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Invisible nuclear-armed submarines, or transparent oceans? Are ballistic missile submarines still the best deterrent for the United States?

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ABSTRACT
The service lives of the US Navy's 14 *Ohio*-class nuclear-powered, ballistic nuclear missile submarines (SSBNs), which make up the undersea leg of the country's nuclear triad, are coming to an end while their replacements, the new *Columbia*-class subs, undergo research and development. This new SSBN is expected to cost about $128 billion to develop, leading critics to ask whether these investments make sense for a naval future where, because of advances in sensing technology, submarines may be harder to hide. Their point is a valid one to raise. But the question of whether submarines are getting harder to hide depends very much on whose submarines you're talking about, who's hunting them, and where. To some degree, undersea geography is destiny, when it comes to hiding and finding nuclear submarines.

KEYWORDS
SSBN; nuclear-powered ballistic missile submarines; passive acoustics; reliable acoustic path; SOSUS; nuclear deterrence

When the first *Ohio*-class submarines, such as the one depicted in Figure 1, were designed and produced at General Dynamics' Electric Boat division in New London, Connecticut in the 1980s, they were the stealthiest nuclear-powered submarines in the world, making them the most survivable of all nuclear weapon delivery systems.

The logic for the merits of survivability, then and now, is simple: If an enemy cannot find the sub, then they cannot sink it – meaning that if there were a nuclear war, these ships would very likely survive a first strike, and then be ready to retaliate with the full force of the Trident nuclear missiles they carried on board, such as the one being tested in Figure 2. (Hence the term "survivable.") And if these submarines cannot be knocked out, then they are considered to have a very stabilizing effect: Enemies are less likely to launch a a nuclear attack if they know that they are bound to fail in taking out all of an opponent's weaponry – and suffer the consequences.

And the keys to it all lie in stealth and survivability.

Or so goes the theory.

But it is a mistake to over-generalize in this fashion because the survivability of nuclear-powered and nuclear-armed ballistic missile submarines, also known as SSBNs, has and will continue to vary greatly, depending upon whose SSBNs one is assessing, who might be looking for them, the state of pro-submarine and anti-submarine technology deployed by the hider and the searcher, and the maritime geography that shapes and channels their competition.

It is deeply ironic that there should be this common (mis)perception that all SSBNs are equally survivable and therefore stabilizing. Instead, American SSBNs proved survivable while Soviet SSBNs did not – particularly during the period from 1960 until the mid-1970s, which is the very era that gave birth to the concepts of nuclear stability and instability. In what follows, I will tell this Cold War story with an eye to demonstrating how a radical new technology that helped to make the oceans "transparent" also helped lead to the absolute survivability of American SSBNs compared to their Soviet counterparts. I will then describe how history may be repeating itself, as the United States and China appear headed toward a more vigorous competition in the Western Pacific.

It is important to have this discussion now, at a time when the United States prepares to make the vast investment required to replace its existing *Ohio*-class SSBNs with the new *Columbia*-class versions. That is because there have always been periods of fear – or hope – for new technologies that might make the oceans transparent to all, and therefore make all SSBNs obsolete (Layne 1985). We are living in another one of those periods today. And as before, these fears are unfounded, at least from a US perspective.

Reassessing the past

Our Cold War story begins in November 1960, when the *USS George Washington* departed from Charleston,

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Figure 1. An SSBN returns home from patrol.

The ballistic missile submarine USS Louisiana travels in Hood Canal, Washington, May 3, 2018 as it returns to Naval Base Kitsap-Bangor following a strategic deterrent patrol. Navy photo by Lt. Cmdr. Michael Smith. Image courtesy of US Defense Department https://www.defense.gov/observe/photo-gallery/igphoto/2002039910/

Figure 2. Submarine launches missile.

An unarmed Trident II D5 missile launches from the ballistic missile submarine USS Nebraska in the Pacific Ocean off the coast of California, March 26, 2018 as part of a Navy Strategic Systems Programs test. Navy photo by Petty Officer 1st Class Ronald Gutridge Image courtesy of US Defense Department https://www.defense.gov/observe/photo-gallery/igphoto/2002039663/

South Carolina to begin its first deterrent patrol (Cote 2003). It was the first of 41 *Polaris*-class SSBNs that would rapidly deploy over the next seven years. The *Polaris* force transformed US views of what Albert Wolhlstetter of the RAND Corporation menacingly referred to in 1959 as the "Delicate Balance of Terror" (Wolhlstetter 1959). Never again would there be any doubt that the United States could destroy Soviet cities after a surprise attack. And when the Soviet Union began deploying their own nuclear ballistic missile submarines in 1960, and especially when they began rapidly deploying in 1969 their *Yankee*-class SSBNs (the ironic name given them by the US Navy), many observers assumed that the Soviets had their own so-called "assured destruction" capability as well. This led to the further assumption that a nuclear war between the superpowers would result in mutual-assured destruction, or MAD, and that acknowledgment of this reality would stabilize the nuclear competition. The key technology underlying these assumptions of such an indelicate balance of terror was the SSBN, because unlike land-based forces it was considered survivable under all conceivable circumstances due to the fact that the oceans were essentially opaque.

