DIVERGING OBJECTIVES

Maintaining Strategic Stability with Russia While Expanding Global Missile Defense

SHAWN A. RUSSELL

WRIGHT FLYER PAPERS

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Foreword

It is my great pleasure to present another issue of The Wright Flyer Papers. Through this series, Air Command and Staff College presents a sampling of exemplary research produced by our resident and distance-learning students. This series has long showcased the kind of visionary thinking that drove the aspirations and activities of the earliest aviation pioneers. This year's selection of essays admirably extends that tradition. As the series title indicates, these papers aim to present cutting-edge, actionable knowledge—research that addresses some of the most complex security and defense challenges facing us today.

Recently, The Wright Flyer Papers transitioned to an exclusively electronic publication format. It is our hope that our migration from print editions to an electronic-only format will foster even greater intellectual debate among Airmen and fellow members of the profession of arms as the series reaches a growing global audience. By publishing these papers via the Air University Press website, ACSC hopes not only to reach more readers, but also to support Air Force–wide efforts to conserve resources. In this spirit, we invite you to peruse past and current issues of The Wright Flyer Papers at https://www.airuniversity.af.edu/AUPress/Wright-Flyers/.

Thank you for supporting The Wright Flyer Papers and our efforts to disseminate outstanding ACSC student research for the benefit of our Air Force and war fighters everywhere. We trust that what follows will stimulate thinking, invite debate, and further encourage today's air, space, and cyber war fighters in their continuing search for innovative and improved ways to defend our nation and way of life.

Evan L. Pettus
Brigadier General, USAF
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Preface

Many recent developments prompted me to look more deeply at Russia's concerns related to US ballistic missile defense (BMD) and how it affects strategic stability. Russia is posing an increasing threat in multiple domains driven by its great power aspirations and revisionist desires. President Putin recently announced that Russia is developing a number of asymmetric nuclear capabilities to counter missile defense, while at the same time it is recapitalizing its traditional, triad-based nuclear deterrent. The rollercoaster ride that is the North Korean threat will continue to drive US missile defense spending, seemingly to the detriment of near-peer strategic stability. Are Russia's concerns more than political bluster? Can we reduce tension with Moscow and what role does BMD actually play? Is further arms control with Russia possible?

I would like to thank my advisors and classmates for their comments and suggestions. Without a doubt, my paper is better because of their help and insights. It is always difficult to see the flaws in your own work when you have been staring at it for too many hours in a row.

Most importantly, I could not have accomplished this without the support of my family. They sacrificed normality so that I could write this thesis and pursue this degree, yet they were still there to encourage and provide well-timed fun and laughs. I cannot repay that debt, and I will be forever grateful that they supported me during this time. Finally, I have to thank my sister for her insight and guidance as she has been through this process multiple times in the past. She was a much-needed sounding board to boost my confidence and reset my compass.

Abstract

Since the US left the ABM Treaty in 2002, the prevailing assumption has been that Russia's consistent concerns with the limited US ballistic missile defense (BMD) system was political bluster, because its nuclear deterrent was large enough to easily defeat any US defenses. Previous studies generally based their arguments on a faulty understanding of Moscow's deterrence requirements, assuming it would accept a minimum deterrence standard of only a few warheads surviving to detonation. The following study shows that Moscow desires a credible threat of unacceptable damage to deter the United States and that an expanding US ballistic missile defense (BMD) system could prevent Russia from achieving this criterion and ultimately degrade bilateral strategic stability. The analysis uses a scenario planning framework to compare four future scenarios of US BMD versus Russia's nuclear deterrent. These comparisons demonstrate that unchecked expansion of the US missile defense system, especially when combined with future arms limitations, will cause legitimate concern in Russia over its ability to deter the United States during a crisis. Moscow's reduced confidence will continue to compel it to find new capabilities to penetrate and circumvent missile defense in order to restore balance, degrading arms race stability between the United States and Russia. Any further BMD expansion will further degrade strategic stability and put at risk future arms control agreements.

Introduction

Overview of the Study

This study will use the scenario planning framework to show how an expanded US ballistic missile defense (BMD) system will affect strategic stability, particularly when combined with further arms limitations. It will start by presenting background on the changing ballistic missile threat, which is driving BMD expansion, provide a short history of the laws surrounding BMD, define crisis stability, and define Russia's perspective on deterrence to enable analysis of four potential scenarios. The four scenarios will consider the effect of the current and expanded US BMD system within a nuclear exchange between the United States and Russia using both today's New START Treaty (NST) limited force and a future, more limited nuclear force. The study will investigate Moscow's criterion of "unacceptable damage" and then use it as a metric to analyze each scenario qualitatively. Each scenario will rely on a statistically modeled outcome of a nuclear exchange at four different levels of crisis response to determine how many Russian warheads ultimately penetrate US defenses. This analysis will show how Moscow may be forced into undesirable escalatory responses because of the advantage that BMD could provide the United States in a future scenario. It will then show that Moscow's response could lead to both crisis and arms race instability. Finally, the paper will make recommendations to restore strategic stability and to build confidence with Russia regarding missile defense to maintain or increase stability, which would then enable future agreements on arms control limitations.

The Nature of the Problem

As Russia and the United States approach the 5 February 2021 expiration of the NST and both sides look to extend New START or to lower the numbers of deployed nuclear warheads through further arms control agreements, missile defense and its effect on strategic stability will once again come to the forefront. Final agreement on the NST was only reached after the parties added wording to recognize an "interrelationship between strategic offensive arms and strategic defensive arms," solidifying the increasing importance of the relationship between the two, as the strategic offensive weapons limit was reduced.[1] This study will show that the link between missile defense and nuclear arms control had been clear and that both sides mutually agreed to this premise as far back as 1972 when they signed the ABM Treaty as a part of the first Strategic Arms Limitation Treaty (SALT) talks.

The ABM Treaty maintained the limitations on strategic defensive arms, so the United States and Soviet Union could move forward with reductions on the offensive side of the equation. Today, as this study will show, Russia maintains this principle of a link between strategic offensive and defensive arms, and it has consistently argued this since the signing of the ABM Treaty. Evidence will demonstrate that Moscow believes this balance was upset when the United States left the ABM Treaty in 2002 and continues because of US reluctance to consider limitations on missile defense. Moscow continues to use US BMD and nonnuclear strategic offensive capabilities as a reason to increase development of its own nuclear and strategic conventional forces. This strategic defensive-offensive arms imbalance is beginning to erode stability between the United States and Russia.

The Research Question

To support policy decisions concerning potential future treaty negotiations, this study will investigate how an increasingly advanced US BMD system will affect strategic stability. If the United States intends to further reduce nuclear arms through a post-NST agreement, it must develop a better understanding of Russia's concerns vis-à-vis BMD. The United States continues to expand its missile defense system primarily to counter the expanding ballistic missile threat from rogue states, such as North Korea. Nevertheless, continued ignorance of Moscow's concerns and fears of a future US missile defense system could prevent agreement and may ultimately develop into an arms race as Moscow tries to maintain a credible capability to deter the US and NATO. Therefore, the research question of this study is how will an increasingly advanced global missile defense system aimed at regional actors affect strategic stability with Russia?

Purpose of the Study and Anticipated Significance

The results of this investigation will show that if the United States continues to deploy an increasingly capable BMD system, it will degrade strategic stability with Russia. Moscow will perceive both short- and long-term proposals to increase the capability of BMD, especially when combined with further nuclear arms reductions, as a threat to Russia's ability to deter the United States and NATO using nuclear force.

Moscow relies on the threat of nuclear force to safeguard its sovereignty through an ability to inflict unacceptable damage on Russia's adversaries due to a perception of conventional inferiority. At the same time, its deterrence efforts in other domains depend on the ultimate backstop of its nuclear deterrent. Expansion of the US global BMD system is intended to protect the United States and its allies from advancements in rogue state and regional actor offensive capabilities. However, this expansion, if not carefully accomplished, could inadvertently cross a threshold, which would provide a substantial capability against a near-peer adversary and upset strategic stability.

Official US government proposals outlined in this study show that a future US global BMD system, if unlimited by treaty or policy, could realistically expand to have an apparent capability to degrade a Russian retaliatory nuclear strike substantially, particularly if combined with a successful US first strike. A global BMD system, even in the mid- to far-term, is unlikely to completely defend against a massed Russian attack, yet even a measurable degradation of its already limited strategic nuclear forces, especially after a US first strike, will create doubt in Moscow that Russia can achieve its unacceptable damage criterion for nuclear deterrence during a crisis. This could leave Moscow with few options other than a preemptive strike to secure its sovereignty. Russian doubts of the ability to achieve its political goals during a crisis could drive Moscow into an unstable arms race to develop further capabilities to overcome missile defense. Crisis instability could result in the long term if Moscow cannot afford to sustain these necessary developments.

The purpose of this study is to inform future US missile defense and arms control policy decision makers that US BMD expansion may have negative effects on bilateral stability with Russia because Moscow still relies on a doctrine of assured destruction. Moscow must have confidence in its ability to deliver unacceptable damage despite US missile defense. The anticipated significance of this study is that future US policy decisions on missile defense will be better informed to reduce Moscow's anxiety if BMD expansion continues. This could be achieved through BMD limits in future offensive arms treaties or other measures to increase Moscow's confidence that future US BMD systems do not threaten its nuclear deterrent. The study will also provide a lens through which US decision makers can better understand future Russian nuclear arms development and hopefully avert an unintentional arms race.

Background and Literature Review

Numerous studies focus on different aspects of missile defense and Russia's reaction to it from historical perspectives to its effect on a nuclear exchange. Nevertheless, few recent studies look at the effect BMD has on strategic stability. Stephen Cimbala and a bevy of authors from the Global Zero movement provide similar studies to the one that follows, but they draw different conclusions because they use different assumptions regarding Russia's modern nuclear doctrine and its deterrent requirements.

History of US BMD and Relations with Russia

In 2014, Keir Giles and Andrew Monaghan provided a detailed study showing the influence that US BMD developments, diplomatic errors, and changing policy over the last 60 years have had on Russia's view of US missile defense. They argued Russia's rejection of US missile defense plans and deployments is often "portrayed [by the West] as irrational, . . . technically flawed, . . . obstructive, . . . and . . . hopelessly out of date"; however, when considering the history of BMD in the US-Russia relationship and Russia's fundamental attachment to nuclear weapons, Moscow's behavior begins to make sense.[2] The basis of their argument is that Russia sees nuclear weapons differently, as the ultimate guarantor of its sovereignty and a symbol of its great power status; therefore, Moscow views any threat to these systems, including BMD, as existential. Because of this perspective, an inconsistent US BMD policy has strengthened Moscow's belief that BMD is aimed at Russia and has reinforced its distrust of nonbinding US declarations. While their report, written before the 2014 Russia-Ukraine crisis, takes a more optimistic view of the future than is likely valid today, it makes a compelling argument with numerous supporting examples to show how US BMD throughout its history has influenced Russia's perspective, anxieties, and reasons for opposing it. Giles and Monaghan's report provided important insight into Russia's current perspective, but it offered no direct link between US BMD and strategic stability.

US BMD and Strategic Stability

Nicholas Khoo and Reuben Steff's 2014 article concluded that near-peer nuclear powers will attempt to rebalance deterrence internally through improving arms and doctrine as the United States expands its BMD system. They provided significant evidence showing both Russia and China are developing new nuclear arms with BMD countermeasures to balance out their perception of an imbalance caused by US BMD advances. For example, Russia is in the middle of a "hard internal balancing" through a substantial upgrade program of its nuclear arsenal including a plethora of new missile systems to be deployed by 2020.[3] The authors use numerous Russian leadership statements, including from President Putin, to link these upgrades to US global BMD expansion because of the "inseparable link between BMD and strategic offensive weapons."[4]

Khoo and Steff's primary thesis of internal rebalancing is important in the debate over expanded missile defenses, and more importantly, it continues to appear valid. For example, President Putin's 1 March 2018 address to the Duma introduced multiple new nuclear weapon systems aimed at securing Russia's ability to strike the United States by circumventing missile defense, including nuclear-armed, nuclear-powered cruise missiles and underwater vehicles, a ballistic missile that can attack from the south, and a ballistic missile–launched hypersonic glide vehicle.[5] This study will further support this idea by showing that Russia realistically could perceive a degradation of strategic stability due to expanding US BMD.

US BMD with Minimum Deterrence Doctrine

In arguing for a reduced reliance on nuclear weapons, Bruce Blair, former Russian Strategic Rocket Forces Commander Victor Esin, and their coauthors assessed the impact on stability of large cuts to US and Russian nuclear deterrents when combined with a lowered alert level. Through a detailed statistical analysis, they assessed that both sides' nuclear forces can be heavily cut and mutually de-alerted without degrading stability, even in the presence of missile defense. The authors concluded in all scenarios that both sides retain enough surviving nuclear weapons in the event of a surprise attack "to retaliate in numbers that satisfy reasonable requirements of deterrence."[6] The authors offered a theory of minimum deterrence as their basis and contend that each side needs only 10 warhead impacts for stable deterrence.

Stephen Cimbala has written numerous articles discussing nuclear deterrence in the face of US missile defense in Europe, all based on his seminal book *Shield of Dreams* published in 2008. While each article is slightly different, he has consistently based his core premise on a standard of minimum deterrence, where the United States and Russia could reduce their nuclear forces down to levels below current treaty limits even in the face of a missile defense system and still maintain the ability to deter the other.[7] Because of the souring of US-Russian relations after the 2014 Crimea crisis, Cimbala began to acknowledge that there were other issues exacerbating the missile defense problem, including Western conventional superiority and cyberattacks before launch, but his premise ultimately remained unaltered.[8]

While Cimbala created a solid foundation for analysis of missile defense and nuclear deterrence, his analysis suffers from numerous weaknesses. First, he uses a very simplistic model of missile defense and does not consider the exact capabilities of the US BMD system or, more importantly, Russia's perception of those capabilities. He does this for simplicity, but it leads him to assess higher survival rates in some instances than Moscow might think it can achieve against a potential future US BMD system. While this may not have altered his ultimate conclusions because of his minimum deterrence assumption, the present study will show that a more realistic representation of the BMD system and Russian perceptions of BMD effectiveness may in fact degrade stability from Russia's perspective. This has two important parts to it. First, Russia overestimates US capabilities, which leads to unrealistic assessments of US missile defense. Second, and most important, Russia still maintains a doctrine of assured destruction in which it believes it needs to create a credible threat of unacceptable damage.

Cimbala and Blair and the others based their work on the assumption of minimum deterrence as a standard that could be acceptable to both sides. All supported a minimum deterrence sufficiency standard based on McGeorge Bundy's 1969 idea of a "disaster beyond history" in which only 10 warheads were to hit 10 cities.[9] From this standard these authors concluded that BMD was only destabilizing if it prevented all but a few warheads from impacting the United States; consequently, they argued that missile defense could not affect the US-Russia strategic balance because Russia's large nuclear force can easily overwhelm any BMD system and get some warheads on target. There are two faulty assumptions in these studies. First, as will be discussed later, changes in US law mean the US BMD system continues to grow unabated because of the advancing threat from nonpeer adversaries.

