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Survivability of China's Sea-Based Nuclear Forces

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The survivability of China's ballistic missile submarines and submarine-launched ballistic missiles is examined. First, the Type 094 ballistic missile submarine is noisy and vulnerable even in shallow waters. This suggests the urgency for China to improve the quietness of the Type 094. Second, after the deployment of the U.S. interceptor missile, SM-3 Block IIA, in 2018, China's intercontinental ballistic missiles and submarine-launched ballistic missiles launched from Chinese coastal waters would face a three-layer engagement, constructed by SM-3 IIAs deployed near China's coastal waters, ground-based interceptors deployed in California and Alaska, and SM-3 IIAs deployed near U.S. coastal waters respectively. These deployments could undermine the credibility of China's nuclear deterrence. It would be well for China and the United States to work together to improve strategic stability between these two states.

INTRODUCTION

The Obama administration's 17 September 2009 European missile defense plan cancelled the Bush administration's proposal to deploy ten land-based interceptors in Poland and one X-band radar in the Czech Republic, and instead to focus on the sea- and land-based Aegis/Standard-Missile 3 (SM-3) system. Russia welcomed the first phase of this plan, but has expressed concerns about later phases.[1] Until now, there has been no research on the impact of this new plan on China's security and Sino–U.S. strategic relations. This paper intends to provide the basis for such an inquiry.

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In Phase 1 of President Obama's plan, the existing sea-based SM-3 Block IA is scheduled for deployment in 2011.[2] In Phase 2 (approximately 2015), the sea- and land-based SM-3 Block IB will be fielded. In Phase 3 (2018 timeframe), the sea- and land-based SM-3 Block IIA, which is jointly developed by the Unites States and Japan, will be deployed to protect NATO allies in Europe from medium- and intermediate-range ballistic missile threats. And finally, during Phase 4 (2020 timeframe), the SM-3 Block IIB, which is in the initial phase of technology assessment and development, will be deployed to protect the United States against potential intercontinental ballistic missiles (ICBMs) launched from the Middle East.[3]

The U.S. Navy's current cruisers (CG-47s, Ticonderoga-class) and destroyers (DDG-51s, Arleigh Burke-class) are called Aegis (Advanced Electronic Guided Interceptor System) ships because all of them are equipped with the Aegis combat system. A total of 22 CG-47s and 62 DDG-51s are in service or under construction. Of the ships in service, 21 are currently equipped with Ballistic Missile Defense (BMD) capability.[4] The Aegis BMD program consists of the Aegis BMD midcourse program and the Aegis BMD terminal program. Only the Aegis BMD midcourse program is considered here.

The Aegis BMD midcourse program was created in 2002. Its earlier names include: the Navy Upper Tier program, the Navy Theater-Wide (NTW) program, and the Sea-Based Midcourse program. This program is a successor of some sea-based BMD projects: the Terrier Lightweight Exo-Atmospheric Projectile (LEAP) Project and the Aegis LEAP Intercept (ALI) Flight Demonstration Project (FDP).[5] The first version of the Aegis BMD midcourse interceptors is called SM-3 Block IA, based on the air-defense interceptor of the Aegis ships, SM-2 Block IV, by adding a third stage and a Kinetic Warhead (KW). The next version, SM-3 Block IB, replaces the KW of the Block IA interceptor (one-color seeker) with a more advanced one (two-color seeker). The diameters of the three stages of both SM-3 Block IA and IB are 21, 13.5, and 13.5 inches respectively. SM-3 Block IIA would widen the missile body to 21 inches. SM-3 Block IIA might be equipped with the same KW as SM-3 Block IB. Finally, SM-3 Block IIB might have a new liquid-propellant third stage and a new KW. The evolution of SM-3 is shown in Figure 1.

China and Russia have conveyed their concerns about the U.S. BMD plans.[6] The U.S. Ballistic Missile Defense Review Report, released in February 2010, states that China and Russia are not the "focus" of the U.S. BMD system,[7] yet in the next section of the same report, China's conventional missile development is listed as one of the primary justifications for the development of U.S. BMD.[8] China maintains a small and relatively vulnerable nuclear arsenal, whose deterrence capacity depends on "first strike uncertainty," which means letting the state who launches a first strike against China remain uncertain of finding and destroying all Chinese nuclear weapons.[9] Although the number of China's nuclear warheads that would survive a first strike from the

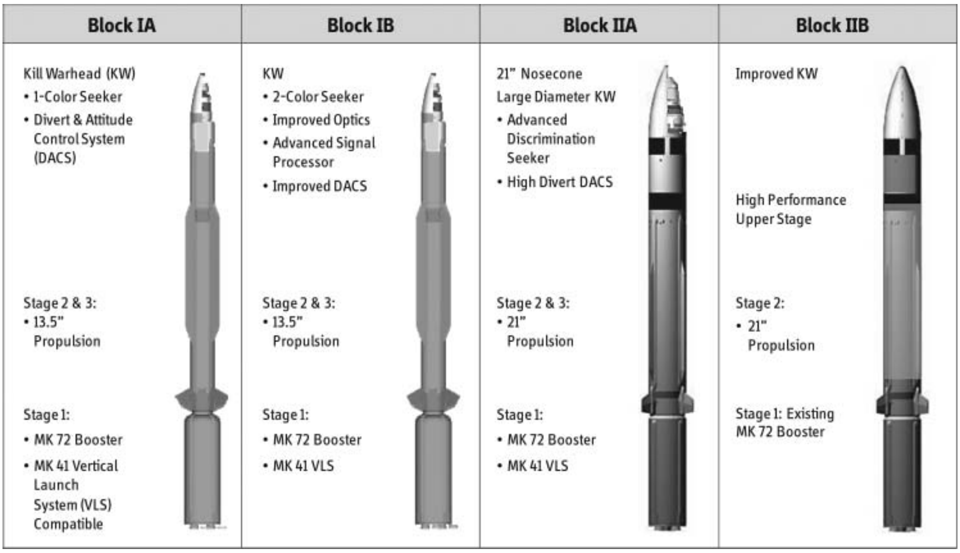

Figure 1: Aegis BMD SM-3 Evolution. Source: Department of Defense, Ballistic Missile Defense Review Report, 2010.

United States is very small, in the absence of missile defense, the uncertainty that some might survive is high enough to deter the United States. However, once the United States possesses an operational BMD system, the situation will become problematic. Even a small scale BMD system could have enough interceptors to engage the small number of survivable warheads. Even with an untested BMD system, U.S. policymakers may try to transform it into a forceful diplomatic tool against China. The U.S. BMD would also create more uncertainty in the minds of Chinese leaders about China's ability to retaliate.

There are two countermeasures that could restore China's confidence in its deterrence: increasing the survivability of China's launch platforms, and increasing the penetration capability of its strategic missiles. Launch platform survivability could be increased by deploying mobile missile systems, including land-based mobile ICBMs and submarine launched ballistic missiles (SLBMs). According to research conducted by U.S. scholars, decoys and infrared stealth are simple and effective measures to penetrate proposed missile defenses. China is adopting both of these countermeasures. China is developing the land-based mobile ICBM DF-31/DF-31A and the ballistic missile submarine Type 094/Jin-class and SLBM JL-2.[10] China has also deployed penetration aids against BMD systems.[11]

At the same time, the United States is trying to negate China's effort. The question arises: what are the security consequences of this strategic interaction between China and the United States? Li Bin has written an article on the subject of the survivability of China's land-based mobile ICBMs.[12] His conclusion is that neither China nor the United States can be completely confident in the survivability or lack of survivability of the Chinese forces.

This article focuses on the survivability of China's sea-based nuclear forces, which can be divided into two interlinked sub-categories: the survivability of China's nuclear strategic submarines (SSBNs), and the survivability of its SLBMs. From China's perspective, the survivability of SSBNs (launch platforms) and missiles are coupled.

The survivability of SSBNs depends on two factors: the quietness of the submarines, and the size and location of the possible patrol area which is limited by the range of the SLBMs. First, a quieter submarine is more difficult to detect. Second, if the range of the SLBMs carried by a submarine is short, then the submarine must patrol near the potential adversary's coast, greatly reducing the size of the patrol area. The potential adversary can deploy extensive anti-submarine warfare (ASW) forces in this relatively small area so that the survivability of the submarine would be decreased.

