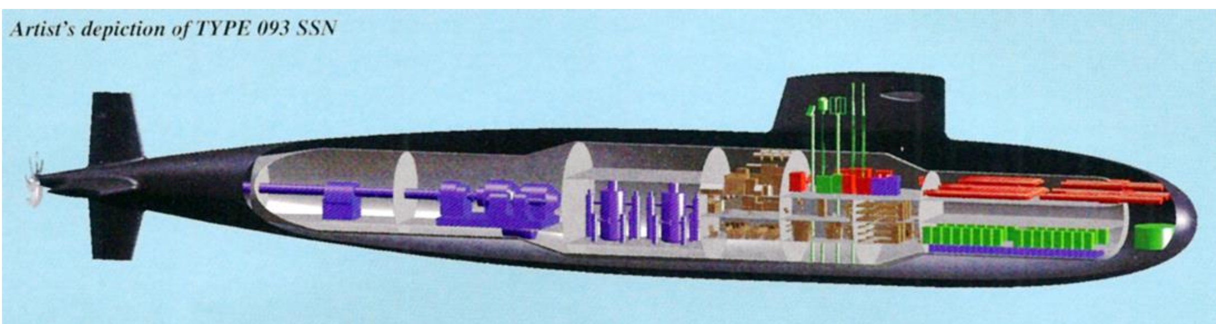


Figure 2. 1997 Office of Naval Intelligence artist's depiction of Type 093 SSN showing two pressurized water reactors.

With two nuclear reactors, it would be feasible to achieve speeds between 28-32 knots depending on the actual power level of the reactors, the overall efficiency of the propulsion plant, and the submarine's total drag. In *Worldwide Submarine Challenges 1997*, ONI claimed the Type 093 would be "comparable to Russian second generation designs from the late 1970s, such as the VICTOR III SSN."[44] Given that a Project 671RTM Victor III was assessed to have a maximum speed of 30-31 knots, estimates suggesting the Type 093 would have a maximum submerged speed of 30

[37] Andrew S. Erickson and Lyle J. Goldstein, "China's Nuclear Submarine Force: Insights from Chinese Writings," in Andrew S. Erickson, Lyle J. Goldstein, William S. Murray, and Andrew R. Wilson, eds., *China's Future Nuclear Submarine Force*, (Annapolis, Md: Naval Institute Press, 2007), p. 185.

[38] Ibid., p. 184.

[39] Erickson's and Goldstein's chapter in *China's Future Nuclear Submarine Force* provides a good overview on the emphasis of these aspects based on Chinese writings.

[40] Lewis and Xue, *China's Strategic Sea Power*, p. 121.

[41] *China Rethinks Its Nuclear Submarine Program*, p. 8.

[42] *Worldwide Submarine Challenges 1997* (U.S. Navy, Office of Naval Intelligence), pp. 21-22.

[43] A.D. Baker III, *Combat Fleets of the World 1998-1999* (Annapolis, Md: Naval Institute Press, 1998), p. 113.

[44] *Worldwide Submarine Challenges 1997*, p. 21.

knots started showing up in the major open source reference books in 1999-2000.[45] For a submarine roughly the same size as a Victor III, and the Type 093 is just a little larger, a maximum speed of 30 knots would require two reactors to generate a total power output between 140-150 MW (thermal).

In the realm of acoustic quieting, the Type 093 has also been strongly linked to the Victor III—the first quiet Soviet submarine class. The initial suggestion was in ONI's *Worldwide Submarine Challenges 1996*, which placed the Type 093 between early and late Victor III SSNs, as shown in Figure 3, in terms of relative radiated broadband noise levels.[46]

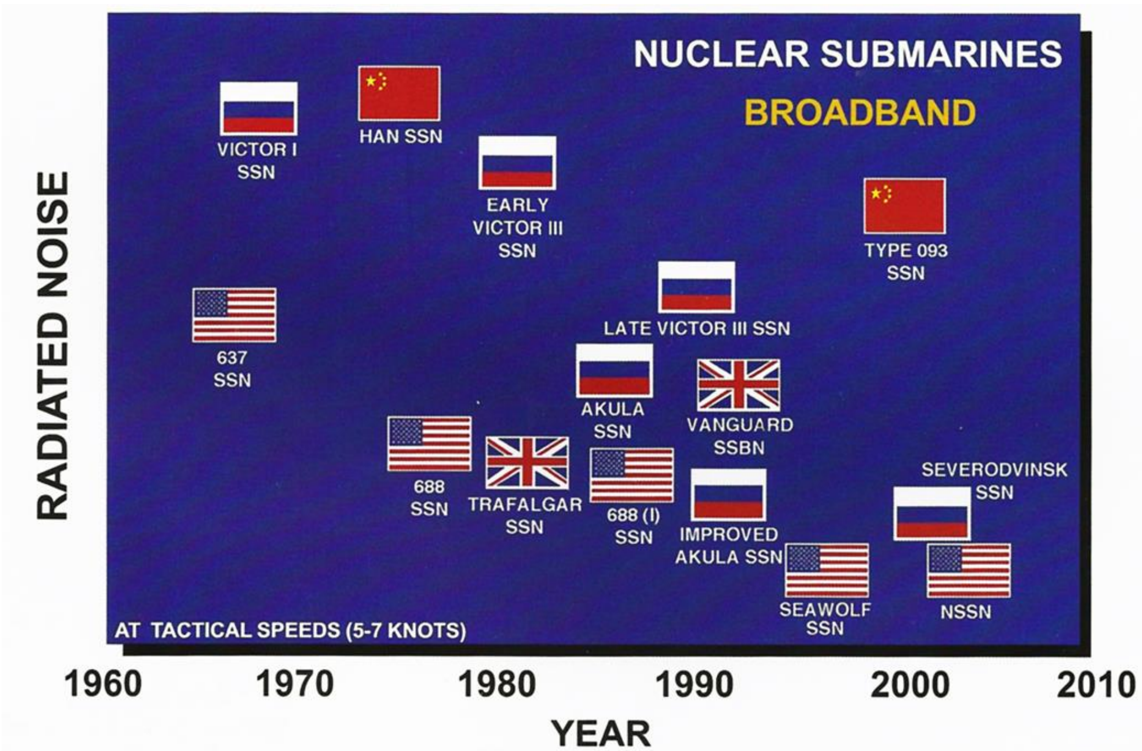


Figure 3. ONI 1996 relative nuclear submarine broadband noise radiated noise ratings.

This assessment was clearly an engineering estimate, and one that implied Russian assistance, as the lead unit had not even been laid down at this point. Supporting statements concerning Russian help would be included in the first Department of Defense Annual Report to Congress on China's Military Power in 2000, which claimed that China's "next-generation nuclear submarine programs are expected to reflect a significant amount of Russian influence."[47] This view was further reinforced in the first Congressional Research Service publication on *China Naval Modernization*, published in 2005, where the Type 093 Shang class "reportedly was designed in conjunction with Russian experts and is derived from the Soviet Victor III class design."[48] Thus, the general consensus was China was

[45] The major references include *Jane's Fighting Ships*, *USNI Combat Fleets of the World*, *Flottes de Combat*, and *Weyers Floften Taschenbuch* (Warships of the World).

[46] *Worldwide Submarine Challenges 1996*, p. 11.

[47] *Report to Congress, Annual Report on the Military Power of the People's Republic of China* (Department of Defense, June 2000), p. 19.

[48] Ronald O'Rourke, *China Naval Modernization: Implications for U.S. Navy Capabilities – Background and Issues for Congress*, (Washington, D.C.: Congressional Research Service, 18 November 2005), p. 67.

about to begin fielding quiet nuclear submarines based on Russian technology and design assistance. This judgement would turn out to be a bit premature.

The first two units of what would become the Shang I class were rolled out in 2002 and 2003 and would undergo 3.5-4 years of extensive sea trials before being commissioned into service in December 2006 and March 2007.[49] If Victor III-like performance was indeed the PLAN's goal, then they were likely disappointed by these submarines. There was little doubt they were more capable than the later Type 091s, but during sea trials it became apparent that the desired speed and quieting goals were not met.

The speed issue was the tougher of the two to substantiate, as the only real source was Chinese navy related website blog postings that described the Type 093 as having a maximum submerged speed of 26 or 28 knots.[50] The former value occurred infrequently and could be attributed to simple confusion with the Type 091. The 28-knot value, however, was the majority view and had some life to it; the figure seemed to hang on over time. However, when one of the first two submarines appeared in 2015-2016 with drag reduction features on its sail it lent credence to the notion that the early boats, as built, were not fast enough for the PLAN.

It is unclear exactly when the sail modifications were made to one of the hulls, as there is really no way to identify which unit had the alterations, but a review of the photographs on the Military Dreamer's Club website provides a best estimate between mid-2013 and 2015.[51] However, in June 2016 a Shang I SSN was photographed on the surface while transiting the Strait of Malacca and the submarine's sail had two noticeable modifications from the one the boat had when it was built.[52] The first was a small cusp or fillet at the bottom of the sail's leading edge, and the second was a slight rounding downward of the top of the sail. Both these techniques are intended to help reduce the sail's contribution to a submarine's total drag, which can reach between 15-30 percent.[53]

It appears, however, that these drag reduction modifications were not particularly effective as only one of the submarines was fitted with the alterations. Indeed, the later Type 093A [Shang II] SSNs would incorporate more robust streamlining to the sails of all four submarines (Figure 4). At best, the Type 093 submarine with the sail modifications may have increased its maximum submerged speed by a knot, but this may be generous.

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[49] Manfred Meyer, *Modern Chinese Maritime Forces* (Admiralty Trilogy Group: Springfield, VA, April 2021 Printing, March 2023 digital update), p. 21.