Their second assumption that Moscow accepts a minimum deterrence doctrine requiring only the threat of a few warheads on target is potentially more dangerous. Moscow retains a doctrine of unacceptable damage, known in the West as assured destruction, and as will be shown below, Russia's criterion is significantly higher than Bundy's standard of 10 warheads. When one considers the relatively recent history of Russia, specifically the over 20 million casualties it suffered during the Second World War, its idea of "disaster beyond history" is almost certainly different the West's. Bundy considers this amount of damage "unthinkable," but the Russians have suffered and survived that much damage within the last century. It would be reasonable for them to consider tens of millions of casualties a minimum necessity for deterrence. The present study will show that minimum deterrence is a faulty assumption because it ignores Moscow's post–Cold War requirement to achieve *unacceptable damage*, whether realistic or not, so it can maintain confidence in a credible deterrence against the United States. This faulty assumption in comparable studies results in potentially destabilizing conclusions.

Russian Deterrence and Perceptions

Importance of a Viable Nuclear Deterrent

At the highest level, the first goal of Russia's foreign policy activities as laid out in its *Foreign Policy Concept of the Russian Federation* from 2016 is to "ensure national security, sovereignty, and territorial integrity."[10] Moscow's *National Security Strategy* from 2015 claims it will use "interrelated political, military, military-technical, diplomatic, economic, informational, and other measures" to "ensure strategic deterrence," but it bases these other measures on the foundation of deterrence created by a sufficiently sized strategic nuclear offensive force kept constantly ready.[11] Despite its move toward nonnuclear and nonmilitary deterrence, according to Bruusgaard, Russia still believes it is inferior in conventional warfighting when compared to the US and NATO and views its nuclear deterrent as critical to its ability to defend its interests, prevent coercion, and protect its "great power" status.[12] While Russia is increasingly adding these nonnuclear and nonmilitary tools to its deterrence toolbox, its strategic nuclear deterrent underpins all its other conventional and nonmilitary deterrence activities. Because Russia relies on its nuclear deterrent for its sovereignty and security, any perceived degradation in the credibility of its nuclear forces presents an existential threat and may force it into increasingly desperate measures, such as preemptive nuclear escalation.

Russia's "Unacceptable Damage" Criterion

According to the Defense Intelligence Agency, Russia's military doctrine requires its armed forces to maintain the threat of "unacceptable damage on any adversary at any time" as a minimum standard to feel confident in its ability to deter adversaries.[13] A standard for unacceptable damage has historically been difficult to define because, to maintain sufficient ambiguity for deterrence, it cannot be negotiated. According to the Institute of World Economy and International Relations in Moscow, which is a part of the Russian Academy of Sciences, the vagueness of the term "unacceptable damage" and the variances within each state prevented any practical agreement on the meaning of this term, which left "rough parity of a retaliatory strike capability" as the only pragmatic deterrence criterion.[14] This idea was the basis behind the SALT and START series of arms control agreements, and it persisted through the Cold War. However, rough parity only worked because both sides maintained large nuclear arsenals and the ABM Treaty prevented defenses against a countervalue retaliation.

The DIA *Russia Military Power* report indicates the Russian military would "calculate" a value of unacceptable damage for each adversary, which suggests Moscow has an objective level of damage for each adversary that it feels it must achieve.[15] This criterion is known in multiple writings as either *unacceptable* or *restraining damage*, and this study will attempt to determine an objective definition that can be used to assess stability qualitatively in each of the future scenarios. Specifically, there are two references directly linked to the Russian General Staff that provide the basis for this study's objective definition of unacceptable damage.

Col Sergei G. Chekinov (retired) and Lt Gen Sergei A. Bogdanov (retired), both currently senior researchers in the Center for Military Strategic Research of the Russian General Staff (the equivalent to the US Joint Chiefs of Staff), contend in the Russian General Staff's *Military Thought* journal that Russia's strategic deterrent is provided by the "threat of unacceptable damage *being delivered to the adversary*" (emphasis added).[16] Kristen Ven Bruusgaard, a Russian expert and predoctoral fellow at the Center for International Security and Cooperation, adds that Russia's deterrent must be delivered to the "military-economic potential of the aggressor *in any conditions*" (emphasis added).[17] When calculating unacceptable damage, Moscow clearly considers the size of its force and the conditions in which it will be used, and this certainly includes the effects that US global BMD will have during a retaliatory strike.

To further the definition, Chekinov and Bogdanov define unacceptable damage through a "*criterion of strategic deterrence* (emphasis added)" as the "assured damage of a *measured* magnitude (emphasis added)" which is objectively unacceptable to the aggressor and its economy. They argue this damage includes the destruction of "fixed assets," the "loss of human life," and the time required for the adversary's economy to recover after the conflict.[18] Given the authors' association with the Russian General Staff, their claim that Russia has a measurable assured damage criterion to ensure it can deter its adversaries is likely credible.

In a second research paper from *Military Thought*, Col A. V. Radchuk (retired), an advisor to the Chief of the Russian General Staff, calculates a criterion of unacceptable damage based on damage to an economic system.[19] While it is 10 years old, this research provides a precise, post–Cold War Russian doctrinal definition of unacceptable damage. Colonel Radchuk's position at the time means his research likely influenced General Staff decision making. Large changes in doctrine do not occur quickly; therefore, this paper provides a good indicator of the type of damage Moscow desires to ensure its retaliation capability is a deterrent.

Radchuk uses economic models to determine a level he defines as "very grave damage" that would take "not less than 12 years" to repair. This damage results in the loss of "centralized national leadership" and leaves the economy in a "critical state" making it impossible for its military to engage in combat operations. He argues that a "reasonable adversary" such as the United States would consider that level of damage unacceptable and that it can be achieved by 25 percent damage to its production capacity.[20] Radchuk's definition fits the one by Chekinov and Bogdanov described above because it results in measurable damage to fixed assets (production capacity) and time for recovery of its economy ("not less than 12 years"). It follows that it would also result in the loss of human life. McNamara's famous requirement of 50 percent damage to the industrial potential and 20–25 percent casualties for assured destruction suggests that Colonel Radchuk's unacceptable damage requirement also equates to the destruction of approximately 12.5 percent of the population.[21] This 25 percent destroyed industrial capacity and 12.5 percent casualty rate is the damage requirement that Radchuk argues would deter the United States from taking aggressive action against Russia.

Twelve-and-a-half percent of the United States' 2018 population of 325 million is approximately 41 million. It is unclear whether the casualty rate as defined by Radchuk or McNamara is death rate or death and severe injuries, but as a part of the qualitative analysis, this study will consider both levels. To determine an approximate level of warhead impacts required to cause 12.5 percent casualties, this study used NukeMap.com, a nuclear detonation simulation hosted by the Stevens Institute of Technology.[22] This is a simple, widely recognized tool to determine nuclear effects based on standard, textbook calculations. For the purposes of this study, each of the city centers of the top 200 cities by population in the United States were hit with a nominal 200-kiloton warhead optimized for the destruction of buildings. From this, it was determined that Russia would need 167 warheads of this size to effect 12.5 percent (41 million) casualties (deaths and injuries).[23] Extrapolating from the 200 impacts, it would take at least 428 warhead impacts to cause 41 million deaths.[24] This estimation is certainly not scientific, and these casualties could likely be achieved with slightly fewer warheads. However, this calculation provided a simple, repeatable method to estimate the number of warheads needed, which is sufficient for this qualitative study.

Despite the limitations of this estimate, it likely represents a conservative estimate for the number of warheads needed to threaten unacceptable damage for several reasons. First, according to the *Bulletin of Atomic Scientists*, many of Russia's missiles likely carry warheads with less than 200-kiloton yield.[25] Second, Moscow will likely choose many targets to strike at the economy and industrial output rather than the population, and this will generally result in fewer casualties since industrial areas tend to be less densely populated than city centers. Finally, even in retaliation, Moscow would still probably target a large number of military facilities to prevent US reconstitution of forces. Since its missiles are preaimed, Russia would likely not know which warheads survive an initial US strike or penetrate US missile defenses. To ensure it can deliver enough warheads to adversary economic and population targets in any condition during a potential nuclear exchange, Russia must be confident that more than 167 warheads penetrate the US BMD system. The actual number is likely less than the 428 warheads required for 12.5 percent fatalities, so this gives us an upper and lower bound for unacceptable damage for the study's qualitative analysis. While on paper minimum deterrence is worth studying as a possible future framework for deterrence between the United States and Russia, Colonel Radchuk's study shows that it does not fit Moscow's post–Cold War thinking, which still follows an assured destruction doctrine. Therefore, minimum deterrence should not be used to determine how missile defense affects strategic stability as has been done in past studies.

Russia's Perceptions of US Capability

Moscow's conservative overestimation of US capability plays a major role in its perception of strategic instability caused by the US BMD system. Russia has an exaggerated view of not only what the current US capability is but also of what it might be in the future. According to Mikhail Tsypkin, a Russian military expert from the Naval Postgraduate School, the Russian government's ability to analyze foreign threats objectively is generally weak. He says for analysis of US missile defense capabilities, the Russian government relies on the military, which always presents the worst-case scenario to drive increased defense spending. More importantly, Russia has traditionally suffered from a concern of "relative economic backwardness" and of an exaggerated technological disadvantage relative to the West.[26] Last, Russians have a hard time believing that the United States has concerns other than Russia since the United States is the primary focus of Russian foreign policy.[27] These aspects drive Russia's fears of BMD's capability to degrade its deterrent along with its dogmatic belief that the United States aims its BMD system directly at the Russian nuclear deterrent, regardless of US claims to the contrary.

Dean Wilkening, in his study of whether US BMD in Europe threatens Russia, posits that Moscow may be concerned its BMD countermeasures are not effective. He argues that these concerns could stem from a fear that the countermeasure design engineers got it wrong or that the United States discovered some "subtle signature" that might allow US BMD to discriminate its decoys from the real warheads. Regardless, he says Russian political leaders likely have doubts because the debate is too complex and cannot be answered definitively, and the answer changes as both defensive and offensive systems evolve.[28] This doubt drives Moscow to want assurances that US defensive systems will not expand. Quite simply, it does not matter whether US BMD can realistically degrade the Russian deterrent, it only matters that Moscow cannot know for sure, and the stakes are too high to accept this uncertainty.

The Advancing Ballistic Missile Threat from Rogue States

Steven Lambakis, managing editor of the *Comparative Strategy* journal at the National Institute for Public Policy, notes, "There are no projections within the US Intelligence community showing a decline in the number of ballistic missiles in the world."[29] According to the Center for Strategic and International Studies' (CSIS) Missile Defense Project, nearly 30 countries maintain over 50 ballistic missile variants, and the threat continues to grow with little reason to believe it will plateau.[30] This has made it imperative that missile defense technology and capability outpaces the expanding ballistic missile threat, much of it from unfriendly nations. Unfortunately, this is proving to be a "Red Queen's race" (The Red Queen's race references a scene in Lewis Carroll's *Through the Looking Glass* in which the Red Queen and Alice are running but getting nowhere); according to CSIS, missile defense technology and capability development to date have not been funded well enough to keep up with an ever-expanding and evolving threat.[31] The long-range ballistic missile developments in North Korea and Iran over the last few years have been significant and have driven many of the missile defense changes and desired increases in capability that this study will examine.

In 2016 North Korea tripled its long-range ballistic missile launches over the year prior yet suffered significant setbacks particularly in its Musudan launches, most of which failed.[32] North Korea showed significant improvement in 2017 with six of its nine tests achieving some level of success.[33] Among these, it launched three successively larger missiles: the Hwasong-12, Hwasong-14, and the Hwasong-15, all which were previously unknown to the international community. Numerous experts including the CSIS Missile Defense Project suggest the Hwasong-15 is potentially a very capable intercontinental ballistic missile (ICBM) that could range the entire continental United States (CONUS) and may be able to carry BMD countermeasures or even multiple warheads.[34] North Korea is making great strides in its ability to strike CONUS, and this has been a significant impetus in US BMD development.

Iran has not yet developed intermediate-range ballistic missile or ICBM capability, but it maintains the most active development and diverse set of ballistic missile systems in the Middle East.[35] Additionally, it has designed and test flown two different space launch vehicles (SLV) that could potentially carry lethal payloads to CONUS or be used to develop ICBM technologies.[36] Finally, US withdrawal from the multi-party Joint Comprehensive Plan of Action nuclear deal could encourage Iran to pursue longer-range ballistic missiles based on technologies it has developed for its SLV. This Iranian threat is also a consideration in the development of the future US BMD system, particularly the European Phased Adaptive Approach (EPAA) Aegis Ashore sites in Romania and Poland.[37]

North Korea and Iran are currently the primary drivers behind the development of the US global BMD system. Nevertheless, other nuclear-armed nations that maintain ballistic missile programs, such as Pakistan, could become a consideration in the mid-term if they grow their current regional capability into a longer-range threat.[38] Ballistic missile proliferation has exploded over the last 20 years and further expansion can be expected over the next 20 if rogue nations continue to derive an asymmetric advantage in deploying these capabilities.

The Missile Defense Response

McNamara and the ABM Treaty

An understanding of the basis behind the ABM Treaty is necessary to contextualize US global missile defense changes over the last 20 years. Ideas for BMD have existed since the end of World War II, which even then incited debates about the balance between BMD and strategic stability. In the 1960s, Secretary of Defense Robert McNamara argued against expansive BMD deployments because he believed them to be fundamentally "destabilizing" in two ways. First, they would reduce arms race stability as each side raced to improve its capabilities and increase the size of its arsenal to overcome the other's defenses. Second, it would result in crisis instability because one side might perceive the development of an extensive BMD system as a "provocative act"—an indication that the other side was planning to launch a disarming first strike and use BMD to mop up residual retaliatory missiles.[39] Further, he maintained that if both sides had an unencumbered ability to strike the other with a large number of warheads, both sides would be deterred through the belief it could not achieve a disarming first strike, opening it to assured destruction from retaliation.

The ABM Treaty, which took effect in 1972, essentially codified McNamara's argument.[40] Its preamble maintains, "Effective measures to limit antiballistic missile systems would be a substantial factor in *curbing the race in strategic offensive arms* and would lead to a *decrease in the risk of outbreak of war involving nuclear weapons*" (emphasis added).[41] The subsequent 1974 Protocol restricted both sides to one protected area, either the nation's capital or an ICBM base.[42] This was stabilizing because a limited BMD system could protect retaliatory nuclear forces against a preemptive counterforce strike, while not allowing enough capability to affect the other side's presumably countervalue, assured destruction retaliation significantly.