The patrol area of SSBNs increases with the range of SLBMs. Eventually, SSBNs operated in home water can hold the adversary's homeland at risk. This was evidenced by the Soviet Union after its deployment of Delta-class SSBNs. The development of China's Type 094 submarine has the same goal. Enlargement of the patrol area of SSBNs can also contribute to increasing SLBM's penetration capability, because SSBNs can launch missiles from certain azimuths without BMD coverage.[13]

China's strategy to construct credible sea-based nuclear deterrent forces can be summarized as "two ways, two steps." "Two ways" refers to improving the quietness of SSBNs and improving the penetration capability of SLBMs. "Two steps" refers to phasing. As a first step, China will seek to improve the quietness of its SSBNs so that the SSBNs themselves can survive. The minimum requirement is that SSBNs must be quiet enough to patrol in the shallow waters off the Chinese coast that are under the protection of friendly forces. If this requirement cannot be realized, then China will not have effective sea-based nuclear forces. If this requirement is realized, China could potentially deploy an effective submarine force, but even so, this system could then face the threat of a potential enemy's multi-layered BMD system. This suggests the importance of China also improving the penetration capability of its SLBMs.

In a second step, after initial deployment, China should continue to improve the quietness of SSBNs so that the SSBNs can survive in deep water. If this is accomplished, the SSBNs can select advantageous launch positions based on the deployment status of the adversary's BMD system. This development would be effective if two conditions are met: the SSBNs were quiet enough; and there were gaps in the adversary's BMD coverage. If these conditions are met, then the penetration capability of the SLBMs would be less important. But these conditions depend on technical developments in both China and the United States and may not always be assured. For that reason, it would also be prudent for China to enhance the penetration capabilities of its missiles. Since China has experience in developing penetration aids while developing its land-based ICBMs, it could apply this experience to SLBMs.

From the American perspective, an effective ASW capability can improve the efficiency of its BMD. If the United States could be confident enough to contain China's SSBNs in the first island chain, then the Unites States need only to deploy BMD systems against threats from this direction. On the contrary, if China's SSBNs can patrol more widely, then the Unites States would have to deploy BMD assets to cover all directions.[14]

Until now, China has tried to achieve the first step, which is to enable its SSBNs to be survivable in shallow waters (less than 200 m). This article focuses on technical evaluation of the survivability of China's SSBNs in shallow waters, and on the BMD threat faced by SLBMs launched from China's coastal waters. The analysis is based on publicly available information.

Only the acoustic detection of submarines is considered. The detection range of Chinese SSBNs in shallow water can be calculated through a passive sonar equation using oceanographic data and ambient noise levels within China's coastal waters. SM-3 interceptors are considered to be the main threat to Chinese SLBMs. SM-3 Block IA/B cannot intercept long-range missile and are not considered here.

This article focuses on the intercept capabilities of SM-3 Block IIA, and its possible upgrade version against China's SLBMs during ascent and descent phases. This article also discusses next-generation sea-based BMD systems and their implications on Sino–U.S. strategic relations.

There are three primary indicators of the effectiveness of the BMD system. The first is the defended "footprint,"—whether the interceptor/kill vehicle (KV) can reach a position/velocity "basket" small enough to begin the endgame engagement.[15] The key elements of this indicator include: the trajectory of the attacking missile; the warning time available; the launch point of the interceptor; and the burnout velocity of the interceptor. A perfect endgame is assumed—that the interceptor/KV will intersect the attacking missile once it reaches the "basket."

The second indicator is the intercept probability, or the probability of the KV actually hitting the target. The key factors of this indicator include: the discrimination capability of warheads from decoys; the accuracy of the KV sensor; the maximum acceleration of the KV; and the KV's agility.

The third indicator is the relative size of the defense versus the offense.[16] If the defense is saturated or exhausted, the offense would leak through it with certainty. In this article it is assumed that the defense has an unlimited number of interceptors.

Only the first indicator (footprint) is considered here and is the main focus of the discussion of the security implications of BMD.[17] This is because the determinant factors of "footprint" are more obvious and the resulting security implications certain. The two sides can easily agree on the "footprint" given the engagement geometry and the characteristics of the interceptor missile. Comparatively, it is very difficult to assess the intercept probability in the presence of decoys. Many important specifications are classified and people have drawn different conclusions about the effectiveness of the system. So in reality, given the inherent uncertainties, policymakers are likely to make worst-case assumptions.

The scenarios discussed here represent a worst-case scenario for the Chinese military. It is assumed that American ASW forces and BMD systems will do everything that they are designed to do. In fact, there are many factors that can downgrade ASW and BMD efficiency. First, because of the uncertainties of the underwater environment, it is difficult for U.S. attack submarines (SSNs) to establish and maintain continuous covert trailing of Chinese SSBNs. Second, SSBNs can evade trailing through a number of operational countermeasures. Third, missile defense interceptors may be unable to discriminate real warheads from decoys, so the offense can penetrate BMD by deploying decoys.

A nuclear war between China and the United States is highly unlikely. With a long-standing nuclear taboo, even if China's nuclear force is vulnerable, this does not mean the United States will launch a first strike against China. During the Cold War, nuclear states did not use nuclear weapons even in situations where there was no fear of nuclear retaliation.[18] Accordingly, the Obama administration's 2010 Nuclear Posture Review Report downplays the role of strategic deterrence, and points out nuclear terrorism and nuclear proliferation as the main threats to U.S. security.[19] But this does not mean that strategic stability does not make sense. China will fear that if the United States believes it has a significant strategic advantage, it may use this to give it coercive leverage during a crisis.[20] Also, during crises, an unstable deterrent structure may cause miscalculations and misinterpretations, or even inadvertent escalation.

ASW-SSBN

Type 094/Jin-class

In October 2007, a close-up photo of the Type 094 began to spread on the Internet (Figure 2), the source of which remains unknown.[21] This picture shows that the submarine has twelve missile tubes. A large missile compartment "hump" at the rear of the sail and the flood openings below the missile hatches are both visible and would contribute to increased noise. On several occasions, commercial satellites captured images of the Type 094 submarine.[22] The Pentagon report on Chinese military power released in 2009 predicted that China will eventually deploy five Type 094s.[23]

Figure 2: Photo of Type 094. This image is widely distributed on the Internet.

Noise Level of Type 094

There are several estimates of the quietness of Type 094. Type 094 is believed to be derived from Type 093 technology.[24] The quietness of the latter was believed to be comparable to Russian Victor III SSN according to an Office of Naval Intelligence (ONI) report released in 1997.[25] Thus, Type 094 was considered to be as quiet as Victor III. But in 2009, ONI released a new report with a chart comparing submarine quietness that showed the Type 094 to be noisier than Delta III SSBNs and Victor III SSNs (see Figure 3).[26]

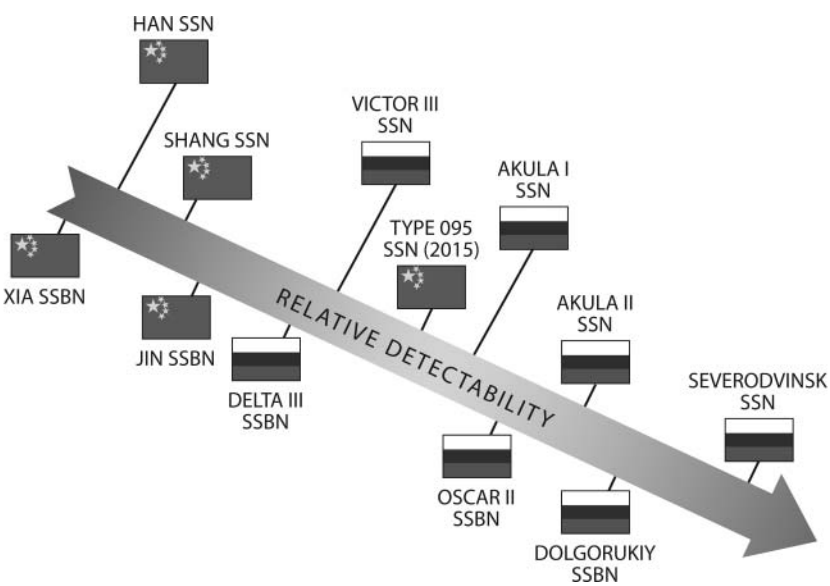

Figure 3: Comparison of quietness of submarines. Source: U.S. Office of Naval Intelligence, 2009.

