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On Submarines

Navies must shift attention from manned to unmanned.

"Submarines Will Reign in a War with China". So did Mike Sweeney of George Mason University entitle his recent prize-winning essay in Naval Institute *Proceedings*. That may be true, but reigning over the seas will require actual submarines. The US Navy has well fewer than the inventory thought needed for a war over Taiwan, and the Chinese Navy has been built for that war. This problem presents four alternatives for naval strategists:

- Increasing the building rate of *Virginia*-class submarines. This is infeasible in the short run, and questionably so in the long run.
- Increasing the repair rate for *Los Angeles*-class submarines. This is possible in the short run, but pointless in the long run.
- Shifting attack submarines to where they are more needed. The Navy has limited latitude to move submarines from the Atlantic to the Pacific.
- Building lots of small robotic submarines. While this is technologically uncertain, it is industrially far more feasible.

The choice pivots strategically on the timeframe of expected aggression from the Chinese regime. If we expect that an attack in the next few years, then repairing old *Los Angeles*-class submarines may be of some utility. If the attack is more than ten years away, then repair is pointless. Regardless, investments should be shifted to development of robotic submersibles, particularly those that can work alongside the fleet of newer *Virginia*-class submarines.

This is most true for the US Navy, but it is arguably so for most others with submarines. The challenge for technologists and industrialists is to demonstrate robotic submersibles with greater range and more reliable communications that can be serviced from impromptu tenders around the Western Pacific. If they can manage that challenging use case, they can serve almost anywhere.

Firms mentioned in this note include Anduril, Atlas Elektronik, Blue Eye Robotics, Boeing, General Atomics, General Dynamics, Huntington Ingalls, Israel Aircraft Industries, Leidos, Saab, Thayer Mahan, and Vigor Industrial.

PROBLEMS: The Chinese Navy has been built to invade Taiwan, and the US Navy lacks the available submarines to oppose it.

The first problem is that China's littoral fleet and missile force are huge.

Much has been made of a vast increase in the size of the Chinese Navy, but we must note carefully the nature of that increase. By the figuring of Ronald O'Rourke of the US Congressional Research Service (CRS), the Chinese Navy grew from 216 ships in 2005 to 351 ships in 2022. However, its inventory of nuclear-powered attack submarines increased only from six to nine, and of diesel-powered attack submarines from 51 to 56. The Chinese submarine fleet has become only slightly larger in 17 years, indicating that China's vast shipbuilding industry is not equally capable at building all types of ships, and that the undersea imbalance will not greatly worsen from further Chinese construction. Rather, the bulk of the increase has come with the addition of 15 destroyers, 50 wholly new light anti-submarines frigates, 33 missile boats, and 14 landing ships. The emphasis indicates the objective within the constraints of technology and industry. The Chinese fleet is a fleet designed to ward off naval attacks while undertaking a nearby amphibious assault.

Because Chinese missile power can keep American surface forces, and specifically its aircraft carrier groups, far from Taiwanese waters, submarines will be the first choice for opposing such an invasion. Today, the US Navy's attack submarine force consists of 49 ships, all nuclear-powered, in three classes: 22 of the *Virginia* class, three of the *Seawolf*, and 24 of the Los Angeles. Since 2005, all new construction has been of *Virginias*, in five "blocks" or tranches. In its shipbuilding and force structure plans submitted to the Congress last year, the Navy Department argued that it would want 66 attack submarines by 2045. This round number matches the maximum sustainable shipbuilding rate that the Navy thinks that it can reasonably achieve, and the average lifespan of the ships. Since 2011, the US Navy has been aiming to buy two *Virginias* annually, in a joint program of Newport News Shipbuilding of Virginia (the oldest subsidiary of Huntington Ingalls Industries) and Electric Boat of Connecticut (the oldest subsidiary of General Dynamics). *Virginia*-class submarines were initially advertised with a design life of 33 years, so construction of two annually should sustain a fleet of 66 ships.

This gets to the second problem: the Navy has actually been buying only 1.2 *Virginias* annually.

America's naval power might challenge China, but her constraints will not. There is thus reason for concern. Perhaps Emperor Xi is starting to worry that his China will grow old before it grows rich. Perhaps a Peak China may then lash out, like an Argentine junta invading the Falklands in a failed attempt to stave off domestic political ruin. If America's strategists believe that Xi has a near-term timetable for invading Taiwan, then planning should focus on the short-term. But if all this is alarmist, then perhaps a long-term view is judicious.

SHIPBUILDING: The US Navy's shipbuilders will likely not produce two *Virginia*-class attack submarines annually.

In this past Monday's *Wall Street Journal*, US Senator Roger Wicker of Mississippi exhorted that the Congress should order up a doubling of production of *Virginia*-class submarines, to "between 2.3 and 2.5 attack submarines a year." Regardless of the dicta of the command economy, there are four reasons to think that the rate of submarine construction will languish:

- Construction times for *Virginias* have been consistently increasing for ten years.
- Construction capacity is far below the end-of-Cold-War peak.
- The learning curve, at this slow pace and with these capacity constraints, cannot be steep.
- Money for increasing production is unlikely to find sustained Congressional appropriation.

I will address each of these in turn.

