MINIMIZING THE LIKELIHOOD OF A CHINESE STRATEGIC NUCLEAR ARSENAL BUILDUP

WWS 591F POLICY WORKSHOP REPORT

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* Contributors provided substantive input and feedback on the report. However, the analysis and policy proposals in the report do not necessarily represent the views or opinions of each contributor.
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Workshop Overview

This report represents the culmination of five months of research evaluating the possibility that China might build up its strategic nuclear arsenal. The end goal of our research is to provide various policy options for U.S. government officials to consider to mitigate this danger, including possible reciprocal actions that the U.S. government could ask the Chinese government to take. The contributors are Masters and Doctoral candidates at Princeton University’s Woodrow Wilson School of Public and International Affairs.

In preparation for field research and interviews, the authors studied a range of relevant literature and conducted interviews with government officials, politicians, scholars, and non-governmental experts during the fall of 2012. Interviews took place in Princeton, Beijing, and Tokyo. Interviewees included senior officials in the U.S. Department of Defense, the Japanese Ministry of Defense, and the Chinese People’s Liberation Army (PLA), as well as current and former diplomatic officials from all three countries. Finally, the authors interviewed academics, non-governmental experts, and journalists from the United States, China, and Japan. Most interviewees with whom we met spoke on a non-attribution basis.

This report represents the collective judgment of the contributors. However, not all analytical claims and policy proposals reflect the views of every contributor. The contributors are solely responsible for any errors or omissions.
Executive Summary

The Obama administration has expressed a desire to maintain stable and cooperative relations with China. The administration has also made clear its goal of leading the international community in efforts to better secure all nations against the threat of nuclear weapons. That goal includes maintaining the commitment to non-acquisition by non-nuclear-weapon states as well as continuing nuclear reductions by nuclear-weapon states. While the onus of this nuclear drawdown lies today with Russia and the United States, the decisions that China makes concerning its own nuclear arsenal will impact future nuclear weapons reductions. If China breaks from its longstanding policy of seeking a small, non-alert, survivable nuclear arsenal based on single-warhead missiles, efforts to reduce U.S. and Russian Cold War nuclear arsenals on a bilateral basis could be severely undermined.

Given the mistrust between, and occasionally competing security interests of, China and the United States, we identify three main dynamics that could lead China to buildup its nuclear arsenal:

1. Destabilizing preemptive military postures. U.S. Air-Sea Battle and Chinese Anti-Access Area Denial are competing preemptive conventional military postures that risk escalating conflict to the nuclear level and raise Chinese concerns about the survivability of China’s nuclear missiles, which are under the same command-and-control structure as its conventional missile forces;

2. The potential thickening of the U.S. national ballistic missile defense beyond levels needed to defend against North Korea and Iran. High-speed Aegis-based missile interceptors currently under development are raising Chinese concerns about the future ability of China’s small strategic missile force to deter U.S. attack; and

3. The United States’ apparent unwillingness to accept the fact that China and the United States have entered a mutually effective nuclear deterrent relationship.

This report offers possible approaches that the United States and China could follow to address these dynamics. We propose:

1. that the U.S. military and the People’s Liberation Army’s 2nd Artillery Corps increase their discussions of the danger stemming from the entanglement of China’s conventional and nuclear command-and-control structures, and the danger that U.S. and Chinese preemptive military postures could spark an unintended war that could cross the nuclear threshold;

2. that the United States consider refraining from deployment of SM-3 Block IIA or IIB interceptors on U.S. Aegis ships or in North America;

3. that the United States and China expand Track 1.5 and 2 dialogues on technical issues relating to the future capabilities of the U.S. national and regional ballistic missile defense systems against China’s strategic missiles;

4. that China disclose how many intercontinental ballistic missiles (ICBMs) and submarine-launched ballistic missiles (SLBMs) it has, unilaterally cap its ICBMs and SLBMs at that level, and agree not to put multiple warheads on single missiles; and

5. that the United States declares that its current nuclear relationship with China is one of “Mutually Effective Deterrence.”
I. The Problem: China’s Possible Buildup of Its Strategic Nuclear Force

In 2009, President Obama committed to reducing America’s reliance on nuclear weapons, and offered U.S. leadership in encouraging global nuclear arms reductions. As a step toward achieving this nuclear reduction goal, the United States and Russia are reducing their strategic arsenals under the New START Treaty. Further reductions will depend in part upon whether the United States and Russia have confidence that other nations, especially China, are unlikely to increase their nuclear arsenals as the United States and Russia downsize theirs.

Developments in East Asia, however, could encourage a Chinese strategic nuclear missile buildup. The United States is currently shifting its military and political energies to the area, in part to reassure its regional allies that are worried about China’s growing assertiveness towards Taiwan and in the East and South China Seas. China is concerned that this shift challenges China’s growing influence in the region. The American rebalancing comes at a difficult time for the Communist Party of China (CPC), which faces mounting domestic problems including ethnic unrest, growing income inequality, an aging population, and widespread corruption.

Escalating competition between China and the United States increases the likelihood of a Chinese nuclear weapons buildup. To date, best estimates suggest that China only has a small nuclear weapons stockpile, with approximately 240 warheads, 40 ICBMs, and only one warhead per missile. However, this nuclear force structure could change.

This report proposes possible strategies to reduce the likelihood that China will build up its strategic nuclear arsenal. While North Korea is currently the most destabilizing regional threat, we focus on China’s nuclear role in the region, given the importance of the U.S.-Chinese security relationship, and the impact that China’s nuclear security decisions could have on future U.S.-Russian nuclear reductions.