Table 1: Noise level estimation. Source: Office of Naval Intelligence, 2009.

Submarine	Noise level at low frequency (dB re 1 μPa)
Delta III	125–130
Type 094 (Jin)	140
Type 093 (Shang)	145
Type 091 (Han)	155
Type 092 (Xia)	160

The actual noise level number of Type 094 is highly classified. The estimate of noise level used in this analysis of Type 094 at low frequency (100 Hz) is based on the 2009 ONI report (Figure 3). It is reported that the Type 092 (Xia) SSBN is very noisy so it can be assumed that the noise level of Type 092 is 160 dB.[27] According to Eugene Miasnikov, the noise level of Russian Delta III SSBN is 125-130 dB.[28] Thus, noise levels of other submarines can be derived according to their relative positions depicted in the ONI report. The results are shown in Table 1.

There are three possible operational patterns for Type 094: bastion strategy, coastal patrol, and open sea patrol.[29] In a bastion strategy SSBNs patrol in heavily defended waters. Typically, the patrol area will be partially enclosed by a friendly shoreline and defended by naval and air forces. The Barents Sea was a bastion for the Soviet/Russia Northern Fleet and the Sea of Okhotsk for the Pacific Fleet.[30] For China, most analysts point to the Bohai Gulf/Yellow Sea as candidate bastions (see Figure 4).[31] Coastal patrol can be seen as an expanded bastion strategy.[32] In this analysis, coastal water refers to the continental shelf region, shallower than 200 m. Open sea patrol would be possible if the Chinese Navy is confident in the survivability of the SSBNs, even without the protection of friendly forces.

The difference between bastion/coastal patrol and open sea patrol is the depth of the water. Acoustic detection of a submarine in shallow water is more difficult than in deep water because, first, in deep water, sound waves propagate through refraction in the deep channel, while in shallow water they propagate through reflection against the sea surface and floor. The transmission loss of reflection is much greater than that of refraction. Second, passive SONAR array gain in shallow water is much less than that in deep water because the coherence of sound waves is greatly reduced in shallow water.[33]

Given the noisiness of Type 094, it is very likely that China would undertake a combination of bastion and coastal patrol strategy. In addition, China doesn't have experience in running an SSBN fleet in the open oceans. Evaluating the effectiveness of this strategy requires a clear understanding of Chinese coastal waters.

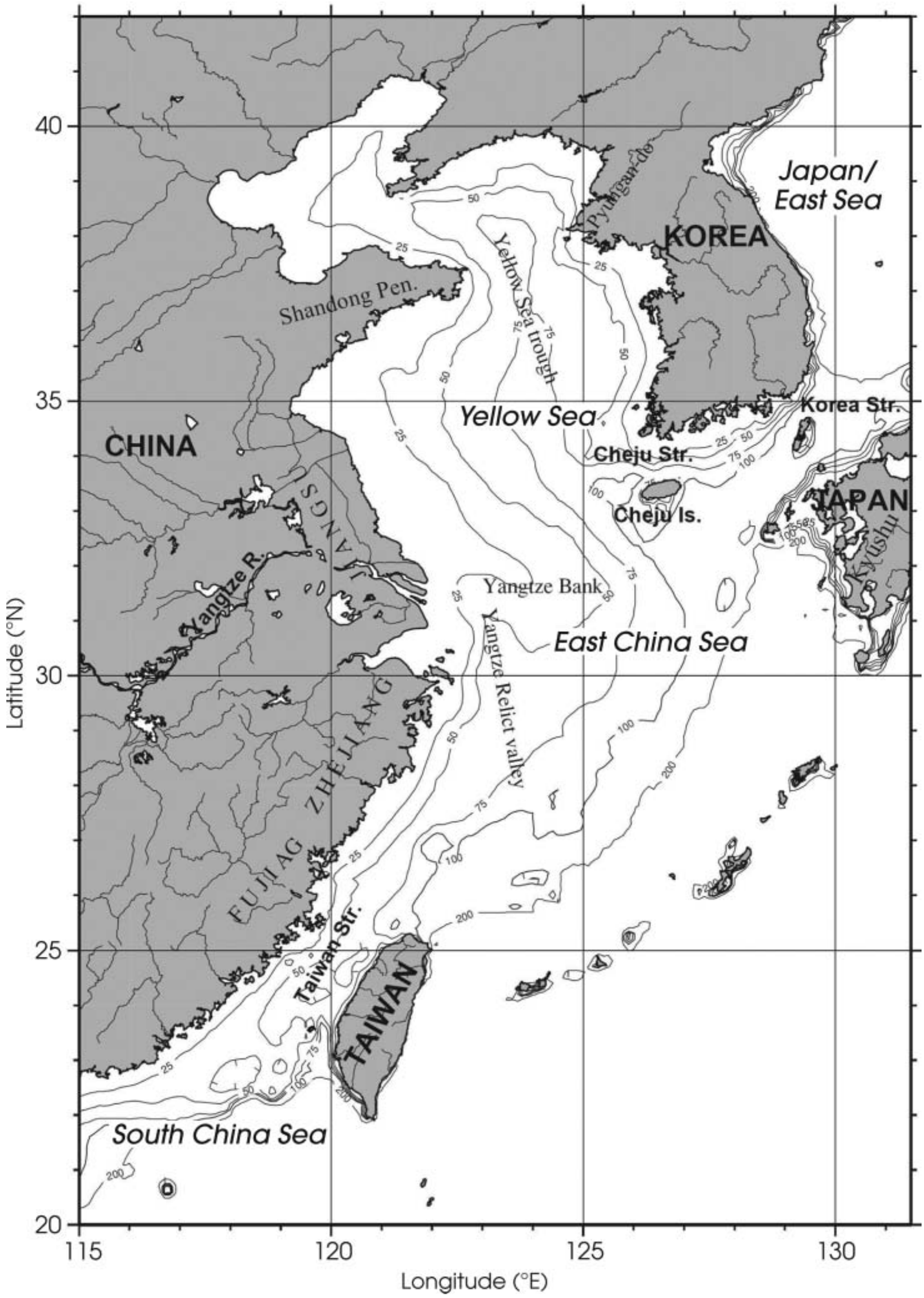

Figure 4: The Bohai Gulf, East China Sea, and Yellow Sea. Source: Park and Chu, 2006.

CHINA COASTAL WATERS

China's coastal waters include the South China Sea, East China Sea, Yellow Sea, and the Bohai Gulf (see Figure 4 and Figure 5).[34] The Bohai Gulf is China's internal sea and the easiest to protect, but it is very shallow with a maximum depth of 86 m and a mean depth of 18 m.[35] Some analysts argue that the Bohai Gulf is too shallow to host SSBNs. The Yellow Sea is a likelier bastion for SSBNs.