[50] 深海蓝鲨一中国海军 091，093 型攻击核潜艇 ["Deep Sea Blue Shark—Chinese Navy 091, 093 Attack Nuclear Submarine"], 网易军事 [Wangyi Military Affairs], 25 July 2009, war.163.com/09/0725/22/5F3P8GRF00011232_all.html.

[51] There are few photographs of the Type 093 with the sail modifications. The earliest that can be verified is the one taken on June 2016 while the submarine transited the Strait of Malacca; however, the Taiwanese website Military Dreamer's Club has a photograph of both Type 093 submarines at the Sanya Submarine Base with a caption that claims the photo appeared online in mid-2013. This photo strongly suggests both submarines had the same sail configuration. Further down on the webpage there is another photo of a closeup of the sail modifications with the caption that it appeared online in 2015. The photographs can be found at http://mdc.idv.tw/mdc/navy/china/plan_sub.htm. The next time a good photo of the modified Type 093 was taken was during the April 2018 Naval Review when it sailed in concert with the unmodified hull, thus confirming only one of the submarines had the modifications.

[52] China Defense Blog, 5 November 2017, https://china-defense.blogspot.com/2017/11/satellite-photo-of-day-type-093-shang.html.

[53] Y.N. Kormilitsin and O.A. Khalizev, *Theory of Submarine Design* (London: Riviera Maritime Media, 2001), pp. 209-212.

Figure 4. Type 093 with sail modifications (left) and Type 093A sail (right).

The noise level issue would be brought to light explicitly by the U.S. Navy. In ONI’s 2009 publication, *A Modern Navy with Chinese Characteristics*, the Shang SSN (Type 093) was displayed as being far noisier than the 1996 estimate had proposed and only marginally better than the Han SSN (Type 091) as shown in Figure 5.[54] Unlike the earlier engineering assessment, this dramatic change was undoubtedly driven by acoustic intelligence that revealed the newer SSNs were much louder than expected.

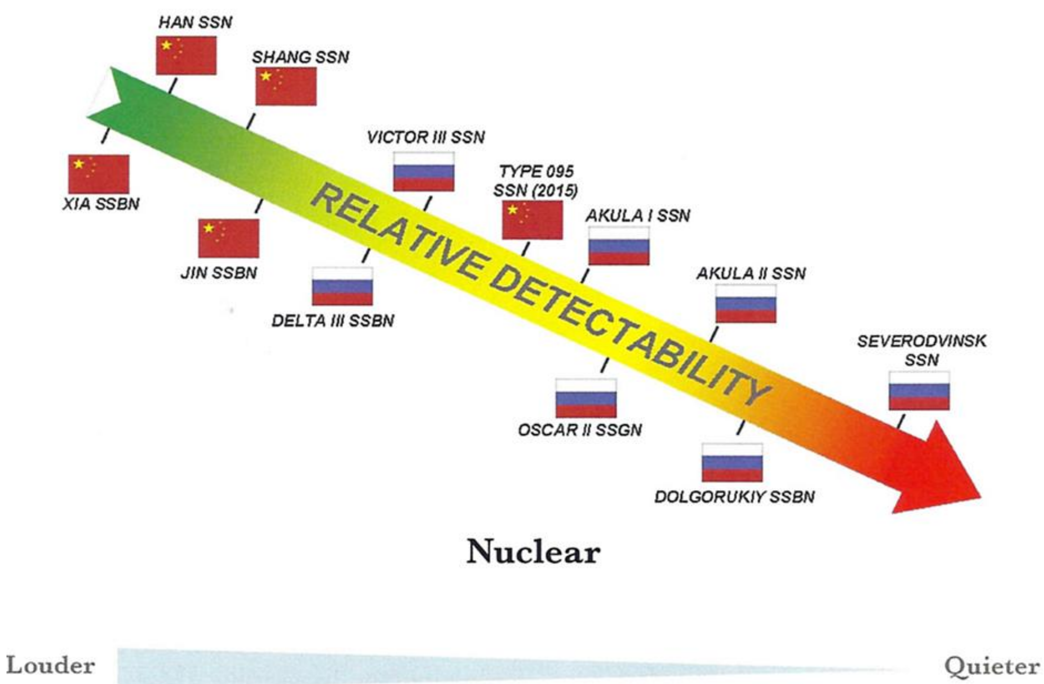


Figure 5. Submarine Quieting Trends (ONI, 2009).

From this, it would appear the first two Type 093 SSNs were designed and built with indigenous Chinese sound silencing technology and techniques. The purchase of the two Project 877EKM Kilos was not finalized until mid-1994, and the PLAN did not receive the submarines until

[54] *A Modern Navy with Chinese Characteristics*, p. 22.

late 1994 and early 1995.[55] So it is unlikely that this purchase had any direct effect on a very mature Type 093 detailed design.

From Chinese-language websites, it was clear the Type 093 was perceived as having improved noise reduction features over the Type 091. One feature that seemed to get a lot of attention was the concept of a raft. Many of the websites claimed the Type 093 used a raft with double isolation for its main propulsion plant machinery and that this would make the new submarines much quieter.[56] The fact that the U.S. Navy had measurements to the contrary suggests the posting individuals misunderstood what type of raft was being used; nor was there any discussion on the impact a raft would have on a submarine's overall design. The general gist of the blog postings and articles was that the Type 093 was using the same free-floating, horizontal raft design found on Western nuclear submarines. However, a typical Western horizontal raft is very large and the double level of isolation that comes with it eats up a lot of volume and probably would not fit inside the Type 093's pressure hull.

The Shang I SSN inherited not only the tear-drop hull configuration from the Han but its pressure hull diameter as well. Based on Google Earth imagery, the Type 093 has a maximum pressure hull diameter of 9 meters, and this is insufficient for a double isolated, or free-floating, horizontal raft based on historical precedence.[57] The smallest maximum pressure hull diameter of a nuclear-powered submarine that is known to have accommodated a free-floating horizontal raft is 9.7 meters found on the U.S. *Sturgeon* class and the Soviet Project 945/945A Sierra I/II classes.[58] Most submarines with a free-floating horizontal raft have a maximum pressure hull diameter of 10 meters or more. The Soviet Navy had developed a ring or cage raft that was used on the Project 705/705K Alfa, Project 671RT Victor II, and the Project 671RTM Victor III with maximum pressure hull diameters of 7.1 and 8.6 meters respectively, but these were not nearly as effective as the more massive horizontal rafts.[59] ONI depicted this cage raft in diagrams of Russian submarines, albeit the wrong classes, in their 1996 and 1997 *Worldwide Submarine Challenges* publications.[60] But what is germane to this discussion is that the Chinese do not appear to have published any technical papers that describe a ring or cage raft; there are, however, numerous papers addressing free-floating horizontal rafts. Thus, it appears that a raft, at least as it is described in regard to modern Western submarines, was absent from the Type 093 submarine design.

What Chinese submarine designers likely did use was compound, or double-level, isolation where a piece of machinery has two levels of sound isolation mounts with an intermediate mass, sometimes referred to as an intermediate raft, between the mounts. This was a common isolation approach used by European conventional submarine manufacturers to reduce the acoustic signature

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[55] Baker, *Combat Fleets of the World 1998-1999*, p. 115.

[56] 09III 型商級攻擊型核潛艇/09IV 型晉級戰略型核潛艇 ["Type 09III Shang-class attack nuclear submarine/Type 09IV Jin-class strategic nuclear submarine"], 军武狂人梦 [Military Dreamer's Club], undated, http://www.mdc.idv.tw/mdc/navy/china/plan_sub.htm

[57] Of note, the pressure hull diameter in the engineering spaces is nearly always smaller than the maximum pressure hull diameter because of the tear-drop hull shape.

[58] Baker, *Combat Fleets of the World 1998-1999*, 1009.

[59] Малахит - Подводным Силам России [*Malachite – Submarine Forces of Russia*], (Saint Petersburg: Gangut Publishing House, 2006), pp. 65, 69, 77.

[60] *Worldwide Submarine Challenges 1996*, p. 23; and *Worldwide Submarine Challenges 1997*, pp. 14, 15.

of a submarine's main propulsion motor and diesel generator sets.[61] The intermediate mass can be considered a mini raft, but its lack of heft made it far less effective than the large horizontal raft discussed earlier. Compound isolation with a small intermediate mass, along with a more powerful, but still noisy, propulsion plant could result in the early Type 093 SSNs acoustic levels that were observed—similar to that of the Soviet Project 671 Victor I SSN.

The next four Type 093 submarines were commissioned into service in rapid succession, one a year from 2015-2018, which suggests the Chinese were more or less satisfied with the design modifications.[62] The nearly 10-year delay in the production of SSNs was caused more by the occupation of the slipways with Type 094 Jin class SSBNs than by a hiatus to address design changes, but the time was well spent as the Type 093A SSNs incorporated several new features.[63] The most noticeable changes were additional drag reduction modifications to the sail, a large bulged area aft of the sail, and the addition of a towed array deployment stern tube. The sail modifications included a more pronounced fillet at the sail's base, greater rounding of the forward top of the sail, and an additional ≈2.5 meters in sail length. These changes would further reduce the sail's overall drag even with the extra length as the skin friction drag from the additional sail area would be more than compensated for by the reduction in form drag.[64] The fact that all four submarines have the same sail modifications suggests the maximum submerged speed concerns had finally been addressed. In addition, the sail fillet would also help to reduce hydrodynamic noise, but this is not a major concern for speeds less than 12 knots. The primary purpose was to get a Type 093A to its probable maximum design speed of 30 knots. [65]

The bulged area behind the sail is the key feature that defines the three versions of the Type 093A class, and despite numerous articles and blog postings, the bump does not house a vertical launching system.[66] The more likely explanation for the bulged area is that is where the submarine's towed array handling gear is stowed.[67] On Type 093A Version 1 submarine, the area is more of a rectangular box-like structure than a bulge, while Version 2 has a tall streamlined hump. Version 3's hump is lower and even more streamlined and appears to be the final hull form

There were also other changes that could only be heard, not seen. The Type 093A Versions 1 and 2 [Shang II] SSNs were among the first Chinese nuclear submarines to incorporate reverse engineered Russian noise reduction technology, specifically the exterior anechoic coating and pneumatic sound isolation mounts. The first set of Project 877EKM Kilo class submarines came with

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[61] "Conventionally Powered Submarines Today: Class 209," *Naval Forces: A Special Supplement HDW Naval Division*, No. VI/1982, p. 76. Chinese submarine designers probably got their first glimpse of this isolation concept with the German MTU diesels purchased in the mid-1990s for the first Type 039 submarines.