China could change its nuclear force posture in three ways by:

(1) **Deploying more missiles.** China could build more long-range missiles capable of reaching the United States. China might do so if it perceives a need to buffer against growing U.S. conventional capabilities that could undermine China’s nuclear deterrent and to ensure penetration of a thickening U.S. national ballistic missile defense (BMD).

(2) **Deploying Multiple Independently Targeted Re-entry Vehicles (MIRVs).** China could deploy multiple warheads on its strategic missiles in response to its concerns about a thickening U.S. BMD. It is unclear whether China has warheads small enough to MIRV its mobile missiles but it could MIRV its large silo-based missiles.

(3) **Alerting its missiles.** In response to China’s concerns about the vulnerability of its nuclear missiles to U.S. conventional attack, China could alert some of its missiles. If alerted during a crisis situation, this could provoke a U.S. attempt to destroy China’s nuclear missiles, especially if the United States perceived alerted missiles as an indication that China had abandoned its No-First Use policy.
II. Minimizing the Likelihood That China Will Increase Its Nuclear Arsenal

This report considers three circumstances that could encourage China to build up its nuclear weapons arsenal: (1) a conventional arms race driven by destabilizing preemptive military postures; (2) a thickened U.S. ballistic missile defense; and (3) the United States’ apparent refusal to accept that it has entered a relationship of mutually effective deterrence with China, which China perceives as an indication that the United States is pursuing policies to neutralize China’s relatively new second-strike capability. This section discusses each of these dynamics and presents various policy options to help address them.

All of these dynamics are symptoms of a broader problem of a lack of trust and transparency in the U.S.-Chinese security relationship and are complicated by communications difficulties between China and the United States, and between Japan and China. Our interviewees often cited a lack of transparency and trust between China and the United States and limited channels for dialogue between China and Japan as key challenges to reducing regional tensions. Poor communications affects all of the described dynamics, and therefore motivate some of the policy options presented below.

1. A Conventional Arms Race with Destabilizing Preemptive Postures

Territorial tensions, particularly over Taiwan, have led to a conventional arms race between the United States and China. During the Third Taiwan Strait Crisis of 1996, the United States effectively used the presence of two carrier battle groups to pressure China to cancel military “exercises” that could have escalated the crisis. Shortly thereafter, China began to develop anti-carrier capabilities. Though the Chinese deny that these capabilities indicate an area denial strategy on their part, the U.S. Navy believes China is seeking anti-access area-denial (A2AD) capabilities.

The Pentagon uses A2AD to describe a state’s set of capabilities that “make others believe it can close off international airspace or waterways and that U.S. military forces will not be able (or willing to pay the cost) to reopen those areas or come to the aid of our allies and partners.” These capabilities include submarines and anti-ship ballistic missiles that could inflict “unacceptable losses” on rival naval powers. Along with the DF-21D anti-ship missiles, China is in the process of developing fifth generation fighters with stealth capabilities, and possibly designing one of those aircraft to be carrier-based. This follows China’s acquisition and testing of its first aircraft carrier from Russia. Figure 1 below shows U.S. estimates of China’s current A2AD capabilities and their ranges relative to key U.S. interests. In the future, these systems may provide the capability to deny the United States access to vital sea-lanes and airfields within 1500 nautical miles of mainland China.
Figure 1: China’s current A2AD capabilities and their ranges relative to key U.S. interests. For locations of China’s military bases and launch sites, see Figure 4.

The U.S. counter to global A2AD threats is Air-Sea Battle (ASB). Much like A2AD, ASB largely represents a set of capabilities and applications, rather than a formal battle plan with specific planning documents. Though little is disclosed about ASB’s components, public reports indicate that ASB envisions stealth bombers, submarines, and missiles blinding an adversary and removing offensive capabilities by knocking out long-range surveillance radars and precision conventional missile systems.

A2AD and ASB are designed to deter potential adversaries from acting aggressively. However, should a crisis arise, these two postures risk escalating tensions into hot conflict because each strategy gives an advantage to the first mover. U.S. precision strikes must hit Chinese missiles before those missiles can be launched at U.S. carriers. Conversely, Chinese missiles must be launched at U.S. carriers before U.S. forces can destroy the Chinese missiles on the ground. The overlap of offensive capabilities and the resulting vulnerabilities of Chinese and U.S. forces exacerbate the security dilemma, increasing the incentives of both the United States and China to build up their respective arsenals.

Although the United States has not threatened a conventional strike against Chinese nuclear targets in the context of ASB, military planners often judge other potentially hostile nations by their capabilities, rather than their stated strategy. Under ASB, the United States has the capability to launch a large-scale conventional strike against Chinese strategic targets. These targets include command-and-control, deployed missiles, and nuclear warhead storage facilities. Given this potential attrition of China’s nuclear missile force, Chinese planners could decide to expand China’s nuclear force to maintain minimum nuclear deterrence.

The vulnerability of China’s nuclear force to conventional strikes is exacerbated by China’s nuclear command-and-control posture. The PLA 2nd Artillery Corps’ command-and-control includes both the conventional A2AD missile systems and China’s land-based strategic nuclear missiles. The organization of the Chinese 2nd Artillery Corps compounds the conventional/nuclear conflation problem because it rotates the same crews between strategic and tactical systems. The crews are trained to react quickly when they are
operating tactical systems. But, when operating strategic systems, they are expected to be deliberative and delay action. This raises questions about how the crews would react in a crisis situation when communication systems are down. The sharing of one command-and-control for both conventional and nuclear systems increases the danger that if a crisis triggers preemptive action, it could also result in unintended escalation across the nuclear threshold.