And indeed, this turned out to be case for US' SSBNs, but not for Soviet SSBNs. A story that occurred behind then-high walls of secrecy explains why.

Using narrow-band, low frequency, passive acoustic listening arrays that were developed during the 1950s and deployed all along the East Coast, the US Navy was able to continuously track the *George Washington* and then her four sisters as they crossed the Atlantic on their way to their first patrols in the Norwegian Sea. Rotating machinery within the hulls of the first five American SSBNs – such as reactor coolant pumps, turbo-generators, and reduction gears – created vibrations at specific low and very low frequencies. Little effort was made during their design to prevent these vibrations from coupling directly to the submarine's hull and then to the water, generating specific, narrow-band acoustic tonals at low frequencies. Beginning in the deep waters where the US Eastern continental shelf ends, and ending where the continental shelf begins in the Western approaches to Britain, these low frequency tonals propagated without significant loss over the breadth of the entire North Atlantic.

The arrays that were collecting these tonals were part of what was soon to be a global network called the Sound Surveillance System, or SOSUS. By 1964, SOSUS or SOSUS-like systems provided oceanwide, passive acoustic surveillance against any submarine that produced such tonals in the deep ocean basins of the North Atlantic and the Norwegian Sea, as well as in large parts of the Pacific. The original impetus behind SOSUS in the early 1950s was to provide warning of the approach of Soviet diesel submarines that US defense leaders feared might be a means of delivering nuclear weapons against US ports. Ironically, the first submarine carrying nuclear weapons that SOSUS detected and tracked was this American, nuclear-powered one.

Largely as a consequence of the ease with which it was tracked by SOSUS, *George Washington* (and her four sisters in what was known as the *George Washington*-class of US SSBN) were the last US nuclear submarines to be deployed during the Cold War that were designed without any significant regard for quieting – particularly the suppression of narrow-band tonals of the type that SOSUS exploited (Polmar and Moore 2004). Instead, starting with the sixth US SSBN, the *USS Ethan Allen*, and the *Thresher/Permit*-class of attack submarines (SSNs), the US Navy focused on making its nuclear submarines immune to the passive acoustic sensors it had developed to counter Soviet submarines. (A word here about naval nomenclature: A ballistic missile submarine, or SSBN, typically fires missiles at shore-based targets, while in contrast an attack submarine – or SSN – fires torpedoes at ships and other submarines. In a way, a ballistic missile submarine can be thought of as the undersea equivalent of the Air Force's B-52 bomber, while an attack submarine can be compared to a fighter plane: One bombs targets on land, while the other shoots at other craft.)

The competition between the development of ever-more sensitive US listening devices and ever-more quiet US submarines started a positive feedback loop that has continued essentially without interruption ever since: Heavily funded US naval research into passive acoustic sensing and signal processing created new opportunities for the US Navy to detect submarines – and these advances in turn provoked compensating innovations in US submarine design to counter these advances, by finding ways to further suppress the acoustic signatures of US submarines.

Thus, when *USS Columbia* first deploys, it will represent one-half of the legacy of more than 50 years of intense, essentially continuous competition between American submarine designers and American anti-submarine warfare sensors. During the Cold War, the Soviet Union only learned of some but not all of the elements of this competition beginning in the late 1960s, and the Soviets did not deploy nuclear submarines designed from the start with quieting in mind until the *Akula* SSN in the early 1980s. Because of this, the USSR also got a late start in developing advanced, passive acoustic sensors. But most important, it did not even attempt to create a Soviet version of SOSUS in American SSBN deployment areas.

More than just sensor technology

This was not the result of any technological asymmetry; early SOSUS technology was not by any means out of reach of the Soviets. Instead it was the result of an asymmetry in the consequences of a common maritime geography. The deep sound channel, a propagation path that only occurred in deep water, is what enabled SOSUS.

SOSUS arrays therefore needed real estate that was reasonably near where the continental shelf ended and the deep ocean began, in order to bring cables deployed at the axis of the deep sound channel ashore to processing facilities where the data from the acoustic arrays could be processed and displayed. The United States had easy access to multiple such locations on its coasts and the coasts of its allies alongside the deep ocean basins that mattered in the Cold War, while the Soviet Union did not.

Therefore, from 1960 to 1975, Soviet ballistic missile submarines were routinely tracked by SOSUS throughout their deployment areas in the North Atlantic and the Pacific, and SOSUS data was increasingly used to direct searches by tactical anti-submarine warfare platforms such as attack submarines and Maritime Patrol Aircraft equipped with their own organic, passive acoustic sensors. The goal was to acquire and continuously trail Soviet ballistic submarines deployed within range of their targets, and therefore hold them at risk of prompt destruction.