[62] Meyer, *Modern Chinese Maritime Forces*, p. 21.

[63] *The PLA Navy: New Capabilities and Missions for the 21st Century*, Office of Naval Intelligence, 2015, p. 19.

[64] Kormilitsin and Khalizev, *Theory of Submarine Design*, p. 212.

[65] Yongwei Lui, Yalin Li, and Dejiang Shang, "The Generation Mechanism of the Flow-Induced Noise from a Sail Hull on the Scaled Submarine Model," *Applied Sciences,* Volume 9, Issue 1 (2019), p. 1.

[66] The waterline length of all the various Type 093 variants from satellite imagery and handheld photography of broad aspect submarines comes in at 103 meters ±1 meter, which indicates the pressure hull length is the same. Without a very noticeable increase in length, a vertical launching system could not be accommodated. There simply is not enough space. In addition, handheld photographs of Version 2 and Version 3 submarines show no presence of any hatches on the bulge area.

[67] Christopher P. Carlson, "Assessment of Type 093B," 2018, https://www.admiraltytrilogy.com/pdf/Type_093B.pdf

Note, the Type 093B designation was widely used in open-source literature to distinguish the three versions of the Type 093A until 2019.

the thick anechoic coating on the outer hull, but the two Project 636 submarines China received in late 1997-98 also had the more advanced pneumatic isolation mounts.[68] Chinese engineers, employing the concept of "imitative innovation," dissected, studied, and modified the external hull coating and pneumatic mount designs to serve their needs and support indigenous production.[69] This assimilation process takes time though, which helps to explain why the introduction of the Chinese-made variants did not occur until the start of construction on the third Type 094 [Jin] SSBN around 2006-2007. In addition to the time delay, there were submarine design aspects that had to be considered as the new pneumatic mounts are taller than the rubber metal mounts that they replaced (Figure 6).


Figure 6. Chinese BE rubber-metal sound isolation mount (left) and pneumatic RKO (airbag) type mount (right).

The height of the PLAN's typical rubber metal sound mounts is on the order of 2.8 to 3.1 inches (70-80 mm) depending on the load bearing capacity.[70] Thus, the compound isolation in the early Type 093 had about 6 inches (152 mm) of isolation mount space to play with. The pneumatic mounts, or airbag vibration isolators as described by Chinese companies, are much taller with heights of 4.3 to 7.1 inches (110-180 mm) depending on the load capacity.[71] Assuming the position of the main propulsion shaft does not change, and that shaft alignment is maintained, then transitioning to the pneumatic sound mounts requires the submarine designers to revert back to single level isolation, and depending on the actual mount used could require the reduction or even elimination of the intermediate mass. That the Chinese submarine designers evidently adopted this approach attests to the superior effectiveness of the Russian-based pneumatic mounts. However, even though the newer sound mounts noticeably reduced the early Shang II SSN variants' narrowband signature, the

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[68] The type of pneumatic mount is likely a rubber-cord sheath (RKO) that is widely advertised by Chinese companies. Also, in ONI's *Worldwide Submarine Challenges* 1995-1997, they consistently show a photo of a RKO-type mount that implies this is a mount that is used in Soviet/Russian submarines.

[69] Andrew S. Erickson, ed, *Chinese Naval Shipbuilding: An Ambitious and Uncertain Course* (Annapolis, Md: Naval Institute Press, 2016), p. 9.

[70] BE 型橡胶减震器 [BE Type Rubber Shock Absorber], 天津市兄弟减震器科技有限公司 [Website of Tianjin Brothers Shock Absorber Technology Company]， accessed 28 July 2023, https://www.tjjzq.com/product/111.html.

[71] There are several Chinese manufacturers of airbag isolation mounts like the JBF and CS series. The height of these mounts varies between 110–180 mm, with the taller mounts having higher load bearing ratings. See JBF 型橡胶减震气囊 [JBF Rubber Shock-Absorbing Airbag], 上海松夏 [Website of Shanghai Songxia], accessed 28 July 2023, http://www.songxiajz.com/air/441.html.

submarines were still rather noisy by Western standards and are estimated to be comparable to a Soviet Project 671RT Victor II SSN. Operational evidence that supported this assessment would be acquired in early 2018.

On 12 January 2018, a Type 093A submarine surfaced in the contiguous zone (within 24 nautical miles) off the disputed Senkaku/Diaoyu Islands. The submarine in question was photographed as it steamed brazenly on the surface and can be identified as the Version 2 boat with the slightly taller, but streamlined bulge (Figure 7).[72] According to the Japanese Defense Ministry, a Maritime Self-Defense Force destroyer and P-3C maritime patrol aircraft had been tracking the Chinese submarine since mid-morning on January 10th.[73] The best estimate of the submarine's speed was around 5-7 knots, which means the narrowband machinery tonals were the dominant acoustic feature.[74] If the Japanese Defense Ministry report is accurate, then the Type 093A Version 2 submarine was not particularly hard to track with passive systems and this suggests a relatively noisy boat. The acoustic tipping point for the PLAN would have to wait for the introduction of the Type 093A Version 3 submarines.

Figure 7. Type 093A Version 2 SSN off the Senkaku/Diaoyu Islands in January 2018.

In the first half of 2002, China went on a multibillion-dollar shopping spree that included the purchase of two Project 956EM modified Sovremenny class guided missile destroyers, eight Project 636M Kilo submarines with 3M54 [SS-N-27B Sizzler] anti-ship missile capability, multirole fighters, helicopters, naval S-300FM [SA-N-20 Gargoyle] ship-based air defense systems, and a wide

[72] Ankit Pranda, "Japan Identifies Chinese Submarine in East China Sea: A Type 093 SSN", *The Diplomat*, 16 January 2018, https://thediplomat.com/2018/01/japan-identifies-chinese-submarine-in-east-china-sea-a-type-093-ssn

[73] Ibid.

[74] Henri Kenhmann, "Chinese SNA Type 09IIIA surfaces near Senkaku/Diaoyutai Islands," 15 January 2018, www.eastpendulum.com/sna-chinois-type-09iiib-surface-pres-iles-sensaku-diaoyutai. For speeds less than about 12 knots, hydrodynamic and propeller noise are very low, essentially negligible. The broadband signature, while detectable, is not as strong, or loud, as the steady state narrowband noise sources associated with the main propulsion machinery.

assortment of missiles.[75] Part of this massive buy also included small scale purchases of individual technologies and technical consultations with some of Russia's premier shipbuilders and component suppliers.[76] While there is no direct evidence available, one of the technologies that was very likely on Chinese submarine designers' shopping list were the large pneumatic shock-absorbers with rubber-cord reinforcement and embedded rubber-metal stop, or more simply using the Russian acronym, APRKu isolation mounts. These mounts represented first-rate sound silencing technology and were used on Russia's most modern third and fourth generation submarines, such as the Project 971 Akula class SSN, Project 949A Oscar II SSGN, and Project 885 Yasen class SSGN.[77]

Assuming the acquisition of the APKRu mounts occurred in 2002-2003, the imitative innovation process would take about 7-8 years based on the timeline with the earlier pneumatic mounts. The first time that the Chinese equivalent, the JYQN mount, was described openly was in 2006, and by August 2009 the People's Liberation Army Naval University of Engineering had applied for a patent for an "intelligent airbag vibration isolation device."[78] The application showed illustrations with a set of pneumatic isolation mounts placed under a single piece of machinery, but interestingly the machine itself was mounted directly to the machinery baseplate without another isolation mount or an intermediate mass—in other words, a single level of isolation approach.[79] Although the JYQN mount is not mentioned by name in the patent application proper, three of the patent applicants wrote the 2006 research paper published in the *Journal of Ship Science and Technology*.[80] This is the only reference that dealt with an actual isolation mount in the application. The patent was formally approved in February 2012.

After 2013, academic articles and some patents described the use of JYQN mounts in floating-raft arrangements. In addition, the Beijing Yantuo Vibration Damping Technology Co., Ltd, posted an online brochure that described the technical specifications of the mounts as well as a photograph and detailed diagram of one of them (Figure 8).[81] An inspection of the diagram shows the mount's Russian lineage, to include an embedded rubber-metal stop to act as a backup isolation mount in the event air pressure is lost. Given the patent approval date, the PLAN probably would have felt comfortable with the mount's design by around 2010-2011. This is consistent with a 2018 article which claimed China had successfully developed a new propulsion plant isolation system based on an "intelligent airbag vibration isolation device" in 2010.[82] While this would be a rather tight fit

[75] Mikhail Barabanov, Vasiliy Kashin, and Konstantin Makienko, *Shooting Star: China's Military Machine in the 21st Century* (Minneapolis: East View Press, 2012), pp. 58-60.

[76] Ibid., p. 53.