**Policy Option:** The United States could increase interactions between the U.S. military and the PLA’s 2nd Artillery Corps to discuss how to mitigate the danger that U.S. and Chinese preemptive military postures could spark an unintended war that could cross the nuclear threshold, and to alert China to the danger stemming from the entanglement of its conventional and nuclear command-and-control structures.

In these interactions, the U.S. military could emphasize that U.S. security policy does not include attacking China’s nuclear capabilities, except in extremely dire circumstances, but that the first priority for the U.S. military in a conflict is to target conventional command-and-control structures.

2. Ballistic Missile Defense

The second dynamic that could give rise to a buildup of China’s strategic nuclear forces is a thickening of U.S. national BMD. China’s leaders fears that regional and national U.S. BMD systems are intended to neutralize China’s nuclear deterrent against the United States, despite numerous assurances from U.S. policymakers stating otherwise. More generally, China argues that “strategic missile defense capabilities or potential” could be destabilizing and impede arms control. In response to a perceived thickening of U.S. national BMD caused by developments in U.S. regional BMD capabilities, China could expand its nuclear arsenal, including increasing its number of strategic ballistic missiles, and potentially MIRVing them.

In discussing U.S. BMD capabilities, this report focuses on the ability of U.S. interceptors to engage with incoming warheads. Engagement is based on the burnout velocities of interceptors, for which reasonably reliable public estimates are available. Engagement does not imply the ability to actually intercept a warhead, especially if the incoming missile uses decoys or other countermeasures. The effectiveness of U.S. BMD systems against countermeasures remains in question, in part because tests with realistic countermeasures have not been conducted. This report does not address BMD system discrimination and radar problems, but rather seeks to identify ways to assuage China’s worst-case scenario concerns given interceptor engagement ability. Despite current limitations of U.S. interceptor discrimination capabilities, our Chinese interviewees expressed the belief that, given enough time and money, the United States could drastically improve these capabilities. Therefore, we believe that limiting Aegis interceptor burnout velocities in a way that does not reduce their effectiveness for regional defense can address some of China’s fears about U.S. BMD developments.

a. The U.S. Ground-Based Mid-Course Defense System

At the core of the current U.S. national missile defense system are thirty ground-based mid-course interceptors. A May 2010 Department of Defense report to Congress stated that the ground-based mid-course defense (GMD) interceptors currently deployed in Alaska and California are sufficient for the purpose of “defending the homeland for the foreseeable future against the projected threats from North Korea and Iran.” In the event of an attack by one of these countries on the United States with one or a few long-range ballistic missiles, these GMD interceptors could in theory engage the incoming missiles over the area shown in Figure 2 below. Because GMD currently has only thirty interceptors, however, China could overwhelm the system by launching multiple missiles or deploying decoys.
b. Aegis Ballistic Missile Defense System

Currently, the ship-based Aegis missile defense system functions as a regional and fleet missile defense against short- to medium-range (up to 3000 km) ballistic missiles. However, if the burnout velocities of its interceptors increase as planned, Aegis could be used to thicken U.S. national missile defense against long-range (above 5000 km) missiles. The currently deployed SM-3 Block IA and IB interceptors, both with burnout velocities of about 3.0 km/s, are not capable of engaging with long-range ballistic missiles along most of their flight paths. This is because the Block IA and IB can only reach a maximum altitude of approximately 500 km, lower than the altitude where long-range ballistic missiles travel for most of their trajectories. This means that Block IA and IB interceptors could only engage incoming ballistic missiles when stationed near their targets.

If the SM-3 Block IIA and IIB missiles are deployed on Aegis ships, however, Aegis could be used to thicken the U.S. national missile defense system. Blocks IIA and IIB are expected to have higher burnout velocities of 4.0-4.5 km/s and about 5.0 km/s, respectively, which would allow the interceptors to engage missiles over a much larger area. While GMD interceptors are faster than the proposed Block IIA and IIB interceptors, the Aegis-based Block II interceptors are controversial because of their mobility. Even if the Aegis ships are not currently positioned to launch interceptors that could engage with Chinese missiles heading toward the United States, those interceptors could easily be brought into position to do so, thereby potentially undermining China’s nuclear deterrent against the United States.
Figure 3: Approximate areas from which Aegis interceptors could be launched to engage a ballistic missile on a minimum-energy trajectory traveling from central China to Washington, D.C.\textsuperscript{36}

For example, consider an ICBM launched from a base in central China heading towards Washington, D.C. The trajectory of the warhead is shown in orange in Figure 3 above. Block IA and IB interceptors could engage this warhead before it reached its target, but, assuming that the warhead is on a minimum-energy trajectory,\textsuperscript{37} they could be launched only from the area shaded in red. If Block IIA has a burnout velocity of 4.0 km/s, interception could be attempted from the purple area. A faster version of the SM-3 Block IIA interceptor, with a burnout velocity of 4.5 km/s, could be used to attempt an interception from the area shaded in yellow. Finally, a Block IIB interceptor with a burnout velocity of 5.0 km/s could be used to attempt an interception from the area shaded in light blue. Block IIA and IIB interceptors greatly increase the area where Aegis ship- or land-based interceptors could be stationed and still engage with a Chinese ICBM.