The NMD Act of 1999 and the Fall of the ABM Treaty

In the late 1990s, the need for national missile defense outside the ABM Treaty's limits again became compelling because of the proliferation of long-range ballistic missile and nuclear weapon technologies among emerging threat countries, such as North Korea, Iran, and Iraq.[43] After a 1998 Taepodong 1 missile test in North Korea, the US government determined that it needed a national missile defense capability to defend against a limited attack using low-tech ballistic missiles.[44] These concerns prompted the passage of the National Missile Defense Act (NMD) of 1999, which called for "an *effective* National Missile Defense system" (emphasis added) that could defend the United States from a "*limited* ballistic missile attack (whether accidental, unauthorized, or deliberate)" (emphasis added).[45] The US subsequently withdrew from the ABM Treaty in June 2002, and in September 2004, the Missile Defense Agency (MDA) declared the ground-based midcourse defense (GMD) system operational. Despite limited testing success and modest growth of the threat since 2004, today it has grown to almost a dozen terrestrial sensors, 33 Aegis BMD ships, and 44 ground-based interceptors (GBI). However, the GBI's exo-atmospheric kill vehicle (EKV) still suffers from low reliability, and the current GBI inventory can only defend against a limited attack from a rogue state.[46]

ABM Treaty, Missile Defense, and the Link to Offensive Arms Treaties

One clear indicator of mutually recognized strategic stability is the ability to agree to arms control limitations. If both sides feel secure in their ability to prevent coercion and deter aggression, they will not fear the transparency and mutual reductions brought about by these agreements. As the United States continues to expand its global BMD system, one potential signpost of instability might be the inability to agree to future arms control limitations.

The signing of the ABM Treaty in 1972 demonstrated that both sides acknowledged a link between missile defense and strategic stability. Since then, Moscow has consistently argued that the ABM Treaty "is the cornerstone of strategic stability."[47] For example, in 2000 during the US ABM Treaty withdrawal debates, the Russian Minister of Foreign Affairs Igor Ivanov argued, "Strategic stability stemmed from mutual renunciation of strategic defensive systems." Further he insisted that all previous arms control agreements "rest on the ABM Treaty" and if "the foundation is destroyed, this interconnected system [of arms control agreements] will collapse."[48]

Between 1972 and 1993, the SALT I and II agreements, INF Treaty, and START Treaty were all enabled by the ABM Treaty's umbrella of defensive limitations. Despite a strong desire to reduce limits on deployed warheads because of fiscal restraints, Russia retracted support for START II in 2002 after the US withdrew from the ABM Treaty.[49] Moscow agreed to the Strategic Offensive Reductions Treaty only after the inclusion of a nonbinding joint declaration on missile defense cooperation.[50] Finally, Russia signed the NST in 2010 only after its concerns were satisfied by the addition of wording that recognized an "interrelationship between strategic offensive arms and strategic defensive arms" and "that this interrelationship will become more important as strategic nuclear arms are reduced."[51] For good measure, Moscow added a unilateral statement to the treaty asserting that it can withdraw if it believes a "qualitative and quantitative" expansion of the US BMD system threatens Russia's strategic nuclear force.[52]

This short history of US-Soviet/Russian arms control agreements demonstrates Russia's sincere belief in a direct link between strategic offensive and strategic defensive capabilities, and it has consistently held this stance since the signing of the ABM Treaty in 1972. Further agreements on reductions will be difficult for Moscow to accept if not directly connected to BMD limitations. Some have argued that this is political bluster;[53] however, this study will show that with a potentially reduced warhead limit in the future Russia could legitimately perceive degradation to its nuclear deterrence of the United States.

The Future of Global Missile Defense

The significant increases in capability in North Korea over the last few years drove changes to the NMD Act of 1999 as some saw an "urgent need for a fundamental review of US missile defense policy and capabilities."[54] During the debate over these changes in front of the House Armed Services Committee (HASC), however, counterarguments recommended the United States maintain a limited missile defense to preserve near-peer strategic stability.[55] Despite this advice, Congress voted for a change in NMD Act wording in the National Defense Authorization Act (NDAA) for FY 2017, which removed most missile defense limitations enacted by the NMD Act of 1999 and essentially directed an expanded US BMD capability. The new wording called for an "*effective*, *robust layered* missile defense system" to defend against a "*developing and increasingly complex* ballistic missile *threat*" (emphasis added).[56] (See table 1 for all changes.)

Table 1. Comparison of wording in NMD Act of 1999 and FY 2017 NDAA

NMD Act of 1999	NDAA for FY 2017
It is the policy of the United States to deploy as *soon as is technologically possible*	It is the policy of the United States to *maintain and* improve
an *effective* National Missile Defense system	an *effective, robust layered* missile defense system
capable of defending the *territory* of the United States	capable of defending the territory of the United States, *allies, deployed forces, and capabilities*
against *limited* ballistic missile *attack* (whether accidental, unauthorized, or deliberate)	against the *developing* and *increasingly complex* ballistic missile *threat*
with funding subject to the annual authorization of appropriations and the annual appropriation of funds for National Missile Defense	with funding subject to the annual authorization of appropriations and the annual appropriation of funds for National Missile Defense

Adapted from Thomas Karako, Ian Williams, and Wes Rumbaugh, *Missile Defense 2020: Next Steps for Defending the Homeland* (New York: Rowman & Littlefield, 2017), 4 (emphasis added).

The unmistakable intent of the original NMD Act was to defend a small attack from a rogue state or an accidental launch from Russia or China. On the basis of HASC testimony, Congress intended this new NMD wording to enable a more capable BMD system primarily to counter potential advances in the rogue-state threat. Yet, during debate on the new NMD wording, some influential lawmakers argued that the original NMD Act was written when "Russia was a peaceful partner" and a change was needed in part to combat the developments in Russia and China of "complex missile technology specifically designed to exploit our weaknesses."[57] Given the open nature of the debates, Moscow will have noticed that Congress enabled BMD expansion despite specific expert objections that this would degrade near-peer strategic stability. Additionally, the statements of those involved in authoring the NMD Act changes could lead Russia to interpret quite reasonably that the inclusion of "robust" and "layered" in the new NMD Act wording proved US intent to move beyond the original purpose and to target Russia's more complex nuclear deterrent rather than the relatively limited rogue-state capabilities.

Unconstrained by the NMD Act of 1999 and driven by sustained advances in North Korea, the FY 2018 NDAA further expanded US global BMD. It authorized deployment of 20 more GBIs, directed plans to increase to 104 total, mandated designation of a third interceptor site to further increase capacity, and requested development of space-based sensors to enhance discrimination and improve the system's overall capability. The law also directed investigation into two capabilities that Moscow has feared since Reagan's Strategic Defense Initiative of the 1980s: boost-phase intercept and a "space-based intercept layer."[58] Since these capabilities are relatively immune to advanced midcourse countermeasures and can destroy multiple warheads with one shot, Moscow would consider them a significant threat to its future nuclear deterrent, even if there were low near-term risks of deployment. The lack of a complex, rogue-state threat to drive these advancements will likely amplify Moscow's belief that these expansions are directed at its deterrent and will compel it to react accordingly.

While the NDAA clearly links these expansions to the North Korean threat, according to Thomas Karako from CSIS, the upcoming 2018 missile defense review will likely shift the focus toward near-peer threats, specifically their high-technology systems such as hypersonic boost-glide systems.[59] (In fact, the 2019 MDR indicates the US will pursue missile defense capabilities in response to rogue state threats.)[60] This is supported by testimony to the HASC by Under Secretary of Defense for Policy John Rood in April 2018, when he said that US missile defense "must address" these emerging capabilities from Russia and China.[61] Further, the DOD or US lawmakers could easily exploit the new NMD wording to demand additional future BMD expansion as a counter to increasingly complex rogue threats, potentially including countermeasures to missile defense and multiple reentry vehicle ICBMs. Viewed within the context of past BMD policy inconsistencies, this might lead Moscow to believe the US will continue to expand missile defense for the foreseeable future. Consequently, expansion without consideration of Russian concerns could lead to strategic instability as it inadvertently creates a BMD system capable of degrading Russia's nuclear deterrent, even within the next few decades.

According to a CSIS study, a future US BMD system could entail significant capacity and capability improvements.[62] A third GBI deployment site on the East Coast would potentially add 60 GBIs, and combined with a new GBI booster it would use the available interceptors more efficiently through a shoot-assess-shoot shot doctrine. If the US also expanded Fort Greely from its current 40 interceptors to its full capacity of 100, the total GBI capacity would then increase to 164. GBIs could be deployed with up to five multi-object kill vehicles (MOKV), allowing each interceptor to target multiple warheads. Additionally, MDA is already working to improve GBI reliability and design new land- and space-based sensors to improve threat warhead discrimination and kill assessment.[63]

The CSIS study also indicates shorter-range interceptors, such as the SM3-IIA, IIA follow-on, or an extended-range Terminal High Altitude Area Defense (THAAD) could provide a lower layer of ICBM defense, potentially including Aegis Ashore sites in CONUS.[64] MDA Director Lieutenant General Greaves said that MDA is evaluating whether the SM3-IIA can defend against an ICBM-class threat.[65] In his study of the Aegis threat to Russia's deterrent, Dean Wilkening determined that an SM3-IIB like system (IIA follow-on) in some scenarios could defend all of CONUS from a Russian missile strike using launch points off the East and West Coasts.[66]

Over the last few years, the United States has emphasized increasing the capability and capacity of the national BMD system to deter and defend against the increasing rogue threat. Despite the arguments to restrict future BMD expansion to prevent degrading strategic stability with Russia, the United States changed the legal basis for NMD and authorized the expansion of the BMD system. Given the current negative bilateral relationship and the history of inconsistent US BMD policies, it is not unreasonable nor should it be surprising that Russia might perceive this as a potential risk to its ability to deter the United States with a credible threat of "unacceptable damage." This is likely exacerbated by a Russian perception that the United States' economic superiority will allow it to afford continual advances to its missile defense system, while Moscow fears it is in a vulnerable financial state and that it will not be able to keep up the pace. Moscow is currently recapitalizing its nuclear forces, and it is likely developing countermeasures to the BMD threat of today and the predictable near future. Nevertheless, Moscow likely knows the countermeasures that Russia deploys today may not be useful against a BMD system in two decades. Can Moscow afford to recapitalize its nuclear forces as fast as the United States can deploy new BMD capabilities? This study will show that some proposed BMD systems could significantly degrade Russia's deterrent, particularly when combined with potential arms limitations.

Strategic Stability

Strategic stability has been the basis upon which both the United States and the Soviet Union or Russia formed decades of arms control. This study, like many before it, seeks to determine the effect that missile defense has on strategic stability and international relations in multiple scenarios. Unfortunately, there is no accepted standard definition of strategic stability, which will make it difficult to judge how BMDs affect the US-Russia relationship. This study's analysis requires a narrow definition that can be precisely applied.

A good place to start would be to look at Moscow's view of strategic stability. According to the Defense Intelligence Agency, Russia believes strategic stability is assured through the concept of deterrence. It defines strategic stability as "the sum total of political, economic, military, and other measures (e.g., force) retained by states in a stable balance whereby *neither side has the opportunity, interest, or intent to carry out military aggression*" (emphasis added).[67] Russia's concept of strategic stability is simple—no incentive to carry out aggression, and because this study is viewing missile defense through the Russian perspective, it is important that this concept is retained. However, this definition lacks the precision necessary for this study.

A RAND study of strategic stability with Russia suggested that strategic stability traditionally had two meanings: crisis stability based on "the incentives to use nuclear weapons first" and arms race stability based on "the incentives to build new nuclear weapons."[68] Edward Warner, the DOD representative to the NST talks, narrowed this more by saying that stability exists specifically when there is an absence of these incentives.[69] Splitting crisis and arms race stability provides a good basis for a usable definition, but this split lacks any link to motivations that might drive the instability. This study will be looking at specific crisis scenarios and assessing the effect of BMD on Russia's possible motivations for escalation. Motivation is critical.

Crisis Stability

Thomas Schelling's influential work *The Strategy of Conflict* best describes the motivation in a situation where two opponents lack trust in each other, by suggesting the fear to strike first is motivated by the fear of being struck first by one's adversary and being disarmed; therefore, a preemptive strike is needed to recapture the advantage.[70] James Acton, a senior associate in the Nuclear Policy Program at the Carnegie Endowment for International Peace, says Schelling provides this definition in his book *Arms and Influence* saying that crisis stability exists "if neither side has or perceives an incentive to use nuclear weapons first out of the fear that the other side is about to do so."[71]

Critically, unlike Warner, Schelling's definition allows stability to break down if one side only perceives an incentive to strike first even if it does not exist in reality. In addition to this, further motivation is given by the possibility of being disarmed by a first strike and not retaining enough force to deter the adversary credibly through assured destruction. This idea is key to the crisis stability definition that will be used by this study.

Finally, an important factor in crisis stability is the incentive to escalate. In addition to the incentive for preemptive nuclear attack previously discussed, the RAND study also includes "general incentives to escalate" in its definition of strategic stability.[72] Even if one side does not feel it must attack preemptively in a crisis scenario, in some situations it may still feel compelled by weakness to escalate to a less stable doctrine such as launch on warning (LOW) to preserve an ability to retaliate effectively. In September 1983, the Soviet early warning system falsely identified multiple incoming missiles, and if not for the individual actions of a Soviet officer ignoring his instruction, the situation would have spiraled into nuclear war on the basis of the Soviet LOW doctrine.[73] This story demonstrates the destabilizing nature of LOW, which is why it is important to include escalation of doctrine in the definition of strategic stability.

While Russia almost certainly retains a LOW doctrine, the Russian president and General Staff would be less likely to make this choice if they felt sufficient retaliatory capability could survive a first strike. However, the existence of a BMD system, for example, increases the threshold for sufficient retaliatory capability since Moscow will feel it requires more warheads to survive a first strike to overcome the effects of BMD. In general, any factor that creates an incentive for one side to escalate to a less stable doctrine or action can be considered destabilizing, even if it is below the level of a full-scale nuclear war. Combining Schelling's definition above with these incentives to escalate and the specific fear of being disarmed, for this study *crisis stability* means *neither side has or perceives an incentive to escalate the crisis because of an inferior strategic situation or to use nuclear weapons first out of fear of being disarmed by a first strike, thereby degrading credible deterrence.*

Arms Race Stability

The arms race stability definitions above are too broad because they also do not provide motivations that might drive instability. James Acton provides this motivation by suggesting that arms race instability is a manifestation of crisis instability but on a different timescale. He defines *arms race stability* as "the absence of perceived or actual incentives to augment a nuclear force—

qualitatively or quantitatively—out of the fear that in a crisis an opponent would gain a meaningful advantage by using nuclear weapons first."[74] His argument is that the adversary's "meaningful advantage" in a crisis if it struck first would pressure the other side to augment its nuclear force before such a crisis occurred to get back to level or to gain an advantage. The other side would then be compelled to react with its own force augmentation resulting in an unstable arms race. For the purposes of this study, Acton's definition of arms race stability is appropriate for the qualitative analysis of each scenario when used in combination with and as a manifestation of the crisis stability definition above.