China's North Sea Fleet headquarters are located in Qingdao, on the coast of the Yellow Sea. The Jianggezhuang Naval Submarine Base near Qingdao is the home port for North Sea Fleet submarines.[36] The maximum depth of the Yellow Sea is 140 m, and the mean depth is 46 m. The Yellow Sea consists of the southern Yellow Sea and the northern Yellow Sea. The entire area of the

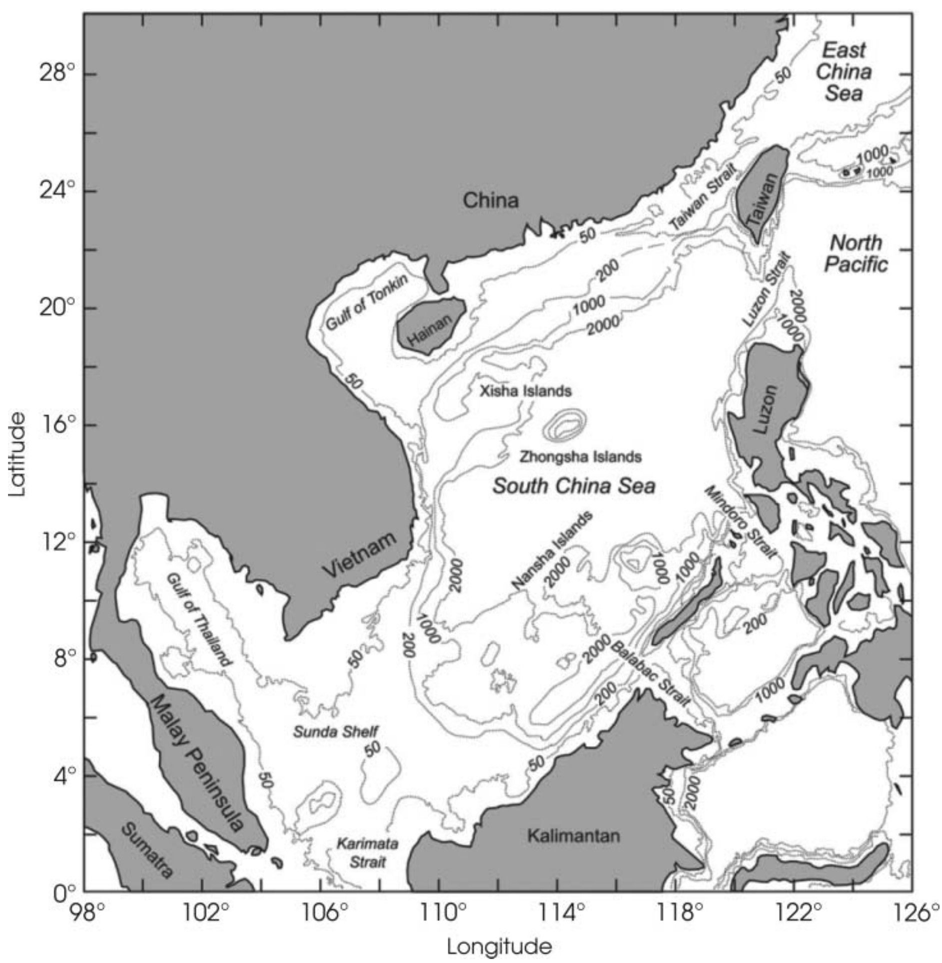

Figure 5: The South China Sea. Source: Beardsley et al., 2004.

northern Yellow Sea is about 80,000 km^2, while the entire area of the southern Yellow Sea is about 300,000 km^2.[37]

The East China Sea is located to the south of the Yellow Sea and to the north of Taiwan. Most of the East China Sea is shelf region, shallower than 200 m. Located to the east of the 200 m isobath is the Okinawa Trough, which reaches a depth of 2700 m. The East China Sea covers about 770,000 km^2.[38] The South China Sea is the largest and deepest marginal sea of the Pacific Ocean, which consists of a central deep basin, continental shelf in the north and west and the continental slope. The entire area of the South China Sea is about 3,500,000 km^2.[39] Reportedly, China is constructing a major underground nuclear submarine facility at the Yulin Naval Base in Sanya, off the southern coast of Hainan Island, facing the South China Sea.[40]

According to aforementioned operational patterns of Chinese SSBNs, the patrol area of Type 094s includes the Bohai Gulf, the Yellow Sea, most of the East China Sea and the north continental shelf region of the South China Sea. The ONI 2009 report says that China has three SSBNs, one of which is affiliated with the South Sea Fleet, and the other two affiliated with the North Sea Fleet.[41] It is well known that China has only one old Type 092 SSBN, so it can be concluded that at present China has two Type 094s, one in the North Sea Fleet (based in Jianggezhuang), the other in the South Sea Fleet (based at the Yulin base).[42]

An underwater sound propagation model is typically calculated with data on ambient noise, sea floor characteristics, wind, sound speed profile, etc. Wind has very little effect on the low frequency (100 Hz) sound propagation considered here. The Marsh-Schulkin model used in this article assumes a fixed sound speed gradient; however, one needs to know the depth of mixed layer.

The mixed layer depth of the South China Sea is 30–80 m, the mixed layer depth of the East China Sea is 5–50 m.[43] In this estimate model the layer depth is set to 40 m. The South China Sea has a mud bottom near the Yulin submarine base, and the majority of the Bohai Gulf and Yellow Sea also have mud bases. Therefore in the model the "bottom" is set to mud.[44] The only ambient noise data for China's coastal waters in the public domain are the 2001 ASIAEX (Asian Sea International Acoustics Experiment) conducted in the shelf region of the northern South China Sea in May 2001.[45] The ambient noise at 100 Hz has a mean of 83 dB, with a standard deviation (σ) of 4.4 dB. Based on these data the "ambient noise" is set to 70 dB–96 dB (mean $\pm 3\sigma$). From these data a simple underwater sound propagation model can be constructed.

DETECTION RANGE OF TYPE 094 IN SHALLOW WATER

There are two methods for submarine detection: narrow band detection (if discrete spectrum predominates), and broad band detection (if continuous spectrum predominates).

In his first article, Miasnikov used narrow band filters, but he later turned to broad band detection explaining that nuclear submarines constructed in the 1980s and later do not have discrete spectrum at frequencies greater than 100 Hz, while in shallow waters (the condition discussed in the second article) the optimal frequency for acoustic detection lies in the 100–5000 Hz band.[46] As discussed previously, Type 094 is noisy, so it is reasonable to conclude that its technology is not as advanced as the designs of the Soviet Union in the 1980s (for example, Delta III) and the noise generated by Type 094 contains discrete spectrum in the 100 Hz band. Therefore, narrow band detection is used here and the central frequency of the filters is assumed to be 100 Hz.

The passive sonar equation is:

$$\mathrm{SL} + \mathrm{AG} - \mathrm{TL} - \mathrm{NL} = \mathrm{DT}$$

Where:

SL—source level/noise level of the target submarine, referred to a distance of 1 m in the direction of the receiver, and referred to a 1 μP plane wave in a 1 Hz band.

AG—array gain. The maximum array gain in shallow water is 10 dB for low frequency.[47]

NL—ambient noise level, also referred to a 1 μP plane wave in a 1 Hz band.

DT—detection threshold.

TL—transmission loss, calculated with the Marsh-Schulkin model.[48]

$$TL = \begin{cases} 20\log \mathrm{r} + \alpha \mathrm{r} + 60 - \mathrm{k_L} & \mathrm{r} < \mathrm{H} \\ 15\log \mathrm{r} + \alpha \mathrm{r} + \alpha_\mathrm{T}\left(\frac{\mathrm{r}}{\mathrm{H}} - 1\right) + 5\log \mathrm{H} + 60 - \mathrm{k_L} & \mathrm{H} \le \mathrm{r} \le 8\mathrm{H} \\ 10\log \mathrm{r} + \alpha \mathrm{r} + \alpha_\mathrm{T}\left(\frac{\mathrm{r}}{\mathrm{H}} - 1\right) + 10\log \mathrm{H} + 64.5 - \mathrm{k_L} & \mathrm{r} > 8\mathrm{H} \end{cases}$$

Where H is the skip distance, $\mathrm{H} = \sqrt{\frac{\mathrm{D+L}}{3}}$; D is the water depth, D = 100 m; L is mixed layer depth, L = 40 m; α is absorption coefficient; $\mathrm{k_L}$ is near-field anomaly; α_T is shallow water attenuation coefficient. The results are shown in Figure 6.