**Policy Option:** The United States could refrain from deploying Block IIA or IIB interceptors on U.S. Aegis ships or in North America.
Given that GMD already has an adequate number of interceptors to defend against foreseeable North Korean and Iranian threats, deployment of additional interceptors in North America is unnecessary. Moreover, such a deployment could trigger a Chinese nuclear buildup.

If the U.S. did not deploy Block IIA or IIB interceptors on Aegis ships, China would be less concerned that U.S. regional BMD interceptors could be used to thicken U.S. national defenses against Chinese ICBMs and SLBMs. If China's concerns about its second-strike capability remain, China may seek to increase its nuclear arsenal. Not deploying Block IIA and IIB on ships or in North America could assuage Russian as well as Chinese fears that the United States is developing a thick national BMD system, and could allow the United States and Russia to agree to further arms reductions.

Choosing not to deploy Block IIA or IIB on Aegis ships is unlikely to harm U.S. regional missile defense capabilities. Our calculations indicate that U.S. Aegis ships, equipped with SM-3 Block IA and IB interceptors and other defenses, would likely allow the United States to maintain its ability to defend its carriers and bases from regional threats. In particular, our calculations indicate that Block IA and IB interceptors likely have the necessary burnout velocity to engage China’s short-range ballistic missiles, including the DF-21D. See Figure 4 for locations of Chinese missile launch sites. Given the BMD coverage provided by land-based interceptors and the Aegis-based Block IA and IB interceptors, it appears unnecessary to deploy sea-based Block IIA or IIB interceptors in East Asia. Additionally, the United States could encourage Japan to consider only deploying the jointly-developed Block IIA interceptors on land, not on Japanese Aegis ships. Japan should consider whether it can adequately defend itself against the North Korean threat with Aegis-based IA and IB and land-based IIA interceptors because deploying IIA on Japanese Aegis ships may risk worsening relations with China.

Figure 4: Chinese ICBM Bases (Red), Intermediate- and Mid-Range Ballistic Missile Bases (Blue), and Short-Range Ballistic Missile Bases (Yellow).
**Policy Option:** In exchange for U.S. restraint in BMD deployment, the United States could suggest that China disclose how many ICBMs and SLBMs it has, unilaterally cap its strategic missiles at that level, and agree not to MIRV them.

While this section suggests that the United States limit missile defense deployments for the sake of not provoking a Chinese nuclear buildup, reciprocal restraint from China could increase the political feasibility of U.S. limits on its ballistic missile defenses. The United States could ask China to disclose to the United States and Russia how many ICBMs and SLBMs it has, unilaterally cap its ICBM and SLBM deployments to the announced levels, and commit not to MIRV these missiles. As with SALT I and II, initial verification would be accomplished by “national technical means.”

Ultimately, the United States should push to ensure that this commitment becomes more verifiable and includes inspections. Agreeing to a verification regime, however, can be a long and arduous process, as shown by the history of U.S.-Russian negotiations. A unilateral commitment and an increase in China’s nuclear transparency would be a first step towards a verifiable arms control regime where the United States, Russia, and China agree to deep arms reductions, once the United States and Russia have reduced their nuclear capabilities further.

**Policy Option:** The United States and China could expand engagement in Track 1.5 and 2 dialogues on technical issues relating to the future capabilities of U.S. national and regional ballistic missile defense.

Track 1.5 and 2 dialogues facilitate information exchange that mitigates the risk that China will build up its strategic nuclear arsenal because it overestimates U.S. military capability. We believe a first step would entail a joint agenda setting meeting to outline specific areas of discussion. One of the key aims of such dialogues should be to address China’s concerns about U.S. BMD. In these dialogues, the United States could explain the limitations of its planned development and deployment of Aegis Block IIA and IIB interceptors, and its understanding of their effects on China’s second-strike capability. The United States should emphasize that its national missile defense is for the Iranian and North Korean threat, and that the U.S. regional missile defense is designed to defend the United States and its allies from both conventional and nuclear threats in the region.

**3. Mutual Vulnerability and the U.S.-Chinese Nuclear Deterrence Relationship**

According to the 2012 Department of Defense report to Congress, *Military and Security Developments Involving the People’s Republic of China*, China currently possesses “a nuclear force structure able to survive an attack and respond with sufficient strength to inflict unacceptable damage on the enemy.” This survivable force is a relatively new development resulting from China’s deployment of mobile ICBMs, and an increasingly extensive deep tunnel complex in which missiles can be sheltered from attack. Among Chinese defense officials, China’s survivable force currently appears to be deemed sufficient to deter the United States from using nuclear coercion. This survivability is also why China seeks to define the U.S.-Chinese relation in terms of “mutual vulnerability.” However, because of the term’s failure to accurately describe the U.S.-Sino relationship and the political difficulty of admitting one is “vulnerable,” mutual vulnerability has been a source of constant contention within the U.S. government and has failed as a paradigm that the United States is willing to accept.

In response to the new reality of China’s survivable second-strike capability, the U.S. government has two options: 1) seek to deny China a second-strike capability by developing more effective ballistic missile defenses and new approaches to disabling China’s deterrent, or 2) accept the concept of mutual vulnerability, as the United States did with the Soviet Union following the Cuban missile crisis, and attempt to stabilize the U.S.-Chinese relationship based on this understanding.
Trying to eliminate China’s second-strike capability may not be possible and could lead to conventional and nuclear arms races. Should the United States seek to neutralize China’s nuclear missiles with ballistic missile defense, China has a number of possible responses. It could MIRV its missiles, build more ICBMs, or develop more sophisticated countermeasures against BMD. It also could continue to hide and harden its strategic forces, which reduces the threats from both U.S. conventional and nuclear attack. These investments would be relatively effective and low-cost for China in comparison to investments the United States would have to make to attempt to counter them.48

Policy Option: The United States could recognize and accept the reality of “Mutually Effective Deterrence” as a description of its current nuclear relationship with China.