Methodology/Explanation of Scenarios

Approach to Answering Research Question

This study applies the scenario planning framework to demonstrate that a potential expanded global BMD system, particularly when combined with future arms control limitations, could destabilize the US-Russia relationship and lead Moscow to believe its options would be limited in a crisis, forcing it into an arms race. Four potential Russian doctrinal responses within each of four future scenarios are used to show the effect of BMD on Russia's nuclear deterrent and the resultant pressure to escalate in some scenarios. The four future strategic scenarios are constructed using current and potential values of the two key factors: nuclear force size and BMD architecture. Each scenario uses a statistical model of the defined BMD system to provide a rough measure of BMD's effect on each crisis response. The results are then measured against Russia's criteria of "unacceptable damage" to determine whether Moscow will feel pressured to escalate a crisis preemptively (crisis instability) so it can ensure that it retains a credible deterrent. The study will then use these results to analyze the pressures on arms race stability felt by Russia based on its perceived imbalance in a potential future crisis.

Modeling Methodology

This study uses a statistical estimation of the number of warheads destroyed within each scenario. First, a US preemptive strike destroys a specific percentage of missiles depending on the Russian response doctrine modeled (covered in detail below). The remaining missiles and warheads are "launched," and the BMD system is statistically simulated using probability of kill to determine its total effect. First, GBIs are employed against the threat according to the specified shot doctrine for each scenario. If the GBIs used MOKVs in a scenario, it is assumed because of likely employment limitations that each GBI could only defend against one ICBM regardless of its number of warheads (multiple GBIs against one missile was allowed). Extra MOKVs beyond the number of warheads on that ICBM increase the chances of intercept. The second shot in a shoot-assess-shoot GBI shot doctrine is dependent on number of warheads remaining from the first missile. The specific doctrine is defined by "doctrine number," and if more than the doctrine number's warheads remain, a second GBI with MOKVs is shot. If no GBIs remain, if fewer warheads remain than the doctrine number allows, or if the defense is in Europe, SM-3s are fired using their shot doctrine as defined below. Finally, THAAD provides a third shot at the remaining warheads. While this THAAD doctrine may not be realistic, in the end, because of the limitations of THAAD, the warheads intercepted by it in all scenarios were a small fraction of the overall BMD success, and it is used only to represent a multilayered capability. The study optimized shot doctrine for each scenario, and all interceptor layers salvo until they run out of missiles.

To account for BMD system limitations and less than perfect performance, this study uses a simplified model from Dean Wilkening's foundational work "A Simple Model for Calculating Ballistic Missile Defense Effectiveness" to determine the overall probability that a specific single interceptor will intercept and destroy a single warhead (P_k).[75] This is his model:

$$P_k = P_{ww} \times P_k^*$$

P_k is equal to the probability that the interceptor would kill a warhead if perfect discrimination is assumed (P_k^*) multiplied by the probability that the warhead it is targeting is discriminated (P_{ww}) from the other objects such as missile stages, debris, and countermeasures by the BMD system.

This study assumed each interceptor attempt was statistically independent from the others; therefore, Wilkening defined the total probability of kill for an entire salvo (P_{ktotal}) using this equation:[76]

$$P_{ktotal} = 1-(1-P_k)^{Nint}$$

^{Nint} is the number of interceptors in the salvo. For MOKVs, each kill vehicle was treated statistically separately and therefore given NMOKV chances to kill the M warheads carried on the missile it was aiming at. Multiple GBIs increase NMOKV.

Some interceptors were modeled to cover only a portion of the territory to add further restrictions. Each interceptor type within each scenario specifies a percent area protected, which is the percent of the attacking warheads covered by that system. For example, a 20 percent coverage for the THAAD system in CONUS does not imply it covers 20 percent of the landmass of CONUS but that THAAD would protect 20 percent of the likely countervalue targets in CONUS. This is the same for targets in Europe. For all scenarios, it is assumed that Aegis Ashore and the Aegis ships deployed in the European theater could cover the entire European landmass from a Russian strike in these scenarios.

Accounting for Moscow's Perspective

The point of this exercise is to show Russia's perception of how BMD might degrade stability. Beyond using Moscow's assured destruction criteria in the analysis, the statistical model used must account for Russia's exaggerated assessment of US BMD capabilities. For its purposes of determining the balance of strategic stability, Moscow will generally have to assume worst-case scenario in a retaliatory strike situation. These scenarios, therefore, are almost certainly not representative of the current or future US BMD capabilities but are intended to represent Moscow's realistic but almost certainly overestimated worst-case fears of the current BMD capability. Russia's belief in US technological superiority gives it exaggerated respect for America's capabilities,[77] and any open reporting by the US of BMD's unreliability actually may solidify this view because Russia believes that everything is propaganda aimed at disinformation.[78] Either way, the proposed BMD system below will almost certainly be more capable than the real system, and this serves two purposes. First, it allows a conservative estimate of Russia's fears, and second, it provides bounding cases to allow diagnostic analysis.

Scenario Key Drivers

Missile Defense

Current BMD scenario. The current US BMD system provides a realistic low-end US BMD capability while the scenario also acknowledges Russia's overestimation of US capabilities (kill probability and discrimination). This scenario provides a relatively conservative foundation from which this study can qualitatively diagnose how Russia views BMD's effect on strategic stability. Accordingly, it uses force deployments that Russia might assume during increased tensions, such as Aegis ships, at each coast to defend CONUS as a last-ditch defense against a massed strike. Table 2 shows the BMD order of battle for this scenario. More detail is available in appendix A.

Table 2. Current US BMD order of battle for scenario

System	Total number of missiles	Kill vehicles per missile
GBI	44	1
Aegis (US, ship-based)	200	1
Aegis (EPAA)	110	1
THAAD (CONUS)	0	1
THAAD (Europe only)	96	1

Table 3 gives the current BMD performance capability for each system concerning its kill probability, shot doctrine, salvo size, and protected area as described in the methodology above. The existing NMD system does not allow for a shoot-assess-shoot doctrine because of booster limitations;[79] therefore, all systems use a salvo firing doctrine with the salvo size listed in table 3 and cannot re-attack if initially unsuccessful. Consequently, SM-3 interceptors in CONUS are not used until the GBIs are exhausted. See appendix A for a more detailed explanation of these values.

Table 3. Current BMD scenario—US BMD capability and doctrine

System	Doctrine number	P_k*	P_{ww}	P_k	Firing doctrine	Salvo size	% Area protected
GBI	1	0.8	0.5	0.4	shoot-shoot-assess	2	100
Aegis (US, ship-based)	N/A	0.3	0.5	0.15	shoot-shoot-assess	2	20
Aegis (EPAA)	N/A	0.8	0.5	0.4	shoot-shoot-assess	2	100
THAAD (CONUS)	N/A	0.3	0.5	0.15	shoot-shoot-assess	2	20
THAAD (Europe only)	N/A	0.8	0.5	0.4	shoot-shoot-assess	3	20

P_k*—Single missile probability of kill with perfect discrimination.
P_{ww}—Probability the warhead will be discriminated.
P_k—Overall single missile probability of kill for the system including the probability of discrimination.
% Area protected—Percent of warheads likely to land in the defended area

Future BMD Scenario. The future "robust, layered" BMD system called for in the 2016 NDAA is difficult to predict accurately because it will be dependent on the evolution of the rogue-state threat, the development of necessary technologies, and funding to acquire and deploy these systems. This future scenario describes a notional robust, layered BMD system based on proposed and relatively realistic future capabilities that the United States could deploy to counter an increased rogue-state threat if given the resources. More importantly, this scenario represents Russian worst-case fears of an unlimited expansion of US global BMD, which Moscow believes in its exaggerated view that the United States could deploy in the period over which it is planning its next generation of deterrent systems. Russia deployed some of its oldest ICBMs almost 40 years ago, and because Moscow is more financially limited than the United States, Russia likely believes it cannot adjust its deterrent fast enough to keep up with US BMD expansion.[80] Therefore, it would be reasonable for Moscow to consider the BMD threat 20 or more years into the future as it designs and develops its next-generation deterrent. Finally, this scenario provides a diagnostic upper bound, allowing qualitative analysis of the potential effect of a future robust, layered BMD system on strategic stability.

This BMD scenario by no means includes all possible capabilities or unpredictable technological breakthroughs. It leaves out some capabilities proposed in the 2018 NDAA such as boost-phased intercept or space-based interceptors because these are less likely and more difficult to evaluate. However, the study will discuss these potential capabilities as qualitative excursions in the analysis section.

This scenario bases its future BMD system on many of the capabilities as discussed in the *Missile Defense 2020* study that Russia will reasonably expect the US to deploy in the next 20 years while it determines its future deterrent needs. This system will consist of three layers. The upper layer protecting CONUS consists of a full complement of 164 GBIs, each deployed with five MOKVs at one of the three proposed US deployment locations.[81] A second overlapping layer consists of both Aegis ships and Aegis Ashore sites in CONUS with SM-3 IIB-class interceptors, and Aegis forms the upper layer in Europe using SM-3 IIA missiles. While the US canceled development of the SM-3 Block IIB interceptor in 2013, Moscow still has concerns, and it will likely make decisions on its future force with a similar capability in mind.[82] Finally, the lowest layer for this scenario consists of THAAD and THAAD-extended range (THAAD-ER) to provide an increased defense of both CONUS and Europe in the terminal phase against ICBMs.[83] The overall order of battle for the future BMD scenario is below in table 4. Table 5 shows the performance characteristics of the future BMD system. Appendix B gives a more detailed breakdown of this scenario's BMD system.

Table 4. Future BMD scenario order of battle

System	Total number of missiles	KVs per missile
GBI	164	5
Aegis (US, ship-based)	602	1
Aegis (EPAA)	253	1
THAAD (CONUS)	288	1
THAAD (Europe only)	144	1

Table 5. Future BMD scenario—US BMD capability and doctrine

System	Doctrine number	P_k*	P_{ww}	P_k	Firing doctrine	Salvo size	% Area protected
GBI	1	0.8	0.75	0.6	shoot-assess-shoot	2	100
Aegis (US, ship-based)	N/A	0.5	0.75	0.375	shoot-shoot-assess	2	100
Aegis (EPAA)	N/A	0.8	0.75	0.6	shoot-shoot-assess	2	100
THAAD (CONUS)	N/A	0.5	0.75	0.375	shoot-shoot-assess	2	20
THAAD (Europe only)	N/A	0.8	0.75	0.6	shoot-shoot-assess	2	20

P_k* - Single missile probability of kill with perfect discrimination.
P_{ww}—Probability the warhead will be discriminated.
P_k—Overall single missile probability of kill for the system including the probability of discrimination.
% Area protected—Percent of warheads likely to land in the defended area

Nuclear Force Size

Current New START treaty-limited Russian nuclear force. This study uses two different Russian nuclear force sizes to show the effect of BMD as future arms control agreements reduce both sides' nuclear forces. One scenario assumes the Russian nuclear deterrent stays approximately the same size it is today—limited in both launchers and warheads by the NST. The other represents a hypothetical future arms-control reduced nuclear deterrent.

For the two current, NST-limited nuclear force size scenarios, this study uses the Russian nuclear ballistic missile force structure from the *Bulletin of Atomic Scientists*' "Russian Nuclear Forces, 2017" listed in appendix C as its basis.[84] For consistency between the current and future scenarios, newer systems replaced any remaining Soviet systems as expected by DIA (see appendix C).[85] A treaty-compliant force with fewer than 1,550 total warheads was constructed by proportionally reducing the warheads on each missile. For qualitative analysis, it is only necessary that the scenario roughly represents the current and future Russian nuclear deterrent; the details are not important. Table 6 gives the Russian ballistic missile order of battle used in this scenario. Appendix C gives an extended explanation of the development of each scenario.

Table 6. Current scenario Russian ICBM and SLBM order of battle

Missile type	Warheads per missile	Missiles deployed	Total warheads	Yield
Silo ICBMs				
SS-18 Mod 5/Sarmat	7	46	322	800
SS-27 Mod 1	1	60	60	800
SS-27 Mod 2	3	30	90	100
Road-Mobile ICBMs				
SS-27 Mod 1	1	18	18	800
SS-27 Mod 2	3	117	351	100
SS-28	3	45	135	100
SLBMs				
SS-N-23	3	80	240	100
SS-N-32	4	80	320	100
Totals		476	1,536	

Future treaty-limited Russian nuclear force. It is outside the scope of this project to predict the size or capability of a notional future treaty-limited Russian nuclear force, and given the variables involved, this would be difficult. Nevertheless, this scenario uses a hypothetical, reduced-size, 1,000-warhead Russian nuclear force to diagnose BMD's effect on strategic stability when facing a smaller nuclear deterrent.

The most stable situation would be if the number of warheads deployed on each missile was reduced while keeping the number of missiles the same. This results in the most first-strike targets for the United States with the lowest payoff for each missile destroyed, which increases strategic stability by improving the overall survivability of the Russian force. For these reasons, the future scenario assumes the same number of missiles while reducing the limit of deployed nuclear warheads to 1,000 from the 1,550 currently allowed. This scenario design minimizes all other destabilizing effects so the analysis can more precisely highlight the specific destabilizing effects of expanding BMD. Therefore, the change in warhead numbers, in this case, is the best-case scenario for strategic stability before including any other factors. Table 7 provides the Russian order of battle used for the future treaty-limited scenarios. Appendix C details the methodology used to reduce the warhead numbers from the current scenario.

Table 7. Future scenario Russian ICBM and SLBM order of battle

Missile Type	Warheads per missile	Missiles deployed	Total warheads	Yield
Silo Missiles				
SS-18 Mod 5/Sarmat	3	46	138	800
SS-27 Mod 1	1	60	60	800
SS-27 Mod 2	2	30	60	100
Road-Mobile Missiles				
SS-27 Mod 1	1	18	18	800
SS-27 Mod 2	2	117	234	100
SS-28	2	45	90	100
SLBMs				
SS-N-23	2	80	160	100
SS-N-32	2	80	160	100
Totals		476	920	

General use of Russia's nuclear forces. For the purposes of the simulation, this study assumes that most Russian retaliatory missiles would target CONUS. However, Moscow would want to hold at risk some targets in Europe as well, especially when considering Russia's concerns about NATO's dualcapable aircraft, the other NATO nuclear powers of the United Kingdom and France, and the general need to deter NATO from further conventional action. According to DIA, the RS-26 (SS-28) is smaller than the SS-27 Mod 2.[86] Additionally the NASIC *Ballistic and Cruise Missile Threat* document quoted the Russian press, which says the SS-28 is "lighter and, consequently, has shorter range" than the SS-27.[87] Therefore, this study assumes that the 45 SS-28 missiles will cover only the shorter-range targets in Europe while the rest of the ICBMs and SLBMs will target CONUS.

Crisis Response Doctrines

To show the instability and escalation pressure caused by BMD, this study considers four increasingly escalatory Russian response doctrines within each of the four scenarios described previously. The study will use the results of an exchange during each of these responses to show how an expanded missile defense system is destabilizing. The analysis will show that Moscow at some point, with no other changes to the strategic situation, will be pressured to choose a less stable doctrine to ensure it can achieve its desired "unacceptable damage" criterion in the face of a robust US BMD system. Therefore, the exact survival rates are less important than the relative effect that a first strike will have on the warheads Moscow has available for retaliation.