The detection index d = 16 is considered, which corresponds to a detection probability $\mathrm{P_d} = 60$ percent and false-alarm probability $\mathrm{P_{fa}} = 1 \times 10^{-4}$.[49] The bandwidth w is equal to 0.1 Hz, the observation time t = 400 s.[50] It is assumed that the signal is completely unknown, and the detection threshold (DT) is then determined by the following formula:[51]

$$\mathrm{DT} = 5\log\frac{\mathrm{dw}}{\mathrm{t}} = 12\ \mathrm{dB}$$

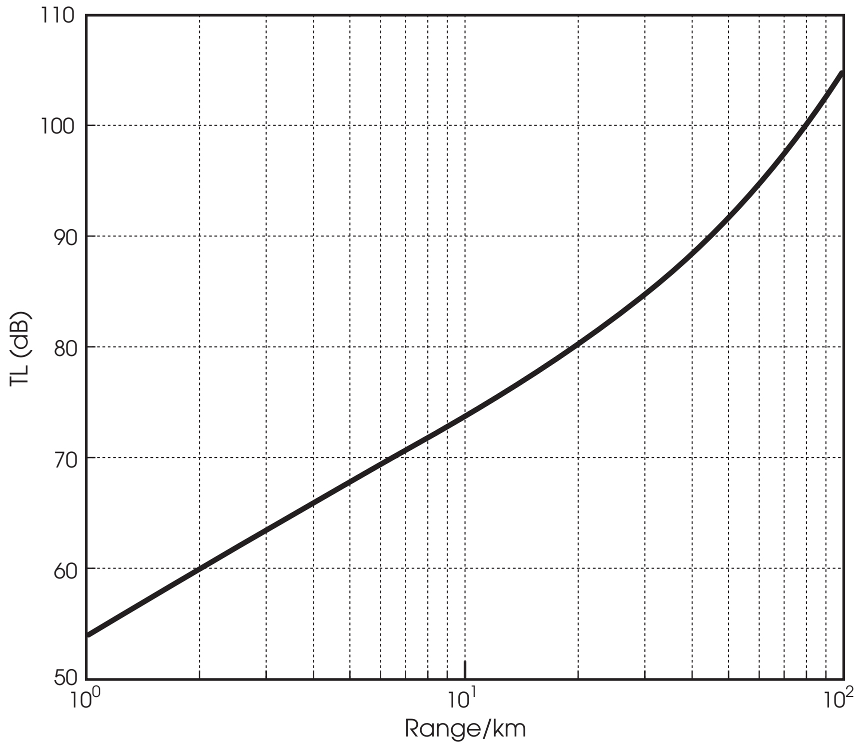

Figure 6: Transmission losses in Chinese coastal waters.

The estimated detection range of submarines in China's coastal waters is shown in Table 2.

The question naturally arises: at what minimum detection range can an SSN conduct protracted covert trailing without risking a collision with the trailed SSBN? Miasnikov set the threshold as 10 km.[52] Table 2 shows that at the current noise levels China cannot guarantee the survivability of its SSBNs.

It should be noted that considering the U.S. BMD capability, which will be discussed in the next section, U.S. SSNs do not necessarily need to trail Chinese SSBNs continuously. For the purpose of cueing the sea-based BMD assets

Table 2: Detection range of Type 094 in shallow waters.

SL (dB)	AG (dB)	DT (dB)	NL (dB)	TL (dB)	R (km)
140	10	−12	70	92	49.8
			96	66	4.1
130	10	−12	70	82	23.7
			96	56	1.3
120	10	−12	70	72	8.2
			96	46	0.4

to intercept SLBMs during boost- or ascent-phase, U.S. SSNs only need to know the rough operational area. In this case, Chinese SSBNs are survivable, but its sea-based nuclear retaliatory forces would still remain vulnerable.[53]

BMD-SLBM

JL-2 and SM-3

The Chinese new-generation SLBM JL-2 will be deployed on the Type 094 submarine. The first test fire of JL-2 occurred in August 2002.[54] Previously, the U.S. military assessed that it will achieve initial operational capability (IOC) sometime between 2009–2010,[55] but the latest assessment shows that the development of JL-2 "appears to have encountered difficulty."[56] It is reported that the range of JL-2 is 7,200 km.[57] Because of the range limitation, JL-2, launched from Chinese coastal waters cannot reach the continental United States (as shown in Figure 7).

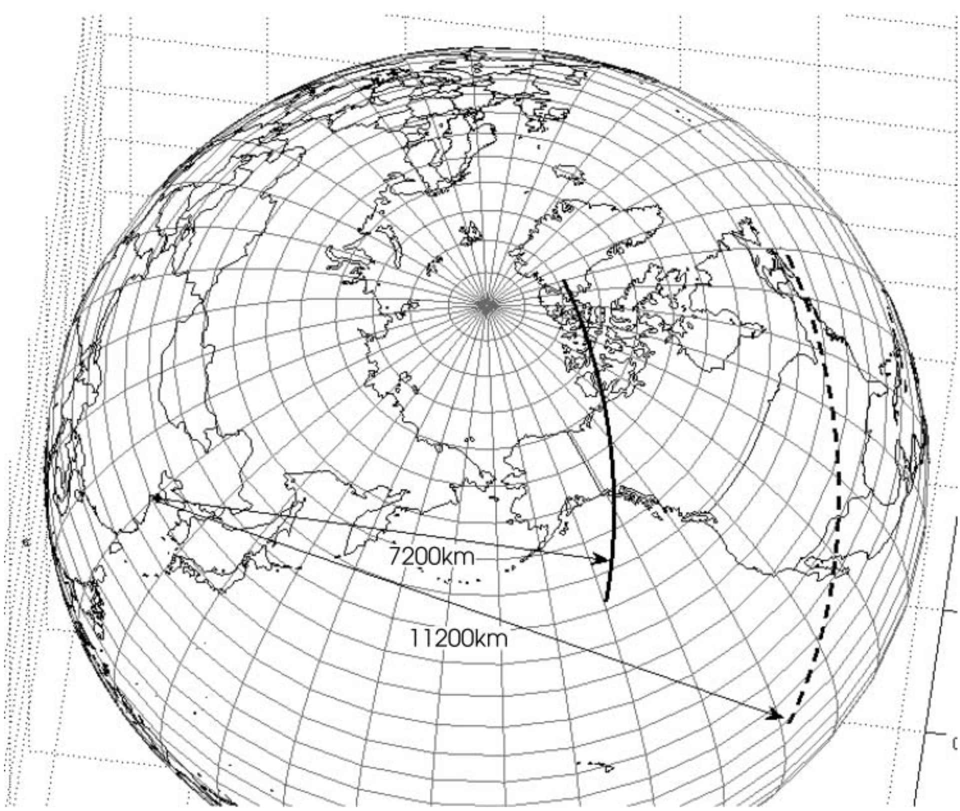

Figure 7: JL-2 coverage.

It is well known that the JL-2 is derived from the land-based DF-31, and the DF-31 has a longer-range version, DF-31A, which has a range of 11,200 km.[58] So this analysis assumes that China can also upgrade JL-2 to a longer-range version (JL-2A?). For simplicity, the maximum range of JL-2 is assumed to be 11,200 km.

The Obama administration's phased adaptive approach calls for an aggressive effort to modernize the SM-3 interceptors over time.[59] The currently deployed version, SM-3 Block IA, has a burnout velocity of 3.0–3.5 km/s.[60] The next version is the SM-3 Block IB, which has the same burnout velocity as SM-3 Block IA, but carries an advanced KV. SM-3 Block IA and IB cannot intercept long-range missiles, so they are not considered here. The burnout velocity of SM-3 Block IIA is reported to be 4.5 km/s,[61] but other sources report that SM-3 Block IIA can reach a higher burnout velocity.[62]

Calculations show that a 21-inch interceptor can reach 5.5 km/s burnout velocity using more energetic propellants and lighter cases. Land-based SM-3 Block IIB, with a new liquid upper stage, can reach higher burnout velocity than Block IIA but the specific number remains unknown.[63] The burnout velocity of the first-generation SM-3 Block IIA is assumed to be 4.5 km/s, and land-based Block IIB and possible "advanced" ship-based Block IIA are considered to be 5.5 km/s.