Meanwhile, increasingly quiet American SSBNs disappeared from Soviet "view" as soon as they submerged on leaving port, only to reappear when they returned some 60 days later. Consequently, the United States used passive acoustic technology and a very favorable geography both to create a monopoly on undersea surveillance in deep water and to exploit that monopoly with increasingly capable tactical anti-submarine warfare platforms. This legacy represents the other half of the 50-year competition between US submarine designers and US anti-submarine warfare capabilities. The only submarines in the world that can know for sure whether they are immune to American anti-submarine warfare capabilities are American, and no countries other than the United States have the global presence and the full spectrum of anti-submarine warfare capabilities needed to make even very quiet submarines potentially vulnerable.

This history should help explain a seeming puzzle about current debates about nuclear modernization, both in the United States and the United Kingdom. SSBNs are universally perceived as the most survivable of all nuclear basing modes, but this consensus coincides with a small but growing number of analysts and commentators who suggest that modern technology may somehow be about to make the oceans transparent – and SSBNs potentially obsolete. This in turn has led to doubts in both the United States and Britain about the wisdom of proceeding with their planned SSBN modernization programs. Technologies like big data, artificial intelligence, and quantum computing – used separately or harnessed together – are cited as potentially enabling (mostly unspecified) new sensing functionalities and signal-processing techniques that might make the oceans transparent (Brixley-Williams and Naughton 2016).

The Cold War experience described above makes it clear that caution should be exercised when assuming that a new technology will have such universal effects. SSBNs were not a universal source of survivable nuclear forces – just as passive acoustics did not make all SSBNs vulnerable. Looking ahead, the emerging competition between the United States and China is elevating the importance of each side's nuclear forces, and focusing attention on their survivability and effectiveness. With this in mind, it is not the United States that should be cautious about the viability of a new generation of SSBNs, but China. As during the Cold War, the interaction between geography and technology will likely have very different consequences for the future viability of US and Chinese SSBNs.

The technologies cited by those seeing transparent oceans in the future are too vague to assess in any detail, but it is very unlikely that any of them will be able to provide persistent, ocean-wide surveillance that SOSUS did (and still does against all but the quietist submarines). More likely is the development of much shorter range, non-acoustic sensors for surveillance in shallow, coastal waters. This is the conclusion of one of the main sources cited by those arguing that the oceans are becoming more transparent, and the threat is to American SSNs operating aggressively, far forward in Chinese coastal waters, not to its SSBNs (Clark 2015).

Ocean surveillance, when it is available, is of inestimable value in anti-submarine warfare because it greatly reduces the ocean area that must be searched by tactical ASW platforms. As with SOSUS during the Cold War, the key to undersea surveillance under modern conditions is a favorable maritime geography – and the maritime geography that the United States and China share in the Pacific greatly favors the US Navy.

The United States has distributed, bottom-mounted listening arrays that can detect any Chinese submarine attempting to pass through any of the exits from the Yellow, East, and South China Seas into the Philippine Sea and the greater Pacific. Meanwhile, the reverse is not true for China, either for American attack submarines entering China's Inner Seas in the other direction, never mind American SSBNs deploying from their base in Washington to their nearby patrol areas. The key technologies here are passive acoustic listening arrays that use what is called the Reliable Acoustic Path, or RAP (Baggeroer and Elliott 2007).

Like SOSUS, RAP arrays are bottom-mounted, deep water arrays, but unlike SOSUS, they are upward-looking, and there are thousands of nodes in a single RAP array. Each individual, upward-looking array node only receives signals from a tea cup-shaped zone of coverage several miles deep and 20 miles wide at the surface. Consequently, an individual RAP array node has two huge advantages over the nodes in a SOSUS array: It is no more than a few miles away from its potential targets (which is point blank range for a sophisticated, passive acoustic sensor) and very little of the broad ocean's noise is competing with the target's signal. The flip side is that even a RAP array with thousands of nodes can only cover a small fraction of the ocean area that SOSUS covered during its heyday. This means that RAP arrays do not provide anything close to ocean-wide surveillance. But they do provide reliable if fleeting, preliminary indications ("cues" in submariner-speak) of even the quietest submarines at natural chokepoints in the ocean, such as the one that exists between Greenland, Iceland, and the United Kingdom – or, more to the point, the Luzon Strait or the Ryukyus (i.e., the main exits from China's Inner Seas to the Philippine Sea).