[77] В.Н.Пархоменко, В.В.Пархоменко [V.N. Parkhomenko, V.V. Parkhomenko], "СНИЖЕНИЕШУМНОСТИ ОТЕЧЕСТВЕННЫХ АТОМНЫХ ПОДВОДНЫХ ЛОДОК В ПЕРИОД С 1965 ПО 1995 г." [Noise Reduction of Domestic Nuclear Submarines in the Period from 1965 to 1995], ФУНДАМЕНТАЛЬНАЯ И ПРИКЛАДНАЯ ГИДРОФИЗИКА, 2012, том 5, № 2 [Fundamental and Applied Hydrophysics, Volume 5, No. 2, 2012], p. 55.

[78] He Lin, Zhao Yinglong, Lu Zhiqiang, Shuai Changgeng, Xu Wei, Xhang Zhanning, Li Yan, Bu Wenjun, Shi Liang, "Intelligent Air Bag Vibration Isolation Device," CN101813152A, Naval University of Engineering PLA, application date 2009-08-19.

[79] Ibid., p. 16.

[80] 赵应龙 [Zhao Yinglong]，吕志强 [Lu Zhiqiang], and 何琳 [He Lin], JYQN 舰用气囊隔振器研究 ["Research on JYQN Ship Airbag Vibration Isolator"], 舰船科学技术 [*Ship Science and Technology*], Vol. 28(S2), (2006), pp. 89-92.

[81] JYQN series of airbag vibration isolator, Beijing Yantuo Vibration Damping Technology Co., Ltd., http://bjyantuo.com/products/airbag/2018/1211/26.html

[82] 敬者阳明 [Dear Yangming], 潜艇设备隔振技术 ["Vibration Isolation Technology for Submarine Equipment"], 知乎 [Zhihu], 2 March 2018, https://zhuanlan.zhihu.com/p/34180878

timewise, as the Type 093 Version 3 SSNs were laid down around 2012-2013, it is quite possible that the new main propulsion plant isolation system was back fitted into them. If one assumes the Chinese JYQN airbag isolation mounts performed as well as their Russian APRKu counterparts, then the Version 3 submarines could approach the noise level of an early Project 671RTM Victor III SSN, even with only a single level of isolation. Should this assumption hold true, then the Type 093A Version 3 SSN would be the first quiet submarine in the PLAN.

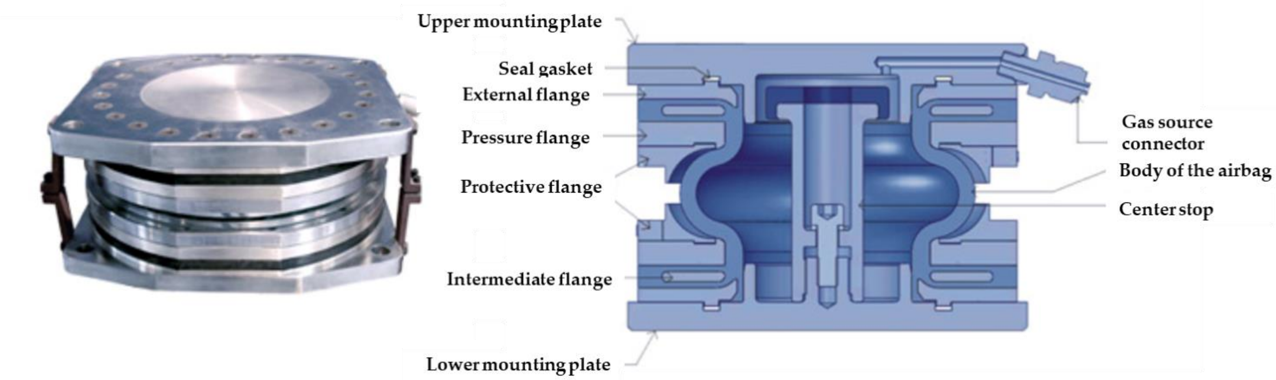


Figure 8. Chinese JYQN advanced airbag mount, derived from Russian APRKu pneumatic sound absorber mount.

Even with the success of the Version 3 isolation system, the PLAN apparently was not finished tweaking the Type 093 design. Since 2017, the U.S. Department of Defense has projected the construction of yet another variant, the Type 093B, and in more recent annual reports the submarine was expected to show up in the mid-2020s.[83] Between 13–18 January 2023, the first Type 093B submarine rolled out of the new construction facility at the Huludao shipyard and was captured in satellite imagery on the launch barge.[84] Although described as a "possible" second hull in open-source articles, the first being a Type 093 submarine spotted on the same launch barge in May 2022, this is unlikely given that the rail line from the construction hall to the launch barge during the months of April and May was obstructed by submarine fabrication equipment and hull components.[85]

The Type 093B submarine is a little longer than the earlier variants and appears to have a pump jet propulsor. Estimated length measurements are consistent among open-source articles at 110 meters length overall, which is to be expected as the pump jet shroud adds a little extra length. Despite being classed as a SSGN in the DoD report, the lack of any appreciable additional length indicates it is unlikely to have a separate vertical launch system.[86]

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[83] *Report to Congress, Annual Report on the Military Power of the People's Republic of China* (Department of Defense, June 2022), p. 53.

[84] Christopher Biggers, "China launches second possible Type 093B hull", Janes, 1 February 2023, https://www.janes.com/defence-news/news-detail/china-launches-second-possible-type-093b-hull

[85] A review of Google Earth imagery indicates that the rail line to the launch barge was obstructed from 1 March 2022 through 15 October 2022. The rail line was unobstructed in the 26 December 2022 imagery—most likely in anticipation of the roll out in mid-January 2023. The imagery that accompanied the Reuters 10 May 2022 news release shows the rail line was still obstructed. See Greg Torode, "Satellite Images Raise Prospect of New Class of Chinese Submarine," Reuters, 10 May 2022, https://www.reuters.com/world/china/satellite-images-raise-prospect-new-class-chinese-submarine-2022-05-10/. Furthermore, subsequent Google Earth imagery from 8 July 2022–26 December 2022 show this Type 093 submarine with considerable outer hull plating removed aft of the sail. This strongly suggests maintenance activity, not new construction, and thus it is more likely this submarine is Type 093 hull 1 coming to Huludao for its mid-life overhaul and modernization.

[86] *Annual Report on the Military Power of the People's Republic of China*, 2022, p. 53.

The new submarine's performance characteristics are expected to be similar to the Type 093A Version 3 boats, with the exception of the acoustic signature. When the Type 093A Version 3 submarines were laid down in 2012-2013, China's precision manufacturing capability was only starting to emerge as a viable computer numerical control (CNC) machine producer on the world market; that is no longer the case. Within the last five years, China's CNC machine tooling has become very competitive globally and the country has developed into one of the largest producers of precision machine tools alongside Germany, Japan, and the United States.[87] And while Chinese companies may not rank in the top-tier, their precision manufacturing know-how is significantly better than 8-10 years ago. The fact that China has been producing indigenous marine gas turbines and diesel engines since 2017 and started producing high performance aerospace turbofan engines in 2021 is proof of this maturation.[88]

With these manufacturing improvements, the Type 093B submarine's propulsion machinery will have tighter tolerances and thus generate less vibration. When coupled with the JYQN mounting system, the Type 093B submarine's acoustic signature could be reduced to that of a Soviet Project 945 Sierra I class SSN—essentially the relative noise level originally estimated by ONI for the Type 093 in 1996. The characteristics of the Shang I, II, and III classes of submarines are listed in the table below.

Table 3. Type 093 [Shang I]/093A [Shang II]/093B [Shang III] SSN Characteristics[89]

| | **Shang I** | **Shang II** | | **Shang III** |
|---|---|---|---|---|
| **Characteristics** | **Hulls 407, 408** | **Hulls 415, 416** | **Hulls 418, 419** | **Hull ?** |
| Type: | Baseline | Version 1, 2 | Version 3 | |
| Length: | 108.5 m | 108.5 m | 108.5 m | 110 m |
| Beam: | 11 m | 11 m | 11 m | 11 m |
| Surf Displacement: | 5,300 tons | 5,300 tons | 5,300 tons | 5,325 tons |
| Subm Displacement: | 6,675 tons | 6,675 tons | 6,675 tons | 6,700 tons |
| Reactor: | 2 x 70-75 MW | 2 x 70-75 MW | 2 x 70-75 MW | 2 x 70-75 MW |
| Propulsion: | 30,000 HP | 30,000 HP | 30,000 HP | 30,000 HP |
| Max Speed: | 28 knots | 30 knots | 30 knots | 30 knots |
| Acoustic Signature: | Loud | Noisy | Quiet | Quiet |

[87] Global and China CNC Machine Tool Industry Report, 2022-2027, Research and Markets, April 2022, https://www.researchandmarkets.com/reports/5575712/global-and-china-cnc-machine-tool-industry?

[88] *Annual Report on the Military Power of the People's Republic of China*, 2022, p. 150.

[89] Hull numbers for Chinese Type 093, 093A, and 094 submarines are maddeningly confusing, with numerous and wildly varying interpretations between traditional open-source references and blog postings. The hull numbers assigned in this chapter are to be considered a best guess.

Like the Xia SSBN before, the Type 094 Jin class SSBN is largely an SSN with twelve, very large missiles stuffed in the middle. The sail modifications are fitted on the Version 1 and 2 submarines and only include the base fillet and the rounded top; the sail length is the same on all six boats, which likely does not significantly reduce hydrodynamic drag given the ponderous missile compartment's turtle back.[90] The sound silencing features of the Type 094 will parallel the Shang variants, although the Jin SSBN will suffer from higher flow noise issues due to the turtle back and the multiple lines of limber holes. The latter will be a significant source of flow induced "coke bottle" effect noise at higher speeds, but the Chinese are aware of this problem and have cut back on the number of limber holes on the Version 2 submarines. The Type 094 Jin submarine variants are summarized in Table 4 below.