SSBNS IN CHINESE COASTAL WATERS

This section discusses the engagement of SM-3 and Chinese SLBMs. As concluded in the previous section, currently, China's SSBNs can only patrol along Chinese coastal waters. The launch points of China's SLBMs are assumed to be in the Bohai Gulf, Yellow Sea, and South China Sea. SM-3 interceptors are launched from forward-deployed Aegis ships, which can be cued by ASW assets and deployed near the SSBNs patrol area. These interceptors attempt to intercept the missile after burnout when the warhead is ascending. Aegis ships can also be deployed off the U.S. coast, where they attempt to intercept the warhead as it descends but is still above the atmosphere. Deployment positions are shown in Figure 8. Figure 9 shows the engagement of JL-2 by SM-3. Once SLBMs are launched, they will be detected by Aegis radars or by other early warning assets. Interceptors are launched five seconds after initial detection.[64] For comparison, engagement of Chinese ICBMs launched from Taiyuan Base by SM-3s is also calculated (see Table 3).[65]

It can be concluded from Table 3 that the SM-3 Block IIA is definitely a strategic missile defense system. "Advanced" SM-3 Block IIAs from one launch point—say, Hokkaido—could engage all the SLBMs launched from China's coastal waters that target the continental United States. One "first-generation" SM-3 Block IIA system deployed in the same location could engage almost all

Figure 8: Deployment positions.
◇ Shows U.S. Aegis missile interceptors.
△ Shows possible Chinese ICBM and SLBM launch points.

the Chinese SLBMs launched from China's coastal waters except some trajectories launched from the Bohai Gulf. As mentioned previously, the Bohai Gulf is not a good patrol area for SSBNs so the inability to intercept missiles launched from Bohai is not significant.

SM-3 Block IIA deployed off Alaska's coast can supplement Ground-based Interceptors (GBIs) deployed in Alaska and California. One "advanced" SM-3 Block IIA system or two "first-generation" SM-3 Block IIA systems could in principle cover the entire United States.

The "first-generation" SM-3 system doesn't have ascent-phase intercept capability against Chinese ICBMs launched from inland China, but the "advanced" SM-3 Block IIA can engage China's ICBMs in ascent phase.

Combined with GBIs, the United States could in principle construct a multi-layered missile defense system against Chinese ICBMs and SLBMs launched from Chinese coastal waters. Such a system would include SM-3s deployed near the Chinese coast; GBIs deployed in Alaska and California; and SM-3s deployed off the U.S. coast. According to American scholars, the penetration probability of Chinese SLBMs against this layered U.S. missile defense system would remain about the same, because all three layers operate in

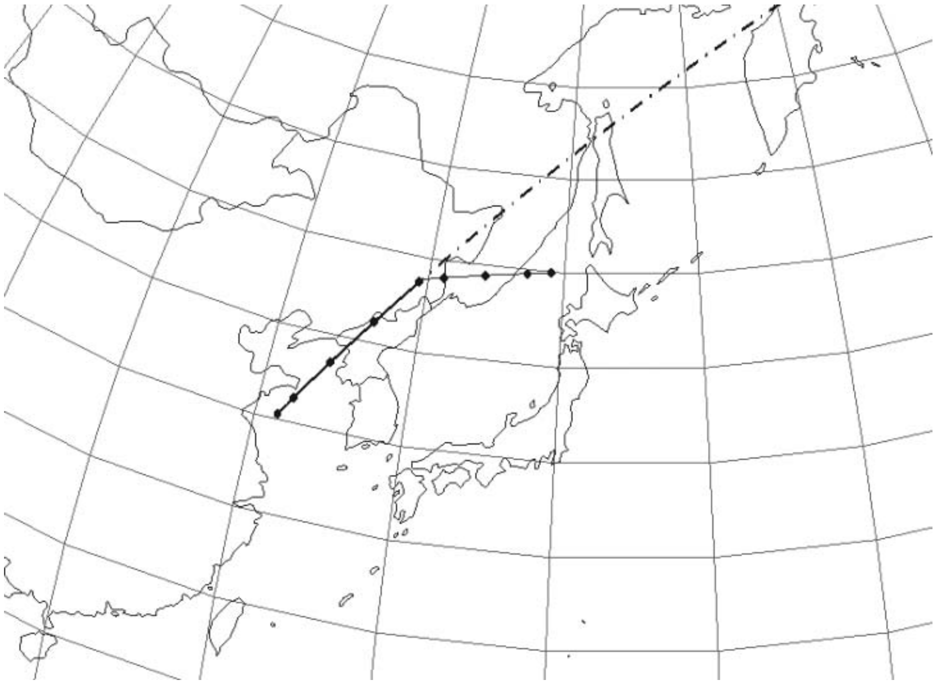

Figure 9: Engagement of JL-2 by SM-3. The interceptor is launched 33 seconds after the SLBM. The tick marks on both trajectories are at 1 minute intervals.

the same mode, so if decoys or other countermeasures could defeat one layer, they could likely defeat all the layers.[66] But the U.S. military argue that by intercepting missiles in early ascent, susceptibility of missile defense to countermeasures would be reduced.[67] From China's perspective, the worst-case assumption is that the penetration probability would be greatly reduced, and this situation may give U.S. planners some confidence in possessing a first-strike capability.

It should be noted that the United States also can deploy land-based SM-3 Block IIB, whose burnout velocity is equal to that of "advanced" SM-3 Block IIA, in Hokkaido, Japan and the continental United States. Land-based SM-3 Block IIB will have the same intercept capability as sea-based "advanced" SM-3 Block IIA, but with higher reliability.

Additionally, the United States may develop and deploy a ship-based boost-phase intercept system in the future. Twenty-one-inch interceptors are unable to conduct boost-phase intercept. The American next-generation destroyer DDG-1000 carries a 28-inch vertical launch system (MK57),[68] which may be used in future air and missile defense ships. Taking full advantage of a 28-inch launch system can produce a burnout velocity of more than 7 km/s. Given the constrained patrol area of Chinese SSBNs, there is a possibility that highly capable American interceptors could engage Chinese SLBMs

Table 3: American SM-3s versus Chinese SLBMs (√ can intercept all the trajectories; X cannot intercept; √~ can intercept part of trajectories).

SLBM/ICBM Launch point	SM-3 Launch point	Early Warning Radar	SM-3 Block IIA (Vbo = 4.5 km/s)	SM-3 Block IIA (Vbo = 5.5 km/s)	
Bohai Gulf	Hokkaido	Aegis, Korea Coast	√~	√	Ascendant phase
Yellow Sea	Hokkaido	Aegis, Korea Coast	√	√	
South China Sea	West of Taiwan	Aegis, West of Taiwan	√	√	
South China Sea	Hokkaido	FBX-T, Aomori, Japan	√	√	
Taiyuan	Hokkaido	Aegis, Korea Coast	X	√	
Bohai Gulf	Alaska Coast	Cobra Dane, Shemya	√~	√	Descendent phase
Yellow Sea	Alaska Coast	Cobra Dane, Shemya	√~	√	
South China Sea	Alaska Coast	Cobra Dane, Shemya	√	√	

during boost phase.[69] Because boost-phase interception occurs well before penetration aids are deployed, susceptibility of missile defense to countermeasures could be greatly reduced.

For both boost and ascent-phase intercepts, having ASW information on where the submarine might be located could be helpful to the defense. As mentioned in the previous section, U.S. SSNs do not necessarily need to trail Chinese SSBNs continuously; they only need to know the rough operation area.

SSBNS IN OPEN SEA

Given the importance of the quietness of submarines, China should, and will work hard to improve the quietness of its SSBNs. If in the future, Chinese SSBNs could be made quiet enough to survive in deep water, Chinese SSBNs patrolling the open seas would have significant security implications.

The current U.S. homeland missile defense system, the Ground-Based Midcourse Defense (GMD) deployed in Alaska and California is designed to counter threats from North Korea, China, and the eastern part of Russia. The only fire control radar, Sea-Based X-band Radar (SBX), is responsible for discriminating a real target from decoys. Its homeport is in Adak, Alaska and it is supplemented by relatively small X-band radar, Forward-Based X-Band Radar (FBX), deployed in Aomori, Japan.

This system may be able to counter threats from China's ICBMs and SLBMs launched from China's coastal waters. But if China's SSBNs patrol in the open sea, SLBMs could be launched from the south of the United States, and it would make this system ineffective. Because of the earth's curvature, neither SBX docked in Adak nor FBX deployed in Japan can detect SLBMs launched from south of the United States. The SBX is a mobile system, which would presumably be put out to sea in a time of crisis. However, it moves very slowly, so presumably an SSBN could still position itself and circumvent the SBX.[70] To defend the United States from Chinese missiles from the south, a global missile defense system is required.