The possibility of creating RAP arrays with thousands of nodes only came about with the replacement of copper cable by fiber-optics as a transmission medium for their vast output. The first, experimental RAP array was deployed by the United States in the mid-1980s in part of the Greenland/Iceland/UK Gap, and its output was (and still is) brought ashore in Brawdy, Wales. This array came to be called the Fixed, Distributed System and it was quite successful at detecting Soviet *Akula*-class nuclear subs in tests conducted in the late 1980s. A modernized version of the original Fixed, Distributed System likely is being deployed in the Western Pacific, if it has not already been done.

Unlike early SOSUS arrays, the Fixed, Distributed System uses very advanced technology for both sensing and signal processing. But like SOSUS, it depends on real estate for shore-based signal processing near where the continental shelf drops off into the deep ocean basin. In the Western Pacific, this real estate lies in what China calls the First Island Chain – meaning on the territory of US allies. Consequently, even if China could copy the Fixed, Distributed System or develop a version on its own (which is by no means guaranteed) deploying it at the entrances to its Inner Seas from the Philippine Sea would require fiber-optic cables spanning the entire East and South China Seas, whose shallow waters would make such cables impossible to protect either in peacetime or wartime.

As a result, the United States is likely to maintain undersea control of chokepoints like the Ryukyus and the Luzon Strait, with significant consequences for the future of the Chinese SSBN force, not to mention its large force of modern, diesel attack submarines. This means that a Chinese SSBN deployed in the Yellow Sea – whose missiles have a maximum range of 5,000 miles – could at best attack Seattle, with the rest of the continental United States out of reach. There is no way for these vessels to deploy in a way that brings them closer to the rest of the United States without passing through at least one the chokepoints that constitute the exits from the Yellow, East, and South China Seas.

When the Soviets discovered they faced a similar problem with their *Yankee* SSBNs as they first deployed in 1969, their solution was to develop longer-range submarine-launched missiles – allowing the next generations of Soviet SSBNs to patrol in the Barents Sea and the Sea of Ohkotsk and still reach all or most of the continental United States. These shallow water seas eliminated the deep sound channel and were therefore beyond the reach of SOSUS.

Later, the Soviets discovered that American nuclear-powered attack submarines with improved tactical sensors could still search for and find deployed SSBNs in the Barents. At this point, the Soviets re-oriented a large portion of their naval posture into what American analysts called a "bastion" strategy, deploying a major portion of the Soviet Navy in home waters where it could protect deployed SSBNs rather than relying on stealth alone. Regardless of how successful one assumes the Soviet bastion strategy to have been, it ended up consuming a substantial portion of the Soviet Navy, and particularly its best attack submarines, to support a mission that American SSBNs conducted essentially alone. As Rear Admiral Mike McDevitt (Ret) has noted, SSBNs are very expensive; bastion strategies might make sense when one discovers that stealth will not protect your existing SSBNs, but does it make sense for the Chinese to make large, future investments in new SSBNs if they are unlikely to be able to rely on stealth alone for survival (McDevitt 2015)?

Contrast this situation with that of the US force of nuclear-powered ballistic missile submarines in the Pacific Ocean, which are based in Washington state. When they leave port, they are 5,000 miles from Beijing. Their Trident II thermonuclear missiles have a range of at least 6,000 miles in their current configuration, giving them a potential patrol area anywhere within an arc extending from the state of Washington to New Zealand – almost the entire Pacific ocean – while still allowing them to reach 1,000 miles inland from China's coast. Within this vast ocean area there are no barriers or chokepoints, and all of the adjoining land features are US or allied with the United States. For deployed *Columbia*-class submarines to become vulnerable, a means of initially finding them in this vast space would need to be developed and deployed without the aid of local land-based facilities for processing data from underwater sensor arrays, or any kind of persistent surveillance by airborne sensor platforms given the vast distances involved. The prospects of such a capability are vanishingly small.

But this is not the end of the SSBN survivability story. SSBNs deployed by states not in the cross hairs of the United States are likely to be quite survivable. Even loud nuclear submarines can defeat the traditional, active sonar-based techniques used by the rest of the world's navies as long as they do not have to pass through confined chokepoints to get within range of their missiles' targets. Thus, for example, Indian and Pakistani SSBNs would be very difficult for opposing Pakistani and Indian anti-submarine warfare forces to find, as would Chinese SSBNs if the threat is Indian or Russian anti-submarine warfare forces, and vice versa.

There is also Cold War data relevant to this point. As noted above, the first five American SSBNs were quite loud, as were the first British and French SSBNs, but they all conducted successful deterrent patrols in the Norwegian and Mediterranean Seas through to the end of the Cold War, even after the Soviets had deployed attack submarines that had pronounced acoustic advantages against them. Absent a surveillance system like SOSUS or the Fixed, Distributed System and the maritime geography needed to support it, traditional anti-submarine warfare forces tend to rely on submarines adopting an offensive posture and attacking in order to obtain their first detections. Needless to say, SSBNs which seek only to hide will not oblige them in this.

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