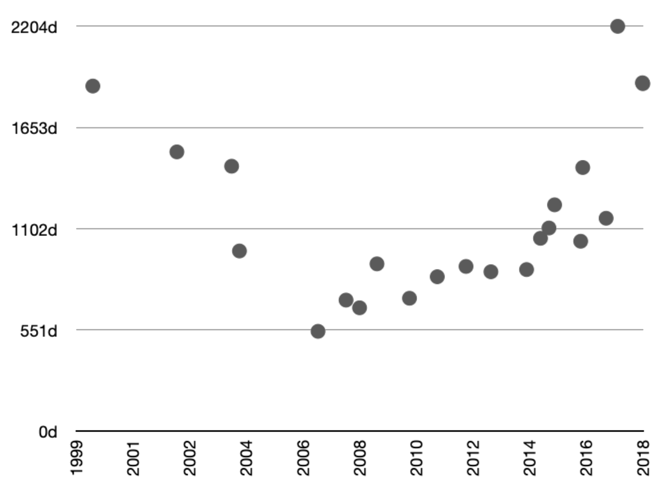
Construction times for Virginias have been consistently increasing for ten years.

As table 1 below shows, the US Navy has taken delivery of just five new submarines in the past five years, though a sixth, the new *Hyman G. Rickover*, should be finished in October.

1. RECENT CONSTRUCTION OF NUCLEAR-POWERED SUBMARINES IN THE UNITED STATES

Ship	Lead yard	Block	Laid down	Commissioned	Building time
South Dakota	GDEB	III	Apr 4, 2016	February 2, 2019	1034 days
Delaware	HII/NN	III	Apr 30, 2016	April 4, 2020	1435 days
Vermont	GDEB	IV	Feb 14, 2017	April 18, 2020	1159 days
Oregon	GDEB	IV	Jul 8, 2017	May 28, 2022	2201 days
Hyman G. Rickover	GDEB	IV	May 11, 2018	October 14, 2023	1894 days
Montana	HII/NN	IV	May 16, 2018	June 25, 2022	1889 days
New Jersey	HII/NN	IV	March 25, 2019		
Iowa	GDEB	IV	August 20, 2019		
Idaho	GDEB	IV	August 24, 2020		
Massachusetts	HII/NN	IV	December 11, 2020		
Utah	GDEB	IV	September 1, 2021		
Arkansas	HII/NN	IV	November 19, 2022		
Arizona	GDEB	V	December 7, 2022		

2. KEEL-LAYING TO COMMISSIONING TIMES FOR *VIRGINIA*-CLASS SUBMARINES



This rate produces not two submarines annually, but the aforementioned 1.2. As chart 2 shows, this has been part of a long-running trend, which began sometime between 2010 and 2013, of continually slowing submarine production in the United States. The situation then worsened markedly sometime in 2015, and at both yards. Note that this first problem in timing had nothing to do with a pandemic. The last three ships delivered—*Oregon*, *Rickover*, and *Montana*—each took at least five years to build, and were were laid down before 2019. The *Delaware*, delivered in April 2020, spent four years under construction.

Construction capacity is far below the end-of-Cold-War peak.

The Navy now estimates that its shipbuilders will not attain the two-per-year pace until at least 2028 (more reporting by Sam LaGrone). I find even that date unlikely. The problem is that all new ships will be Block V ships. The *Arizona*, the first of the Block Vs, is already under construction. From Block IV to V, tonnage increases from 8,700 to 11,200 tons, with the addition of a cruise missile module, to expand the ships' carriage of long-range weapons from 12 to 40. This is a great concept, providing ample firepower for sinking entire Chinese surface flotillas from standoff range. It also makes for the ship more expensive, requiring more labor and parts to build.

Moreover, at the same time, the Navy is aiming to procure 12 wholly new *Columbia*-class, nuclear-powered, ballistic missiles submarines, each of 21,140 tons. As O'Rourke at the CRS estimates, building two Block V *Virginias* and one *Columbia* (for 43,540 tons of submarine) is roughly equivalent to building five Block IV *Virginias* (see note 46 on page 23 of his recent report RL32418). Tonnage is a reasonable metric for cost and the burdens on construction capacity, because submarine design affords precious open space, so every additional ton is packed with all the things that makes submarines so expensive.

There is possibly no trade space here, as top management in both the Navy and Defense Departments are thoroughly committed to the plan for 12 *Columbias* to replace those 14 quite aged *Ohios* that still serve in the ballistic missile role. The first *Columbia*, the *District of Columbia*, was laid down just over a year ago at Electric Boat. Notably, the first four *Ohios*—*Ohio*, *Michigan*, *Florida*, and *Georgia*—were converted between 2002 and 2008 to cruise missile submarines, each carrying 154 Tomahawks. Each ship is now more than 39 years old, and thus due for retirement, starting with *Ohio* herself in 2026. That progressive loss will make the Block V *Virginias* all the more important.

But cannot the Navy and its shipbuilders just take another turn on the capstan, and work harder or smarter or whatever now? After all, "by comparison," Senator Wicker argues, "during the 1980s we bought four times as many" submarines. Presumably he means 4.8 annually. That is not quite true, and it is definitely not an even comparison. From 1980 to 1989, American shipbuilders launched 43 submarines of the *Los Angeles* and *Ohio* classes. (Here I use the launch dates to center on the process of shipbuilding.) As shown in table 3 below, annual construction averaged 4.3 ships, but only 36,835 tons. That constituted slightly more annual output in submarine tonnage than building one *Columbia* and one Block V *Virginia*.