Upgrades are required to the Aegis radar (SPY-1) in order for it to contribute to this global missile defense strategy. First, SPY-1 radar is "too small to detect and track missile warheads at ranges of thousands of kilometers."[71] If the position of the SSBN can be determined roughly by ASW forces, Aegis ships can be deployed near the suspected launch site in advance. Then SPY-1 radar can track the target missile in its early trajectory, as described in the previous section. But when Chinese SSBNs are quiet enough to patrol in the open sea, it would be difficult for U.S ASW forces to determine their positions. Secondly, SPY-1 radar works on S-band (3.1 to 3.5 GHz), so it is less capable than X-band radar in discriminating warheads from decoys.

The Air and Missile Defense Radar (AMDR) is the next-generation ship based missile defense radar, which was originally designed for the now-cancelled CG(X) cruiser. AMDR is a dual S/X-band active phased array radar (for comparison, SPY-1 is a passive phased array S-band radar). Designed for anti-air warfare and missile defense missions, the AMDR planned for CG(X) is larger and more powerful than SPY-1.[72] The U.S. Navy cancelled the CG(X) program in FY11 budget in favor of procuring stretched and modified DDG-51 Aegis destroyers (DDG-51 Flight III).[73]

The AMDR envisioned for an improved DDG-51 would be a scaled-down version of the AMDR originally envisaged for the CG(X) cruiser, and physically comparable with, but more powerful than, SPY-1.[74] It is the improved confidence of the U.S. Missile Defense Agency's Space Tracking and Surveillance Satellites (STSS) that allows the U.S. Navy to downgrade the requirements for AMDR. The U.S. Navy believes that data collected by less capable ship-based radar would be augmented by data collected by STSS, so highly sophisticated and technologically immature radar is not necessarily needed.[75] The first DDG-51 Flight III is expected to launch in 2016.[76] After deployment of AMDR, the United States can construct a mobile, re-locatable global missile defense system based on AMDR, STSS, and SM-3 Block IIA.

In summary, if China's SSBNs are quiet enough in the future to patrol in the open sea, present U.S. missile defense structure cannot engage SLBMs launched from the south of the United States. But the United States is working on a ship-based, mobile, re-locatable, and scalable global missile defense system. As such, China's SSBNs in the open sea will have to face this threat and it could raise questions about the survivability of missiles they would launch.

POLICY IMPLICATIONS

Sino–U.S. strategic competition with respect to China's sea-based nuclear forces may unfold in two phases: first, China deploys SSBNs in its coastal waters, and the United States deploys a multi-layered BMD system capable of engaging missiles launched from the coastal waters; second, China's SSBNs enter into the open sea, which will force the United States to deploy a global BMD system that can counter threats from any direction. For China to maintain credible sea-based nuclear deterrence, China's SSBNs will have to be quiet enough to evade U.S. ASW, and their SLBMs contrived to penetrate the U.S. missile defense system with high probability.

This Sino–U.S. competition is now in its first phase. According to a U.S. military report, China's Type 094s are noisy. Calculations show that China's SSBNs are not survivable even in shallow water. China is therefore working hard to improve the quietness of its SSBNs, however, even if this effort succeeds, the credibility of China's sea-based nuclear deterrence may still be questionable. This is because the United States and Japan are jointly developing SM-3 Block IIAs, aimed for deployment in 2018, which appear capable of engaging SLBMs launched from China's coastal waters during the ascent phase.

In a second phase of Sino–U.S. competition, China will seek to improve the quietness of Type 094s, to allow the submarines to patrol in the open sea, while at the same time, the United States will be seeking a global missile defense.

The prospect of this competition is uncertain. The prospects are high that the offensive side can decrease the intercept probability greatly by deploying advanced penetration aids. The problem is that, with respect to intercept probability, there may be great differences between evaluations done by different people, unlike the case with the detection range of SSBNs and the "footprint" of BMD. The two sides may not be able to reach the same conclusion on the penetration probability in the absence of an actual nuclear exchange. Such uncertainties may lead to misunderstandings or overreaction by both sides. U.S. policymakers may be led to make bold and dangerous decisions based on an illusory first strike capability. Chinese leaders might overreact through worst-case assumptions regarding the survivability of its nuclear retaliatory capability, for example, by greatly increasing the number of their missiles.

The key policy-related question of this technical race is: will or should the United States accept that China maintain a credible nuclear deterrent? Or, in other words, will or should the United States accept mutual but unequal vulnerability with China? To this question, there are two points of view among U.S. experts.[77]

The first is that mutual vulnerability with China is unacceptable and avoidable. The United States can and should exploit its commanding technical lead over China to neutralize China's nuclear deterrent capability.[78] "Washington should also make clear that it will not accept a mutual vulnerability relationship with China."[79] The second is that "mutual vulnerability is a fact, not a choice,"[80] and the United States should "acknowledge mutual vulnerability as a fact of life."[81] Until now, a formal and clear U.S. policy about China's nuclear deterrence has yet to be declared.[82] This gives the U.S. military an opportunity to go as far as possible to develop capabilities and doctrines in both BMD and ASW fields, trying to neutralize China's nuclear capability.

President Obama's new missile defense plan blurs the distinction between theater and strategic missile defense. According to the 2010 Ballistic Missile Defense Review Report, the United States will develop regional missile defense capabilities pursuing a Phased Adaptive Approach. The Aegis ship or its future upgrade version is one of the key pillars of this global missile defense system. This approach provides huge upgrade potential both qualitatively and quantitatively.[83] On the one hand, the MK41 vertical launch system of the Aegis BMD ship is a standard component widely deployed on U.S. and allied ships, so it is very easy for the United States to expand the inventory of SM-3

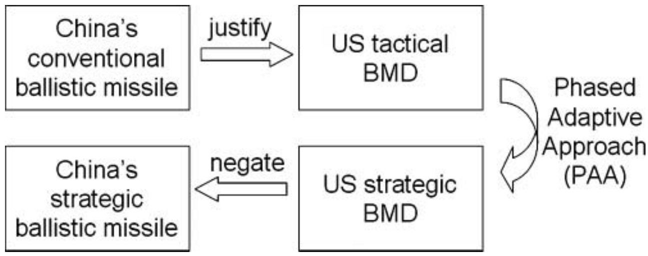

Figure 10: Blurring the distinction.

interceptors. On the other hand, the United States can improve the intercept capability of SM-3 by taking full advantage of the 21-inch launch tube. Eventually, the United States may be able to achieve a mobile, re-locatable, scalable, ICBM-intercepting ship-based BMD system of substantial effectiveness.

Under this developing approach, the U.S. BMD looks like a wolf in sheep's clothing. In the U.S. Ballistic Missile Defense Review Report, the United States justified its BMD system citing the threats of China's conventional short-, medium-, and intermediate-range ballistic missiles. But this "tactical" BMD system could be gradually upgraded to a "strategic" one, able to engage China's ICBMs and SLBMs (as shown in Figure 10). So the United States can develop a strategic BMD system in the name of a tactical one.

Another element that may induce instability is ASW. Because the Type 094s have not yet entered into service, the specific strategy of the United States to counter China's SSBNs remains unknown. But the aggressiveness of the future strategy can be derived from present marine activities of the United States. In March 2009, intelligence gathering activities of the U.S. ocean surveillance ship USNS Impeccable (T-AGOS 23) in the South China Sea resulted in a serious confrontation between China and the United States.[84] The Impeccable was specially designed to deploy a surveillance towed-array sensor system.[85] Analysts believed that the purpose of Impeccable was to track and determine the detection range of Chinese nuclear submarines deployed at the Yulin base, and to map the navigational channels emanating from Yulin.[86] United States officials said the U.S. Navy will continue to operate in the South China Sea.[87]

During the Cold War, the United States pursued very aggressive ASW strategies against Soviet SSBNs. After deployment of Delta-class SSBNs, the longer ranges of SLBMs allowed SSBNs to patrol in the marginal ice seas of the Soviet Arctic littoral and later, under the permanent ice of the Arctic Ocean. Deployed close to home, SSBNs could be protected by the rest of the Soviet Navy. The reciprocal strategy adopted by the United States is to surge U.S. SSNs into Soviet SSBNs patrol area, searching and attacking Soviet SSBNs, holding Soviet SSBNs at risk.[88] In times of peace, this strategy could increase the probability of a submarine clash, with unpredictable results. During wartime, such a strategy could result in an inadvertent nuclear war.[89]

China faces a similar geographic situation to that faced by the Soviet Union. China's SSBNs have to pass through the so-called first island chain in order to enter into open sea. The situation between China and the United States after the Type 094s/JL-2s entered into service is similar to the U.S.–Soviet situation after the Delta-class deployment. But current China–U.S. strategic relations are definitely different from Soviet–U.S. relations during the Cold War. First, China doesn't possess the same size conventional force as the Soviet Union had during the Cold War, so generally the United States does not need to rely on nuclear weapons to balance China's conventional forces. Second, the Soviet SSBN fleet was much larger than that of China. During the Cold War, it was well recognized that the United States could not simultaneously destroy all of the Soviet SSBNs.[90] The maximum estimate of the total number of China Type 094s is six, keeping two boats at sea at any given time.[91] So China's SSBNs are more vulnerable than those of the Soviet Union. China leaders will face a much harder "use it or lose it" choice during a crisis. The situation is more dangerous than during the Cold War. Third, the strategic objective of China is different from that of the Soviet Union. The Soviet Union's strategic objective was parity, or in other words, mutual and equal vulnerability, while China's strategic objective is mutual but asymmetric vulnerability.