Mutual vulnerability applies only to the ability of each state to deliver a nuclear payload to the other, yet the term itself is unpalatable. It may seem to imply that Chinese and U.S. conventional and nuclear forces are on par with each other, which is inaccurate. More importantly, U.S. leaders are uncomfortable admitting vulnerability because it could have domestic political repercussions. The Obama Administration seemingly attempted to sidestep this term and implicitly recognize that China has an effective deterrent against U.S. nuclear attack by discussing the concept of “strategic stability” in the 2010 Nuclear Posture Review.49 However, the term “strategic stability” is vague, and still leaves the Chinese questioning the specific aims of U.S. nuclear policy towards China.50

An alternative formulation that more accurately describes the U.S.-Chinese nuclear deterrence relationship is “mutually effective deterrence.” This articulation makes clear the recognition by both countries that the other has an effective deterrent against nuclear threats. Within the United States, mutually effective deterrence would project a sense of strength and preparedness, while acknowledging the reality of China’s second-strike capabilities. This step would be critical in demonstrating to China that the United States is not pursuing policies to undermine China’s second-strike capability.
Appendix 1: Calculating Effects of SM-3 Interceptor Burnout Velocity on Coverage Area

This appendix presents basic estimates of how improvements to the SM-3 interceptors could increase the Aegis BMD system’s ability to intercept missiles launched from China. At present, SM-3 Block IA and IB missiles are installed on Aegis ships. These interceptor missiles have burnout velocities of approximately 3.0 km/s.\(^5\) The SM-3 Block IIA interceptor, planned for deployment in 2018, is estimated to travel between 4.0-4.5 km/s, and the SM-3 Block IIB interceptor is estimated to reach 5.0 km/s when deployed in 2020.\(^5\) The higher burnout velocity of the Block IIA and IIB missiles should allow the Aegis missile defense system to intercept longer-range ballistic missiles, which travel at higher velocity and higher altitude than short- or medium-range missiles. The following procedure is used to determine the locations from which an Aegis system (with SM-3 Block IA, IB, IIA, or IIB missiles) can intercept a given ballistic missile (a schematic of this method over a flat Earth is shown in Figure A-1):

1. The trajectory of a given ballistic missile is determined.
2. The maximum height that the interceptor can reach is calculated from the interceptor’s burnout velocity.
3. Points on the ballistic missile’s trajectory that lie below the interceptor’s maximum height are determined.
   When the ballistic missile is above or near international waters (or territorial waters of U.S. allies) at any of these altitudes, it is prone to interception, and is in a ‘protected area.’\(^5\)
4. Where an interception is possible, the width of the band on either side of the ballistic missile trajectory from which an interceptor missile can be launched is calculated.\(^5\)

![Figure A-1: Schematic for Aegis BMD protected areas.](image-url)
Calculations

Step 1: Determining a ballistic missile’s trajectory

The trajectory calculations in this section are based on equations published by Albert D. Wheelon. These equations allow for calculation of the trajectory of a ballistic missile as a function of the missile's radial position, along with its burnout velocity and burnout angle.

For this analysis, we will analyze a missile traveling from a point in central China to Washington, D.C., which is a distance of 11,900 km. We assume a burnout height of 200 km, and a burnout velocity of 7.28 km/s, which is the minimum velocity required to cover the distance (the trajectory that uses minimum missile velocity also uses the minimum energy). The optimum burnout angle corresponding to this missile’s burnout height, burnout velocity and intended range is 72.9 degrees. If a slightly faster missile is used, the missile can be launched on a ‘lofted trajectory,’ which will take the missile on a significantly higher path than the ‘minimum energy trajectory,’ which is analyzed in this report. A comparison of the minimum energy trajectory and lofted trajectory for a missiles traveling from central China to Washington, D.C., is shown in Figure A-2. These trajectories were calculated with a MATLAB program.

![Figure A-2: Plotted trajectories of missiles launched from a missile based in central China, heading to Washington, D.C. The burnout velocity of the minimum-energy missile is 7.28 km/s, and the burnout velocity of the lofted missile is 7.38 km/s. The maximum height of the minimum energy missile is 1320 km, and the maximum height of the lofted missile is 2360 km.](image)

Step 2: Determining an interceptor’s maximum height

The maximum height an interceptor can attain is determined by calculating the path of a ballistic missile with the interceptor’s burnout velocity, but with a burnout angle of 0° (i.e., the interceptor travels straight up). The predicted maximum heights for the four versions of the SM-3, calculated with MATLAB, are shown in Table A-1. To be conservative, the burnout height of the missile in each calculation is assumed to be 0 km.
Table A-1: Predicted maximum heights of SM-3 interceptors

<table>
<thead>
<tr>
<th>Interceptor</th>
<th>Burnout velocity (km/s)</th>
<th>Max. height (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM-3 Block IA/B</td>
<td>3.0</td>
<td>490</td>
</tr>
<tr>
<td>SM-3 Block IIA</td>
<td>4.0-4.5</td>
<td>880-1230</td>
</tr>
<tr>
<td>SM-3 Block IIB</td>
<td>5.0</td>
<td>1530</td>
</tr>
</tbody>
</table>

Step 3: Determining the locations where the missile can be engaged

We have calculated the heights of missiles to be intercepted at each kilometer along the missiles’ flight paths. We know the maximum height that each type of SM-3 interceptor can reach. We now can determine the points along the missiles’ paths at which they can be engaged.