3. CONSTRUCTION OF NUCLEAR-POWERED SUBMARINES IN THE UNITED STATES, 1980 TO 1989

Class	Tonnage each	No. launched	Total tonnage	Years building	Tons per year
Los Angeles	6,082	33	200,706		
Ohio	16,764	10	167,640		
			368,346	10	36,835

As shown in table 4, the long-term pace, across the latter half of the Cold War and beyond, was more measured. From 1972 through 1996, American shipbuilders launched 86 submarines of the *Sturgeon*, *Los Angeles, Seawolf*, and *Ohio* classes. Production was equivalent to 2.5 Block V *Virginias* annually, but not quite one *Columbia* and one Block V.

4. CONSTRUCTION OF NUCLEAR-POWERED SUBMARINES IN THE UNITED STATES, 1972 TO 1996

Class	Tonnage each	No. launched	Total tonnage	Years building	Tons per year
Sturgeon	3,698	5	18,490		
Los Angeles	6,082	62	377,084		
Seawolf	8,600	1	8,600		
Ohio	16,764	18	301,752		
			705,926	25	28,237

In contrast, as shown in table 5 on the next page, the Navy's shipbuilders have managed just a fraction of that since the end of the Cold War. From 1996 to the present, the two yards have built 23 submarines in 25 years—22 *Virginias* and the *Jimmy Carter*, the specially modified and enlarged *Seawolf*. That has constituted just 8,142 tons of submarine annually, or about a single *Virginia*—Block I through IV.

Building 43,540 tons of nuclear-powered submarines annually is not likely to happen, as it has never happened on a sustained basis in the United States, and today's tighter industrial constraints will persist for quite a few years. If the Navy and its shipbuilders could reattain the old long-term pace of the Cold War, the service could aim to get Wicker's 2.5 Block V *Virginias* annually, or one *Columbia* and one *Virginia*. Because it will definitely get the *Columbia*, it should anticipate just one *Virginia*.

5. CONSTRUCTION OF NUCLEAR-POWERED SUBMARINES IN THE UNITED STATES, 1999 TO 2023

Class	Tonnage each	No. launched	Total tonnage	Years building	Tons per year
Seawolf (JC)	12,139	1	12,139		
Virginia	8,700	22	191,400		
			203,539	25.0	8,142

The learning curve, at this slow pace and with these capacity constraints, cannot be steep.

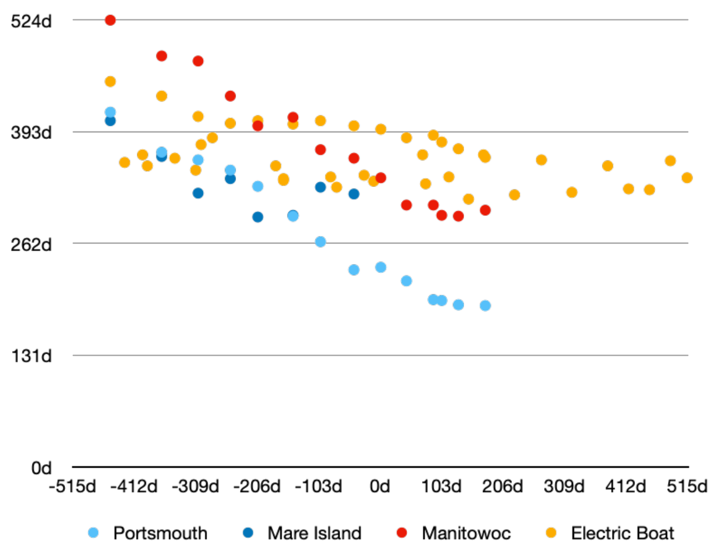
So again, cannot the Navy and its shipbuilders just learn how to do this all much faster? If the two yards were building many ships in parallel, the building time for any single ship might not affect fleet numbers in the long run. In actuality, the two yards are struggling to increase the production rates just back to their earlier reduced pace of 2014. At least two factors are currently holding them back.

Last September, the Navy told the Government Accountability Office that both shipbuilders were 25 percent short of the workforce they needed to execute just their existing book of business. Training shipbuilders to build vessels that dive to great depths with nuclear reactors takes years, and in the American industrial economy today, such skilled labor is in high demand. Much of the problem with the recovery of Gulf Coast shipbuilding after the successive hurricanes of the 2000s lay with the alternatives. Shipbuilders and otherwise-aspiring shipbuilders often found outdoor construction work more pleasant and better paying.

In May, Newport News president Jennifer Boykin told Sam LaGrone of *USNI News* that the issue was the supply chain. The legions of subcontractors who provide the millions of parts for those submarines are still working off the after-effects of their own Covid chaos. Again, however, the economic reaction to the pandemic was not the initial problem. As noted above, things began to go truly awry in 2015. As table 7 on page 9 notes, the average number of *Virginia*-class submarines under construction, by year, has grown alarmingly over the past fifteen years. In short, the shipbuilders' backlog seems far better than the Navy's future fleet.