With the much larger JL-2 submarine-launched ballistic missile (SLBM), the PLAN's striking range has increased significantly to 7,200 km, but this is still insufficient to target the continental U.S. from China's littoral waters.[91] If China wishes to be able to reach east coast targets, the Jin SSBNs will have to venture far out into the Pacific Ocean. Should the Type 094s be backfitted with the 10,000+ km range JL-3 (CSS-NX-20) SLBM as currently expected, then the PLAN can cover the entire U.S. while operating within deep bastions near the mainland China coast.[92]

Table 4. Type 094 [Jin] SSBN Characteristics[93]

| Characteristics | Hulls 409, 410 | Hulls 413, 414 | Hulls 420, 421 |
|---|---|---|---|
| Type: | Baseline | Version 1 | Version 2 |
| Length: | 137 m | 137 m | 137 m |
| Beam: | 12 m | 12 m | 12 m |
| Surf Displacement: | 9,000 tons | 9,000 tons | 9,000 tons |
| Subm Displacement: | 11,500 tons | 11,500 tons | 11,500 tons |
| Reactor: | 2 x 70-75 MW | 2 x 70-75 MW | 2 x 70-75 MW |
| Propulsion: | 30,000 HP | 30,000 HP | 30,000 HP |
| Max Speed: | 25 knots | 26 knots | 26 knots |
| Acoustic Signature: | Loud | Noisy | Quiet |

[90] There are many online comments on the unsightliness of the Type 094 Jin's turtle back. But a large built-up outer hull section is unavoidable. The JL-2, and most likely the JL-3, submarine launched ballistic missile is estimated to be 13 meters long and 2 meters in diameter. Add in a meter below the missile for the eject pressure chamber, part of a gas-steam ejection system, and the tube length is at least 14 meters, and this does not include the missile tube's hatch. This means about four meters of missile tube is outside the missile compartment's 10-meter pressure hull diameter.

[91] *Annual Report on the Military Power of the People's Republic of China*, 2022, p. 53.

[92] Ibid., p. 96.

[93] This article does not use the Type 094A submarine designator as it is most likely an Internet creation and not an official PLAN platform code. While the Type 094A is used extensively in Internet blog posts, newspaper articles, and even semi-official Chinese journals, it does not appear to be used in official Chinese government documents or pronouncements. In addition, the U.S. government does not recognize the Type 094A designation as neither ONI or the Department of Defense use it in their unclassified documents; even though the Type 093A and 093B designators have been used for years.

### Third Generation: Type 095 SSGN and 096 SSBN[94]

There is little firm information concerning the PLAN's third generation submarine designs. However, there have been the occasional snippets from individuals that likely have some understanding of China's intentions. These clues, as well as the considerable, and often insightful, online discussions provide a basis to at least reflect on the likely priorities. The main points that tend to dominate the online debates are:

- Use of a pump jet propulsor
- A single, high-powered nuclear reactor with natural circulation capability
- Integrated electric propulsion system (IEPS)
- Significant reduction in radiated noise using a free-floating horizontal raft
- Long-range strike capability
- Hybrid hull design (single hull & double hull)

Each of these topics will be briefly touched upon as well as the implication for the submarines' overall design. What will not be addressed is the possible inclusion of an X-stern control surface configuration or an escape chamber in the sail in Chinese third generation boats, as well as specifics on the sonar suite or the type of torpedo ejection system.[95]

*Pump Jet Propulsor*

With the roll out of the lead Type 093B submarine in January 2023 with a likely pump jet propulsor, it seems clear that the PLAN is pursuing this option with determination.[96] Even if this submarine is a one-off testbed, which is possible but unlikely given the persistent rumors of possibly up to eight more submarines in this class, the PLAN would gain valuable operational experience with a full-scale pump jet. This would be akin to the U.S. Navy's testing of the *Seawolf* class pump jet on USS *Hartford* (SSN 768).[97] Thus, it should be considered a near certainty that the third-generation submarines will be so equipped. The advantages of a pump jet in reducing cavitation and blade rate noise have been well documented and strongly endorsed by the Royal Navy since the early 1970s.[98] The disadvantages include the much heavier weight—three to four times that of an open seven-bladed propeller—and the considerably greater cost.

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[94] Contrary to many online references, the class nicknames "Sui" and "Tang" have not been officially approved by the Five-Eyes committee (United States, United Kingdom, Canada, Australia and New Zealand) with that responsibility for the Type 095 and 096 submarines – this is not a NATO function. A nickname is rarely provided before the lead unit is rolled out/launched, and in current U.S. government documents neither of these nicknames are used. Thus, the two popular nicknames are to be considered speculative.

[95] There are numerous examples of "fan art" with both a standard cruciform control surface configuration and an X-stern, and while there are advantages and disadvantages to both options—there are others—it is not critical to discussing third generation submarine designs. As for the concept of the escape chamber, the Type 032 Qing is equipped with one and will conduct tests on its utility in the future. No doubt there has been plenty of discussion with Russian designers as modern Russian boats have escape chambers.

[96] The pump jet that was observed is undoubtedly a shaft driven variant, similar to those used by Western and Russian submarines. Despite the considerable fanfare and doom saying in open press articles, RADM Ma Weiming never mentioned a shaftless, rim driven propulsor during his 30 May 2017 CCTV interview. Rick Joe has posted a masterful response to the numerous articles on this subject at https://plarealtalk.com/lost-in-translation-how-one-chinese-submarine-breakthrough-was-mistaken-for-another-5bfd07d58004 .

[97] Norman Friedman, *U.S. Submarines Since 1945, Revised Edition* (Annapolis, Md: Naval Institute Press, 2018), p. 175.

[98] Norman Friedman, *British Submarines in the Cold War Era*, (Barnsley, Great Britain: Seaforth Publishing, 2021), p. 52.

*Nuclear Reactor*

China has struggled to develop compact, high power naval reactors. With a power rating of 48 MW (thermal), the original Type 091 reactor vessel is a little smaller than the Russian OK-150 reactor with a power rating of 90 MW (thermal) that is often cited.[99] When the Type 093 first appeared in 2002-2003, most references suggested the submarine had a maximum power capability of 150 MW (thermal), which would demand two reactors given the PLANs basic mid-1990s technological capabilities.[100] A number of individuals posting on line did not seem to appreciate this estimate and claimed a single reactor with the same power rating was in the second-generation submarines. If this claim were accurate, then the PLAN would really have no reason to seek Russian assistance for their third-generation boats; but that is exactly what occurred.

On September 2, 2010, Rosatom head, Sergei Kiriyenko and Chen Quifa, chair of the China Atomic Energy Authority, agreed to expand Russian and Chinese joint nuclear power programs, to include floating nuclear power plants.[101] This agreement ultimately gave China access to detailed technical information on the nuclear reactors Russia was installing on their nuclear power barges and new icebreakers—the KLT-40S and the RITM-200. These reactors would serve as the baseline inspiration for China's ACPR50S and the ACP100S.

For the purposes of this report, both the RITM-200 and ACP100S will be excluded from further consideration as the combined reactor vessel and control rod drive mechanism's height is very tall for a marine reactor and would not fit inside even a 13-meter diameter submarine pressure hull.[102] By comparison, both the KLT-40S and ACPR50S have a maximum height of about 7.2 meters and will fit in most modern submarine hulls.[103] However, the maximum pressure hull diameter of 9 meters for the Type 093 is insufficient to house this reactor.

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[99] A CCTV 7 documentary from December 2022 (https://www.youtube.com/watch?v=Mzw85grTdIA) shows short video clips of the original Type 091 reactor vessel that is smaller in diameter and has only 19 holes for control drive rod mechanisms in comparison to OK-150 photos that show a slightly larger diameter reactor vessel and 24-25 control rods.

[100] A.D. Baker III, *Combat Fleets of the World 2002-2003* (Annapolis, MD: Naval Institute Press, 2002), p. 108.

[101] World Nuclear News, "Further cooperation for China and Russia," 2 September 2010, http://www.world-nuclear-news.org/NP_Further_cooperation_for_Russia_and_China_0209101.html .

[102] Technical drawings of the RITM-200 show the reactor's height is just over 11 meters, and this is before any hull foundations and supporting structures are taken into consideration. Artist conceptual drawings of the ACP100S suggest it's even larger, which is not surprising as the RITM-200's maximum power rating is 165-175 MW (thermal) whereas the ACP100S is 375 MW (thermal).

[103] China General Nuclear Power Corporation (CGN), "Design, Applications and Siting Requirements of CGN ACPR50(S)", October 2017, p. 13.

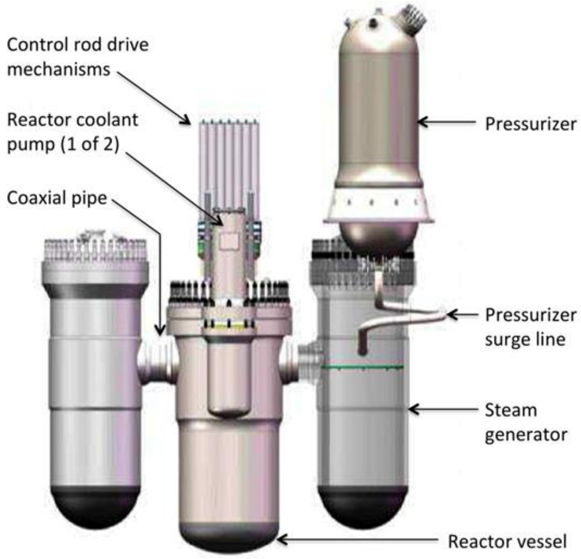

Figure 9. Chinese ACPR50S (left) and the Russian KLT-40S reactor (right).