CONCLUSION

China's Type 094 SSBN is one important step toward building a credible minimum deterrence. However, according to a report released by the U.S. Navy, the Type 094 is noisy. If this information is correct, then presently China cannot be confident as to the survivability of its SSBNs. China should improve the quietness of the Type 094, so that in the near future it will be quiet enough to survive in China's coastal waters.

After the deployment of SM-3 Block IIA in 2018, Chinese ICBMs and SLBMs launched from Chinese coastal waters would face a three-layer intercept: SM-3s deployed near Chinese coast; GBIs deployed in Alaska and California; and SM-3s deployed off the U.S. coast. In these circumstances, the credibility of China's sea-based nuclear deterrence will be questionable.

China could increase the range of the JL-2 so that it can reach the continental United States launching from Chinese coastal waters. At the same time, China could work hard to reduce the noise level of its SSBNs, so that they can patrol in the open sea in the future, which would allow it to launch SLBMs from the south of the United States to circumvent the present U.S. missile defense system. But the U.S. next-generation ship-based missile defense system, which is under development, plans to deploy high-performance AMDR radar, augmented by the Space Tracking and Surveillance Satellites system, and SM-3 interceptors or their upgrades. Thereby, the United States would be able to build a global BMD system based on these ship- and space-based assets. China will at the same time, put additional effort into penetration aids to increase the penetration probability. The prospect of this technical race will remain uncertain.

For the United States, demarcation between theater and strategic missile defense should be maintained. The scale and performance of the ship-based mobile BMD system should be strictly limited, making China and Russia confident of their nuclear retaliatory capability. In addition, the United States should end its provocative surveillance activities in Chinese coastal waters and not challenge the survivability of China's SSBNs.

The original purpose behind China's pursuit of sea-based nuclear capability is the improvement of strategic stability. But because of U.S. activities to negate this effort, this process induces uncertainty and instability. China and the United States should work together to eliminate the instability of this process.

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64. This a strong assumption for ascent-phase intercepts. SM-3 is launched during the early phase of JL-2's powered flight. That means the defensive side does not know the exact target of the offensive missile, so several SM-3s have to be launched to cover different targets. This is the worst-case scenario from China's perspective. A

conservative assumption is that SM-3 is launched in the end phase of JL-2's powered flight, i.e., 130 s. Under this conservative assumption, SM-3's ascent-phase intercept capability against China's ICBMs remains unchanged, while the ascent-phase capability against China's SLBMs decreases. The "first-generation" SM-3 Block IIA has very limited intercept capability against SLBMs launched from the Bohai Gulf; it can cover southwest America against SLBMs from the Yellow Sea; and it can engage all SLBMs from the South China Sea. The "advanced" SM-3 Block IIA can engage almost all the SLBMs from the Yellow Sea and South China Sea; against SLBMs from the Bohai Gulf, it can cover the southwestern United States. It can be seen that even under the conservative assumption that SM-3 is still a serious threat to China's strategic missiles.

65. The coordinates of Taiyuan Base can be found at GlobalSecurity.org, "Base 25 Taiyuan Space Facility," http://www.globalsecurity.org/space/world/china/taiyuan.htm (accessed April 2011).

66. The author thanks Dr. David Wright for pointing this out.

67. Statement of Lieutenant General Ronald T. Kadish, U.S.A.F., Director, Ballistic Missile Defense Organization, on "The Ballistic Missile Defense Program, Amended Fiscal Year 2002 Budget," before the Senate Armed Services Committee (12 July 2001), 24. Dr. David Wright argues that it is unlikely that ascent phase intercepts can be made early enough to avoid the difficulty of countermeasures discrimination. Personal communication with David Wright.

68. Raytheon, BAE Systems, "MK 57 Vertical Launching System: Zumwalt Class Destroyer Program," Raytheon/BAE systems, http://www.raytheon.com/businesses/rtnwcm/groups/public/documents/content/rtn_bus_ids_prod_mk57_pdf.pdf (accessed April 2011).

69. Richard D. Fisher, Jr., "The Impact of Foreign Technology on China's Submarine Force and Operations," in Andrew S. Erickson et al., *China's Future Nuclear Submarine Force, op. cit.*, 134–61. Han Binnendijk, George Stewart, "Toward Missile Defense from the Sea," in Alexander T. J. Lennon ed., *Contemporary Nuclear Debates: Missile Defense, Arms Control, and Arms Races in the Twenty-first Century* (Washington D.C.: MIT Press, 2002), 56.

70. According to a Union of Concerned Scientists report, the moving speed of SBX is 6 km/h. Union of Concerned Scientists, "Technical Realities: An Analysis of the 2004 Deployment of a U.S. National Missile Defense System," (May 2004), 65. Others have said the speed is 8 knots (about 15 km/h). Missile Defense Agency History Office, "A Brief History of the Sea-Based X-Band Radar-1," (1 May 2008), 4.

71. Union of Concerned Scientists, *op. cit.*, 70–74.

72. "The power requirement of the CG(X) combat system, including the new radar, could be about 30 or 31 megawatts, compared with about 5 megawatts for the Aegis combat system." Spoken testimony of Navy officials to the Seapower and Expeditionary Forces Subcommittee of the House Armed Services Committee (1 March 2007), as quoted in Ronald O'Rourke, "Navy CG(X) Cruiser Program: Background, Oversight Issues, and Options for Congress," CRS Report RL34179 (21 October 2009), 5.

73. Statement of Ronald O'Rourke, Specialist in Naval Affairs, Congressional Research Service, Before the House Armed Services Committee Subcommittee on Seapower and Expeditionary Forces Hearing on Navy Force Structure and Capabilities, (20 January 2010), 16–20.

74. AMDR has a 14 ft (4.27 m) aperture. Each of the four radar faces of SPY-1 radar is a 3.65 m $\times$ 3.85 m octagon. Christopher P. Cavas, "Interview: U.S. Navy Undersecretary Robert Work," *Defense News* (4 February 2010), http://www.defensenews.com/story.php?i=4486791 (accessed April 2011). Union of Concerned Scientists, *op. cit.*, 71.

75. Amy Butler, "STSS Prompts Shift in CG(X) Plans," *Aerospace Daily Defense Report* (11 December 2009) 1–2, as quoted in Ronald O'Rourke, Navy CG(X) Cruiser Program: Background, Oversight Issues, and Options for Congress, *op. cit.*, 9–10.

76. Christopher P. Cavas, "Interview: U.S. Navy Undersecretary Robert Work," *op. cit.*

77. Brad Roberts, "China-U.S. Nuclear Relations: What Relationship Best Serves U.S. Interests?" Institute for Defense Analyses, IDA Document P-3640 (August, 2001), 2.

78. R. Pfaltzgraff, Jr., "China-U.S. Strategic Stability," presentation prepared for the Carnegie Endowment for International Peace, The Nuclear Order—Build or Break, Washington, D.C. (6 April 2009).

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81. Linton Brooks, "The Sino-American Nuclear Balance: Its Future and Implications," in Abraham Denmark and Nirav Patel eds., *China's Arrival: A Strategic Framework for a Global Relationship* (Washington, DC: Center for a New American Security, 2009), 60–76.

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