In this context, "recovery" means attaining that budgeted building pace of two. In the short run, that is unlikely. Expansion within labor and supply constraints demands productivity improvements, and American shipbuilding productivity has been slow-growing and globally uncompetitive for about 120 years. Even wartime emergencies have not fully mattered. Consider the *Gato*-class diesel-electric submarines of the Second World War, the last class to be fully built out before the Japanese surrender. As chart 6 on the next page shows, most of the learning-by-doing had actually been achieved before the attack on Pearl Harbor. Over the 966 days of construction, building times declined from as much as 524 days to as little as 189, but improvements were also quite specific to individual yards, with the public ones leading the private. Electric Boat never built a *Gato* in less than 314 days. The issue is not what Electric Boat could or could not do now, but how much better it could get how fast. The difficulty is that the *Gatos* were 1,525-ton craft, and the each of the building yards was producing one every eight weeks. As Rodney Watterson's book is entitled, the Portsmouth Naval Shipyard alone built 32 submarines in 1944. Today's Block V *Virginias* are seven times the size of the *Gatos*, and include atomic reactors. Two yards are together producing slightly more than one annually. Learning will not proceed so quickly.

6. KEEL-LAYING TO COMMISSIONING TIMES FOR *GATO*-CLASS SUBMARINES, INDEXED TO THE PEARL HARBOR ATTACK (DAY 0)



Money for doubling production is unlikely to find sustained Congressional appropriation.

Under the Trump Administration, the Navy Department cheerfully endorsed the intention of then-Defense Secretary Mark Esper that the Navy eventually obtain three *Virginias* annually, as part of a 500-ship fleet (see the several articles in the references by Megan Eckstein). Under the Biden Administration, the service has backed off such shipbuilding goals as questionably attainable. For as David Larter argued at the transition of governments, “no matter who takes the reins at the department after Esper, the next defense secretary will face the same problem set: how to meet a rising Chinese naval threat on a flat budget.”

As Jason Sherman reported, three years ago, a single *Virginia* Block V was expected to cost more than $3.5 billion each. With inflation, according to O’Rourke, the price of new *Virginias* will now be $4.3 billion each, and the cost of each *Columbia* over their twelve-ship run will be $9.7 billion. As O’Rourke noted more recently, the Navy requested $32.8 billion for shipbuilding in fiscal year 2024. This sum would fund nine new ships, including one *Columbia*, two Block V *Virginias*, two *Arleigh Burke*-class destroyers, two *Constellation*-class frigates, one *John Lewis*-class oiler, and a wholly new submarine tender. This last item replaces one of the Navy’s two remaining submarine tenders, which are both commissioned in 1979. Even if building two more *Virginias* annually were industrially feasible, it would be financially unlikely. Funding 2.5 *Virginias* and a *Columbia* over the long-haul would consume 62 percent of the Navy’s 2024 budget request. Over the next decade and beyond, this would leave no room for further *Ford*-class aircraft carriers to replace the retiring *Nimitzes*. And despite Senator Wicker’s enthusiasm, Congressional sentiment appears to have shifted. Many Republican and Democratic legislators are looking for ways to trim $9 billion from military spending, not add $9 billion to it.

For all these reasons, the Navy's submarine shipbuilding strategy can be likened to shoving peanut butter down a pipe, which is good for neither the peanut butter nor the pipe. Continuing to order two more Block V *Virginias* annually is meaningless. Trying to build more submarines faster has not worked in decades, and will not work anytime soon.

In theory, the Navy could ask Electric Boat or Newport News to design a new, much smaller, and thus more affordable and producible manned submarine. The aforementioned *Sturgeon* class of 38 ships served admirably during the Cold War, and displaced under 3,700 tons each. There are two problems with this idea. First, it is improbable as a marketing concept. The history of the US Navy's shipbuilding since the 1960s has featured continuously larger concepts, whether in aircraft carriers, destroyers, or submarines. The American admiralty has great difficulty weaning itself from big shiny objects. Indeed, the Navy recent plan for its next class of attack submarine, to be built after 2033, includes fifty weapons in the torpedo room, so each ship would probably displace about 9,000 tons, rather like a *Seawolf* (see reporting by Ben Werner and Joseph Trevithick).

Second, a new submarine presents new costs up front, when the Navy's budget should be expected to flatten, at best. Designing a new submarine would take years, and its introduction would create a wholly new learning curve.

REPAIR: The Navy and its ship-repairers cannot maintain the existing submarines either, and may not clear the backlog until the old ships retire.

The next problem is that Navy and its ship-repairers cannot maintain the submarines already in the fleet. As Sam LaGrone reported this past weekend, citing a Navy official, "as of [last] Friday, about a third of the Navy's 51 nuclear [powered] attack boats are in maintenance due to backlogs in repair work in all four of the U.S. Navy's public shipyards." Throughout most of 2023, only 31 attack submarines have been available for service, as the Navy's maintenance backlog has averaged 18 ships. Fifteen years ago, about the same number of ships in commission could produce a third more ships in service.

As table 7 on the next page indicates, the problem is not that the average submarine has been getting older. The fleet has been aging only slightly overall. The problem could be that almost half the submarines, the *Los Angeles* class, are getting quite old, while the other almost half, the *Virginias*, are relatively new. This is because of a gap in time between those halves. As O'Rourke noted, in every fiscal year from 1998 to 2010, the Navy requested procurement of a single *Virginia*-class submarine, except in fiscal year 2000, when it requested none (RL32418, p. 8). This slow pace of procurement was intentional, as nuclear-powered attack submarines were not particularly cost-effective in globe-spanning counterinsurgency campaigns. That did leave a bathtub of block obsolescence facing the service. Today, six of the eight submarines listed by the Naval Register as currently in the yards—the *Newport News*, *Montpelier*, *Columbus*, *Toledo*, *Greenville*, and *Cheyenne*—are 27 to 37 years old. The other two are *Virginia*-class ships—*Texas* and *North Dakota*—which at 17 and nine years of age may pose fewer unforeseen maintenance difficulties. This suggests that older *Los Angeles* ships may be three times as likely to require heavy maintenance as newer *Virginias*.