We consider $h_{\text{max}}$ to be the maximum height that can be attained by an interceptor launched directly upwards. An interceptor can engage a ballistic missile at any point where the missile is below $h_{\text{max}}$.

When dealing with Chinese ballistic missiles, however, the United States is limited in where it can position its Aegis ships, which can only travel in international waters, or territorial waters of countries that are friendly to the United States. A Chinese ballistic missile heading towards the eastern United States would travel north over Siberia, over the polar ice cap, and then across northern Canada, the Hudson Bay and Quebec. The United States’ first chance to engage the missile with a sea-based missile defense system would be over Nunavut (north central Canada and the archipelago north of Canada) or over the Hudson Bay. At this point, the missile would be descending towards its target. Engagement of Chinese missiles bound for the East Coast during the ascent phase appears to be impossible with the Aegis system, because there would not be enough time to track and launch an interceptor before the ballistic missile has passed the interceptor launch location.

Distances from Washington, D.C., where the SM-3 interceptors could engage incoming Chinese missiles are given in Table A-2. Data in this table assume that interceptors are launched from directly below the ballistic missiles’ path.

Table A-2: Coverage areas for vertically launched SM-3 interceptors towards Washington-bound missiles. The missile on the lofted trajectory must be closer to Washington to be vulnerable to interception than the missile on the minimum-energy trajectory.

<table>
<thead>
<tr>
<th>Interceptor</th>
<th>Points at which engagement is possible, if interceptor is launched vertically</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum energy ($v = 7.28$ km/s)</td>
</tr>
<tr>
<td>SM-3 Block IA/B</td>
<td>Up to 1540 km before impact</td>
</tr>
<tr>
<td>SM-3 Block IIA</td>
<td>Up to 3170 km before impact</td>
</tr>
<tr>
<td>(assuming 4.0 km/s burnout)</td>
<td></td>
</tr>
<tr>
<td>SM-3 Block IIA</td>
<td>Up to 4730 km before impact</td>
</tr>
<tr>
<td>(assuming 4.5 km/s burnout)</td>
<td></td>
</tr>
<tr>
<td>SM-3 Block IIB</td>
<td>Any point during flight</td>
</tr>
</tbody>
</table>
Step 4: Determining locations from which interceptors can be launched

For this step, a MATLAB algorithm calculates the maximum distance on either side of the incoming missile’s trajectory from which an interceptor could be launched.\textsuperscript{57} The user specifies the burnout velocity of the interceptor and the path of the incoming missile, and the algorithm subsequently works through the following steps:

1) A point on the missile’s trajectory that lies below the interceptor’s maximum height is identified. The height of the missile at this point is $h_i$.

2) A hypothetical launch position for an interceptor is positioned at $\theta = 1^\circ$ away from the point identified in Step 1 relative to the center of the Earth.\textsuperscript{58}

3) 
   a) The trajectory of the interceptor launched $\theta$ degrees away from the missile\textsuperscript{59} is calculated, first using a burnout angle $\gamma$ of 90 degrees. $\gamma$ is then reduced in increments of 1 degree, and the trajectory of the interceptor is calculated after each iteration.
   b) If there exists a $\gamma$ at which the height of the interceptor at $\theta$ equals or exceeds $h_i$, then $\theta$ is increased by 0.1 degrees, and Step 3a is repeated.
   c) If there does not exist a $\gamma$ at which the interceptor can reach the missile at $\theta$, then the last iteration of $\theta$ is identified as the maximum angular distance from which the missile can be engaged from the side at the point determined in Step 1.

4) $\theta$ is converted into a distance along the Earth’s surface ($\theta$ is multiplied by the Earth’s radius).

5) Steps 1 through 4 are repeated for every point along the missile’s trajectory that lies below the interceptor’s maximum height.

The output of the MATLAB program is a dataset that lists (for a given incoming missile trajectory and interceptor speed) the maximum distances from which an interception can be attempted from either side at each point along the missile’s trajectory. These distances are shown in Figure A-3 for a minimum-energy Chinese missile aimed at Washington, D.C., for Block IA, IB, IIA, and IIB interceptors.
Figure A-3: Maximum distances from which an interception attempt can be made from either side of a minimum-energy trajectory missile heading from central China to Washington, D.C. Interception attempts cannot realistically be made for the first ~5000 km of the missile’s flight, as the missile is flying over Chinese territory, Russian territory, and the polar ice cap, where Aegis interceptors cannot be stationed.

The SM-3 Block IIA and IIB missiles offer the United States more options for positioning Aegis ships than with Block IA and IB missiles. A Block IIA/IIB interceptor can engage with a descending ballistic missile sooner and from further away than a Block IA/B interceptor. However, China could offset increases in interceptor velocities to some degree by putting its missiles on lofted trajectories.
Appendix 2: Interviews and Presentations

Below is a list of interviews conducted in Princeton, New Jersey, Tokyo, Japan, and Beijing, China.