The ACPR50S reactor is a block design with minimal main coolant piping (Figure 9). It shares with the KLT-40S the uniquely Russian "pipe inside a pipe" main coolant piping configuration where the "hot leg" pipe is nested inside the "cold leg" pipe.[104] The maximum power rating of the ACPR50S is 200 MW (thermal) and this would be sufficient to propel even a large submarine at high speed.[105] Thus, using the ACPR50S for the Type 095 and 096 submarines would seem to make a lot of sense, as this reactor would meet the necessary propulsion requirements and would fit in a larger pressure hull. However, from a quieting perspective, this reactor design would be found lacking. Both the KLT-40S and ACPR50S are forced circulation reactors. That is, the reactors must use coolant pumps during power operations. Both designs have a minimal natural circulation capability, but only for emergency cooling purposes of a shutdown reactor.[106] If natural circulation during power operations is indeed a requirement, and it is reasonable to make such an assumption, then a different reactor design will have to be used.

Fortunately for the PLAN, the KLT-40S is in the same family as the OK-650 reactor found in Russian third-generation submarines. The OK-650 has a maximum power rating of 190 MW (thermal) and can achieve up to 30 percent of reactor power using natural circulation.[107] The OK-650 will fit in pressure hulls as small as the Project 945/945A Sierra I/II SSNs (9.7 meters in diameter) and has a solid operational history. Photographs of an OK-650 reactor show the main coolant piping connects to the steam generator down low, near the bottom third of the total steam generator height, which generates the thermal driving head necessary for natural currents to move the coolant. It is probable that China received detail technical information on the OK-650 as part of this overall technology exchange. Thus, a 200 MW (thermal) reactor with a 30 percent reactor power natural circulation capability is quite probable for PLAN third generation submarines.

[104] Ibid., p. 9.

[105] Ibid., p. 13.

[106] V. Beliaev and V. Polunichev, "Basic Safety Principles of KLT-40C Reactor Plants," p. 32, https://www.osti.gov/etdeweb/servlets/purl/20114845.

[107] Rosatom, Industry Evolution: History of reactors: OK-650, http://www.biblioatom.ru/evolution/istoriya-osnovnyh-sistem/istoriya-reactorov/ok-650/

*Integrated Electric Propulsion System*

During a 30 May 2017 interview for CCTV13, RADM Ma Weiming reportedly made some interesting claims regarding an Integrated Electrical Propulsion System (IEPS) for the next generation nuclear submarine.[108] In addition, Ma stated this particular system is the third generation of IEPS. Curiously, neither pronouncement matches any of his academic papers. What RADM Ma does write on are Integrated Power Systems (IPS), and the variant he has championed since 2003 relies on medium-voltage direct current (MVDC) rather than on alternating current (AC). In a 2015 article in the *Journal of Electrical Engineering*, he defines the MVDC system as a second generation IPS.[109] These inconsistencies suggest that RADM Ma was talking about something different than the IPS concept for the next generation of submarines.

There are two supporting reasons for this hypothesis. First, with rare exceptions, the academic papers address the use of large gas turbine or diesel engine prime movers to generate tens of megawatts, not steam turbines using saturated vice superheated steam.[110] These power generation options are massive and take up a lot of volume, space that is hard to come by in a submarine hull. Second, a second-generation IPS is supposed to feed power to an advanced DC motor, typically a permanent magnet motor. China has yet to build a permanent magnetic motor in the 30–35 MW (40,250–46,950 HP) range and has apparently turned to advanced induction motors for electric propulsion. These are incredibly large and heavy: a single 34.6 MW (46,400 HP) advanced induction motor on the DDG 1000 Zumwalt class is reported to weigh 280 tons.[111] Such a motor could not be fitted into a submarine hull. Thus, it should not be a surprise that the platforms described thus far to be equipped with the second generation IPS have all been surface ships (Type 003, 076, 055A and 054B) which enjoy more engineering space volume.

This suggests third generation PLAN nuclear submarines could have a hybrid propulsion system. A combination of turbo-reduction for high-speed operations and a turbo-electric drive for quiet, slow speed propulsion with a maximum speed on the order of 8-10 knots depending on the submarine design (SSGN vs SSBN). This is reportedly the same propulsion plant arrangement that the Russians have put into the Project 955/955A Borey class SSBNs.[112]

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108 Rick Joe, "Lost in Translation: How One Chinese Submarine Breakthrough Was Mistaken For Another," PLA RealTalk, 4 August 2017,

https://medium.com/pla-realtalk/lost-in-translation-how-one-chinese-submarine-breakthrough-was-mistaken-for-another-5bfd07d58004

109 马伟明, [Ma Weiming], 舰船综合电力系统中的机电能量转换技术 ["Electromechanical Power Conversion Technologies in Vessel Integrated Power System"], 电气工程学报 [*Journal of Electrical Engineering*], no. 4 (2015), p. 4.

110 Photographs of a 21MW DC generator with a GT25000 gas turbine show just how large these machines are. A 20MW steam turbine generator was developed by the 704 Research Institute of China Shipbuilding Industry Corporation probably for the Type 003 aircraft carrier. Again, this is a huge machine that produces far more electricity than a typical modern nuclear submarines turbine generator that produces between three to four megawatts. 中國海軍艦用中壓直流綜合電力系統 ["Medium-Voltage DC Integrated Power System for Chinese Naval Ships"], 军武狂人梦 [Military Dreamer's Club], undated, www.mdc.idv.tw/mdc/navy/china/ieep-dc.htm

111 Swarn S. Kalsi, "Design of MW-Class Ship Propulsion Motors for the US Navy by AMSC, presentation, slide 32.

https://indico.cern.ch/event/760666/contributions/3390601/attachments/1880202/3099643/Navy_Motors-20190715.pdf

112 Bruce Rule, IUSSCAA Message Board, 14 November 2016.
http://pub10.bravenet.com/forum/static/show.php?usernum=774301397&frmid=32&msgid=1356633&cmd=show

*Free-Floating Horizontal Raft*

There is little doubt that the PLAN's third generation submarines will have a large, free-floating horizontal raft. Indeed, there are several patent applications that describe large rafts with very low frequency airbag isolation systems. One application in particular presents an isolation concept that is very similar to those on the Project 971 Akula I and the Project 949A Oscar II submarines (Figure 10). The isolation system design in this application includes lateral, as well as vertical, large pneumatic (airbag) mounts to isolate the raft platform from the submarine pressure hull.[113] The use of a large horizontal raft with two levels of JYQN series of pneumatic isolation mounts will demand a much larger pressure hull diameter than the 9 meters of the first two generations of nuclear submarines.

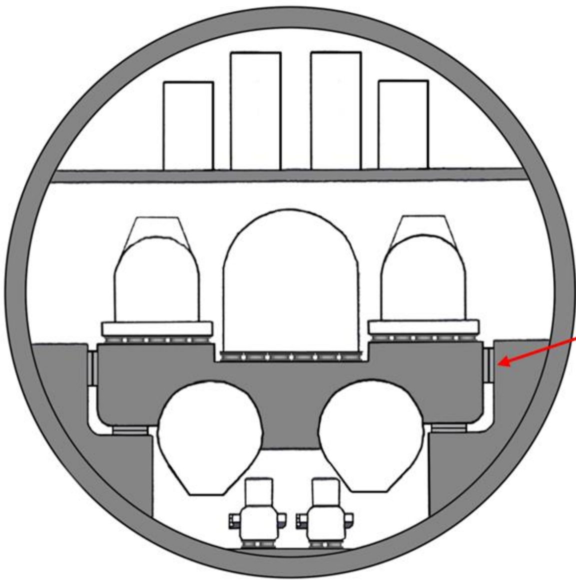

Figure 10. Project 971 Akula class SSN horizontal floating raft with large APRKu pneumatic sound isolation mounts.

*Long-Range Strike*

Having the ability to covertly launch land-attack cruise missiles (LACMs) like the CJ-10 with a range of 1,500 km is likely high on the PLAN's wish list.[114] The PLAN's Universal Vertical Launch System (VLS) can accommodate a transport launch canister (TLC) of up to 9 meters in length and 0.85 meters in diameter.[115] The CJ-10 would require a TLC of this size, which is considerably larger than the U.S. Tomahawk capsules associated with the Mk 45 Mod 1 SSN VLS. Other weapon options include the anti-ship ballistic missile (ASBM), tested from a Type 055 destroyer in April 2022, and the YJ-18A ASCM.[116] The ASBM would require the largest TLC the Universal VLS can accommodate, and this may be true of the YJ-18A as well depending on how much canister length is needed for the exhaust vent channels. Thus, the launch system and hatches

[113] Shuai Changgeng, Li Buyun, Yang Zhaohao He Lin, "A Very Low Frequency Airbag Vibration Isolation System," CN112682461A, Naval University of Engineering PLA, application date 2021-01-05.

[114] *Annual Report on the Military Power of the People's Republic of China 2022*, p. 64.

[115] General Requirements for Generalized Vertical Launcher of Shipborne Missiles, GJB 5860-2006, 2006-12-15, 3.

[116] The anti-ship ballistic missile (ASBM) has been described as the YJ-21 in many open-source articles and blog postings, but this is incorrect. At the Zhuhai 2022 Expo a much smaller missile, designed to be fired from an uncrewed air vehicle, was displayed with the designation YJ-21E on it. The designation of the ASBM fired from a Type 055 destroyer in April 2022 is unknown.

for a similar Chinese submarine system should be noticeably bigger than those on a U.S. SSN. The ability to launch the YJ-18 ASCM from a VLS, while critical for surface ships, is not necessarily a requirement for submarines as current Type 039A,B,C and 093 submarines can launch this ASCM from their torpedo tubes. A VLS system, however, does give a submarine the ability to significantly increase its salvo size.