7. THE US NAVY'S ATTACK SUBMARINE FLEET MANAGEMENT, FISCAL YEARS 2008 TO 2023

Fiscal Year	Number in the fleet	Average age in years	Number in or awaiting depot maintenance	Number ready for service	New subs budgeted for construction	Average number under construction	Number commissioned
2008	51	18.2	11	**40**	1	2.1	1
2009	52	19.1	11	**41**	1	2.7	1
2010	52	19.1	10	**42**	1	2.4	2
2011	52	19.1	11	**41**	2	2.4	0
2012	53	19.7	11	**42**	2	2.1	2
2013	53	20.4	12	**41**	2	2.5	0
2014	53	20.5	15	**38**	2	2.5	1
2015	53	21.1	10	**43**	2	4.0	2
2016	52	21.7	13	**39**	2	5.2	0
2017	50	21.8	14	**36**	2	5.6	1
2018	50	21.7	16	**34**	2	6.2	2
2019	50	21.8	16	**34**	2	6.2	2
2020	50	21.7	15	**35**	2	6.0	2
2021	49	21.5	18	**31**	2	7.6	0
2022	49	20.6	16	**33**	2	7.1	2
2023	49	20.6	18	**31**	2	7.8	1

The saddest story concerns the *Boise*, which has not been underway on patrol since 2015. She may get underway again this year, but her age suggests that she will be decommissioned around 2028 (see below). This begs the question of what the point of repair at this point might be. Similarly, the *Connecticut*, which hit a seamount in the South China Sea in 2021, will not return to service until at least 2026, because of congestion in those ship repair yards (see reporting by Anthony Capaccio). In January 2005, the *San Francisco* was similarly damaged in collision with a seamount. After emergency repairs in Guam, she steamed back across the Pacific to the Puget Sound Naval Shipyard, where her entire bow was replaced with that of the retiring *Honolulu*. The *San Francisco* returned to service in April 2009—over four years after her accident, when the ship-repair enterprise with afflicted with no such congestion. As Craig Hooper has argued, repairing the *Connecticut* may be much more difficult. As one of a class of just three ships, out of production since 2005, many of her replacement parts will need to be fashioned by hand, by technicians who have never built them.

If there is good news, it is that the ship-repair problem mostly disappears over the next ten years, as the *Los Angeles*-class ships retire.

Let us first consider how much longer they may last. Many of the *Los Angeles* were retired early, in two waves. Between 1995 and 1999, eleven ships were paid off, after 17 to 19 years of service. Retiring the ships before a costly and lengthy mid-life reactor change seemed a reasonable choice as part of that post-Cold-War peace dividend. Between 2004 and 2009, another six ships were retired early, after 21 to 24 years of service. This increase suggest that in some cases, the Naval Reactors organization and the Navy's submarines crews had learned how to better manage nuclear fuel consumption. In all cases, in both waves, all ships retired early were Block I *Los Angeles*, without those vertical launch tubes for Tomahawk cruise missiles. Of the *Los Angeles*-class submarines not retired early, the average lifespan has been 36 years. (I do not include in this calculation the *Miami*, burned by arson in 2014 at the age of 24.) To avoid recriminations, let us note that almost none of the ships retired early would be available today. The newest of those, the *Augusta*, was 24 years old when retired in 2009.

8. PLANNED (TO 2027) AND PROJECTED RETIREMENTS OF ATTACK SUBMARINES

Year	Ships (year of commissioning)
2024	*Topeka* (1989), *San Juan* (1988)
2025	*Helena* (1987), *Pasadena* (1989)
2026	*Newport News* (1986), *Scranton* (1988), *Alexandria* (1991)
2027	*Annapolis* (1992)
2028	*Asheville* (1990), *Albany* (1991), *Jefferson City* (1992), *Boise* (1992)
2029	*Springfield* (1993), *Montpelier* (1993), *Columbus* (1993), *Hampton* (1993)
2030	*Santa Fe* (1994), *Charlotte* (1994), *Hartford* (1994)
2031	*Toledo* (1995), *Tuscon* (1995), *Columbia* (1995)
2032	*Greenville* (1996), *Cheyenne* (1996)
2033	*Seawolf* (1997)
2034	*Connecticut* (1998)
2035	—
2036	—
2037	*Virginia* (2004)

The *Los Angeles*-class ships remaining are thus rather old. As table 8 above indicates, ten are due to retire in the next four years, and we can project that with a lifespan of about 36 years, all could be gone by 2032. It is possible that some could last two to three years longer, as Justin Katz reported in 2021, simply because those maintenance backlogs have extended the lives of their refueled reactors.

The newer ships may last a few years less than earlier ones, though counterintuitively. Unlike the S6G and S6W reactors of the *Los Angeles* and *Seawolf*-class ships, the S9G reactors of the *Virginias* were designed to last 33 years. Refueling such an old ship would be not economical, and is thus not intended. (See Magdi Ragheb's chapter on naval nuclear propulsion for comparisons.) Regardless, by 2033, the overall submarine maintenance problem will go away naturally, as the newer submarine fleet will simply require less maintenance.