The results of a US first strike for each of the response doctrines is based on Stephen Cimbala's research work with minor alterations to account for the change in force size since the time he did most of his work. Dr. Cimbala used a higher fidelity model for his work, but analyzing a full nuclear exchange is beyond the scope of this study, so this research will use his survival percentages to account for Russian nuclear forces lost during a US first strike in each of the four responses. Dr. Cimbala used these exchanges in multiple studies over the last few years; however, because of the volume of data presented, the survival rates could only be derived from his seminal work *Shield of Dreams* published in 2008.[88] Table 8 gives these survival rates.

Table 8. Russian nuclear force percent survival rates based on Dr. Stephen Cimbala's research

Crisis response	Silo ICBM	Mobile ICBM	SLBM
Full Preemptive strike	100	100	100
Force generated with LOW	90	90	80
Force generated, ride-out-attack	10	50	80
Day-to-day alert, ride-out-attack	10	10	10

ICBM—intercontinental ballistic missile
SLBM—submarine-launched ballistic missile
LOW—launch on warning
Adapted from Stephen J. Cimbala, *Shield of Dreams* (Annapolis, MD: Naval Institute Press, 2008).

Retaliatory strike—nongenerated force. The first and least likely response option is a retaliatory strike after a US "bolt-from-the-blue" strike. In this response scenario, a majority of the Russian strategic forces ride out a surprise US first strike while not on wartime alert and not away from garrison. While not realistic, this scenario provides a worst-case scenario from which Moscow likely derives a significant amount of its doctrine and force size requirements.

Retaliatory strike with a generated force. In this second response doctrine, most of Russia's nuclear missile forces are on alert, generated, and ready to fire, and they retaliate after riding out a US first strike. A significant portion of the mobile ICBMs are away from garrison for survivability. Most of the ballistic missile submarines (nuclear-powered) (SSBN) with their SLBM complement are on patrol allowing 80 percent survivability; however, the United States can still target and destroy half the road-mobile force. Moscow would have to account for a relatively high loss rate for these systems given their relative overtness and vulnerability to a nuclear blast. This doctrine represents a relatively stable strategic situation if it can be maintained since it provides a relatively overt show of nuclear readiness but does not rely on the hair-trigger situation that is LOW.

Retaliatory strike—launch-on-warning. In the third response doctrine, almost all Russia's nuclear forces are on alert, generated, and deployed to the field or on patrol like in the previous response doctrine, but Moscow decides to launch its missiles immediately upon warning of an incoming US nuclear strike. Based on table 8, this response doctrine results in a robust Russian retaliation with an 80- to 90-percent survivability for all of Russia's nuclear forces. This response option is destabilizing because it relies on quick recognition of an incoming strike and a rapid decision to counter without the time to understand the situation fully. Forces standing on launch-on-warning are in an unstable situation.

Full Russian preemptive strike. The final response doctrine is a Russian preemptive strike on the United States. It would choose to do this only if Moscow believes it is about to be struck first by US forces and that this first strike would degrade its forces to the extent that it could not achieve punitive damage against the United States and NATO. In this preemptive strike response doctrine, Moscow would launch all available nuclear forces against the United States and NATO.

Analysis of Scenario Results

Scenario A: New START Treaty-Limited Nuclear Force vs. Current US BMD

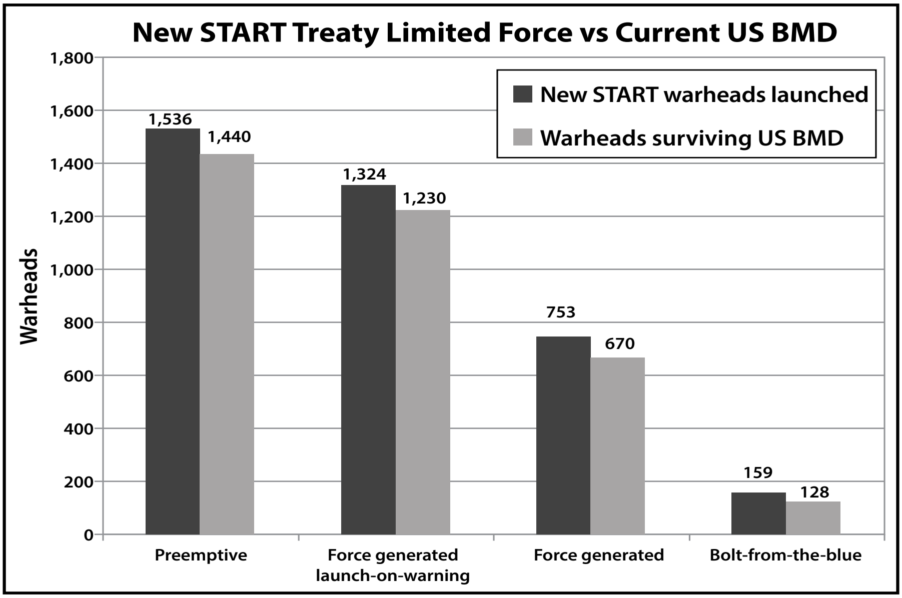

Figure 1. Number of Russian warheads to survive to impact for various types of US threats

The current BMD and NST-limited nuclear force size scenarios represent the current strategic balance between the United States and Russia. Except for the bolt-from-the-blue retaliation, a nuclear exchange against US BMD still results in Russia achieving its desired threat of unacceptable damage, regardless of the damage criterion used. In those three cases, around 90 percent of the warheads launched penetrate the BMD system, with a minimum of 670 warheads penetrating defenses in the force-generated, ride-out-attack doctrine (see figure 1).

In a US bolt-from-the blue strike, Moscow may not achieve its desired damage level with only 128 warheads hitting targets. While missile defense could tip the balance in Russia's ability to achieve its damage requirement with this response, this result has little to do with BMD as over 80 percent of the warheads launched still penetrate the defenses. If Russia feels compelled to escalate to a continually generated force, it is due primarily to the vulnerability of its strategic forces. Even considering Russia's overestimation of US BMD capability, it is fair to say that Moscow may in fact believe the strategic balance is currently stable. Consequently, missile defense does not significantly alter the strategic stability situation between the United States and Russia in this scenario.

Scenario B: New START Treaty-Limited Nuclear Force vs. Future US BMD

A future US BMD system presents a challenging situation for strategic stability even in a scenario where Russia retains its current NST-limited nuclear force size. Moscow would have legitimate concerns with respect to the number of warheads that could penetrate BMD. In the two response doctrines requiring Russia's missiles to ride out a US first strike, the results show that Moscow could not achieve its desired damage criterion, with at most 110 warheads penetrating US defenses (see figure 2). With the uncertainties inherent in this analysis, Moscow may feel it can retain enough threat to deter the United States even when riding out the attack. Nevertheless, Moscow's inflated perceptions of US BMD might also lead it to believe fewer warheads would penetrate to achieve its desired effects. Regardless, Moscow would certainly not believe the 11 penetrating warheads in the day-to-day alert doctrine would provide sufficient deterrence.

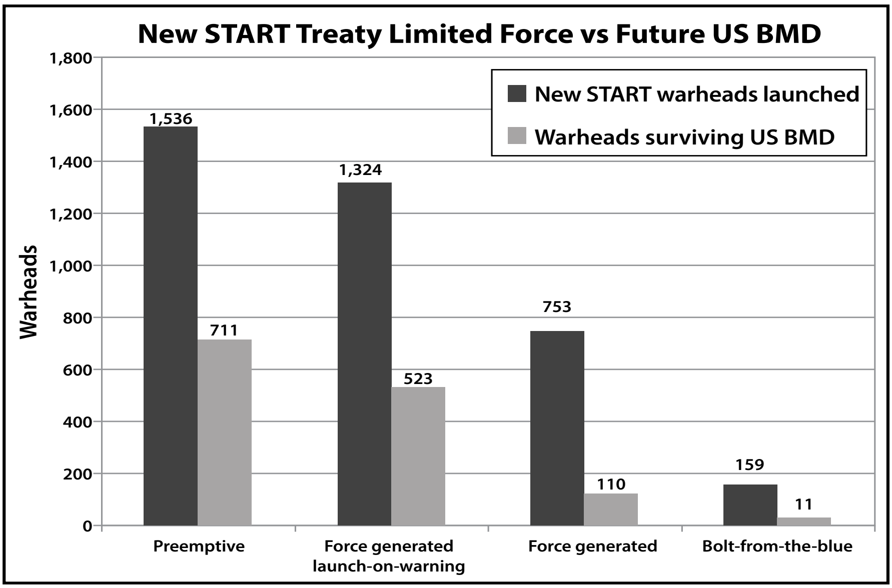

Figure 2. This graph illustrates Russia's perceived inability to inflict desired damage if the US proceeds with enhanced BMD development.

Unlike the previous scenario, missile defense plays a key role in these results. Russia would expect to create unacceptable damage in a retaliatory strike with the 753 warheads that survive a US first strike; however, the future US BMD system would subsequently defeat 85 percent of the surviving warheads, preventing Moscow from achieving its desired effects. In this case, Moscow would be compelled to escalate to a less stable, continually force-generated, launch-on-warning doctrine to ensure a credible threat of unacceptable damage. In this scenario, the future expanded US BMD system is crisis destabilizing because it places Russia in an inferior strategic situation relative to the current BMD system and gives Moscow an incentive to escalate.

Scenario C: Future Treaty-Limited Nuclear Force vs. Current US BMD

This scenario represents a future in which the US BMD system has not grown but both sides have agreed to further arms reductions. As with the larger NST-limited nuclear force, the current US BMD system in this scenario has only a marginal effect. Unlike the first scenario, the force-generated doctrine in this scenario results in borderline unacceptable damage capability with fewer than 390 warheads surviving to targets (see figure 3). BMD reduces the penetrating warheads under the 428-warhead upper end of the unacceptable damage spectrum described earlier despite the launch of a sufficient 456 warheads. Even though US BMD destroys less than 15 percent of Russia's launched warheads, the uncertainties in this study suggest this doctrine could result in marginal Russian confidence in its deterrence performance and, therefore, a less stable response doctrine.

The nongenerated force doctrine with only 69 warheads penetrating BMD after a US first strike would certainly not allow Russia to achieve its desired deterrence effect. This scenario leaves little allowance for the uncertainties in Russian perceptions involved in this study, and it shows that future nuclear reductions would shrink Russia's nuclear capacity enough that it might not believe it has any remaining margin to achieve its unacceptable damage criterion even against today's US BMD system. Nevertheless, the primary cause of instability is the US first strike, and the current BMD system plays only a marginal role in affecting the strategic balance. It would not be surprising if Russia, under future arms limitations, reduced the number of vulnerable silo-based missiles and continuously maintained its nuclear forces generated and on alert to ensure first-strike survivability. Even a relatively small increase in US BMD capability in this scenario could incentivize Russian escalation to a LOW doctrine and potentially result in Russian fears of crisis instability.

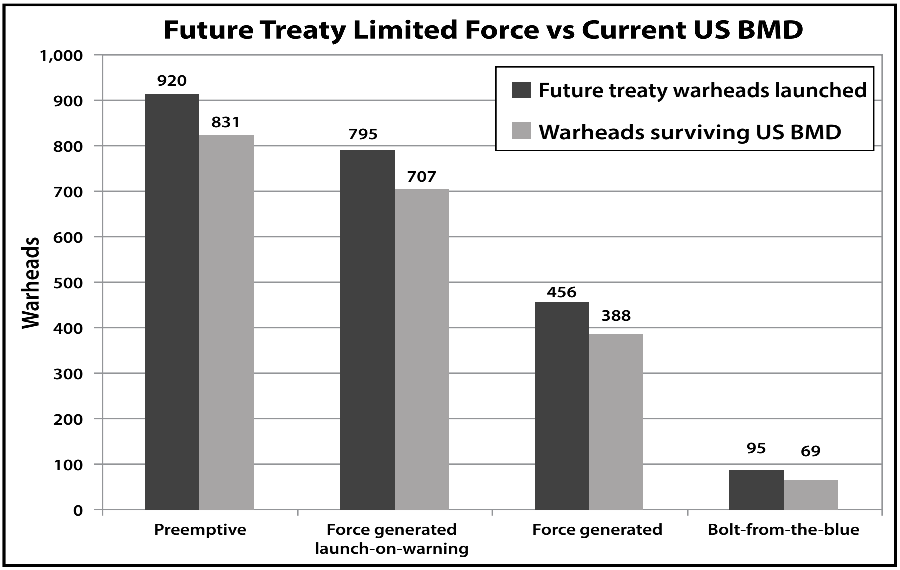

Figure 3. Shows that this scenario might result in a relatively low survivability of Russian warheads launched in this scenario

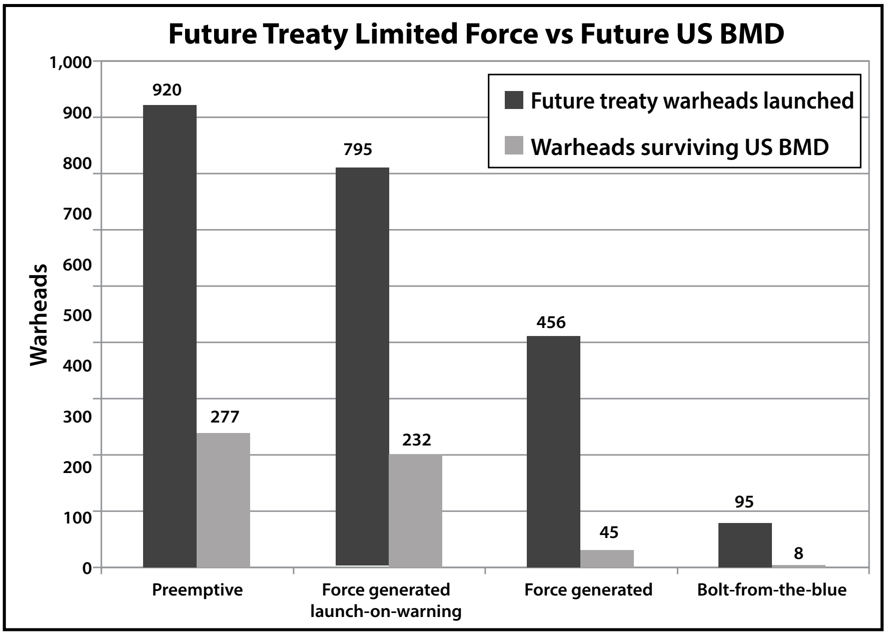

Figure 4. Indicates the likely low survivability of Russian warheads vs. US defenses in this scenario

Scenario D: Future Treaty-Limited Nuclear Force vs. Future US BMD

The scenario of a future treaty-limited Russian nuclear force against a potentially expanded US global BMD system provides a bounding case for diagnosing BMD's effect on strategic (see figure 4) stability. The results are a worst-case scenario for Moscow and substantiate that unlimited expansion of the US BMD system could destabilize strategic stability especially when combined with future reduced treaty limitations. In this scenario, even a Russian preemptive strike only marginally achieves assured destruction based on the study's unacceptable damage criteria spectrum established earlier, with only 277 warheads penetrating the expanded BMD. The 920 and 795 warheads launched in the two least stable doctrines would no doubt give Moscow confidence it can threaten unacceptable damage in these responses; however, in both scenarios, the future BMD system defeats 70 percent of the warheads launched.