Google Earth imagery from 4 December 2019 through 30 June 2020, reveals the Type 032 Qing experimental test submarine at the Lyshunkao Naval Base with a large square area removed from the outer hull near the bow. Subsequent handheld photography shows four new large VLS hatches in a 2x2 arrangement. The tube hatches appear to be slightly larger than those of the surface ship Universal VLS cells, but this may be due to the need for the submarine launch tubes to be watertight at depth.

Figure 11. Vertical launcher hatches on Type 032 Qing class submarine.

Online estimates of the Type 095 SSGN design include several drawings and a potential model showing separate VLS tubes.[117] Although there have been descriptions of a Virginia Payload Tube-like launcher with three cells per tube, this seems to be more of a conceptual design. Given the Type 032 is fitted with individual VLS tubes for testing (Figure 11), it seems likely this is what the Type 095 SSGN will probably have as well. The number of VLS tubes is open for debate, but the average number runs between 12 or 18, based on fan art conceptions and drawings. However, in a

[117] 王瑶 [Wang Yao], 提前领略中国 095A 核潜艇风采 ["Appreciate the Style of China's 095A Nuclear Submarine in Advance"], 新华军事首页 [Xinhua Military Homepage], 2 June 2016, tabs 4-6. http://www.xinhuanet.com//mil/2016-06/02/c_129036173_2.htm.

2016 article published in *Ship Science and Technology*, PRC experts displayed a single row of submarine launch tubes three across. The missile tubes clearly penetrate the pressure hull, as they do in the Type 032, and the authors seem to take the number of tubes in the row as a given in their analysis.[118] If three-tube rows are what the PLAN is planning to install in the Type 095, a pressure hull diameter larger than 9 meters will be necessary as the Type 032 has a maximum beam of 10 meters, which means the pressure hull is between 8-9 meters in diameter.[119]

*Hybrid Hull Design*

The last point deals more with how the third-generation submarines could be built, and less with the overall design. Previous PLAN nuclear submarines featured a double hull design where the pressure hull is enveloped in a lighter outer hull. However, recently there has been a lot of discussion of a hybrid construction method where most of the submarine is built to a double hull standard, but the remainder is single hull. Numerous arguments claim the hybrid hull design is superior, but most of the reasons supporting this view are misleading.

The arguments for hybrid construction claim that the submarine will be cheaper to build, have greater underwater speed, have less hydrodynamic noise, and lower active target strength. Many of these points would be true to a degree if there were a significant difference in the hull diameters of the designs involved. However, most of the designs being discussed have the hybrid design being only one meter smaller in overall diameter. With such a small difference there would be little advantage over a standard double hull submarine.

Cost wise these submarines would be very close, with the hybrid submarine being a little cheaper—the expensive stuff inside the pressure hull is what drives cost. Same for greater underwater speed. The total drag of a hybrid hull might be reduced enough to enable a hybrid submarine to have a knot, or two, speed advantage. There would be virtually no difference in hydrodynamic noise, and that difference would only become apparent at near maximum speed. At this point, there are other noise sources to worry about. From an active target strength perspective, a full double hull and a hybrid hull would be virtually identical. The dominant dimension as far as active sonar target strength is concerned is the platform’s length, not diameter.[120] So, a slight change in a submarine’s diameter would be negligible. In addition, it is the air-backed pressure hull that is the main reflecting body, not the outer hull, and in the case of a hybrid hull the pressure hull would actually be larger than a double hull design.[121]

Balancing this debate is the issue of platform survivability. Chinese engineers inherited their submarine design mentality from Russians, who firmly believe in the double hull design concept. Russian designers have long held that combat survivability is best provided by a double hull that has a much higher reserve buoyancy, 25-35 percent of surface displacement vice 14-16 percent of single

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[118] 李四超 [Li Sichao]，潘渊 [Pan Yuan]， and 唐超 [Tang Chao], 某型导弹垂直发射筒底部与潜艇 连接方式对比分析研究 [“Contrast Analysis of Connections Between Submarine Shell and Bottom of Certain Vertical Missile Launch Tube”], 舰船科学技术 [*Ship Science and Technology*], no. 3 (2016), pp. 156-157.

[119] Meyer, *Modern Chinese Maritime Forces*, p. 24.

[120] Robert J. Urick, Principles of Underwater Sound 3rd Edition (New York: McGraw-Hill Book Company, 1983), pp. 302-303.

[121] Laurent Maxit and Christian Audoly, “Target Strength Modelling of Submarines,” Undersea Defence Technology 2004 Conference paper, pp. 8-9

hull submarines, and the ability to survive with one compartment flooded.[122] For the most part, it appears that the reserve buoyancy benefit can be preserved with a hybrid hull. On the other hand, the single flooded compartment requirement would probably not be met by the single hull portion of a hybrid hull. In addition, the section of the submarine that is single hull would be more vulnerable to lightweight anti-submarine torpedoes used by maritime patrol aircraft and helicopters and as the payload of ASW missiles. Finally, another benefit of a double hull design is the ability to use two layers of coating; an anechoic or anti-sonar coating on the outer hull and a decoupling layer on the pressure hull. While the engineering spaces would benefit from a decoupling coating in both a double and a hybrid hull, auxiliary equipment in the single hull sections of a hybrid hull would not.

The issue with a hybrid hull design is that it seems to be a design compromise, the hull construction option that is accepted when another performance characteristic of the submarine forces the designers' hand. For example, in the case of the Project 885/885M Severodvisnk/Kazan classes of SSGN, the number and placement of the torpedo tubes, as well as the necessary volume for a large magazine, likely forced the Malakhit designers to make the second compartment single hulled.[123]

When combining all these factors, it is clear the Type 095/096 submarines will have to be much larger than the second generation. The reactor, large floating raft, and to a lesser degree the VLS all mandate an increase in the pressure hull's diameter. If Chinese designers are using a reactor and sound isolation concept of Russian origin, then it makes sense that the new designs will need a hull size similar to a Russian submarine with equivalent features—specifically the Project 971 Akula with a pressure hull diameter of 10.9 meters. There is evidence to support this case.

In August 2017, retired RADM Zhao Dengping gave a lecture to students at the Northwestern Polytechnical University on PLAN modernization.[124] One of his lecture slides, later posted online, depicted a potential new SSN design with many of the characteristics discussed above (Figure 12). The propulsion plant had a large horizontal free-floating raft, with what appeared to be large airbag isolation mounts, that drove a pump jet propulsor. The diagram also showed twelve vertical launch tubes. The cited displacement was undefined, no reference as to whether it was for the surfaced or submerged condition, but the value was 7,000 tons.[125]

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[122] Kormilitsin and Khalizev, *Theory of Submarine Design*, p. 188.

[123] H.I. Sutton, Pr885 Severodvinsk Class, 13 April 2019, http://www.hisutton.com/Pr885_Severodvinsk_Class.html

[124] Richard D. Fisher, Jr, "The PLA Navy's Plan for Dominance: Subs, Shipborne ASBMs, and Carrier Aviation," 24 October 2017, CIMSEC, https://cimsec.org/pla-navys-plan-dominance-subs-shipborne-asbms-carrier-aviation/.

[125] Ibid.

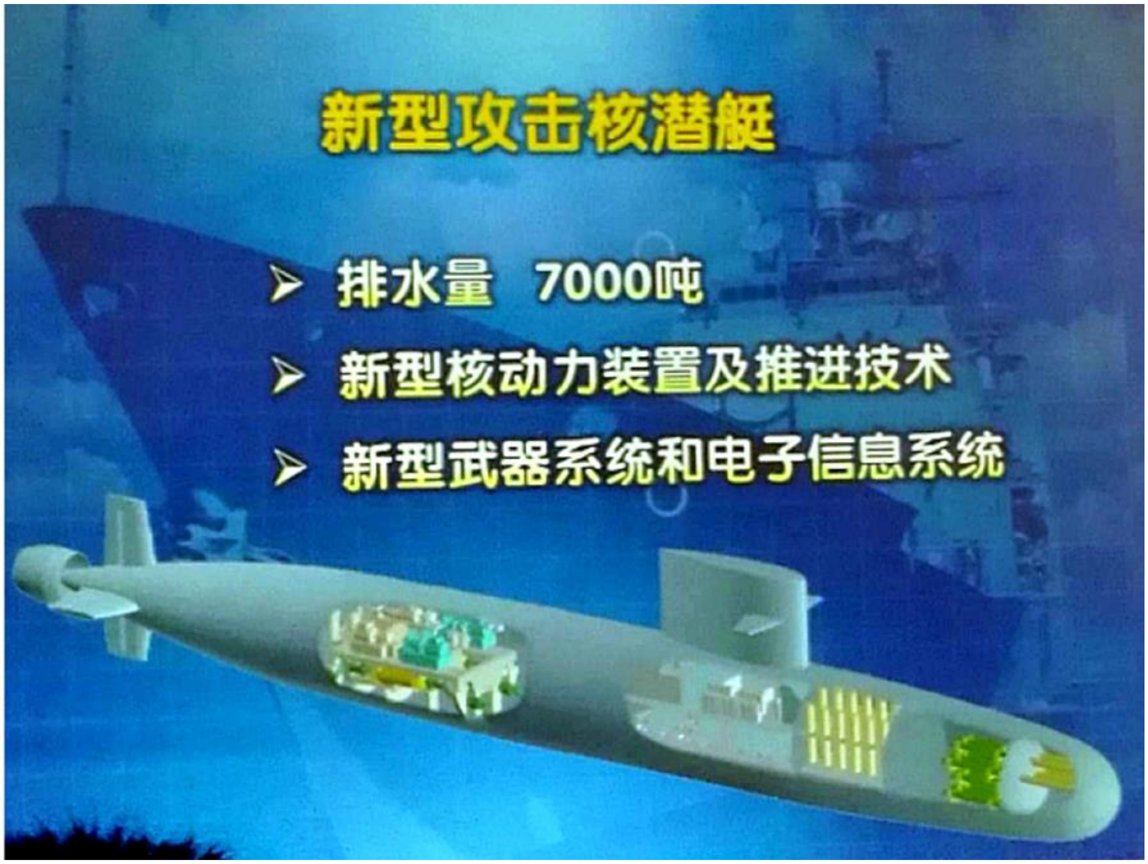

Figure 12. New SSN design in RADM Zhao's presentation.