With this, we can project the size of the US Navy's attack submarine fleet over the next ten years. For an optimistic scenario, assume that the Navy's shipbuilders manage to build two Block V *Virginias* annually starting in 2028, and that the Puget Sound Naval Shipyard can repair the *Connecticut*. For a pessimistic scenario, assume that the Block V building rate remains at about 1.25 ships annually, or just four ships every three years, as the industrial recover effort is consumed by the growing *Columbia* program, and that the *Connecticut* is a write-off. In 2034, the difference in fleet size is five submarines. A strong effort by the Navy and its shipbuilders may matter, but it may not win the war.

9. PROJECTED SIZE OF THE US NAVY'S ATTACK SUBMARINE FLEET, 2024 TO 2034, OPTIMISTIC AND PESSIMISTIC SCENARIOS

	Optimistic case, by ship class				Pessimistic case, by ship class			
Year	*LA*	*Seawolf*	*Virginia*	Total	*LA*	*Seawolf*	*Virginia*	Total
2024	24	3	22	**49**	24	3	22	**49**
2025	22	3	24	**49**	22	3	23	**48**
2026	20	3	25	**48**	20	2	24	**46**
2027	17	3	26	**46**	17	2	26	**45**
2028	15	3	28	**46**	15	2	27	**44**
2029	11	3	30	**44**	11	2	28	**41**
2030	7	3	32	**42**	7	2	29	**38**
2031	4	3	34	**41**	4	2	31	**37**
2032	2	3	36	**41**	2	2	32	**36**
2033	0	2	38	**40**	0	2	33	**35**
2034	0	1	40	**41**	0	1	35	**36**

On the other hand, if availability rates returned to those of ten years ago (perhaps 78 percent), with a less-stressed ship repair enterprise, then the Navy could actually send about 29 attack submarines to sea. The smaller overall fleet could produce almost the available fleet of today.

BASING: The Navy has limited latitude for increasing availability by moving submarines closer to the anticipated action.

In addition to increasing availability, the Navy could try to increase availability in relevant parts of the world. This begs the question of where the submarines live. Of the 18 attack submarines out of service, eight are awaiting maintenance at their long-standing homeports. According to the Naval Register, and as shown in the table below, of the 39 active ships not currently in the yards, 11 are with the Atlantic Fleet, and 21 with the Pacific.

10. CURRENT BASING SCHEME OF ACTIVE ATTACK SUBMARINES

Homeport	*Los Angeles*	*Seawolf*	*Virginia*	Total active
Pacific Fleet				21
Pearl Harbor	4		7	11
San Diego	4			4
Guam	1			1
Puget Sound	2	3		5
Atlantic Fleet				11
Groton	2			2
Norfolk	4		5	9

This suggests that the Navy's priorities are about one-third Atlantic, two-thirds Pacific. The Navy has limited latitude for shifting this further towards the Pacific. Keeping two attack submarines in Connecticut is important for intercepting any Russian submarines making for the East Coast. (Note that does not include the *Connecticut*, as all *Seawolfs* are based in Washington State.) Some of the nine in Norfolk may continuously trail Russian ballistic missile submarines, to destroy them quickly should they attempt to launch their missiles. Moving more ships already in the Pacific Fleet to Guam might be helpful for reducing transit times. On the other hand, that would also expose them to easier attack by the Chinese, and even in port, single hits on submarines tend to render them *hors de combat* for extended periods.

The notion of Guam, however, suggests other possibilities.

ROBOTICS: A fast clock-cycle of development is opening possibilities for extending the undersea fleet.

Submarine duty can be *dull*, the loss of a nuclear-powered ship might be considered *dirty*, and combat is definitely *dangerous*. These three Ds comprise the trifecta of demand for robotics. Consider just the policing of infrastructure. As Alessio Patalano of King's College London has written, all those undersea pipelines and power conduits and telecommunications cables are vital to modern economies around the world. As Elisabeth Gosselin-Malo reports, there is a growing general sense that robots are necessary for guarding it, as the number of available submarines will never be enough. Even so, navies may not institutionally wish to supplement their submarine fleets with robots, so their best efforts may not be focused there. Besides its noted challenges in procuring and repairing large manned submarines, the US Navy has also been having problems procuring with small unmanned ones. In a report last September, the US Government Accountability Office noted that its Orca project with Boeing for a robotic submarine was “$242 million or 64 percent over its original cost estimate and at least three years late.” This is hardly the state of the possible, as others are doing much better.

- Consider subsea reconnaissance, a mission that occupies much of the peacetime activity of submarine crews. At the Norwegian-American Defense Industrial Conference in Virginia this past March, James Nixon of Blue Eye Robotics undertook show-and-tell with the robotic submersible that his firm used to reconnoitre the damage to the Nord Stream pipeline under the Baltic. Blue Eye sent a single operator, on a commercial flight, with a 20-pound robot in a bag, to board a 30-foot fishing boat, to swim inside the pipeline and recover a fragment of it. Nixon further reported that Blue Eye’s robots were already on every Norwegian Coast Guard ship. More notable, the firm has 1,100 units—all built in Norway, “without any parts from China”—in service in 53 countries. At least one is in service in Ukraine. All on-boarding training is accomplished via Microsoft Teams.