The number of penetrating warheads in the two doctrines requiring Russia to ride out a US first strike falls short of the desired damage criterion by a significant margin. With fewer than 50 penetrating warheads in both responses, BMD is responsible for mopping up over 90 percent of the surviving warheads. Even when considering the study's uncertainties, there is little doubt that BMD incentivizes Russia to escalate to a launch-on-warning doctrine at a minimum, so it can achieve unacceptable retaliatory damage, but even this result is marginal.

Moscow's own uncertainty in its forces' survivability and US BMD capability, in this case, may lead to a decision that LOW will not suffice. This may incentivize a further escalation to a preemptive strike, particularly using its most vulnerable silo-based missiles to reduce the United States' ability to carry out an anticipated disarming first strike. BMD in this scenario is undoubtedly destabilizing. Its effects would compel Russia to escalate the crisis and possibly use nuclear weapons first out of fear that it could not credibly deter a US first strike with unacceptable damage because of a perceived inferior strategic situation.

Discussion of Results

Analysis of Crisis Stability

The previous section's results confirm suggestions from a majority of analysts that even in Russia's perception, the current US BMD system is unlikely to offer any significant detrimental capability against Russia's deterrent, except at the margins, and this is likely not what Moscow fears. Nonetheless, it is apparent that Russia could legitimately perceive future unlimited expansion of US BMD as destabilizing in a crisis scenario even when restricted only to currently discussed plans. In both future BMD scenarios presented (scenarios B and D), Russia could reasonably feel compelled to escalate into a launch-on-warning doctrine or higher to protect its ability to threaten credibly the unacceptable damage criterion it believes it needs to deter the United States and NATO. In the future BMD scenario with the future treaty-reduced nuclear arms (scenario D), it may even fear US defenses will neuter its ability to preemptively strike so much that it cannot effectually protect itself from a US first strike and still hold weapons in reserve as a further deterrent. While this study is relatively imprecise, most of the results showing destabilizing effects have large margins to account for these inherent uncertainties. Some effort will be made below to account for the effects of some of these uncertainties. It would not be surprising, then, if Moscow is indeed leery of future US BMD expansion plans or of further treaty limitations without accompanying treaty restrictions on strategic defense.

Other Missile Defeat Capabilities

The scenarios analyzed in this study did not include all potential missile defense or defeat capabilities, partly because they would have been difficult to evaluate with little specific data available. Congress has requested the Defense Department study numerous other missile defeat capabilities to counter rogue and regional threats including nonkinetic prelaunch missile defeat, boost-phase intercept, and space-based interceptors.[89] The US is developing new technologies to improve regional terminal defense, such as rail-guns and hypervelocity projectiles.[90] Additionally, Moscow fears that the increased deployments and capability of US long-range conventional strike systems could destroy Russia's nuclear forces before launch, further aggravating its fears that it will not be able to deter the United States.[91] Regardless of actual US intentions, if the United States chose to attempt to defend against Russian nuclear forces in a future crisis, these capabilities would certainly achieve some level of effectiveness. Combined with an expanded BMD system, these new capabilities could serve to (1) reduce the number of Russian missiles and warheads launched, (2) destroy significantly more warheads as multi-warhead missiles are destroyed during boost, and (3) serve as an earlier BMD layer to reduce the number of warheads that the ground-based midcourse and terminal defenses would have to defeat. None of these potential capabilities alone are likely to be a panacea resulting in absolute defense from a Russian massed nuclear strike. However, if used together and/or combined with expanded ground-based defenses, they could ultimately result in fewer launched and penetrating warheads in all the crisis responses studied above, further preventing Russia from achieving its desired damage criterion and reducing crisis stability.

Accounting for Uncertainties

Predicting the future is inherently an uncertain endeavor, and this analysis is no different. The ability of a future BMD system to discriminate warhead and countermeasures is difficult to predict, as is the likely probability of kill for a particular interceptor of the future. An entire study could focus on the uncertainties in the analysis completed here, but this section will attempt to provide a brief insight into how the major uncertainties would generally affect the outcome.

If future warhead discrimination or interceptor probability of kill were improved, it would exacerbate the already tenuous strategic situation in some scenarios and make the unstable scenarios even less stable. Some response doctrines that were previously stable may degrade to marginally stable, and other marginal response doctrines would become unstable; however, the overall trend would not change. It is more likely that the discrimination and probability of kill values were overestimated. If so, the analysis presented above represents the bounding scenarios, and the results would fall somewhere between the current and future BMD scenarios.

As a brief example, if the study increased the THAAD and SM-3 probability of kill (Pk) to 80 percent (from 50 percent) for defense of CONUS, it would result in a significant decrease in surviving Russian warheads in the future BMD scenarios. This would halve the surviving warheads (22 versus 45) in a force-generated, ride-out-attack response for the future treaty-limited scenario (scenario D) above. Worse, the marginally stable launch-on warning response in this future scenario would result in too few surviving warheads (162) for Russia to achieve its minimum desired damage criterion of 167 warheads. Finally, a Russian preemptive strike becomes even more marginal than in scenario D above and almost untenable under the potential limitations of a future treaty. This change in probability of kill is certainly not outside the capabilities of the United States to field in the future, and it shows how the inherent uncertainties in predicting the future could further exacerbate the instability caused by future US BMD expansion.

Russia's Air Leg of the Triad

This study focuses primarily on ballistic missile defense; consequently, the analysis has thus far ignored the air leg of Russia's nuclear triad. One method to bolster Russia's strategic position would be to enhance the air leg of its triad, which there is evidence it is doing with new production of the Tu-160M2 and development of the PAK-DA stealth bomber.[92] Nevertheless, it is unclear whether Moscow can afford these new aircraft or if it would ever comfortably rely on the air leg of its triad to mitigate the loss of assured damage through its ballistic missile forces. Additionally, these aircraft are more vulnerable in a US preemptive strike than its ballistic missile forces, even if Moscow has generated its forces. That said, in a launch-on-warning scenario, aircraft can be recalled if necessary, increasing the stability of that response doctrine.

Consequences for Arms Race Stability

The potential inability of Russia to deter the United States in a future scenario without escalating a crisis will force Moscow to re-evaluate its nuclear deterrent capabilities. It will seek to develop new capabilities to better penetrate, circumvent, or target the US BMD system so that it can restore its ability to deter the United States with a credible threat. Before a crisis erupts, this crisis instability will manifest itself in arms race instability over the long term.

In March 2018, President Putin announced the development of numerous asymmetric nuclear delivery systems designed to circumvent missile defense.[93] While it is not certain that Russia will ever deploy these weapons, their development signals Moscow's discomfort with the potential future strategic situation. Russia would not spend its increasingly constrained resources to develop these asymmetric capabilities if it truly felt that the future situation was secure. Still, it is doubtful that Russia is developing these weapons to counter current US defenses. Even conservatively, as shown in the analysis above, the current US BMD system is not a threat to crisis stability. Additionally, it will be years before Russia can deploy many of these systems, so they are likely intended to counter a future US BMD system. The development of these new systems should serve as a clear warning that US BMD has in fact degraded arms race stability and that Russian BMD concerns are legitimate. Unfortunately, US lawmakers have not received this message and have demanded that the Defense Department develop defenses to counter some of these asymmetric threats.[94] If the US continues to pursue similar counters to these new asymmetric nuclear capabilities, it will again risk destabilizing the situation and lead to further balancing and nuclear arms development efforts by Moscow.

Consequences for Future Arms Limitations Treaties

The result that becomes clear from this analysis is that a future arms control treaty exacerbates the strategic instability caused by a future BMD system and that future treaty reductions focused only on offensive weapons will no longer work. As seen in the earlier results, even the current US BMD system combined with a future treaty-reduced nuclear arms limit (scenario C) shows only marginal stability. Russia has likely come to a similar conclusion as this study, that BMD combined with future arms reductions is a recipe for strategic instability.

Russia has continually argued since 1972 that limits on strategic defensive arms are a critical foundation to offensive arms limitations. In fact, the last two treaties (SORT and New START) required explicit statements acknowledging that BMD was a critical factor in stability and that future expansion could cause instability as a condition of agreement. Therefore, it seems unlikely, particularly given the strength of the statement in 2010's NST, that Russia will agree to further arms reductions without specific, verifiable limits on missile defense.

Conclusions

Strategic Stability

In Russia's view of strategic stability, where neither side has an incentive to carry out aggression, a future BMD system combined with more restrictive arms control will result in instability. Specifically, Moscow perceives that the United States may have an incentive for aggression because it will have a strategic advantage, and Russia may need to preempt a US attack. When using the more restrictive definitions of stability for this study, the future scenarios show that the proposed expanded BMD systems could easily cross a threshold and degrade strategic stability, especially in Russia's view. Additionally, historical US BMD policy inconsistencies combined with less-than-subtle indications that the US is retargeting its BMD policy toward portions of the Russian nuclear deterrent have forced Moscow to conclude that Russia must begin to counter the future US BMD system in both policy and capability.

The analysis presented above substantiates Russia's historical concerns of US missile defenses because it shows that unlimited expansion, now possible under the new NMD language, may result in crisis instability. If Russia does not improve its strategic situation through the development of more survivable strategic arms, in some future situations, a preemptive strike may be Russia's only viable option based on its current damage requirements.

Continued US willful ignorance or portrayal of Russian concerns as simply political bluster will almost certainly manifest itself in an arms race that neither side wants nor can really afford. Moscow views its strategic disadvantage as untenable and existential, and as described by President Putin earlier this year during his speech to the Duma, it has already begun to explore ways to fund development of new deterrent capabilities that can penetrate or more critically circumvent US missile defenses.

The Future of Arms Control

Russia believes there is a fundamental link between strategic offensive and defensive arms, and this study has substantiated that claim. The United States must accept that it will not be able to achieve its nonproliferation goals or further mutual offensive nuclear arms reductions unless it accepts limits on the deployment of future BMDs. These limits could be on overall interceptor numbers, defense capabilities, or a combination of offensive and defensive arms limitations, and these limits could be enforced by intrusive inspections of BMD systems on both sides for confidence building. The US must accept that BMD cannot expand indefinitely to account for increased nonpeer threat capabilities. At some point, deterrence by punishment must replace deterrence by denial for these rogue states so that limits on national missile defense can remain at acceptable levels for near-peer strategic stability. Given Moscow's acceptance of regional missile defenses in the 1990s, similar systems will likely remain acceptable from a crisis stability point of view. Still, the US must be able to convince Moscow that the EPAA is limited to regional defense.

Recommendations

Convince Russia to Change Doctrine

Earlier studies looked at using a minimum deterrence doctrine to stabilize the strategic situation with Moscow; however, Russia's continued reliance on the Cold War idea of assured destruction invalidated these arguments. This threshold was critical for the conclusion drawn in this study that BMD is destabilizing. Still, all but the bolt-from-the-blue retaliation in every scenario analyzed above resulted in numerous warhead impacts, which would suffice for a minimum deterrence doctrine. More importantly, a minimum deterrent threat is realistically a sufficient deterrent for current and future US decision makers. No US president would risk the political and economic consequences of even a single warhead detonating in a densely populated area in any situation except the most desperate or existential, yet Moscow remains unconvinced. As both sides seek to reconstruct a relationship likely built around arms control, they must also develop a shared understanding of deterrence thresholds and attempt to move all sides away from potentially destabilizing assured destruction doctrines, particularly in the presence of BMD.

Avoiding an Arms Race—Russia's New Weapons

The US should not react to the new, asymmetric nuclear capabilities in Russia with development of methods to defeat them. Congress has already asked MDA to develop capabilities to defeat hypersonic boost-glide weapons,[95] potentially including the one that President Putin announced in March 2018, while at the same time, US policy continues to claim that Russia and other near-peers are not a primary target of BMD. Putin claimed that Moscow designed these new weapons, including its hypersonic glide vehicle, to penetrate or bypass missile defense to restore Russia's ability to hold targets in the United States at risk of nuclear attack.[96] Russia sees these novel weapons as restorative to stability because they are survivable against future BMD capabilities. Regardless of US perceptions of these potential capabilities, if the US now shifts focus to building defenses against these new asymmetric capabilities it only serves to further exacerbate the arms race and will degrade strategic stability once again.

Move to Assured Destruction Doctrine with Rogue States

The US must choose not to indefinitely expand its BMD system to ensure perfect defense against a continually improving rogue-state threat. This expansion is expensive and, as shown in this study, degrades near-peer strategic stability. Additionally, using BMD to deter rogue state long-range ballistic missile proliferation and development has effectively failed. In the future, if a state develops more than a limited ballistic missile capability, the US should move to a stated assured destruction deterrence doctrine, backed by either nuclear or conventional arms. BMD still plays a role in regional missile defense and assurance, and it may continue to deter limited ballistic missile attacks on CONUS by denial of effect; however, the demonstrated threat to near-peer stability should dissuade future BMD expansion as an answer to growing rogue threats.

Finally, a potential outcome of the political agreements currently being discussed between North Korea and the United States is that the nuclear and ballistic missile threat from North Korea is significantly reduced or eliminated. If the United States has been truly sincere in its argument that BMD was only to act as a deterrent to rogue states, then US BMD policy makers should not search for a new threat to justify its existence and expansion. Russia and China will perceive expansion at this point as proof that the US BMD system was only ever aimed at them. Reductions in the size of the system will show both peers that the US was in fact sincere.

Accept Limits on Future BMD Systems

If there is ever a follow-on arms control treaty with Russia, the US must be willing to put North American missile defense on the negotiating table. This study has shown that Russia has a reasonable argument that future BMD expansion could degrade its ability to deter the United States using a threat of unacceptable damage and that a treaty-reduced force would make the situation worse. Given this result and Moscow's consistent argument that offensive and defensive strategic arms are linked, it is unlikely that Russia would agree to further reductions in its nuclear forces without US agreements to limit future national BMD expansion.

Other options are possible such as strict, verifiable agreements to limit terminal defenses against aerodynamic threats (i.e., cruise missiles, boost-glide weapons, etc.) around national BMD sites. Rogue states are unlikely to have capability to strike these sites directly, while Russia could significantly degrade them with other nonballistic capabilities if they remain undefended. This would maintain these capabilities for the rogue-state threat but provide Russia with confidence that it could degrade US defenses if necessary. This could support US goals of nuclear reductions without requiring significant BMD sacrifices.