Princeton, New Jersey (either in person or via phone)

• Case, Sarah (Non-Proliferation Officer, U.S. Department of State), 16 Nov. 2012
• Christensen, Thomas (Professor, Woodrow Wilson School, Princeton University), 1 Oct. 2012
• O’Hanlon, Michael (Senior Fellow, Brookings Institution), 21 Nov. 2012
• Kristensen, Hans (Director of the Nuclear Information Project, Federation of American Scientists), 24 Sept. 2012
• Kulacki, Gregory (China Expert, Union of Concerned Scientists), 8 Oct. 2012
• Lewis, George (Researcher, Cornell University), 8 Oct. 2012
• Postol, Theodore (Professor, Massachusetts Institute of Technology), 27 Sept. 2012
• Yoshida, Fumihiko (Deputy Director, Editorial Board, the Asahi Shimbun), 1 Oct. 2012

Tokyo, Japan

• Hayashi, Yoshimasa (House of Councilors, LDP, Former Defense Minister), 30 Oct. 2012
• Iizuka, Hisako (Chinese Nuclear Specialist), 28 Oct. 2012
• Inoguchi, Kuniko (House of Councilors, LDP, Former Ambassador Extraordinary and Plenipotentiary of Japan to the Conference on Disarmament, Geneva), 29 Oct. 2012
• Kawada, Tomohiro (Deputy Director, Defense Policy Division, Defense Policy Bureau, Ministry of Defense), 1 Nov. 2012
• Kawaguchi, Yoriko (House of Councilors, LDP, Former Foreign Minister, Co-Chair, International Commission on Nuclear Non-Proliferation and Disarmament), 30 Oct. 2012
• Kodama, Keisuke (Deputy Director, Japan-U.S. Security Treaty Division, North American Bureau, Ministry of Foreign Affairs), 31 Oct. 2012
• Kono, Taro (House of Representatives, LDP, Former Chair of the Foreign Affairs Committee of the House of the Representatives), 30 Oct. 2012
• Sugiyama, Shinsuke (Ambassador, Director General, Asian and Oceanic Affairs Bureau, Ministry of Foreign Affairs), 29 Oct. 2012
• Takamizawa, Nobushige (President, National Institute for Defense Studies), 30 Oct. 2012
• Takubo, Masa (Independent Researcher, Member of the International Panel on Fissile Materials), 28 Oct. 2012
• Yoshida, Fumihiko (Deputy Director, Editorial Board, the Asahi Shimbun), 29 Oct. 2012
Beijing, China

- Chen, Huaifan (Chinese People’s Association for Peace and Disarmament), 1 Nov. 2012
- Graduate Students from Tsinghua University, 2 Nov. 2012
- Gu, Guoliang (Deputy Director, Institute of American Studies, Chinese Academy of Social Science), 1 Nov. 2012
- Guo, Xiaobing (China Institutes of Contemporary International Relations), 2 Nov. 2012
- Han, Hua (Professor, International Studies, Peking University), 1 Nov. 2012
- Hu, Side (Former President, China Academy of Engineering Physics), 1 Nov. 2012
- Huang, Weiguo (Institute of Structural Mechanics at China Academy of Engineering Physics), 1 Nov. 2012
- Li, Hong (Secretary General, China Arms Control and Disarmament Association), 2 Nov. 2012
- Liu, Chong (China Institutes of Contemporary International Relations), 2 Nov. 2012
- Ma, Yuan (Major PLA Air Force, National Defense University), 1 Nov. 2012
- Ouyang, Liping (China Institutes of Contemporary International Relations), 2 Nov. 2012
- Pan, Zhenqiang, (General, Former Director, National Defense University), 1 Nov. 2012
- Qu, Changhong (Institute of Structural Mechanics at China Academy of Engineering Physics), 1 Nov. 2012
- Shen, Dingli (Vice Dean, School of International Studies, Fudan University), 1 Nov. 2012
- Shepherd, Ronald C. (Cole), (Senior Advisor, U.S. Embassy Beijing, Defense Attaché Office), 1 Nov. 2012
- Sun, Xiangli (Center for Strategic Studies at China Academy of Engineering Physics), 1 Nov. 2012
- Wu, Chunsi (Shanghai Institutes for International Studies), 2 Nov. 2012
- Wu, Riqiang (Professor, Renmin University), 1 Nov. 2012
- Xia, Liping (Dean, School of International Relations, Tongji University), 2 Nov. 2012
- Yang, Mingjie (China Institutes of Contemporary International Relations), 2 Nov. 2012
- Yang, Yi (Rear Admiral (ret.), Former Director, Institute of Strategic Studies, National Defense University), 2 Nov. 2012
- Zhou, Huan (Institute of Structural Mechanics at China Academy of Engineering Physics), 1 Nov. 2012
- Zhu, Rui (Chinese People’s Association for Peace and Disarmament), 1 Nov. 2012
- Zou, Yunhua (China Defense Science and Technology Information Center), 2 Nov. 2012
IV. Notes


3. “Remarks by President Barack Obama in Prague – as delivered” (op. cit.).

4. Though nearly 92% of the Chinese population is Han, the country is still home to around 119 million minorities. Tibetans and Uighurs, for example, make up 5% of China’s population, but they occupy 25% of the country’s landmass. See Frank Jannuzi, “Six Dragons confronting China’s leaders and threatening China’s rise” (lecture, Princeton University, Princeton, NJ, October 17, 2012). See also “World Report 2012: China,” *Human Rights Watch*, January 2012, http://www.hrw.org/world-report-2012/world-report-2012-china (documenting the Kirti Monastery uprising, where Tibetan monks self-immolated in protest of their lack of religious freedom, and the Urumqi riots in 2009, the most deadly episode of ethnic unrest in recent Chinese history, among others).