- As Xavier Vavasseur reported from Sweden, Saab is busy designing self-propelled naval mines. Just as so-called “one-way drones” like the Iranian Shahed blur the distinction between aircraft and missiles, Saab’s creation will blur the distinctions amongst mines, torpedoes, and submarines. The Baltic is sufficiently narrow and shallow that undersea robots could reign there.

- As H. I. Sutton has been reporting for some time, we will eventually see yet crazier things from Ukraine, as necessity and genius force further invention. Russia’s diesel-powered submarines are the only ships of its Black Sea Fleet with freedom of maneuver close to Ukrainian shores, but a robust fleet of undersea drones (very long-range torpedos?) could end that as well.

- At this year’s Paris “Air” Show, Israel’s Elta Systems (a subsidiary of Israeli Aerospace Industries) and German sonar manufacturer Atlas Elektronik debuted their new *Blue Whale* unmanned submarine (see the reporting by Seth J. Frantzman and by Elizabeth Gosselin-Malo). The match of Israeli drone expertise with German submarine expertise seems compelling. As advertised, the *Blue Whale* can travel at seven knots submerged, to a range of 1,600 nautical miles, and sports a periscope for gathering intelligence and finding targets. She is transportable in a 40-foot shipping container, which suggests T. X. Hammes’ thoughts about containerizing weapons for commercial ships.

- For all the talk of the new “AUKUS” accord, no new manned submarines will arrive for the Royal Australian Navy before 2030. Moreover, those submarines will come at the expense of submarines for the US Navy, and later, the Royal Navy. That explains the Australian hedge with the *Ghost Shark* robotic submarine from Anduril. The smaller and current

> version, the size of a small car, took up some space on the company's pad at the 2023 Sea-Air-Space show in Maryland. As Colin Clark reported, the first prototype has been delivered, with another two to follow over the next two years. The overall cost of that three-ship program, including development, is about US $100 million. A larger and later *Ghost Shark*, the size of a bus, may be armed eventually with torpedos. Either way, as Australian Rear Admiral Peter Quinn said last December at the unveiling, "once your potential adversaries understand what a *Ghost Shark* is — not that we're going to give them any specifics at all — we expect they will generate doubt and uncertainty… Hopefully, they'll even start hearing the *Jaws* theme in their head if they suspect one is about."

As Admiral Quinn's comments suggest, even an unarmed robotic submersible must be treated as an armed vessel, as its target cannot inspect it visually before an engagement. For that matter, for deterrent effect, the robots need not even work well right out of an air-transported box. As Lachlan McGovern of Australian Embassy put it at this May's Nexus 2023 conference in Washington DC, Anduril's *Ghost Shark* and similarly named Ghost Bat flying drone (see below) are "not the end of crewed platforms for us, but…" The economics are compelling. The space and life support for the 100 people in the crew dominate the displacement (the 11,200 tons) and thus expense (the $4.3 billion) of a modern American nuclear-powered submarine. In contrast, robotic submersibles require a few people ashore, and none aboard, for perhaps tens of millions of dollars. Such economics are better than those of fighter aircraft, and rather akin to those of combat drones. As such, one can imagine production rates not of one or two units annually, but hundreds.

This will be very important for replacing wartime losses. In a recent series of wargames, by Mark Cancian's team at the Center for Strategic and International Studies, casualty rates were high. As their report noted, inside the Taiwan Strait,

> *U.S. submarines wreaked havoc on Chinese shipping. Based on the agent-based modeling found in RAND's U.S.-China Military Scorecard [see Heginbotham, RR392] and historical evidence from World War II, each submarine would sink two large amphibious vessels (and an equal number of decoys and escorts) over the course of a 3.5-day turn. Every submarine squadron (four submarines) in the strait sank eight Chinese amphibious ships and eight escorts or decoys, but at a price of roughly 20 percent attrition per 3.5 days… although that attrition increased as Chinese ships emplaced more [antisubmarine] minefields over the course of the game (p. 135).*

This suggests that the US Navy could lose three or four submarines <u>in the first two weeks</u> of a war to defend Taiwan. Their crews notwithstanding, the ships could not be replaced in the course of even a four-year war. That is why Cancian's team argued that "investment in unmanned underwater vehicles (UUVs) should be prioritized" (p. 136).

Note that while robotic submersibles cannot replace manned submarines in all missions, they can undertake that minelaying much more cost-effectively. In talking recently with some retired submariners associated with the Connecticut firm Thayer Mahan, I heard the assertion that the days of manned submarines are not necessarily numbered, but that their freedom of action will be increasingly constrained in ways like the now-circumscribed operations of aircraft carriers.

Thayer Mahan is instrumenting the seabed with listening devices in strategically significant regions around the world, though seemingly not yet in the Baltic or Black Seas, which seem logical next places. As David Hambling wrote several years ago in the *New Scientist*, Chinese scientists are working to instrument the seas with all manner of systems, with multiple physical methods of detection. Such surveillance nets will be far denser than the American Sound Surveillance System (SOSUS), and later Integrated Undersea Surveillance System (IUSS). How does one slip a large submarine through such a network of sensors? Even successfully fighting through creates flaming datums, and hazards multi-billion-dollar ships with hundred-person crews. When you lose a submarine, you generally lose the whole crew, a problem that Karl Dönitz experienced in the 1940s. Not so with drones.