Confidence Building—Bring Moscow Back to Reality

If the US accepts limits on its national BMD system to gain agreement on future offensive arms reductions, it will likely come with specific verification requirements to build Russian confidence that the US is in fact abiding by its agreements. These requirements could also help soften Russia's exaggerated view of US BMD capability. The US could increase transparency and predictability for Russia by agreeing to exchange data confidentially on the general location and defensive loadout of BMD capable Aegis ships. Additionally, the US could accept limits to BMD interceptor capability against ICBMs. Like the original START Treaty, each side could confirm the capability of the other side's weapons through weapon exhibitions, intrusive inspections, and exchange of weapon technical specifications and flight test data. These measures could help convince Moscow that US BMD interceptors are not intended and do not have a capability to intercept Russian intercontinental missiles.

Other Nuclear Arms Limitations—Reducing First-Strike Vulnerability

While future BMD expansion played the primary role in destabilizing the strategic situation with Russia in this study, degradation of Russia's nuclear deterrent caused by the US first strike was the next biggest contributor. Russia and the United States should reconsider the general concept of the START II Treaty, which restricted land-based missiles with multiple warheads. Specifically, both sides should reconsider the stability of multiple-warhead, silo-based missiles, which are particularly vulnerable to a first strike. In the study's scenarios, each missile lost prelaunch resulted in the loss of multiple warheads. Reducing the number of warheads vulnerable to prelaunch destruction will help stabilize future scenarios and increase the number of warheads that could potentially penetrate postlaunch missile defense systems.

Future Studies

Numerous further studies could better explore the extent of the specific problem covered in this paper. The results of this study were critically linked to the Russian idea of unacceptable damage. A more precise and accurate quantification of this damage criterion in terms of BMD survivability and warhead impacts required will increase both sides' understanding of the precise effects of missile defense and the allowable size of a BMD system. The quantification of unacceptable damage through warhead impacts used in this study was at best an estimate. Further study using a higher fidelity exchange model might more accurately define the warhead impact threshold required by Moscow using Radchuk's GDP damage condition.

The second critical factor used in this study was the sizing and capability of a future US BMD system. There were uncertainties in this study's analysis that affected its results and conclusions. Executing a more detailed uncertainty analysis in the BMD simulation used in this study will help develop a better understanding of the BMD system characteristics that drive strategic instability and quantify how differences in BMD capability perception might improve or exacerbate the predicted future strategic situation.

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Appendix A

Detailed Explanation of Current Ballistic Missile Defense (BMD) Scenario

BMD Order of Battle

The current scenario BMD system consists of 44 GBIs (Ground Based Interceptor) backed by 10 Aegis ships with 200 SM-3 block IIA interceptors to defend CONUS. Regional European defense is covered by three Aegis ships, two Aegis Ashore batteries, and two, 48-missile THAAD (Terminal High Altitude Area Defense) batteries. Table A1 shows the BMD order of battle for this scenario.

Table A1. US BMD order of battle for current BMD scenario

System	Total number of missiles	Kill vehicles per missile
GBI	44	1
Aegis (US, ship-based)	200	1
Aegis (EPAA)	110	1
THAAD (CONUS)	0	1
THAAD (Europe only)	96	1

GBI—ground-based interceptors
EPAA—European Phased Adaptive Approach
CONUS—Continental United States
THAAD—Terminal High Altitude Aerial Defense

According to MDA the US currently has 33 Aegis ships deployed capable of performing in the BMD role, including five Ticonderoga class cruisers and 28 Arleigh Burke class destroyers.[1] A portion of these, barring a lasting peace on the Korean Peninsula, will almost certainly remain in support of Pacific and Asian US allies, and it is unlikely, on the basis of its current limited counter-ICBM capability, that a significant number of these Aegis ships would stay close to CONUS for BMD support. However, to account for Russian overestimation of US capability conservatively, this scenario will assume eight destroyers and two cruisers will remain close to the US for BMD support. This deployment doctrine is unlikely and the capability of Aegis with its SM-3 missiles is likely not sufficient to effectively defend the US from ICBM attacks. The study assumes that another two Arleigh Burke class destroyers and a Ticonderoga cruiser will support regional BMD in Europe along with the two Aegis Ashore batteries that are soon to be deployed in Romania and Poland.[2]

The little data that exists suggests that up to two-thirds of an Aegis ship's complement could consist of standard missiles for air and missile defense.[3] However, these ships must carry both air and missile defense weapons combined with the current limited inventory of around 350 total SM-3 missiles; therefore, 20 percent of the launchers carrying SM-3 BMD interceptors is a more likely scenario.[4] The Aegis Ashore facilities each have 24 launchers according to CSIS reporting, and this study assumes, for this scenario, that all are SM-3 launchers.[5] See table A2 for a full accounting of the Aegis assets and the number of missiles available.

Table A2. Aegis order of battle for current BMD scenario

Ship Class	Number of ships for BMD	Number of SM-3 launchers (20% of complement)	Total launchers
SM-3 Launchers—CONUS			
Ticonderoga Class	2	24	48
Arleigh Burke Class	8	19	152
Aegis Ashore	0	24	0
		Total CONUS	200
SM-3 Launchers—Europe			
Ticonderoga Class	1	24	24
Arleigh Burke Class	2	19	38
Aegis Ashore	2	24	48
		Total Europe	110

According to MDA, there are currently six THAAD batteries available for deployment.[6] Each battery has a standard complement of 48 missiles but can expand to 72 missiles.[7] This scenario assumes that the US would deploy only two batteries to protect European regional targets while maintaining two in the Asia-Pacific region and two in reserve. Only the two batteries in Europe will play a role in this scenario as it is assumed that Russian targets in the Asia-Pacific region will not be significant in number and that the US will not attempt in the near term to use the THAAD to protect targets in the US. Table A3 presents the THAAD order of battle for the current scenario.

Table A3. THAAD order of battle for current BMD scenario

Deployment	Number of batteries	Number of missiles per battery	Total missiles
THAAD (CONUS)	0	48	0
THAAD (EUCOM)	2	48	96
THAAD (PACOM)	2	48	96
THAAD (CONUS Reserve)	2	48	96

BMD Performance Characteristics

The existing NMD system does not allow for a shoot-assess-shoot doctrine because of booster limitations;[8] therefore, all systems use a salvo firing doctrine with the salvo size listed in table A4 and cannot reattack if initially unsuccessful. Consequently, SM-3 interceptors in CONUS are not used until the GBIs are exhausted. To account for Russian overconfidence in BMD's capability, this scenario assumes each GBI carries the redesigned kill vehicle (RKV) with an assumed two-on-one shot doctrine due to its higher reliability, even though the US will not deploy it before 2020 according to CSIS reporting.[9]

Table A4. Current BMD scenario—US BMD capability and doctrine

System	Doctrine number	P_k^*	P_{ww}	P_k	Firing doctrine	Salvo size	% Area protected
GBI	1	0.8	0.5	0.4	shoot-shoot-assess	2	100
Aegis (US, ship-based)	N/A	0.3	0.5	0.15	shoot-shoot-assess	2	20
Aegis (EPAA)	N/A	0.8	0.5	0.4	shoot-shoot-assess	2	100
THAAD (CONUS)	N/A	0.3	0.5	0.15	shoot-shoot-assess	2	20
THAAD (Europe Only)	N/A	0.8	0.5	0.4	shoot-shoot-assess	3	20

P_k*—single missile probability of kill with perfect discrimination
P_{ww}—probability the warhead will be discriminated
P_k—overall single missile probability of kill for the system including probability of discrimination
% area protected—Percent of warheads likely to land in defended area

According to CSIS estimates, the RKV will have an increased reliability over the EKV and will theoretically allow the GBI to operate using a smaller, two-missile shot doctrine against rogue threats to provide a high chance of intercept.[10] Based on this calculation, the study assumed a *system probability of kill* (P_k*) for this missile of approximately 80 percent, which would provide a 96 percent probability of kill for a two-missile shot-doctrine against an incoming warhead assuming it can be perfectly discriminated. To account for Moscow's likely robust penetration aid technology and the limited discrimination capability that the US currently has deployed in its BMD system, this scenario will use a 50 percent *probability of warhead discrimination* (P_{ww}) for the GBI. This gives the GBI in this scenario an *overall probability of kill* (P_k) of 40 percent, which is a reasonable estimation of Moscow's perception of the US BMD system capability.

The SM-3 interceptor has a limited capability against ICBM systems, and this scenario is intended to account for a potential Russian overestimation of the BMD threat it faces.[11] According to the testimony of Lieutenant General Greaves, director of the Missile Defense Agency, to the Strategic Forces Subcommittee of the HASC in April 2018, MDA is in fact evaluating the ability of the SM-3 Block IIA missile to defend CONUS against an ICBM. Greaves testified that it "could add a layer of protection, augmenting the currently deployed GMD system."[12] This means at some high level of analysis, this missile has some ICBM defense capability.

Like SM-3, THAAD also currently has a limited ability to defend against ICBM threats,[13] therefore, the study uses a low system probability of kill (P_k^*) of 30 percent for these systems against ICBMs with perfect discrimination. Admittedly, this is an estimate because effectiveness of these systems against an ICBM is not available as it is almost certainly classified if it has even been determined, but the only necessity for this study is to represent some limited capability. Since Aegis, as currently deployed, and THAAD are more capable against regional medium- and intermediate-range missiles, this study assumes they will both have a significantly higher system probability of kill (P_k^*) when used against regional missiles than when used against intercontinental threats. Therefore, this study has assumed an 80 percent system probability of kill for both defensive systems when based in Europe, which gives a two-on-one shot doctrine more than a 90 percent chance of intercept, barring discrimination errors. These values are somewhat arbitrary; nevertheless, based on Moscow's perception of the current BMD system and what it must account for during nuclear strike planning, these values are likely conservative and will provide enough fidelity for a qualitative discussion of the results.

The study will assume that all systems will have a similar probability of discrimination since they are all presumably linked to the same ground-based sensors. For the current BMD system, this study uses a probability of warhead discrimination of 50 percent, meaning that the BMD system will correctly determine the warhead half the time. This warhead discrimination probability is admittedly arbitrary; still, it is low enough to account for significantly less than perfect discrimination while providing a value close enough for a qualitative assessment of the net effect on stability of the current BMD system. Although it is difficult to know how Moscow might assess the capability of the current US BMD system, its targeting requirements likely overestimate BMD's capabilities to ensure it can get enough weapons on target for its needs; therefore, an overestimated value for discrimination is probably representative.

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Appendix B

Detailed Explanation of Future BMD Scenario

BMD Order of Battle

This scenario bases its future BMD system on many of the capabilities as discussed in CSIS's *Missile Defense 2020* study that Russia will reasonably expect the US to deploy in the next 20 years while it determines its future deterrent needs. The upper layer protecting CONUS consists of a full complement of 164 GBIs, each deployed with five MOKVs at one of the three proposed US deployment locations.[1] A second overlapping layer consists of both Aegis ships and Aegis Ashore sites in CONUS with SM-3 IIB-class interceptors, and Aegis forms the upper layer in Europe using SM-3 IIA missiles. While the US canceled development of the SM-3 Block IIB interceptor in 2013, Moscow still has concerns, and it will likely make decisions on its future force with a similar capability in mind.[2] Finally, the lowest layer for this scenario consists of THAAD and THAAD-extended range (THAAD-ER) to provide an increased defense of both CONUS and Europe in the terminal phase against ICBMs.[3] The overall order of battle for the future BMD scenario is below in table B1.

Table B1. Future BMD scenario order of battle

System	Total number of missiles	KVs per missile
GBI	164	5
Aegis (US, ship-based)	602	1
Aegis (EPAA)	253	1
THAAD (CONUS)	288	1
THAAD (Europe only)	144	1

This future scenario will have approximately the same number of Aegis ships available as today, but each ship will have more BMD interceptors available with up to half their complement loaded with SM-3 missiles. This scenario will also use four Aegis Ashore sites in the United States. This is a cheap alternative to deploying more GBI silos, and these systems are currently being deployed beyond the two sites in Europe. The US is currently considering making the Aegis Ashore test site in Hawaii an operational platform, and in December 2017, Japan approved a plan to purchase two Aegis Ashore systems.[4]

It is a realistic possibility that a future US missile defense system that included an upgraded SM-3 missile designed to defend against ICBMs could be deployed to CONUS as a less expensive alternative to deploying more GBI silos. While this is less likely than filling out the three GBI deployment sites, it is a possibility that US adversaries would have to consider when looking at their future nuclear deterrent plans. Table B2 shows the SM-3 order of battle.

To provide a bounding-capability-future-BMD scenario against the Russian nuclear deterrent, this study will assume that Aegis developments would be focused on qualitative advancements to counter rogue-state ICBM threats. This might result in restarting development of the SM-3 IIB interceptor, which according to Dean Wilkening could, in a future scenario, provide full defensive coverage of CONUS when based off the East and West Coasts of the US.[5]

Table B2. Aegis order of battle for future BMD scenario

Ship Class	Number of units for BMD	Number of SM-3 launchers (1/2 of complement)	Total launchers
SM-3 Launchers–CONUS			
Ticonderoga Class	2	61	122
Arleigh Burke Class	8	48	384
Aegis Ashore	4	24	96
		Total CONUS	602
SM-3 Launchers–Europe			
Ticonderoga Class	1	61	61
Arleigh Burke Class	3	48	144
Aegis Ashore	2	24	48
		Total Europe	253

This future BMD scenario will have all nine planned THAAD batteries deployed each with the maximum 72 interceptors, with four batteries deployed in CONUS and two in Europe.[6] Two would remain in PACOM; however, the study will not account for these because the number of targets in the PACOM region will be relatively small. The CONUS batteries will field the THAAD-ER interceptor, which will provide it with an increased, though not ideal, capability against ICBMs.[7] The THAAD order of battle for this future scenario is below in table B3.

Table B3. THAAD order of battle for future BMD scenario

Deployment	Number of batteries	Number of missiles per battery	Total missiles
THAAD (CONUS)	4	72	288
THAAD (EUCOM)	2	72	144
THAAD (PACOM)	2	72	144
THAAD (CONUS Reserve)	1	72	72

BMD Performance Characteristics

In this scenario, the study assumes that THAAD and Aegis would both see qualitative increases in capability against the ICBM threat while maintaining current capability against regional missiles. It also assumes that Moscow would assess in its future scenario analysis that the US would continue improving its discrimination capability through new sensors, such as the new satellite-based discrimination system planned for by the US Congress in the 2018 NDAA.[8] Additionally, it would assess that sensors such as the long-range discrimination radar currently undergoing deployment will also improve US capability against Russia's current decoy and countermeasure capabilities providing increased warhead discrimination capability in the future if Moscow does not continue to invest in new penetration methods.[9] To account for these potential US technology breakthroughs and a lack of Russian ability to continually invest in BMD countermeasures in Moscow's worst-case scenario prediction, this scenario uses a relatively high (75 percent) probability of warhead discrimination (P_{ww}) across the board.

This study holds the probability of kill for GBI and the regional interceptors in Europe at the same 80 percent used in the previous scenario, which gives these interceptors over a 90 percent chance of kill using a two-on-one shot doctrine with perfect discrimination. THAAD and SM-3 probability of kill for CONUS are held at a much lower 50 percent because it is assumed that these systems will continue to have much less capability against ICBM threats even with THAAD-ER and an SM-3 IIB-class Aegis interceptor deployed. This is admittedly a conservative scenario, but it still provides a useful diagnosis of the stability problem, and the results analysis section details potential changes due to a higher CONUS probability of kill.