Several authors assumed this was submerged displacement, and that led some to conclude that the presented design had to be single hull. This assumption is most likely incorrect. The displacement figure is not even 10 percent larger than the Type 093's submerged displacement, and the pressure hull diameter for that class could not hope to accommodate the technology on RADM Zhao's slide; a larger boat is clearly called for. Conversely, if one assumes the displacement is for the surface condition, then the new SSN design is nearly one-third larger than the Type 093 SSN, which makes far more sense.

Subsequent to the tantalizing lecture by RADM Zhao, Google Earth imagery from Huludao revealed possible test pressure hull sections for third generation submarines. In October 2022, a pressure hull section with ≈12-meter diameter was imaged in the storage area by the graving dock. The hull section had two cylinders inside it that are almost certainly large SLBM missile tubes. Two months later, another pressure hull section measuring ≈11.0-12.0 meters in diameter was imaged just outside the new BSHIC shipyard construction facility.[126] Neither hull section appeared to have any framing, making a judgement on the design type impossible. While the first hull section is very likely for the Type 096, the second could be for either the SSGN or SSBN. But the bottom line is that the Huludao shipyard is working up to produce submarine hull sections with large pressure hull diameters.

[126] A screen capture of this hull section, when enhanced and blown up, shows the hull section has a slight distortion that affects measurements of the diameter. Using the Google Earth circle measurement tool, a best fit of ≈11.5 meters is obtained.

Wrapping this altogether into a very rough design is challenging, but the estimated designs for the Type 095 SSGN and Type 096 SSBN are provided below (Figures 13 and 14). The more probable option remains a double hull submarine; however, Tables 5 and 6 include a hybrid option for comparative purposes. In both cases for the Type 096, the missile compartment is projected to be 12 meters in diameter. Both submarine classes will likely be very quiet, comparable to the Project 971 Akula I if the propulsion plant uses a turbo-reduction approach only. If the hybrid turbo-reduction/turbo-electric approach is adopted as suggested above, then the acoustic noise levels could compare favorably to a Project 971U Improved Akula I SSN at tactical speeds.

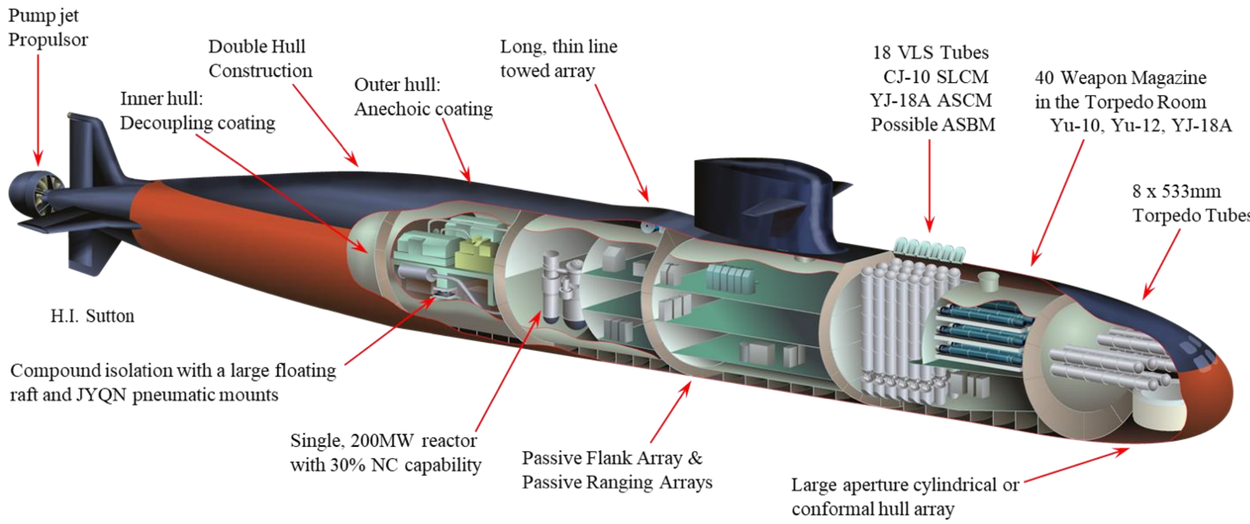


Figure 13. Type 095 SSGN Estimated Design

Table 5. Type 095 SSGN Estimated Characteristics

| Characteristics | Double Hull | Hybrid Hull |
|---|---|---|
| Length: | 115 m | 115 m |
| Beam: | 13 m | 12 m |
| Surf Displacement: | 8,500 tons | 8,000 tons |
| Subm Displacement: | 10,700 tons | 10,100 tons |
| Reactor: | 1 x 200 MW | 1 x 200 MW |
| Propulsion: | 45,000 HP | 45,000 HP |
| Max Speed: | 31 – 32 knots | 32 – 33 knots |
| Acoustic Signature: | Very Quiet | Very Quiet |

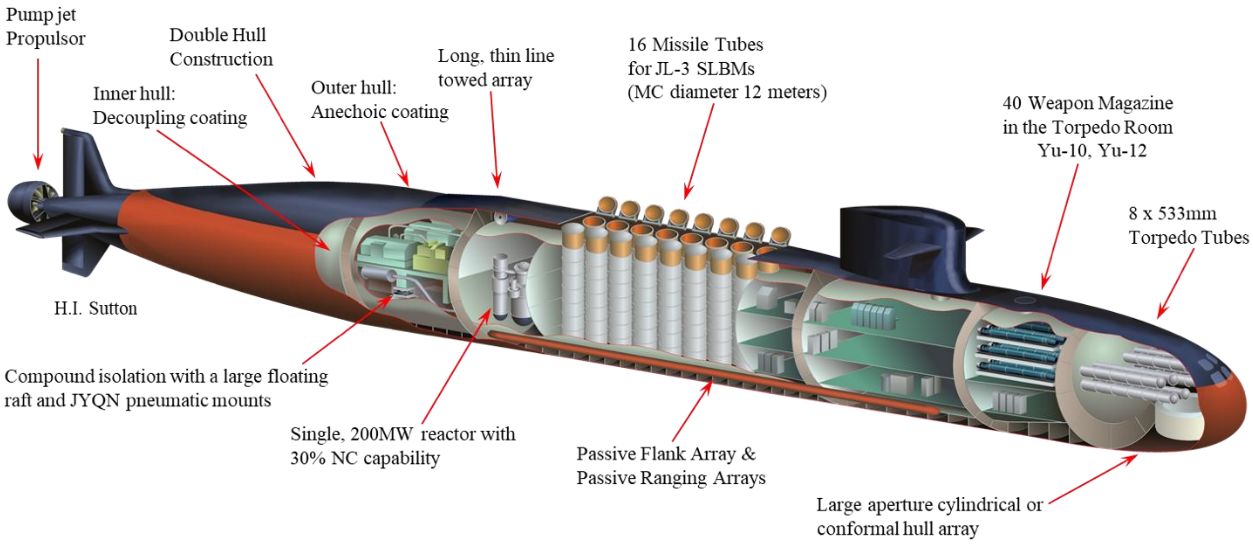

Figure 14. Type 096 SSBN Estimated Design

Table 6. Type 096 SSBN Estimated Characteristics

| Characteristics | Double Hull | Hybrid Hull |
|---|---|---|
| Length: | 150 m | 150 m |
| Beam: | 13.5 m | 12 m |
| Surf Displacement: | 12,500 tons | 11,200 tons |
| Subm Displacement: | 15,750 tons | 14,100 tons |
| Reactor: | 1 x 200 MW | 1 x 200 MW |
| Propulsion: | 45,000 HP | 45,000 HP |
| Max Speed: | 27 – 28 knots | 28 – 29 knots |
| Acoustic Signature: | Very Quiet | Very Quiet |

## Conclusion

The PLAN has had a rough road to travel in achieving its goal of producing nuclear-powered submarines. After being denied technical support by the Soviet Union numerous times, China proceeded on the path of self-reliance to design and build nuclear submarines with indigenous capabilities only. The result was that China built functional, but not very effective submarines.

In an ironic historical twist, China was able to obtain submarines, technologies, and design assistance from cash-strapped Russia starting in the mid-1990s. Through the process of "imitative innovation" Chinese engineers learned how to duplicate and then improve the technologies they had purchased. But this process took time, and the existing Type 093 and 094 submarine hulls were just too small to take full advantage of the technology that had been developed. After nearly 50 years since the first Type 091 SSN was commissioned, China is finally on the verge of producing world-class nuclear-powered submarines.

If the analyses presented above prove to be accurate, then the Type 095 has the potential to approach the propulsion, quieting, sensors, and weapons capabilities of Russia's Improved Akula I class SSN. The Type 096 will also see significant improvements over its predecessors and could compare favorably to Russia's *Dolgorukiy* class SSBN in the areas of propulsion, sensors, and weapons, but more like the Improved Akula I in terms of quieting. Should China successfully make the jump in capabilities from the current Victor III-like platform (Type 093A Version 3) to an Improved Akula I-like platform, the implications for the U.S. and its Indo-Pacific allies would be profound.

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