On its website, Thayer Mahan notes an argument from Bryan Clark of the Hudson Institute, that this current approach to undersea warfare "is expensive, does not scale, and is ripe for disruption." His long essay on the subject, with Seth Cropsey and Timothy Walton, similarly recommends that future efforts rely on a mix of drones, under, on, and over the seas. Defensive operations will leverage unmanned submarine-chasers like the US Navy's 135-ton *Sea Hunter*, from Vigor Industrial and Leidos, and as Yannick Smaldore outlines, long-endurance aircraft like General Atomics' SeaGuardian, carrying sonobuoys and torpedos. Future offensive operations, Clark argued in shorter essay in 2022, "will depend on [undersea drones] with substantial endurance, depth and payload." Where there are technical shortfalls in autonomy, developers could address these by treating robotic submersibles not as "extensions of submarines, but instead as teammates that could be deployed from air, surface ships or shore." That latter concept is akin to what the US Air Force wants to accomplish with its Collaborate Combat Aircraft, and the Royal Australian Air Force with that Ghost Bat drone from Boeing Australia. In a more recent study, Clark and Timothy A. Walton describe robots with active sonars almost as flushing submarines, as Jack Ryan would say, "from the hounds to the hunters."

ACTION: Industry must produce better demonstrations of capability and capacity.

Clark has been on this idea for at least eight years (see his study for the CSBA in 2015), and his known influence with the American admiralty may be helpful. Naval circles have been talking about these ideas for yet longer. As O'Rourke recently wrote, well back in 2004, when USS *Virginia* herself was being commissioned, an internal Navy Department study reportedly made three long-term recommendations for undersea warfare (see RL32418, page 50, note 87, citing articles by Bryan Bender and Lolita Baldor). Nineteen years on, we can sense not just the sensibility, but the inevitability. I have added in <u>underlined text</u> my extensions on the recommendations of this study of almost 20 years ago.

Reducing the attack submarine force to as few as 37 ships—<u>so plan for 36</u>.

The Navy's old number 37 is close to the 36 in the pessimistic case that I have modeled above. The Navy's number was likely foreseen because the analysts knew that the forthcoming

Virginias would be so large and expensive. As the Navy now seeks to build all new attack submarines, the Block Vs, at almost twice the size of a *Los Angeles*, something must give.

Granted, this smaller future attack fleet will have higher availability, and much greater ship-killing power, per ship. The two or three remaining *Seawolfs*, even later in their service lives, will bring 50 torpedos and missiles to any fight. Each of the first 28 *Virginias* will carry 25 torpedos and 12 missiles, but the next ten will be Block Vs, with 25 torpedos and 40 missiles. Any of the *Virginias* could carry that 300-kilowatt mast-mounted laser, whose purpose is still unclear (see H. I. Sutton, in Forbes). If two-thirds of those were in the Pacific Fleet, and four-fifths of those were available for duty, the Navy could bring almost 20 submarines to the war, as Cancian's team foresees, in rotating sets of four. Fighting their way through fifty submarines and a hundred or more sub-hunting surface ships of the Chinese Navy would be more than daunting.

Relying on satellites and underwater drones for surveillance—<u>and minelaying</u>.

Such an inevitable shortage of attack submarines at the point of actual war demands robotic reinforcement. Undersea reconnaissance and surveillance are obvious, but minelaying will economize on the manned submarines' limited magazines, and the need to husband them from the worst danger. This indicates how technologists and industrialists should be extending their developmental concepts into kinetic applications, as Anduril's team in Australia is heading. They will also need reliable ways to communicate with command afloat and ashore, with low probabilities of intercept. Ukrainian experience may be useful here. The robotic shipbuilders must further follow through, as Anduril is now attempting, with high rates of constructions, even of prototypes, to demonstrate the possible.

Home-porting nine attack submarines on Guam—<u>and some robotic submarines in Okinawa</u>.

This is possible with manned submarines, but all the more sensible with robotic submarines. Continual improvements in battery technology suggest that they will attain yet better ranges, and the Blue Whale can certainly cover Taiwanese waters as a stand-in force from bases in the Ryukyus, specifically Okinawa, and quite possibly from Kyushu. While all this is within Chinese missile range, robots represent much less interesting targets than manned submarines, and replacements can be flown in. This means that technologists and industrialists should be showing how their robotics are easily transported by sea and air, and how they can be serviced by submarine tenders—whether purpose-built or makeshift from amphibious ships. This means working with more industrial marine suppliers on automating boat-handling and refueling systems, to manage large flotillas of boats without actual boatswains aboard.

Because the United States is not going to outbuild the Chinese shipbuilding industry, or out-staff the Chinese Navy, robotics are needed to offset Chinese numbers. The US Navy needs hundreds of robotic submarines, coming from steady production lines, distributed to avoid easy destruction. Industry has an opportunity to show how to build this fleet, leveraging experience from developments around the world—in Australia, Sweden, Israel, Germany, and

Ukraine. While the US Navy's submarine community has been chauvinistic about its sense of technological superiority, its comparative shortfalls in robotics offer opportunities for developers both foreign and domestic to bring better ideas. That process is clearly already underway. Firms from around the world should be interested, because what they can demonstrate as useful in the Western Pacific should rule beneath the waves everywhere.

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