The shot doctrine of this future scenario when confronting a massed strike is designed to defeat as many warheads as possible rather than to provide a high probability of preventing a small number of missiles from leaking through defenses, which is not a realistic possibility in any case. This represents the worst-case scenario (i.e., lowest number of penetrating warheads) for Russian planners when trying to meet Moscow's unacceptable damage criteria. In a massed strike scenario, the defense must not chance wasting interceptors to achieve extremely high probability of kills against individual missiles or warheads. In some cases, the second and third interceptors launched would be wasted if the first interceptor successfully intercepts the missile or warhead.

The future scenario modeled here has dispersed GBI deployment sites (East and West Coast), new GBI boosters, improved command and control, and improved kill determination provided by the new sensors. This combination of capabilities will allow a shoot-assess-shoot capability with the GBIs providing the first shots and either GBIs or CONUS-based Aegis SM-3 shooters the second depending on the number of remaining warheads (defined by the "doctrine number" described below in table B4). The study assumes that only the GBI has the capability to perform the first shot in a shoot-assess-shoot doctrine with both the SM-3 and THAAD shooters providing shoot-shoot-assess capability using salvo size described in table B4. This table provides the BMD capability and doctrine used to model this future scenario.

Last, regardless of future BMD capability, Russia would likely be able to alter the timing and spacing of an attack to prevent the kill vehicles of a single GBI from intercepting warheads released from separate missiles. Therefore, despite each GBI having multiple kill vehicles (MOKV), each interceptor would only be able to target a single ICBM (i.e., if an ICBM deploys three warheads, a GBI with five MOKVs will have five chances to intercept those three warheads, but in no circumstances will it be able to target two warheads from a different missile). If a missile has more than five warheads, multiple GBIs can be used against it, but the extra kill vehicles deployed will similarly only provide increased chances at killing the warheads carried by that single ICBM and cannot be used against a different ICBM.

Table B4. Future BMD scenario—US BMD capability and doctrine

System	Doctrine number	P_k*	P_{ww}	P_k	Firing doctrine	Salvo size	% Area protected
GBI	2	0.8	0.75	0.6	shoot-assess-shoot	2	1
Aegis (US, ship-based)	N/A	0.5	0.75	0.375	shoot-shoot-assess	2	1
Aegis (EPAA)	N/A	0.8	0.75	0.6	shoot-shoot-assess	2	1
THAAD (CONUS)	N/A	0.5	0.75	0.375	shoot-shoot-assess	2	0.2
THAAD (Europe Only)	N/A	0.8	0.75	0.6	shoot-shoot-assess	2	0.6

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Appendix C

Detailed Explanation of Current and Future Russian Nuclear Force

To ease the creation of the nuclear force size for both scenarios, consistency was needed in the ICBM and SLBM force between the current and future scenario. The following table provides data from multiple sources on the current order of battle for the Russian strategic nuclear forces. Because of its detailed nature without gaps, the data from the *Bulletin of Atomic Scientists* from 2017 was used; however, much of the data matches across the board, so it is used as the baseline with confidence. The current scenario assumes that the nuclear force has been held at the New START Treaty (NST) limit of 1,550 warheads, and the *Bulletin* force size is 1,844.

Table C1. Data on Russian nuclear forces order of battle

System	Missiles (warheads per missile)		
	National Air and Space Intelligence Center	Defense Intelligence Agency	*Bulletin of Atomic Scientists*
SS-18 Mod 5	About 50 (10 warheads)	46 (10 warheads)	46 (10 warheads)
SS-19 Mod 3	About 50 (6 warheads)	30 (6 warheads)	20 (6 warheads)
SS-25	About 100 (1 warhead)	72 (1 warhead)	90 (1 warhead)
SS-27 Mod 1 (Road Mobile)		18 (1 warhead)	18 (1 warhead)
SS-27 Mod 1 (Silo)	About 80 (1 warhead)	60 (1 warhead)	60 (1 warhead)
SS-27 Mod 2 (Road Mobile)	More than 50 (multiple warheads)	73 (multiple warheads)	70 (4 warheads)
SS-27 Mod 2 (Silo)			12 (4 warheads)
SS-X-28 (Rubezh, RS-26)	In development (multiple warheads)	In development (unk.)	0 (4 warheads)
Sarmat (SS-30, RS-28)	In development (multiple warheads)	In development (unk.)	0 (10 warheads)

Table C1. (*Continued*)

System	Missiles (warheads per missile)		
	National Air and Space Intelligence Center	**Defense Intelligence Agency**	***Bulletin of Atomic Scientists***
SS-N-18	96 (3 warheads)	3 DELTA III x 16 launchers = 48 missiles (3 warheads)	2 DELTA III x 16 launchers = 32 missiles (3 warheads)
SS-N-23	96 (4 warheads)	6 DELTA IV x 16 lauchers = 96 missiles (4 warheads)	6 DELTA IV x 16 launch-ers = 96 missiles (4 warheads)
SS-N-32	48 (6 warheads)	3 DOLGORUKIY x 16 launchers = 48 missiles (6 warheads)	3 DOLGORUKIY x 16 launchers = 48 missiles (6 warheads)
Warhead totals	**2,040**	**1,898**	**1,844**

Adapted from Defense Intelligence Ballistic Missile Analysis Committee, *Ballistic and Cruise Missile Threat*, NASIC Report NASIC-1031-0985-17 (Wright-Patterson AFB, OH: National Air and Space Intelligence Center, June 2017); Defense Intelligence Agency, *Russia Military Power 2017* (Washington, DC: Defense Intelligence Agency, 2017); and Hans M. Kristensen and Robert S. Norris, "Russian Nuclear Forces," *Bulletin of the Atomic Scientists* 73, no. 2 (February 2017).

The first requirement was to make a consistent force by removing all older Soviet weapons and replacing them with the missiles that would be around for the future scenario. According to DIA's *Russia Military Power: 2017,* SS-19s will be replaced in the force by SS-27 Mod 2 and that the SS-25 will be replaced by SS-27 Mod 2 and SS-28 (RS-26). Finally, DIA's report says Russia will ultimately have 10 SSBNs each deployed with 16 missiles.[1] *The Bulletin of the Atomic Scientists*' "Russian Nuclear Forces" report from 2017 by Hans Kristensen and Robert Norris says there were 12 SS-27 Mod 2 silo missiles and 20 SS-19 Mod 3 missiles.[2] These were added together and then rounded to the nearest 10, on the basis of the *Bulletin*'s reporting that each silo-based SS-27 Mod 2 regiment has 10 missiles. The SS-27 Mod 2 and SS-25 numbers from the *Bulletin* were added together and rounded up to a multiple of 9 to make full regiments, based on the *Bulletin*'s indication that road-mobile units have regiments of 9 missiles. Since it is unclear from all sources how many SS-28s are to be deployed, half the remaining SS-25s (45) were arbitrarily replaced with SS-28s. Table C2 shows the resultant nuclear force, before any attempt to make it fit the NST limits.

Table C2. Resultant ICBM and SLBM order of battle in 2017

Missile Type	Warheads Per Missile	Number Deployed	Total Warheads
Silo ICBMs			
SS-18 Mod 5/Sarmat	10	46	460
SS-27 Mod 1	1	60	60
SS-27 Mod 2	4	30	120
Road-mobile ICBMs			
SS-27 Mod 1	1	18	18
SS-27 Mod 2	4	117	468
SS-28	4	45	180
SLBMs			
SS-N-23	4	80	320
SS-N-32	6	80	480
Totals		**476**	**2,106**

Current, New START Treaty-Limited Nuclear Force

NST limits Russia and the United States to 1,550 warheads including each heavy bomber counted as a single warhead. According to the *Bulletin*, Russia currently has 68 bombers;[3] therefore, Russia would be limited to 1,482 warheads on its ICBMs and SLBMs. The order of battle presented above in table C2 would be more than 600 warheads over the limit, but according to the Federation of American Scientists, Russia claims it has reduced its force to be in compliance with the NST, meaning it has reduced its warheads to below the 1,550 warheads limit.[4] Without further evidence, this was done for this study by scaling each missile's warhead complement based on the ratio of the NST limit (1,550 warheads) minus the number of bombers (1,550 warhead limit minus 68 warheads attributed to bombers equals 1,482 warheads for ballistic missiles) to the total number of ballistic missile warheads listed by the *Bulletin* (2,106 warheads) while keeping the total number of missiles the same. That is a ratio of approximately 0.7 (1,482 divided by 2,106). Thus as an example, the SS-18 Mod 5 as listed in the *Bulletin* has 10 warheads, but the current New START Treaty-limited scenario assigns it seven warheads, which is 70 percent of the original 10-warhead loading. Table C3 shows the development of the scale factor.

Table C3. Math to reduce warheads to current scenario

New START Treaty (NST) Total Warheads Allowed	1,550
Total Bombers	68
NST Total BM Allowed under NST	1,482
Total BM Warheads	2,106
Ratio of Total BM Allowed to Current Total BMs	0.7037

This is only intended to be representative of the Russian order of battle to provide some level of realism to the analysis. For the purposes of this qualitative analysis, it is not necessary for this to be a perfect reflection of reality. The math does not perfectly work as many missiles have a single re-entry vehicle (RV) and cannot be scaled down. The resultant number of warheads is above the 1,482 warheads desired, but this is close enough for the purposes of this study. Table C4 gives the resultant Russian nuclear force order of battle. The yields provided are from the *Bulletin of Atomic Scientists*.[5]

Table C4. The resultant current Russian nuclear force order of battle

Missile Type	Warheads per Missile	Number Missiles Deployed	Total Warheads	Yield
Silo ICBMs				
SS-18 Mod 5/Sarmat	7	46	322	800
SS-27 Mod 1	1	60	60	800
SS-27 Mod 2	3	30	90	100
Road-Mobile ICBMs				
SS-27 Mod 1	1	18	18	800
SS-27 Mod 2	3	117	351	100
SS-28	3	45	135	100
SLBMs				
SS-N-23	3	80	240	100
SS-N-32	4	80	320	100
Totals		476	1,536	

Future Treaty-Limited Russian Nuclear Force

A similar method was used to reduce the original force from the *Bulletin* to a lower threshold of 1,000 warheads, while keeping the same number of bombers and missiles. Each missile's warhead complement was reduced proportionally to get below the 1,000-warhead limit. In this case, as seen in table C5, the ratio used was 0.4425.

Table C5. Math to reduce nuclear warhead numbers for future treaty-limited scenario

New START Treaty (NST) Total Warheads Allowed	1,000
Total Bombers	68
NST Total BM Allowed under NST	932
Total BM Warheads	2,106
Ratio of Total BM Allowed to Current Total BMs	0.4425

This reduction resulted in the force depicted in table C6. This resulted in no missiles with more than three warheads. Again, the math is not perfect, but this result is good enough for the purposes of this study.

Table C6. Future treaty-limited Russian nuclear force order of battle

Missile Type	Warheads per Missile	Missiles Deployed	Total Warheads	Yield
Silo Missiles				
SS-18 Mod 5/Sarmat	3	46	138	800
SS-27 Mod 1	1	60	60	800
SS-27 Mod 2	2	30	60	100
Road-Mobile Missiles				
SS-27 Mod 1	1	18	18	800
SS-27 Mod 2	2	117	234	100
SS-28	2	45	90	100
SLBMs				
SS-N-23	2	80	160	100
SS-N-32	2	80	160	100
Totals		476	920	

Notes

1. *Defense* Intelligence Agency, *Russia Military Power 2017* (Washington, DC: Defense Intelligence Agency, 2017), 30, 48.
2. Hans M. Kristensen and Robert S. Norris, "Russian Nuclear Forces," *Bulletin of the Atomic Scientists* 73, no. 2 (Feb 2017), 118. The Russian Nuclear Forces 2018 report came out too late for inclusion in this study, but it has similar numbers and conclusions.
3. Kristensen and Norris, 116.
4. Hans M. Kristensen, "After Seven Years of Implementation, New START Treaty Enters Into Effect," *Federation of American Scientists*, 8 February 2018, https://fas.org/.
5. Kristensen and Norris, "Russian Nuclear Forces," 116.

Appendix D

Full Simulation Results

Table D1. Full simulation results for study

Scenario	Missiles Before US Strike	Warheads Before US Strike	Missiles Launched	Warheads Launched	Warheads Defeated by GBI	Warheads Defeated by SM3	Warheads Defeated by THAAD	Warheads Defeated by BMD	Warheads Survived to Impact
NST, Current BMD									
Preemptive	476	1,536	476	1,536	18	62	16	96	1,440
Force Generated Launch On Warning	476	1,536	412	1,324	18	62	14	94	1,230
Force Generated	476	1,536	233	753	15	63	5	83	670
Bolt-from-the-blue	476	1,536	49	159	16	14	1	31	128
NST, Future BMD									
Preemptive	476	1,536	476	1,536	442	291	92	825	711
Force Generated Launch-on-warning	476	1,536	412	1,324	441	287	73	801	523
Force Generated	476	1,536	233	753	424	204	15	643	110
Bolt-from-the-blue	476	1,536	49	159	124	24	0	148	11
Future Treaty, Current BMD									
Preemptive	476	920	476	920	18	62	9	89	831
Force Generated Launch On Warning	476	920	412	795	18	63	7	88	707
Force Generated	476	920	233	456	15	50	3	68	388
Bolt-from-the-blue	476	920	49	95	16	9	1	26	69
Future Treaty, Future BMD									
Preemptive	476	920	476	920	343	260	40	643	277
Force Generated Launch On Warning	476	920	412	795	278	253	32	563	232
Force Generated	476	920	233	456	306	100	5	411	45
Bolt-from-the-blue	476	920	49	95	74	13	0	87	8

Abbreviations

ABM	antiballistic missile
BM	ballistic missile
BMD	ballistic missile defense
CONUS	Continental United States
CSIS	Center for Strategic and International Studies
DIA	Defense Intelligence Agency
DOD	Department of Defense
EKV	exo-atmospheric kill vehicle
EPAA	European Phased Adaptive Approach
GBI	ground-based interceptors
GDP	gross domestic product
GMD	ground-based midcourse defense
HASC	House Armed Services Committee
ICBM	intercontinental ballistic missile
LOW	launch on warning
MDA	Missile Defense Agency
MOKV	multi-object kill vehicle
NASIC	National Air and Space Intelligence Center
NDAA	National Defense Authorization Act
NMD	National Missile Defense
NST	New START Treaty
PACOM	United States Pacific Command
RKV	redesigned kill vehicle
RV	re-entry vehicle
SALT	Strategic Arms Limitation Treaty
SLBM	submarine-launched ballistic missile
SLV	space launch vehicle
SORT	Strategic Offensive Reductions Treaty
SSBM	Submersible ship ballistic missile nuclear
START	Strategic Arms Reduction Treaty
THAAD	Terminal High Altitude Area Defense

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