5. China’s richest provinces have ten times the per capita income of poorest Chinese (in the United States, this ratio is two to one). China also has more billionaires than any country other than the United States, with the net worth of average CPC National Congress members exceeding the net worth of average members of the U.S. Congress. See Frank Jannuzi, “Six Dragons confronting China’s leaders and threatening China’s rise” (op. cit.).

6. Corruption allegations include land expropriation, injustice, and official malfeasance. See Frank Jannuzi, “Six Dragons confronting China’s leaders and threatening China’s rise” (op. cit.).


8. As Li Bin notes, “the key factor that will shape China’s future nuclear policy is how the Chinese security elite understands the roles of nuclear weapons,” and U.S. nuclear weapons policy has a great impact on the elite’s understanding. Li Bin, “Building Toward a Stable and Cooperative Long-Term U.S.-China Strategic Relationship” [Draft on file].


11. China and Japan have struggled to maintain open channels of communication in the recent past. For example, despite the encouraging precedent of twelve rounds of ministerial talks since 1993, these talks are scheduled on an ad-hoc basis and easily discontinued by either of the two nations, as shown by the suspension of the Sino-Japanese “hotline” recently. See “The 12th Japan-China Security Dialogue,” *Ministry of Foreign Affairs of Japan*, January 18, 2011, http://www.mofa.go.jp/announce/event/2011/1/0118_01.html. In public reports, Chinese officials cite the country’s leadership transition as the reason for suspension, whereas Japanese defense authorities reportedly believe that conflicting claims over the Senkaku/Diaoyu Islands is the real cause. See “Japan-China ‘hotline’ unlikely in ’12,” *The Yomiuri Shimbun*, October 21, 2012, http://www.yomiuri.co.jp/dy/national/T121020001963.html.
China’s anti-carrier capabilities are thought to include the DF-21D anti-ship ballistic missile. The DF-21D is a mobile ballistic missile equipped with a maneuverable re-entry vehicle, which is believed to be the world’s first anti-ship ballistic missile. With an estimated range of 1500 to 3000 kilometers, such a system has the potential to push U.S. carrier strike groups out of range so that the United States would be unable to defend Taiwan in a crisis. The DF-21D is still in the design phase, however, and may be years from operational deployment, so its true capabilities remain unknown. See Michael Kelley, “Don’t Believe the Hype about China’s DF-21 Carrier Killer,” Business Insider, July 24, 2012, http://www.businessinsider.com/dont-believe-the-hype-about-chinas-df-21d-carrier-killer-missile-2012-7.


The distinction between “global” and “regional” A2AD threats is important because U.S. ASB is not aimed at any specific state; it is a broader plan for freedom of access in any operating environment.


A full explanation of the Joint Operational Access Concept (JOAC) can be viewed online in the JOAC handbook at http://www.defense.gov/pubs/pdfs/JOAC_Jan%202012_Signed.pdf.


Similarly, the United States judges China to have an A2AD capability though China denies it has an A2AD strategy.


Information Office of the State Council of the People’s Republic of China, “China’s National Defense in 2010,” March 31, 2011, http://www.china.org.cn/government/whitepaper/2011-03/31/content_22263885.htm (“China maintains that the global missile defense program will be detrimental to international strategic balance and stability, will undermine international and regional security, and will have a negative impact on the process of nuclear disarmament. China holds that no state should deploy overseas missile defense systems that have strategic missile defense capabilities or potential, or engage in any such international collaboration.”).


Defense Agency (MDA) never has conducted tests against realistic countermeasures, in part because the systems have had enough trouble against targets without decoys and in part because planners assume that countries such as Iran and North Korea would not initially deploy countermeasures on their missiles. The [congressionally-requested National Research Council] report said that the MDA has canceled research programs that would try to deal with countermeasures and that committee “could not find anyone at MDA who could explain much of the past research in this area.”


32 This report, for purposes of evaluating military policy, takes the DOD statement that BMD is effective against the North Korean or Iranian threat at its word. However, questions about the effectiveness of U.S. GMD against even a limited threat still remain. See Tom Z. Collina, “Report Critiques U.S. Missile Defense” (op. cit.).


34 See Appendix 1.


36 Calculations and graphic by Mark Walker, report contributor.

37 A minimum-energy trajectory is one for which the burnout velocity is the minimum velocity required to reach the target.


39 The DF-21D is thought to possess a maneuverable re-entry vehicle, the biggest difficulty in defending against it will involve developing better BMD discrimination and more-maneuverable kill vehicles, not burnout velocity and engagement potential of U.S. interceptors.

40 See generally Progress Despite Disagreements: The Sixth China-US Strategic Dialogue on Strategic Nuclear Dynamics (op. cit.).


43 Ibid.

44 A Chinese ballistic missile cannot be intercepted by the Aegis system during boost phase, or during the first few minutes of midcourse travel. This is because it takes time for the system to track the missile and for the interceptor to reach the missile.

45 These calculations neglect effects due to the rotation of the Earth.

To obtain a copy of the code, please contact Mark Walker at markew@princeton.edu.

These distances are calculated assuming that the projection of the interceptor’s trajectory along the surface of the Earth is perpendicular to the projection of the incoming missile’s trajectory along the Earth’s surface.

Ideally, the algorithm would begin by calculating a trajectory where $\theta = 0$ degrees, but this is impossible when missile height is specified as a function of $\theta$. If a missile were launched straight up, then both the launch of the interceptor and the interception of the missile would take place at $\theta = 0$ degrees, which is impossible to define with a function.

This calculation is relative to the center of the Earth.